Environmental & Water Quality Operational Studies

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WATER QUALITY, MACROINVERTEBRATES, AND FISHERIES IN TAILWATERS AND RELATED STREAMS

An Annotated Bibliography

By Charles H. Walburg, Jerry F. Novotny
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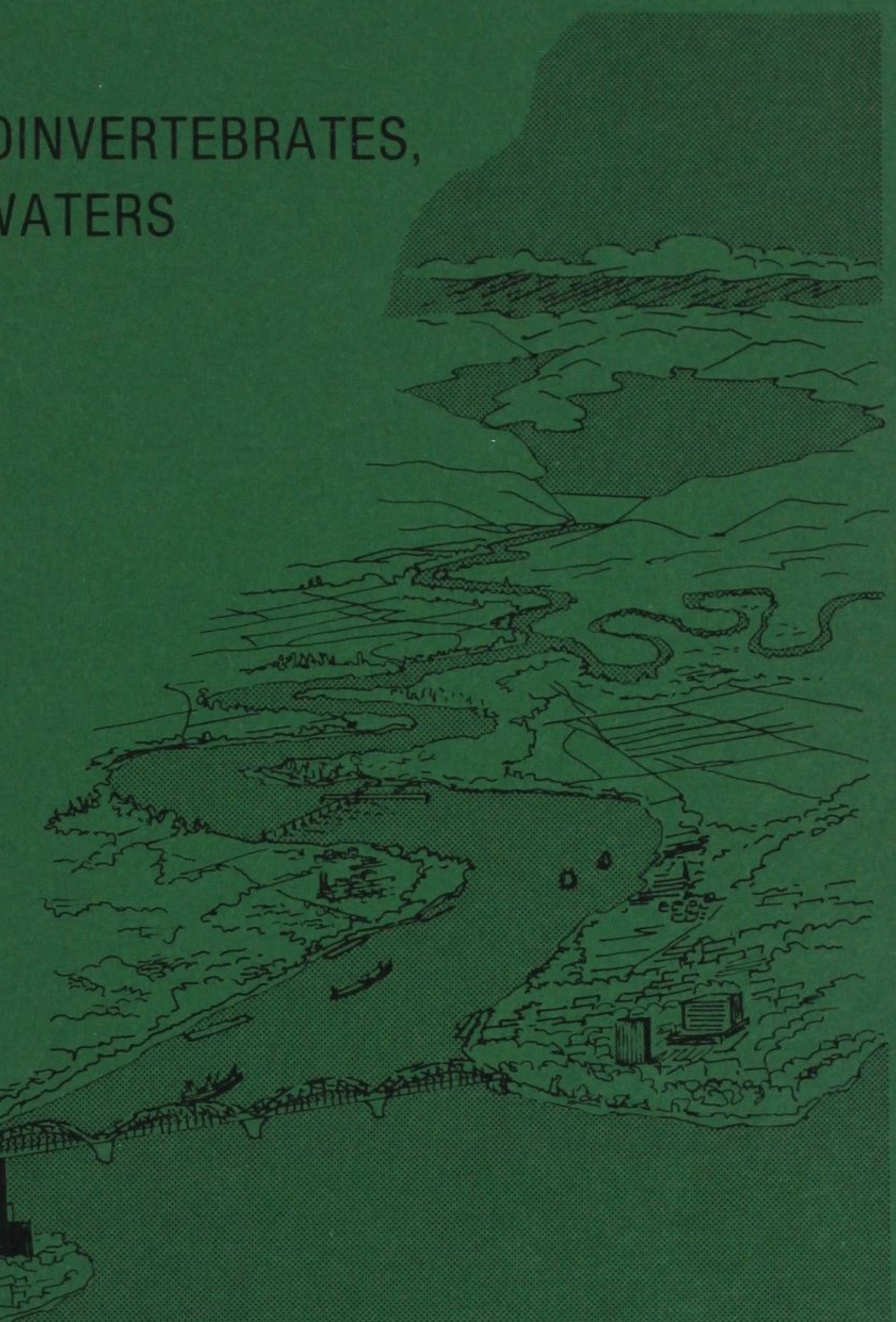

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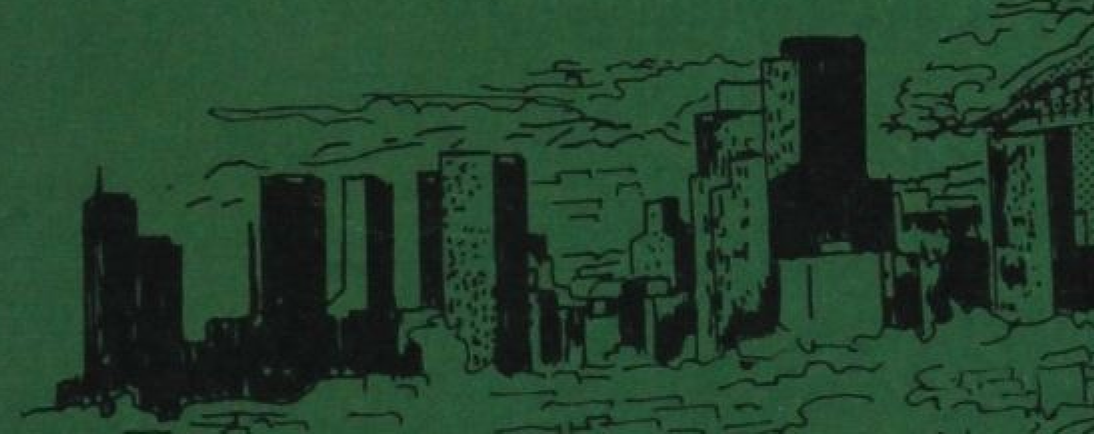

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This two-part annotated bibliography presents available literature information on water quality, macroinvertebrates, and fish in tailwaters and related streams. References in the first section outline the effects of project-imposed changes in flows and water quality on the tailwater environment and the downstream biota. The second section includes selected stream references that have application to tailwater research. Each entry is prefaced by a code indicating the subject matter contained.

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PREFACE

This report was prepared by the U. S. Department of the Interior, U. S. Fish and Wildlife Service, East Central Reservoir Investigations (ECRI), Bowling Green, Kentucky, for the U. S. Army Engineer Waterways Experiment Station (WES) under Interagency Agreement WES-79-04, dated 1 April 1979. The study forms part of the Environmental and Water Quality Operational Studies (EWQOS), Task IIB, Guidelines for Reservoir Release to Meet Environmental Quality Objectives. The EWQOS Program is sponsored by the Office, Chief of Engineers, and is assigned to the WES under the management of the Environmental Laboratory (EL).

This report was prepared by Messrs. Charles H. Walburg, Jerry F. Novotny, Kenneth E. Jacobs, Terry M. Campbell, and William D. Swink. Mr. Walburg is the Chief of ECRI.

This work was under the direct supervision of Drs. Gary E. Saul and John M. Nestler and under the general supervision of Mr. Donald L. Robey, Chief, Water Quality Modeling Group; Dr. Robert M. Engler, Acting Chief, Ecosystem Research and Simulation Division; Dr. Jerry Mahloch, Program Manager, EWQOS; and Dr. John Harrison, Chief, EL.

The Commander and Director of WES was COL Nelson P. Conover, CE. The Technical Director was Mr. Fred R. Brown.

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WATER QUALITY, MACROINVERTEBRATES, AND FISHERIES IN TAILWATERS AND RELATED STREAMS

An Annotated Bibliography

PART I: INTRODUCTION

1. The U. S. Army Corps of Engineers (CE) is responsible for providing reservoir releases of sufficient quantity and quality to maintain downstream fisheries and aquatic habitat. Presently there are no quantitative approaches or reliable guidelines for determining reservoir releases required to ensure the maintenance of a desired downstream aquatic environment. In many cases, environmental quality requirements for downstream habitat and biota are not well understood and/or substantiated. Reliable methods for determining the releases required to meet environmental quality objectives are difficult to develop due to conflicting requirements of water users.

2. Project operations affect downstream aquatic habitats in a number of ways, depending on project purposes and specific downstream biota requirements. Large flow variations associated with power peaking operations may adversely affect downstream fisheries during spawning periods, disrupt benthic communities that serve as food for fish, and limit stream-based recreation. Temperature, dissolved gases, and other reservoir release water quality parameters vary with project design and operation. These parameters greatly influence the species and abundance of downstream aquatic life.

3. In an effort to better understand the impacts of reservoir operation and releases on downstream communities, the CE entered into an agreement with the U. S. Fish and Wildlife Service (USFWS) for studies to determine the effect of reservoir releases on tailwater biota. The initial task of the USFWS was to conduct a literature search to define factors which affect the tailwater environment and to evaluate this information as a basis for developing operational guidelines for reservoir releases.

4. This annotated bibliography is a compilation of references which were used by the East Central Reservoir Investigations, USFWS, to review the ecology of tailwater biota. Included are abstracts of studies which concern fish, invertebrates, and water quality in the tailwater environment. Because biological work on tailwaters has been limited, references and abstracts are included from selected stream and river studies which have application to tailwater problems. No attempt was made to include the extensive literature concerning anadromous fish.

5. The purpose of this bibliography is to provide a reference on studies which concern tailwater biota. An attempt was made to locate all available literature through 1979, but some papers were probably missed or are no longer obtainable. All papers listed in this bibliography were reviewed, except in those instances when abstracts only were available. Many of the abstracts in this report are those of the author or are a portion of the author summary, and this is noted at the end of such abstracts. Where no credit is given, the abstract was prepared by the authors of this report.

6. The references are grouped alphabetically under two headings: "Tailwater Studies" and "Stream Studies." To aid users of this bibliography, the subjects covered under each heading are identified by letter code, i.e., F for fish, I for invertebrates, and W for water quality, on the first line of the reference. Productivity and stream metabolism papers are included with invertebrates. Some references concern one subject, while others concern two or three. The following is an example of a reference, which can be found in the "Tailwater Studies" section, that includes information on fish, invertebrates, and water quality.

F,I,W Bauer, B. H. 1976. The effects of the Cordell Hull impoundment on the tailwaters of Dale Hollow Reservoir. Tenn. Wildl. Resour. Agency, Tech. Rep. 52. 82 pp.

PART II: BIBLIOGRAPHY

Tailwater Studies

I Abbott, T. M. and E. L. Morgan. 1975. Effects of an hydroelectric dam operation on benthic macroinvertebrate communities of a tailwater stream. Assoc. Southeast. Biol., Bull. 22(2):38.

The purpose of this study was to test the hypothesis that controlled flow during critical summer periods prevented establishment and maintenance of stable macroinvertebrate communities in the tailwaters of an hydroelectric dam located on the Caney Fork River in middle Tennessee. Physical effects of the hydroelectric dam operation on the tailwater stream included fluctuating stream levels (max. 9 m), significant losses of riffle habitat (max. 63 percent), and rapid thermal fluctuations (max. 5°C). Effects of these variables on species diversity, density and abundance of macroinvertebrates were used as indicators of community disruption.

The combined physical effects produced variations in the aquatic habitats which severely limited the number of species in this stream. Diversity values increased as the distance increased below the dam.

Additionally, importance values for the fifteen predominant macroinvertebrate species were calculated from the percentage wet weight, frequency of species occurrence, and density of individual species collected at each sample station. Near the dam, physical variations were more severe and several species shown to be tolerant of these same parameters in other studies exhibited high importance values. With increasing distances below the dam where physical variations were lower the number of species intolerant of the extreme physical variations increased; these species yielded intermediate importance values. (Author abstract.)

F Abdurakhmanov, Y. A. 1958. The effect of regulation of the flow of the Kura River on the behavior and abundance of fishes in the region below the Mingechaur Hydroelectric Station. Rybn. Khoz. 34(12):13-15. (Fish. Res. Board Can., Transl. Ser. 258.)

Construction of the Mingechaur Reservoir has drastically altered the hydrological conditions in the Kura River below the dam. Water temperatures were altered throughout the year; summer temperatures were cooler while winter temperatures were warmer. Water transparency has also increased. Dam construction blocked spawning migration of salmon and sturgeon. Spawning of other species was also affected. Overall numbers of fish species have been reduced. A fish rearing station is being constructed below the dam to compensate for fish losses caused by dam construction.

F Aggus, L. R., D. I. Morais, and R. F. Baker. 1979. Evaluation of the trout fishery in the tailwater of Bull Shoals Reservoir, Arkansas, 1971-73. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies. 31:565-573.

A seasonal boat fishery for rainbow trout (Salmo gairdneri) has developed in the Bull Shoals tailwater which in peak years provides more than 250,000 angler days of fishing and a catch of more than 750,000 trout. Use was concentrated along the upstream one-third (48.3 km) of the tailwater in 1971-73, where about 60 percent of the total fisherman effort and 50 percent of the total catch occurred.

Erratic patterns of water release strongly influenced fisherman use and harvest. During 1971 and 1972, years of below average water release, fishermen caught about 95 percent of the trout stocked. Sustained high water releases in 1973 were associated with marked reductions in angling effort and in numbers of fish caught. Regression equations are presented to describe relations between angling activity and patterns of water release over a wide range of flows.

F,I,W Anderson, D. 1975. Design and evaluation of method for utilizing hypolimnetic lake water to reduce outlet stream temperatures. Minn. Dep. Nat. Resour., Fed. Aid Proj. F-26-R. 33 pp. (Mimeogr.)

Structures designed and installed at the outlet of Grindstone Lake, a deep oligotrophic lake, in Pine County, Minnesota, to provide cold water from the lake depths to cool the outlet stream temperatures so they would be suitable for rainbow trout are described. Calculation procedure used to estimate potential flows from the structure are given.

The deepwater outlet was operated in the summers of 1970 and 1971. Water chemistry, pH, dissolved oxygen, water clarity, and temperature regime in the lake showed no significant changes as a result of the withdrawal of up to 0.12 m^3/sec of deep water.

The deepwater outflow achieved the predicted cooling effect on the stream. In the 2 years of operation, only slight changes in the distribution and density of bottom fauna and aquatic vegetation were recorded. Trout populations were established and maintained in the upper 1.6 km of stream during coldwater conditions but nearly disappeared in 1972 after return of normal conditions.

F,W Anderson, K. R. 1972. Report to the Federal Power Commission on the fish and wildlife aspects of the relicensing of the Potter Valley Hydroelectric Project (F.P.C. Project No. 77), Lake and Mendocino Counties, California. Calif. Dep. Fish. Game. 59 pp. (Mimeogr.)

The Scott Dam and Cape Horn Dam on the Eel River and Coyote Valley

Dam on the Russian River were examined in relation to their effects on fish. Regulated releases from Scott Dam provide a suitable nursery area for steelhead but have altered the downstream migration of smolts.

Reduced flows at Cape Horn Dam have inhibited migration of salmon and steelhead and have resulted in the stranding of some adults. The flushing of accumulated sediments from behind the dam has destroyed pool and riffle areas from 1.6 to 3.2 km downstream.

Flows from Coyote Valley Dam have helped maintain populations of smallmouth bass, catfish, and American shad in the mainstream of the Russian River. The single hypolimnial release has caused oxygen deficiencies directly below the dam and has extended the period of turbid flows in the main river.

F Arizona Game and Fish Department. 1972. Evaluation of trout stocking program below Davis Dam. Fed. Aid Proj. F-7-R-14. 18 pp. (Mimeogr.)

During 1971-1972 the trout management program on the Colorado River below Davis Dam was evaluated by conducting a creel census and analyzing tagging data.

A total of 208,170 trout were planted between Davis Dam and Needles, California. Fifteen thousand of the stocked trout were marked to determine percent return and downstream movement. Sixty-four percent were caught within 10 days following their stocking. Predation by striped bass on trout was highest within a few days after stocking. Few stocked fish remained in the area immediately below Davis Dam because of downstream movement.

F Armbruster, D. C. 1962. Observations on the loss of walleyes over and through Berlin Dam. Ohio Dep. Natur. Resour., Div. Wildl. Pub. W-64. 7 pp.

An estimated 19,000 walleyes were lost from the reservoir between March 1956 and April 1961. Most fish were 22.9 to 29.9 cm long. It was estimated that 42 percent of the fish lost were dead or would soon die, while 58 percent would survive in the waters below the dam. Most fish loss occurred between December and April when ice cover was present and rapid reductions in lake levels were made. Largest numbers of fish were lost over the spillway, but these fish survived the passage. A smaller number were lost through the sluice gates, but most were dead or soon died. In spite of losses of walleye from Berlin Reservoir, there has been rather consistent production within the reservoir and definite improved angling downstream.

I Armitage, P. D. 1976. A quantitative study of the invertebrate fauna of the River Tees below Cow Green Reservoir. Freshwater Biol. 6:229-240.

Monthly samples were taken in the River Tees below Cow Green Dam from four sites differing in flow conditions.

Of the 72 taxa found, 14 made up 95 percent of the total numbers. Hydra, Polycentropodidae, and the molluscs Limnaea peregra and Ancylus fluviatilis were the most abundant animals in the slower flowing water (10-26 cm s^{-1}), and Simuliidae, Orthocladiinae, and Baetis rhodani dominated the riffle (50-75 cm s^{-1}) fauna numerically. Some organisms, Nais spp., Caenis rivulorum, and Baetis scambus, favored intermediate flows of 20-60 cm s^{-1}. The slowest flowing water contained the largest number of taxa and the site with the fastest flow supported the least.

A mean monthly weight per square metre of 14.56 g (95 percent limits from 7 to 31) was calculated using data from all four sites.

It is suggested that the relative richness of the fauna in terms of biomass is attributable to the organic enrichment of the river following the building of the Cow Green Dam. The regulation of the flow has allowed the dense growth of algae and mosses and the development of large molluscan populations, and the reservoir itself provides a rich source of food, particularly zooplankton and phytoplankton, for the river benthos. (Taken from author summary.)

I Armitage, P. D. 1977. Invertebrate drift in the regulated River Tees, and unregulated tributary Maize Beck, below Cow Green dam. Freshwater Biol. 7:167-183.

A total of 95 taxa were recognized, of which 86 occurred in Maize Beck and 71 in the Tees. The Tees fauna was dominated numerically and in terms of biomass by a large population of microcrustaceans originating in the reservoir. Hydra and Naididae also formed a large proportion of the Tees drift but contributed little to the biomass. Emphemeroptera were most abundant in Maize Beck samples. Diptera were abundant in drift catches in both streams with simuliid larvae most numerous in Maize Beck and chironomid larvae most numerous in the Tees.

The greatest drift densities of the benthic fauna were observed between April and October; the mean number of organisms per 10 m^3 were 73 in Maize Beck and 144 in the Tees. The mean densities in winter were very low, respectively 2 and 17 per 10 m^3 in the two rivers. There was no significant difference between the mean levels of the total bottom fauna (numbers and biomass) in the drift in the two rivers during the period April-October, but winter biomass was significantly greater in the Tees.

In July 1970, microcrustaceans represented 29 percent (14 per 10 m^3) of total drift numbers and 3 percent (0.7 mg wet-weight per 10 m^3) of the biomass, whereas in 1973 they represented 99 percent of both the numbers (37,670 per 10 m^3) and weight (2.2 g wet-weight per 10 m^3).

In the drift Plecoptera and Baetidae were more abundant in Maize Beck than in the Tees. Only Chironomidae and Nais spp. were more abundant in the Tees. In the benthos the density of Plecoptera and Baetidae was not significantly different in the two rivers, but all other groups with the exception of Simuliidae occurred at greater densities in the Tees. The proportion of baetids present in the drift was greatest in Maize Beck.

Diel rhythms were observed in baetids and simuliids with densities greater in night catches. Nocturnal peaks of these organisms were less pronounced in the Tees. Chironomid larvae showed no diel changes in abundance. Significant diel changes in the mean weights of individual animals were not detected in baetid nymphs or chironomids. Microcrustaceans showed no nocturnal peaks of abundance.

In the Tees, the bulk of each sample consisted of algal filaments derived from the river and microcrustaceans from the reservoir. In Maize Beck, algae were uncommon and the sample was composed of peat and mineral particles. (Taken from author summary.)

I Armitage, P. D. 1978a. Downstream changes in the composition, numbers, and biomass of bottom fauna in the Tees below Cow Green Reservoir and in an unregulated tributary Maize Beck, in the first 5 years after impoundment. Hydrobiologia 58(2):145-156.

Changes in composition, numbers, and biomass of benthic fauna of the Tees below Cow Green Reservoir and an unregulated tributary Maize Beck were followed between 1972 and 1975 and pre- and post-impoundment conditions were compared. Species diversity was lowest just below the dam and numbers and biomass were highest 250 m downstream of the dam. Faunal densities increased in the Tees after impoundment, but in Maize Beck no major changes were observed.

I Armitage, P. D. 1978b. The impact of Cow Green Reservoir on invertebrate populations in the River Tees. Freshwater Biological Association, Annual Report. 46:47-57.

Microcrustaceans flushed from the reservoir dominated the tailwater drift; numbers were progressively fewer downstream. The microcrustacean and sestonic components probably provided a more rapidly available source of energy and protein below the dam than that normally present in unregulated streams. Benthic diversity was lowest at the site nearest the dam. Downstream values were similar to those in unregulated streams.

I Armitage, P. D. and M. H. Capper. 1976. The numbers, biomass, and transport downstream of microcrustaceans and Hydra from Cow Green Reservoir (Upper Teesdale). Freshwater Biol. 6:425-432.

Fluctuations in numbers and biomass of Copepoda, Cladocera, and Hydra drifting out of the Cow Green Reservoir via the outflow were investigated during the period August 1972-November 1973. Cladocera, chiefly Daphnia hyalina var. lacustris Sars and Copepoda, were most abundant between July and September, occurring at mean densities of 1,278 and 215 m^{-3}, respectively. Hydra was most abundant between August and October at a mean density of 19 m^{-3}. Winter densities of all groups were low and 98 percent of the total annual output occurred between July and October. An estimated 150-kg (136 kg of Cladocera, 13 kg of Copepoda, and 1 kg of Hydra) dry weight was released from the reservoir during the year November 1972-October 1973. During periods of peak abundance about 1-2 percent of the total fauna drifting out of the reservoir was found 6.5 km below the dam. The effect of reservoir discharge and flow in tributaries of the Tees on this transport downstream is discussed. It is suggested that the microcrustaceans and Hydra, even if not fed upon directly, will have considerable influence on the Tees benthos when they settle out and decompose to produce a nutrient-rich detritus. (Author abstract.)

F Axon, J. R. 1975. Review of coldwater fish management in tailwaters. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 28:351-355.

A trend in the stocking procedure of trout in tailwaters has developed as an outcome of increasing fishing pressure. Fingerling stocking of trout was initially recommended in tailwaters where an adequate food supply was available, and predation by predatory fish was not considered a problem. Eventually fishing pressure increased and the fingerling trout were harvested before reaching a desirable size necessary to maintain a quality put-grow-take fishery. Consequently, stocking of larger catchable-size trout was resorted to, this procedure resulted in a quality put-and-take fishery. Several basic concepts pertaining to the development of trout fisheries in tailwaters were conceived after intensive investigation. The fishing pressure and harvest must first be known in order to stock trout at a proper rate and at the proper time to sustain a quality fishery. One technique that has had a great impact on the harvest in tailwaters that are relatively inaccessible to bank and wading anglers is the development of boat fishing. The major problem of most tailwater trout fisheries is that of erratic flow; a more sustained flow would provide better fishing conditions, alleviate periods of low dissolved-oxygen levels and elevated water temperatures that are detrimental to trout, and prevent periods of high flow that can retard bottom fauna productivity and consequent trout growth. (Author abstract.)

F Bacon, E. J., Jr., S. H. Newton, R. V. Kilambi, and C. E. Hoffman. 1969. Changes in the ichthyofauna in the Beaver Reservoir tailwaters. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 22:245-248.

Collections of the fishes in the tailwaters of Beaver Reservoir were made during the spring and summer of 1968. The present study is a continuation of an investigation designed to follow the development of the ichthyofauna in the cold tailwaters below Beaver Dam, Arkansas. A total of 527 fishes representing 21 species, 12 genera, and 7 families have been identified. Eight species collected in 1968 were not reported in earlier collections taken in 1965 and 1966, and 7 species reported earlier were not collected in this study. Campostoma anomalum was still the most abundant cyprinid and darters were also abundant. More species of centrarchids were collected than previously reported. Both Salmo trutta and Salmo gairdneri are now present in the tailwaters of Beaver Dam.

F Baker, R. F. 1959. Historical review of the Bull Shoals Dam and Norfolk Dam tailwater trout fishery. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 13:229-236.

Beginning with a stocking of 600 four- to six-inch (10.2-15.2 cm) rainbow trout in 1948 in the Norfork Dam tailwater located in North Central Arkansas, a fishery soon developed which was entirely new to the area.

With the completion of Bull Shoals Dam in 1952, investigations began which soon showed that the native fishery was destroyed for many miles below the high dams. A trout stocking program carried on in conjunction with an investigational project produced such excellent trout fishing that the area became nationally famous within a few years, and a modern trout hatchery was constructed just below Norfork Dam by the U. S. Fish and Wildlife Service for the purpose of producing trout for stocking the White River and its tributaries. By 1957, trout were being stocked in 91 miles of tailwater streams which supported 47,792 man-days of fishing generating $684,732.00 worth of business to the fishing service operators alone. (Author abstract.)

F Ball, K. and S. Pettit. 1974. Evaluations of game and rough fish populations below Dworshak Dam and relationship to changes in water quality. Idaho Fish Game Dep., Dworshak Fish. Studies, Proj. DSS-29-4. pp. 20-62. (Mimeogr.)

A creel census was conducted in the Clearwater River in the vicinity of Dworshak Dam to evaluate changes in the fish population in relation to changes in water quality. Coldwater releases from the reservoir and removal of a dam at Lewiston resulted in a decrease in the smallmouth bass population. Steelhead and rainbow trout populations have increased mainly as a result of hatchery stocking. Oxygen-poor water was released from the multilevel outlet gates at Dworshak Dam during July and August.

F Banks, R. L., J. W. Mullan, R. W. Wiley, and D. J. Dufek. 1974. The Fontenelle Green River trout fisheries - considerations in its enhancement, including test flow studies of 1973. U. S. Fish Wildl. Serv., Salt Lake City Area Office. 74 pp. (Mimeogr.)

The study was conducted on the Green River between Fontenelle Dam and Flaming Gorge Reservoir, Wyoming, to evaluate the impact of reduced flows on fish and wildlife and to formulate an optimum flow regime. Information is presented to explain ways in which the trout population is regulated under different stream conditions.

During the summer and fall of 1973, a series of in-stream measurements were taken at four representative stations at flows of 45.3, 22.6, 14.2, and 8.5 m^3/sec. Aerial photos were taken of the entire river at each flow to supplement in-stream measurements. The hydraulic parameter most severely reduced by flow reduction was volume, followed by velocity, transect cross-section area, and transect depth. Least affected were surface width and total wetted surface area.

Specific depth-velocity criteria considered to be optimum for food production, shelter, and potential spawning flow relationships for trout were delineated. Total surface area of water available at each flow to provide these specific habitat requirements was determined. Of the four flows studied, 22.6 m^3/sec appeared to provide the most balanced habitat diversity in meeting most production and survival needs for all sizes of trout.

To perpetuate the existing fisheries resource, a winter (November through March) survival flow of 14.2 m^3/sec was recommended and, if necessary, an emergency short-term (30 days) winter survival flow of 8.5 m^3/sec; a minimum production flow of 22.6 m^3/sec (April through October); and when necessary, a sediment flushing or habitat maintenance flow of 22.6 to 45.3 m^3/sec. Such a flow regime is compatible with fishability and floatability of the stream and with most wildlife-related water requirements.

F Barannikova, I. A. 1962. An analysis of the effect of the Narvskaya Hydroelectric station on the ichthyofauna of the Narova River. Sci. Proc. Leningrad State Univ., imeni A.A. Vhdanov. Biol. Sci. Ser. 311(48):109-125.

The Narvskaya tailwater (Narova River) fishery has declined since the construction of a hydroelectric station. Daily water level fluctuations of 1.5 to 2.0 m and increased water velocity have adversely affected lamprey, eel, vimba, and pike reproduction. The station has inundated Baltic salmon spawning grounds and increased competition between salmon and other species (vimba and roach). Desirable species have been replaced by perch and roach. Fish food organisms (Gammarus, chironomids, opossum shrimp) were also reduced.

F,I,W Bauer, B. H. 1976. The effects of the Cordell Hull impoundment on the tailwaters of Dale Hollow Reservoir. Tenn. Wildl. Resour. Agency, Tech. Rep. 52. 82 pp.

The impoundment of Cordell Hull Reservoir has backed water within 4.8 km of the Dale Hollow Dam, thus impounding over half of the tailwater at full pool. The objective of this study was to determine the effects of the Cordell Hull Reservoir on the trout fishery of Dale Hollow tailwater. Previous to the construction of Cordell Hull, the trout fishery was maintained by stocking fingerling and subadult rainbow trout (Salmo gairdneri). Rough and predatory fish have increased in the Dale Hollow tailwaters and are in direct competition with the stocked trout for food and space; the predators prey heavily on the stocked trout.

The benthic fauna of the tailwater is depauperate and does not contribute significantly to the diet of the stocked trout. Water quality of the tailwater is suitable for trout survival with the possible exception of turbidity levels found at the lower end of the tailwater at its junction with Cordell Hull Reservoir.

The most detrimental effect that the impoundment of the Cordell Hull Reservoir has had on the trout fishery of the Dale Hollow tailwater has been an increase in water levels. This increase has resulted in a loss of large shallow areas thus decreasing productive shallow riffles. To decrease predation it is recommended that trout not be stocked in the tailwater at less than 25.4 cm total length.

F,I,W Baxter, R. M. 1977. Environmental effects of dams and impoundments. An. Rev. Ecol. Syst. 8:255-283.

This article is a literature review and only the effects of reservoirs on their tailwaters are summarized here. The complex flow pattern in many reservoirs has an important influence on downstream water temperatures. In reservoirs with hypolimnial releases, stream temperatures were cooler in the summer and warmer in the winter than before the dam was built. Cold downstream temperatures can reduce stream bottom fauna abundance. Variations in volume of downstream releases are destructive to benthic organisms and cause considerable reduction in diversity. Cooling of a stream may make it habitable to trout, but cold temperatures and variations in flow may limit food supply. Waters below dams may be supersaturated with gases and cause gas-bubble disease which can be fatal to fish. Dams create serious obstacles to the upstream and downstream movements of anadromous fish.

F,W Baxter, R. M. and P. Glaude. 1980. Environmental effects of dams and impoundments in Canada: experience and prospects. Can. Bull. Fish. Aquat. Sci. 205. 34 pp.

Although dams and reservoirs have contributed immeasurably to the well-being of Canadians, they may have side effects which may be detrimental to the environment and to human welfare. In this Bulletin, the authors survey the environmental consequences that have ensued from dam construction and the impoundment of water in Canada in the past, and attempt to alert environmentalists and engineers to the types of problems that may be associated with such activities in the future.

Some of these effects are immediate, direct, and obvious, such as the loss of resources by flooding, interference with the passage of fish, and environmental damage and pollution as a result of construction activities. Others may manifest themselves only over a period of time, such as changes in water chemistry and modification of the new shoreline. This last is likely to be of particular importance in reservoirs on permafrost. Large impoundments may influence the climate in their vicinities and sometimes induce earthquakes. Still other consequences follow from the mode of operation of the reservoir. Low-level discharge through turbines may radically alter the temperature regime in the stream below. The induction of an unnatural seasonal pattern of water level fluctuation may lead to the formation of a virtually barren drawdown zone around the reservoir, and induce geographical and ecological changes downstream, sometimes at great distances.

Many of these effects act in various and sometimes opposing ways on the living organisms in the reservoir and the stream so that the ultimate biological consequences often cannot be confidently predicted.

It is sometimes difficult to reconcile the interests of those who stand to benefit from a given project and the interests of others who are likely to suffer a loss from it. This conflict is particularly acute when the project affects communities of native peoples following a traditional way of life. Such fragile societies are likely to be gravely disrupted unless particular care is taken. (Author abstract.)

F,W Beiningen, K. T. and W. J. Ebel. 1970. Effect of John Day Dam on dissolved nitrogen concentrations and salmon in the Columbia River, 1968. Trans. Am. Fish. Soc. 99(4):664-671.

Concentrations of dissolved nitrogen gas were measured in the lower 640 km of the Columbia River from April to September 1968 to determine the effect of newly constructed John Day Dam on nitrogen saturation downstream. Observations were also made of symptoms of gas-bubble disease and mortality in juvenile and adult salmon.

Heavy spillway discharge at the dam caused abnormally high (123-143 percent) supersaturation downstream, and mortalities of juvenile and adult salmon (Oncorhynchus spp.) and steelhead trout (Salmo gairdneri) were substantial. Delays in passage at John Day and the Dalles Dams coupled with supersaturation of nitrogen gas caused the mortalities.

The authors recommended that in future dam construction one or more turbines should be operable before the reservoir is filled. Increasing the flow through the turbines while decreasing flow over the spillways will reduce concentrations of nitrogen. In addition, every possible effort should be made to reduce the delay of salmon passing over dams. (Author abstract.)

F Bishop, K. A. and J. D. Bell. 1978. Observations on the fish fauna below Tallowa Dam (Shoalhaven River, New South Wales) during river flow stoppages. Aust. J. Mar. Freshwater Res. 29:543-549.

Some observations on the consequences of construction work at Tallowa Dam (Shoalhaven River, New South Wales) on the fish fauna below the dam are described. In total, 17 species of freshwater fish were collected on four occasions between 29 November and 22 December 1976 when water flow was terminated for short periods below the dam wall. Large numbers of individuals belonging to several fish species died on each occasion, including 312 Australian grayling, Prototroctes maraena (an "endangered" species), on 29 November. It is suggested that water resources authorities should give careful consideration to the ecological effects of constructing and maintaining impoundments on downstream fish communities. (Author abstract.)

I Blanz, R. E., C. E. Hoffman, R. V. Kilambi, and C. R. Liston. 1970. Benthic macroinvertebrates in cold tailwaters and natural streams in the state of Arkansas. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 23:281-292.

Dominant macroinvertebrates in established tailwaters were Isopoda, Amphipoda, Chironomidae, and Oligochaeta. As reservoir tailwaters aged, chironomids became more abundant. Isopods increased in abundance at the stations nearest the dam. Higher forms of aquatic vegetation were scarce, but in some areas filamentous green and blue-green algae were relatively abundant.

Samples from stations nearest the dam yielded lower numbers than those from stations downstream. The fauna below a reservoir would eventually stabilize when flows and substrates become more consistent.

F Boehmer, R. J. 1973. Ages, lengths, and weights of paddlefish caught in Gavins Point Dam tailwaters, Nebraska. Proc. S. D. Acad. Sci. 52:140-146.

Age, length, and weight were determined for 57 paddlefish (Polyodon spathula) taken from the tailwaters of Gavins Point Dam. This information was compared with similar data collected from fish taken from Big Bend Dam tailwaters in South Dakota.

F Boles, H. D. 1969. Little Tennessee River investigations. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 22:321-338.

A cooperative fishery survey of the lower 53 km of the Little Tennessee River, a tailwater environment, was made using an unequal probability sampling creel census and limited population sampling.

From June 1964 to June 1965, 29,349 anglers caught 64,714 fish at a rate of 0.75 fish per angler-hour, or 2.2 fish per angler-day. Of all anglers, 56 percent were successful, 91 percent lived within 64.4 km of the stream, and the average expense per trip was $2.41. The catch was 70.5 percent trout, 16.3 percent sauger, and 13.2 percent other species. All trout and 83 percent of all fish were caught in the upper half (22.5 km) of the river. The catch in the lower half was 80 percent sauger.

Various sizes and species of marked trout were stocked at different times to determine best management methods. Returns from catchable-sized brown trout were slow but extended. Catchable rainbow returns ranged from 78 to 96 percent. Early spring stocking gave best distribution of fish to more anglers. Summer stocking gave the highest, most rapid returns. Later stocking resulted in inefficient harvesting. Returns from all groups of catchable rainbows were too rapid to realize significant growth. Brown trout growth was apparently no better than rainbow.

Fingerling trout stocked in early spring gave better survival and growth than fingerlings stocked later, which apparently suffered severe predation by other fish species.

I Briggs, J. C. 1950. The quantitative effects of a dam upon the bottom fauna of a small California stream. Trans. Am. Fish. Soc. 78:70-81.

The effect of a dam upon the bottom-fauna production of Stevens Creek was tested for a 9-month period. The function of this dam being to catch floodwaters and subsequently release them gradually, it has reduced the variations in water flow of the rainy season and has brought about a marked change in the physical appearance of the streambed below the dam.

Production of bottom organisms, both in number and weight, was much greater in the area below the dam than above. A sharp, spring peak of production occurred on March 1 in both of the sampling areas. The period of minimum production coincided with the periods of greatest fluctuations in flow and lowest water temperatures. The greatest extremes of flow and temperature took place above the dam. The population above the dam fell to a much lower point during the period of minimum production than did the population below the dam.

Three types of aquatic insect larvae formed 81.3 percent of the total number of organisms taken. Caddicefly larvae contributed 45.1 percent, mayfly larvae 25.8 percent, and stonefly larvae 10.4 percent. The caddicefly larvae alone accounted for most of the increased faunal production below the dam. The mayfly larvae showed remarkable resistance to the floods and lower temperatures above the dam and were taken in much greater numbers in this area.

The numbers and weights of animals taken from the riffle areas greatly exceeded the numbers and weights from the pool areas. Pool organisms were somewhat protected from flooding but were exposed to the same temperature conditions that affected the riffle areas. Low winter temperatures did not result in a marked reduction of organisms in this habitat. (Author abstract.)

I Brook, A. J. and W. B. Woodward. 1956. Some observations of the effects on water inflow and outflow on the plankton of small lakes. J. Anim. Ecol. 25:22-35.

Many lakes are actually parts of river or stream systems where the flow is temporarily impeded. The rate of movement of the water through the lake may be the most important factor limiting zooplankton densities. The quantity of plankton present in flowing water systems is inversely related to current speed.

The presence of zooplankton was noted for relatively short periods of the year and was associated with slow movement of water through the lake system. Rapid rates of flow through the system adversely affected zooplankton densities contained therein. Effects of spates on open-water plankton was devastating, and replenishment of these open-water populations was initiated from the protected areas. The rheotactic responses of large zooplankton species enable them to resist the draw of some outflows.

It is very likely that rapidly reproducing species or species with relatively low nutritional requirements are the only ones capable of succeeding in lakes with fast flow-through rates. Otherwise, an abbreviated planktonic community would be found in fast flow-through systems.

I Brooker, M. P. and R. J. Hemsworth. 1978. The effect of the release of an artificial discharge of water on invertebrate drift in the R. Wye, Wales. Hydrobiologia. 59(3):155-163.

An artificial discharge of water (3.0 m^3/sec), over a 48-hr period, from an impoundment into the R. Wye did not substantially affect water temperature or concentrations of dissolved oxygen and suspended solids at a site 16 km below the impoundment. However, the load of suspended material on the second day of the release was about 10 times greater than the prerelease load. The total number of drifting macroinvertebrates on the first and second days of the release were about 7 and 3 times greater than the number of the day preceding the release. The initial increase in flow at 1500 hr resulted in an immediate increase in the number of drifting larvae of Rheotanytarsus, a tubicolous chironomid. Subsequently, there was an enhanced nighttime increase in the total number of drifting invertebrates, particularly the mayfly, Ephemerella ignita (Poda), and this also occurred on the second night of the release. Increases in the number of drifting Rheotanytarsus and Ephemerella, the most abundant invertebrates, resulted in increases in drift density. (Author abstract.)

F Brown, J. D. 1967. A study of the fishes of the tailwaters of three impoundments in northern Arkansas. M. S. thesis. Univ. Ark., Fayetteville. 45 pp.

The fish populations of Beaver, Bull Shoals, and Norfork tailwaters (White River) were studied and compared to the fauna of the Buffalo River, Arkansas. The coldwater releases from all three dams have reduced the number of species (particularly cyprinids) found below the dams. Mottled sculpins were common in the Bull Shoals and Norfork tailwaters but rare in the warmwater tributary, the Buffalo River. In the Norfork tailwaters, redhorse, hogsuckers, green sunfish, longear sunfish, and bluegills have all disappeared from collections. Madtoms, silversides, and longear sunfish were common in the Buffalo River but rare in the tailwaters. The cold temperatures on the three tailwaters appear to be the chief factor for the differing species composition of the Buffalo River versus the cold tailwaters.

F,I,W Brown, J. D., C. R. Liston, and R. W. Dennie. 1968. Some physicochemical and biological aspects of three cold tailwaters in northern Arkansas. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 21:369-381.

Physicochemical factors, plankton, benthic macroinvertebrates, and fishes occurring in cold tailwaters below Beaver, Bull Shoals, and Norfork Dams in northern Arkansas were sampled regularly from July 1965 through December 1966.

Physicochemical conditions were similar in the three tailwaters throughout the study. The older tailwaters below Bull Shoals and Norfork Dams were more productive than the Beaver tailwater in both phytoplankton and zooplankton. The greatest number of genera of plankton occurred in the Beaver tailwater, and the Bull Shoals tailwater had the least number.

The majority of the benthic macroinvertebrates were comprised of only a few taxa. Samples from the Norfork tailwater contained more organisms and a higher average wet weight per square foot than did samples from the other two localities. Tendipedidae and Oligochaeta made up 91.0 percent of the total number of benthic macroinvertebrates in the Beaver tailwater; Tendipedidae and Amphipoda comprised 70.1 percent in the Bull Shoals tailwater. Isopoda and Tendipedidae accounted for 87.9 percent in the Norfork tailwater.

Lists of fishes for the three tailwaters include 38 species. Five of these (Campostoma anomalum, Notropis galacturus, Notropis pilsbryi, Etheostoma caeruleum, and Cottus carolinae) were common to all three tailwaters. Cyprinids and sculpins were abundant below Bull Shoals and Norfork Dams. The ichthyofauna below Beaver Dam exhibited a scarcity of cyprinids, with the exception of Campostoma anomalum, and an abundance of darters. Sculpins were rare below Beaver Dam. (Author abstract.)

I Brusven, M. A., R. C. Biggam, and K. D. Black. 1976. Ecological strategies for assessing impact of water fluctuations on fish-food organisms. Natl. Mar. Fish. Serv., Contract No. 03-4-208-243, Univ. Idaho, Moscow. 69 pp.

Fluctuating water levels caused by hydroelectric releases may be more devastating to the benthic community than normal seasonal fluctuations because they are usually of much shorter duration. Stoneflies, caddisflies, and mayflies do not readily colonize shore areas that are constantly in a state of fluctuation and chironomids are usually the principal inhabitants of these areas. Each species of insect has specific levels of adaptation and resiliency to adverse environmental disturbances. In addition, communities of insects are dynamic and complicated life cycles are involved with various life stages which react differently to changing conditions. Drift is a reflection of the magnitude of the stream insect's reaction to environmental disturbances.

F,I Brusven, M. A. and C. MacPhee. 1976. The effect of river fluctuations resulting from hydroelectric peaking on selected aquatic invertebrates and fish. Tech. Completion Rept., Proj. A-035-IDA, Idaho Water Resour. Res. Inst., Univ. Idaho, Moscow. 46 pp.

Diel changes in discharge caused by hydroelectric peaking directly affect water levels and velocities and indirectly alter benthos and fish abundance and distribution. The effect of discharge on aquatic insect populations below Dworshak Dam on the Clearwater River, Idaho, was measured during different peaking regimes. The benthic insect community below Dworshak Dam remained relatively stable during and after the filling of Dworshak Dam, but shorelines experiencing daily fluctuations are not readily colonized by stoneflies, mayflies, and caddisflies; chironomid midges are the most resilient stranded insects in these unstable areas and the first ones to recolonize the flooded areas. The insects collectively reflected an obvious diel drift pattern with largest numbers drifting at night. Samples selected from three depths (15, 30, and 45 cm) yielded the largest numbers of insects at the 45-cm depth. When converting numbers of drifting insects to a volume-flow relationship, largest numbers of insects were captured at the 15-cm depth. Sampling at depths of 1 and 2 m revealed no major differences in the insect community at these depths. A total of 98 species from eight orders of insects were recorded from the Clearwater River.

Flows in a diversion channel (3.5 m in width) on the South Fork of the Salmon River were manipulated to experimentally simulate flow fluctuations below a power dam. An upstream section (20 m in length) tested insects; a downstream section (60 m in length) tested fish at 24-hour sequences of 57, 17, 3, and 51 ℓ/sec. Analysis of vertical distribution of insects in the controlled flow channel indicated that the insects did not generally seek greater interstitial depths during dewatering and that many of the insects had become displaced via drift during the dewatering cycle. Stepwise reduction of discharge caused corresponding reductions in the number of chinook salmon (Oncorhynchus tshawytscha). The carrying capacity of the channel was 250 percent greater in the summer when salmon were smaller (<59 mm) and stream temperatures were higher (8-17°C) than in the fall when fish were larger (95-102 mm) and temperatures lower (4-15°C). Although the summer and fall carrying capacities differed, the proportion of fish remaining in the channel after each reduction in flow was about the same. The number of chinook in an experimental laboratory flume also changed directly with variation in the rate of flow. These findings corroborated with those for the diversion channel. Extreme reductions in flow significantly increased the amount of insect drift and the rate of ingestion by salmon in the diversion channel. (Author abstract.)

I Brusven, M. A., C. MacPhee, and R. Biggam. 1974. Effects of water fluctuations on benthic insects. Pages 67-69 in Anatomy of a River. Pacific Northwest River Basins Commission Report, Vancouver, Washington.

Most insects, except for chironomids, were found in areas that did not experience daily water levels fluctuations. Drift served as a means of survival of insects experiencing shoreline dewatering. Cool air temperatures allowed insects to survive dewatering for longer periods than hot temperatures. Chironomidae, Trichoptera, and Lepidoptera had a high survival rate during the first 48 hours of dewatering. However, higher air temperatures and longer exposure periods resulted in increased mortality. Mayflies and insect egg stages appeared to be the most sensitive to dewatering. Vegetative mats, if present, act as a refuge for dewatered insects because of the natural retention of moisture. Insects which reside near the "mat-rock" interface (chironomids) had higher survival rates than those which lived on or near the surfaces of Cladophora mats (mayflies). If this study had been completed during the summer months, rather than March, a higher insect mortality probably would have been found.

I Brusven, M. A. and E. F. Trihey. 1978. Interacting effects of minimum flow and fluctuating shorelines on benthic stream insects. Tech. Completion Rep. No. A-052-IDA, Idaho Water Resour. Res. Inst., Univ. Idaho, Moscow. 78 pp.

A 50-mile (80-km) reach of the Clearwater River, Idaho, was studied from its confluence with the Snake River upstream to Orofino, Idaho. The study examined two important changes in river: (1) effects of hydropower releases from Dworshak Dam on the aquatic insect community in the free flowing reach of the Clearwater River, and (2) backwater effects of Lower Granite Dam on benthos in the lower 5 miles (8 km) of the Clearwater River.

As a result of the operational mode of Dworshak Dam, late summer and fall flows are greater than during the preproject era. Although hydropower releases cause frequent and marked fluctuations in discharge, there is a stable postproject low flow. This higher rate summer flow guarantees the submergence of additional substrate, thereby increasing macrobenthic habitat.

Over 120 species of aquatic insects exclusive of Chironomidae have been collected from the Clearwater River. While small to moderate shifts in seasonal densities of principal species have occurred between intensive study sites above and below the influence of Dworshak Dam, present evidence does not indicate these shifts are attributable to hydropower releases. Approximately one month was required for sterile rocks to support a standing crop similar to that of continually watered rocks. In most instances, numbers of species and densities increased with increasing depths of 15, 30, and 45 cm. Numbers of drifting insects were greatest during the night. Drift rates and standing crop relationships above and below the influence of Dworshak Dam suggest insects drifted more in response to daily fluctuations than to the factor of bottom density.

Within the lower 5 miles (8 km) of the Clearwater River, variable backwater effects of Lower Granite Reservoir have a far more pronounced effect on the amount of potential benthic habitat available than do releases from Dworshak Dam. Formation of Lower Granite Reservoir has resulted in insect community shifts from a riverine to a lentic community as a result of physical changes in water depth, velocity, and substrate with dipteran midges the dominant insect group.

F Burkhard, W. T. 1977. Taylor River flow investigations. Colo. Div. Wildl., Fed. Aid Proj. F-51-R. 49 pp. (Mimeogr.)

The Taylor River tributary of the Gunnison River was selected to study the effects of streamflow patterns on the downstream fishery. Streamflows have been regulated by Taylor Park Dam since 1937. The release pattern has been fairly constant for the past several years. Using this release pattern as a base flow for study, a biological and physical inventory was conducted on the river between 1973 and 1975. A creel census, population estimates, and age and length frequency structure of the natural brown trout population were determined. Additional data were obtained on hydrology, temperature, water quality, and invertebrates, as well as general information on the area. An altered flow-release pattern from Taylor Dam which will simulate that of an uncontrolled river will be carried out for a minimum of 5 years. It was recommended that the survey presented in this report be duplicated during the last 3 years to determine if there are any differences in the fish populations that can be attributed to the change in streamflow.

F Butler, D. W. 1973. Evaluation of a catchable trout fishery. Tex. Parks Wildl. Dep., Fed. Aid Proj. F-2-R-19. 20 pp. (Mimeogr.)

Catchable rainbow trout, Salmo gairdneri, were stocked in the Guadalupe River below Canyon Reservoir during March 1966, when it was established that the deep discharge from Canyon Reservoir might provide suitable habitat. Creel census indicated a return of 59 percent of the 6,000 rainbow trout stocked during the 7-month period following the stocking. Studies indicated that the tailrace waters would provide suitable conditions for trout during most years unless severe drought conditions existed. Catchable rainbow trout have been stocked in the fishery every spring and fall at a rate of approximately 9,000 per year. Over 60,000 have been stocked since the program began. The program has proven to be a great boost to the economy of the area and increased the fishermen utilization of the river over 2,000 percent.

F Carter, E. R. 1955a. Harvest and movement of game fishes in Kentucky Lake and its tailwaters. Ky. Dep. Fish Wildl. Resour., Fish. Bull. 15. 14 pp.

During tagging studies on Kentucky Lake, 2,170 fishes of seven species were netted, tagged, and released. One hundred forty-two fishes of four species (largemouth bass, yellow bass, white crappies, and black crappies) were recaptured by fishermen. Largemouth bass were retaken in greater relative numbers than other species.

Fifty-six fish, or 39.4 percent of the fishes recaptured, moved less than 0.8 km from the point of release and 64.8 percent moved less than 1.6 km. The 50 tagged fish moving more than 1.6 km averaged 8.2 km per fish. Five fish, all white crappies, moved downstream at least 11 km and passed through the lock chambers of Kentucky Dam. The greatest distance traveled by any fish tagged in the lake was that of a yellow bass that was recovered 47.2 km up the lake from the release point.

In the Tennessee River tailwaters of Kentucky Lake, 5,125 fish of nine species were collected, tagged, and released. One hundred forty-four fish of six species (Kentucky bass, white bass, yellow bass, saugers, white crappies, and black crappies) were recaptured. A greater percentage of Kentucky bass was recaptured than any other fish.

Eighty-two recaptures moved less than 0.8 km from the point of release, while 115 fish moved less than 1.6 km. The 29 fishes moving more than 1.6 km averaged 27.5 km per fish. Most extensive movement was noted for a sauger which moved 112.7 km from the release point. One white bass traveled 107.9 km.

Eleven fishes, 7.6 percent of the total number recovered, went upstream through the lock chambers of Kentucky Dam.

F Carter, E. R. 1955b. Growth rates of the white crappie <u>Pomoxis annularis</u> in the Tennessee River. Ky. Dep. Fish Wildl. Resour., Fish. Bull. 17. 5 pp.

A study of 237 scale samples procured from fishermen's creels revealed that white crappies had an average length of 8.6 cm their first year of life, 16.5 cm the second year, 22.6 cm the third, 26.4 cm the fourth, and 30.2 cm the fifth year.

Comparing the growth of white crappies in Kentucky Lake tailwater and Kentucky Lake proper, it was found that lake fishes grew approximately 2.54 cm more the first year than the tailwater fish, and this advantage was retained throughout life.

F,W Carter, J. P. 1968. Temperature control of reservoir releases in Nolin and Barren tailwaters. Ky. Dep. Fish Wildl. Resour., Fish. Bull. 49. 28 pp.

Investigations were conducted to evaluate success in controlling tailwater temperatures through the utilization of multilevel releases, to determine the fish population composition, and to measure fishing intensity, creel composition, and fishing success on the tailwater.

The U. S. Army Corps of Engineers attempted to duplicate preimpoundment temperatures in the tailwaters during the period April through August of 1965 and 1966.

Mean monthly tailwater temperatures during the months of April, May, June, and July ranged from 2 to 4 degrees below the scheduled mean, whereas in August the scheduled mean was achieved.

Electrofishing studies revealed that substantial numbers of fishes emigrated from the reservoir into the tailwaters. Species dominance in the section immediately below the dams fluctuated with the reservoir regulation period. During the seasonal pool period in the summer, game fishes and panfishes were most abundant; after drawdown in the fall, threadfin shad was the dominant species; and prior to the seasonal pool period in early spring, carp was the dominant species.

The annual fishing effort ranged from 4,353 fisherman hours on Nolin tailwater (3,840 man-hours/ha) to 21,002 fisherman hours (12,059 man-hours/ha) on Barren tailwater. The catch rate fluctuated from a low of 0.33 fish per hour at Barren to a high of 1.47 fish per hour at Nolin. The estimated annual harvest ranged from 3,386 fishes at Nolin to 15,852 fishes at Barren. At Nolin the creel was numerically dominated by crappies the third year of impoundment and sunfishes the fourth year. At Barren the creel was numerically dominated by suckers, carp, and crappies, respectively, during the first 3 years of impoundment.

F,W Carter, W. R., III. 1968. Ecological study of Susquehanna River and tributaries below Conowingo Dam. Md. Dep. Natur. Resour. Anadromous Fish Program AFSC-1. 30 pp. (Mimeogr.)

Below Conowingo hydroelectric dam on the Susquehanna River, Maryland, clupeids move into the tailrace in such abundance that dissolved oxygen (D.O.) can drop to lethal levels if turbines are shut off. If a minimum release of 141.6 m^3/sec is allowed from each of two turbines, the D.O. in the tailwaters can be maintained in the 5- to 6-mg/ℓ range. In 1968 this management technique avoided any clupeid die-off.

F,W Cashner, R. C. 1967. A survey of the fishes of the cold tailwaters of the White River in northwestern Arkansas; and a comparison of the White River with selected warm water streams. M. S. thesis, Univ. Ark., Fayetteville. 143 pp.

The fish populations in the cold tailwaters of Bull Shoals, Beaver, and Norfork Dams were compared with the warmwater Kings, Buffalo, and Black Rivers. The number of species was additive as one moved downstream except in Bull Shoals tailwater where only seven species were found compared to 18 and 29 in Norfork and

Beaver tailwaters. Cold tailwaters had fewer cyprinid and centrarchid species.

The confluence of the cold White River and the warm Buffalo River presents a complex ecological system with 50 species present.

Riffle species were percids, cottids, catostomids, and some cyprinids. Pools contained centrarchids and cyprinids. Main channel habitat contained large catostomids, clupeids, salmonids, and gar.

F Cavender, T. M. and R. L. Crunkilton. 1977. Impact of a mainstream impoundment on the fish fauna of Big Walnut Creek, a Scioto River tributary in central Ohio. Water Resources Center, Ohio State Univ., Columbus. 191 pp.

Hoover Reservoir changed the composition and distribution of fishes in Big Walnut Creek. Resultant changes created by the reservoir were inundation of the stream channel, prevention of migration, and alteration in water velocity, substrate turbidity, temperature, and dissolved oxygen. These alterations affect species by changing the stream's ecology.

Reduction of water temperature in the tailwater area affected the reproduction of 22 species that normally migrate to spawn. Reduced turbidities in the tailwater allowed two species of turbidity-intolerant fish to become established.

It was found that species diversity remained unchanged in stream sections above and below the reservoir but the qualitative makeup of the fish fauna had changed. Approximately 18 percent of the total fish fauna were lost from the drainage.

F,I,W Charles, J. R. and W. N. McLemore. 1973. Reservoir discharge investigation at Barren River and Nolin River Reservoirs. Ky. Dep. Fish Wildl. Resour. Fish. Bull. 59 (Part 1). 94 pp.

The effects of epilimnial versus hypolimnial discharge regimens on water quality, benthos, fish populations, and sport fisheries of two south-central Kentucky flood-control reservoirs, and their respective tailwaters, were compared over a 4-year period (1968-1971).

The relationships between discharge outlet location and dissolved oxygen distribution at both reservoirs was obscured by hydrological events and inadequate epilimnial discharge facilities at each reservoir. Substantial supplemental discharge was required from the floodgates (hypolimnion) to maintain seasonal pool elevations during 1 year of the 2-year cycle scheduled for epilimnial discharge at both reservoirs. Hydrological factors, such as rainfall and patterns of inflow, appeared to influence dissolved oxygen content and distribution more than did discharge location. Findings indicate that hypolimnial discharge regimens tend to augment the vertical distribution of dissolved oxygen in reservoirs that are subject to frequent and extensive summer precipitation.

Dipterans and Oligochaeta were the most abundant macroinvertebrates in both reservoirs. Benthic organisms generally were most abundant at the 4.6-m depths and least abundant at the 12.2-m depths. They were more abundant during the late summer than during the early summer. The upper and mid-reservoir stations were more productive than the lower main pool. Reservoir discharge regime had no discernible effect on the abundance or distribution of benthos in either reservoir.

No differences in either fish population composition or fish biomass attributable to discharge regime were found at either reservoir. Discharge regime had no discernible effect on reservoir sport fishing success.

It was recommended that: (1) since no adverse effects were found, choice of discharge regime at any particular reservoir in Kentucky is an administrative decision, with each case being decided on its individual merits (downstream water quality needs, two-story stocking plans, local angler preferences, etc.); (2) future reservoir discharge facilities be of sufficient capacity and of adequate design to provide maximum water quality control flexibility; and (3) any future field investigations pertaining to reservoir discharge regimes be designed for a minimum of 5 years under each discharge regime at each reservoir in order to preclude domination of the study design by prevailing weather conditions.

F Chikova, V. M. 1968. Species and age composition of fishes in the lower reach (downstream) of the V. I. Lenin Volga Hydroelectric Station. Pages 184-192 in B. S. Kuzin, ed. Biological and Hydrological Factors of Local Movements of Fish in Reservoirs. Academy of Sciences of the USSR. Institute of Biology of Inland Waters, Trudy, No. 16(19) (Translated from Russian, U. S. Dep. Commerce, 1974.)

Thirty-one fish species were found in the river section from the dam up to Kuibyshev City. The largest accumulation of fishes and variability of the species composition were observed in the river parts adjoining the dam. There were no large fish accumulations in the lower parts.

Because of the peculiarities of the hydrological regime caused by the unequal working load of the hydroelectric station, seasonal as well as daily displacement of fishes took place in the river below the dam. The largest catches were observed in the summer and fall periods.

The age composition of the majority of the phytophilic fish species (bream, zope, and roach) shows a predominance of the old age groups and low enrichment of the stock with the younger generations. Only the populations of sichel, sterlet, and sandre are better enriched with new generations.

Because of a large concentration of males of valuable commercial fishes (sturgeon, sterlet, bream, sandre, and others), it is essential to enforce fishing prohibition in the tailwaters.

W Churchill, M. A. 1963. Control of temperature through streamflow regulation. Pages 179-192 in Symposium on Streamflow Regulation for Quality Control. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. PHS Publ. 999 - WP - 30.

If water is released through low-level outlets in the dam, significant effects on downstream water temperature result during the warmer months. If water is released through high-level outlets, the reservoir may have little effect on water temperatures. This paper presents data observed in, and downstream from, certain impoundments operated by the Tennessee Valley Authority. The data have been collected over a period of approximately 26 years. The paper not only includes information to illustrate the magnitude of thermal effects produced, but also data designed to explain why and how these effects are produced. (Author synopsis.)

F Clark, C. F. 1942. A study of the loss of fish from an artificial lake over a wasteweir, Lake Loramie, Ohio. Trans. N. Am. Wildl. Conf. 7:250-256.

Nineteen of the thirty species found in the lake were taken in a trap set below the dam. Approximately 58,000 fish, of which 20 percent were pan fish, left the lake in 2 years. Lake samples of white crappies, bluegills, and gizzard shad correspond closely in size with those recovered in the trap. Of the three species leaving the lake in greatest numbers, only bluegills are stocked. The passage of white crappies and bluegills over the weir followed a season-temperature relationship with minimum air temperature of 10°C. Volume of overflow and turbidity were not noticeably significant. Test-net data on white crappies and information from anglers indicate that fish movements over the dam have no detrimental effects on the fish population or fishing in the lake.

F Cobb, E. S. 1960. A report on the sauger fishing in lower Tennessee River reservoirs. Tenn. Game Fish Comm., Fed. Aid Proj. F-12-R. 16 pp. (Mimeogr.)

From November 1, 1953, to December 3, 1958, 5,197 saugers were tagged and released below Pickwick Dam. Of this number, 555 (10.6 percent) have been recaptured. Twenty-five percent found their way through the locks and were subsequently recaptured in waters above the dam, primarily in the tailwaters of Wilson Dam. Four saugers from a group tagged at Kentucky Dam in December 1954 were recaptured at Pickwick Dam within 16 days, and another from this same group was recaptured at Wilson Dam after 18 days. This evidence seems to indicate that many saugers entering the Pickwick area are originally from other areas outside the Tennessee River Valley.

Saugers in the known areas of concentration appear to reach maximum numbers by late December and decline in numbers as the season progresses. The distribution of size groups from rotenone samples indicates that the sauger is a resident in the lower Tennessee River system at all seasons, but constitutes a small percentage of the total fish population when dispersed throughout the waters of the reservoirs.

F Combs, D. L. 1976. Striped bass research study. Okla. Dep. Wildl. Conserv., Fed. Aid Proj. F-29-R-7. 2 pp. (Mimeogr.)

Little difference was found in striped bass food habits above and below Keystone Dam, Arkansas River. Gizzard shad occurred in over 60 percent of the striped bass stomachs in both the reservoir and tailwater.

F Combs, D. L. 1979. Food habits of adult striped bass from Keystone Reservoir and its tailwaters. Proc. Annu. Conf. Southeast. Assoc. Fish. Wildl. Agencies. 32:571-575.

During 1974, 1975, and 1976, stomachs of 467 adult striped bass (*Morone saxatilis*) from Keystone Reservoir and its tailwaters were collected and examined for content. Gizzard shad (*Dorosoma cepedianum*) was the most abundant food item found in striped bass stomachs. The relationship between the length of striped bass and the length of gizzard shad consumed was not significant (0.5 percent). Seasonal and habitat variations in the diet were not significant (.05 percent). (Author abstract.)

F,W Corning, R. V. 1970. Water fluctuation, a detrimental influence on trout streams. Proc. Annu. Conf. Southeast Assoc. Game Fish Comm. 23:431-454.

Stream fluctuations strongly influenced the biotic populations of three Colorado trout streams during a 3-year study. Extreme water fluctuations (94 percent variation in surface area), combined with stream bedload accumulations, reduced a productive trout water to a nonproductive series of intermittent pools. One study station produced the highest consistent production of benthos and the largest standing crops of trout by number but the fourth largest according to weight. The discrepancy was attributed primarily to adverse feeding conditions of trout, a result of streamflow reductions during summer months. Rapid reductions in streamflow produced an abnormal concentration of benthos at another station, followed by a rapid decline in the benthos population within a 2-week period.

Unusual oxygen deficits were recorded in one instance, with oxygen levels lowest during photosynthetic periods and highest during periods of darkness. Oxygen concentration deficits were traced to two factors, decomposing cow manure in the stream and low streamflow.

Egg survival studies pointed out other adverse effects of stream fluctuation. Artificial redds and baskets containing rainbow trout eggs were placed in stream gravels of 2 of the 3 study streams. High streamflows at one station, due to a sudden release of water from an upstream reservoir, disinterred 75 percent of the buried eggs. Viability of the remaining eggs appeared to be lowered. Sharply declining water levels at a lower station on the same stream left all of the artificial trout redds and baskets free of water 1 or 2 days prior to fry emergence, after the eggs had withstood flood conditions. Cessation of water releases from the same reservoir that produced flood conditions caused the decline in water levels. At a third station located on a different stream, eggs were also exposed to air when the stream level receded. This time, water recession was due to natural rather than man-caused conditions.

The only vascular plant common to all three drainages was Veronica americana. Veronica was found on moist ground, sand bars and emersed, seemingly well adapted for areas of extreme water fluctuation. Other macroscopic aquatic plants were common only in George Creek, the stream with the most stabilized streamflow. (Author abstract.)

I,W Coutant, C. C. 1962. A preliminary study of the macroinvertebrate riffle fauna above and below Green Lane Reservoir, Montgomery County, Pennsylvania. Lehigh Univ. Dep. Biol. 12 pp (Mimeogr.)

Macroinvertebrates were sampled in riffles in the river above and in tailwaters below Green Lane Reservoir, a summer stratified reservoir in Pennsylvania. Riffles above the reservoir had more taxa present (28 vs. 17), but riffles below the reservoir had more biomass (37.7 g/m^2 vs. 26.9 g/m^2).

Ephemeroptera and Coleoptera were absent or extremely rare below the reservoir, but common in the stream above. Simuliidae and Empididae were common in the coldwater discharges.

During periods of coolwater discharge from lower levels, coldwater species (such as Simulium larvae) were present downstream. Periods of warmer discharges (took place when water was released over the spillway) occurred occasionally, contributing to the absence of taxa below the reservoir which were present in the natural stream above the reservoir. The author suggests that the presence of reducing conditions in the reservoir (as evidenced by strong H_2S odor and rusty precipitate in surfaces below the reservoir) could adversely affect the organisms downstream.

I Coutant, C. C. 1963. Stream plankton above and below Green Lane Reservoir. Proc. Pa. Acad. Sci. 37:122-126.

Stream plankton was studied above and below Green Lane Reservoir during the month of September 1961 when the impoundment was thermally stratified. Distinctly different plankton populations were found to exist above and below the impoundment, the former being predominantly diatoms and green algae while the latter were largely anaerobic bacteria derived from the hypolimnion and moribund diatoms and blue-green algae from the epilimnion. Simple enumeration of organisms suggests a richer plankton population below the reservoir than above it both numerically and in terms of volume of protoplasm per unit of water volume, while a more critical analysis leads to the conclusion that most of the plankton below the dam is not a viable population but a contribution in the order of one part per million to the stream's load of decomposable organic debris. (Author abstract.)

I Coutant, C. C. 1965. A comparative study of stream plankton populations upstream and downstream from a eutrophic impoundment with hypolimnetic discharge. Ph.D. thesis. Lehigh University, Bethlehem, Pa. 123 pp.

Distinctly different stream plankton populations were found upstream and downstream from a 19.8-m-deep eutrophic impoundment with bottom discharge, which undergoes strong thermal and biogenic chemical stratification in the summer months. Diatoms and green algae derived from the periphyton dominated the upstream population of all dates while the population below the dam reflected the ratio of surface overflow to bottom discharge and the degree of stratification prevailing at the time of each collection. Typical epilimnetic plankters were abundant when surface overflow perdominated, while the main components of bottom discharge were small amounts of surface plankters in July, bacteria associated with the anaerobic hypolimnion in late August and September, and a mixture of surface organisms and bacteria following reservoir overturn in early October.

Total volumes of organisms were not consistently greater immediately below the dam than in the tributary stream, which is generally typical for natural lakes and reservoirs with surface discharge. At the height of chemical stratification the greater biomass downstream was due to the inclusion of bacterial plankton in the analyses.

A decrease in numbers of most lake-derived plankters was observed 0.6 km below the dam in the outlet stream. (Author abstract.)

I Cowell, B. C. 1970. The influence of plankton discharges from an upstream reservoir on standing crops in a Missouri River reservoir. Limnol. Oceanogr. 15(3):427-441.

The influence of discharges from an upstream reservoir, Lake Francis Case, on the standing crops in Lewis and Clark Lake, 71 km down the Missouri River, was assessed by automatic plankton samplers installed in the powerhouses. Composite samples were collected weekly from January 1966 through December 1967. Densities of total Copepoda and Cladocera were significantly greater in the upstream reservoir; populations downstream were dependent on upstream discharges. Discharge and water exchange rates in Lewis and Clark Lake were too rapid for significant development of Copepoda and Cladocera; only three species showed population increases between powerhouses. In contrast, phytoplankton and rotifers were more abundant downstream, especially in summer when introductions from the Niobrara River and production within Lewis and Clark Lake produced marked differences between reservoirs.

Phytoplankton and zooplankton populations in both reservoirs were exceptionally low during summer. Low concentrations of nutrients and low photosynthetic rates in the upstream reservoir appear to be the limiting factors. (Author abstract.)

F Cramer, F. K. and R. C. Oligher. 1964. Passing fish through hydraulic turbines. Trans. Am. Fish. Soc. 93(3):243-259.

Beginning in 1959, the Walla Walla District, U. S. Army Corps of Engineers, under auspices of the Corps of Engineers' Fisheries Engineering Research Program, has conducted extensive tests on downstream passage of fish through hydraulic turbines, utilizing both model and prototype installations. Purposes of the tests were (1) to establish design criteria for high-head Francis-type turbines that will provide optimum fish passage, and (2) to establish the best method of operating existing Kaplan- and Francis-type turbines that will provide maximum survival of fish under prevailing conditions.

Tests at Allis-Chalmers' Hydraulic Laboratory, York, Pennsylvania, using 12-in.-diam (30.5-cm) model turbines, demonstrated that mortality among fish passing through a model was of appropriate magnitude to allow comparative studies of mortality in various model installations, that mortality was greatly influenced by turbine operating conditions (efficiency) and relationship of tailwater elevation to runner setting, and that increased clearances in the water passageways reduced mortality if turbine efficiency could be maintained. Prototype tests at Cushman No. 2 hydroelectric plant, Skokomish River, Washington, and Shasta hydroelectric plant on Sacramento River, California, verified model findings, with survival rates ranging from 45 to 77 percent at Cushman and reaching 91 percent in some instances at Shasta, depending upon turbine operating conditions and tailwater levels. These studies have given hope that through proper design, setting, and operation, successful fish passage through high-head turbines can be achieved. (Author abstract.)

W Crisp, D. T. 1977. Some physical and chemical effects of the Cow Green (upper Teesdale) impoundment. Freshwater Biol. 7:109-120.

The paper describes observations on water temperature and dissolved oxygen in Cow Green Reservoir and also changes caused by impoundment to temperature, chemistry, dissolved oxygen, and the discharge regime of the River Tees immediately downstream of the dam.

Impoundment and river regulation have considerably smoothed out fluctuations in discharge of the Tees and have eliminated the very low and very high discharges which were characteristics of the natural river.

Reservoir water levels show an annual pattern of drawdown during summer, refilling in autumn, and overflow during winter and spring. Thermal stratification of the reservoir occurs rarely and is generally of short duration. Water temperatures at mid-reservoir correspond closely to those of water discharged from the reservoir. The temperature regime in the river downstream is modified as follows: (1) reduction in amplitude of annual temperature fluctuations by 1-2°C, (2) marked reduction of diel fluctuations, and (3) delay of the spring rise in water temperature by 20-50 days and of the autumn fall by 0-20 days. These temperature changes could reduce the annual maintenance ration of a 10-g brown trout (Salmo trutta L.) by about 15 percent and delay the annual peak of metabolism by about 1 month. The effect upon growth rate of trout would be negligible.

Fluctuations in ionic content at the reservoir inflow are comparatively large and can be related approximately to river discharge. Fluctuations at the outflow are smaller and appear to be largely seasonal. Regulation has not appreciably altered the dissolved oxygen content of the River Tees. (Author abstract.)

F Crisp, D. T., R. H. K. Mann, and J. C. McCormack. 1978. The effects of impoundment and regulation upon the stomach contents of fish at Cow Green, Upper Teesdale. J. Fish. Biol. 12(4):287-301.

The stomach contents of 1,003 brown trout, 1,551 bullheads, and 800 minnows taken from the reservoir basin and below the dam, before and after impoundment of the River Tees, were examined. Their composition reflected observations by other workers on river and reservoir benthos, except for the increase in numbers of Hydra and Nais below the dam, and Mollusca, Hirudinea, and Oligochaetes in the reservoir.

Trout below the dam ate more Ephemeroptera nymphs and Chironomidae larvae but fewer terrestrial casualties after river regulation, whereas bullheads ate more Mollusca but fewer Plecoptera nymphs. In both species Baetidae nymphs increased in numerical importance relative to Ecdyonuridae. Trout, but not bullheads, took zooplankton discharged from the reservoir.

Before impoundment, trout within the reservoir basin ate chiefly benthic organisms and terrestrial casualties. Inundated terrestrial material, mainly earthworms, formed the bulk of their food for at least 3 years after impoundment, whilst from the second year onwards Chironomidae and, in some years, Gammarus became increasingly important. Zooplankton was taken by all sizes of reservoir trout.

Bullheads within the reservoir basin ate chiefly river benthos before impoundment, with Ephemeroptera and Plecoptera nymphs predominant in older fish, and aquatic Diptera and Coleoptera also important in the fry. After impoundment, Chironomidae and Gammarus were the main items taken by older bullheads, and Chironomidae and microcrustacea by the fry. Among all sizes of minnow, Chironomidae, microcrustacea, and detritus increased in numerical importance after impoundment. (Author abstract.)

F,W Cross, F. B. 1950. Effects of sewage and of a headwaters impoundment on the fishes of Stillwater Creek in Payne County, Oklahoma. Am. Wildl. Nat. 43(1):128-145.

A comparison of data from 1938 and the present survey carried out in 1947 and 1948 indicates that raw sewage emptied into Stillwater Creek has benefited the fish fauna. Despite periods of almost complete depopulation, the abundance of fishes was, on the whole, much greater than found earlier.

Although minnows and rough fishes, principally the gizzard shad and carpsuckers, have profited most from the sewage influx, increased populations are also measurable in angling success. Catches, consisting chiefly of white bass, channel catfish, black bullheads, flathead catfish, and carp, are materially greater than in the past, fishermen report.

Current abundance of fishes is not entirely attributable to sewage effects. Blackwell Lake, through stabilization of flow and introduction of new forms, has contributed to the increase.

I Cummins, K. W. and G. L. Spengler. 1978. Stream ecosystems. Water Spectrum. 10(4):1-9.

Annual floods (even though stressful) are important in maintaining the normal community structure in the stream because the stored organic matter lying in the stream bottom is redistributed during floods. Usually these events take place during the spring months. The author suggests pulsed releases from reservoirs resemble the normal flooding situations which take place in unaltered streams.

Two primary zones of invertebrate habitation are identified: (1) riffles characterized by well-oxygenated sediment-free water with rapid flows and (2) pools and other depositional zones where fine sediments may accumulate. Low dissolved oxygen conditions may exist in the pool areas retarding organic processing. Organisms inhabiting either of these two areas are adapted morphologically for survival.

Leaf litter in the fall may compose 60 percent of the organic matter entering a stream system. The leaves are rapidly colonized by microorganisms. Primary groups of prey in the stream are shredders, collectors, and scrapers. Shredders break the leaf into particles of organic matter. Collectors utilize the particles which the shredders have processed. Scrapers utilize the small amount of production in the stream which is present as attached algae.

F Curtis, B. 1959. Changes in a river's physical characteristics under substantial reductions in flow due to hydroelectric diversion. Calif. Dep. Fish. Game 45(3):181-188.

The purpose of this study was to determine the relation between quantity of river flow and stream depth, water velocity, and area of submerged bottom. Studies were conducted in the Pit River and Feather River in California at regulated flows of 1.4, 2.8, 4.2, 5.7, and 7.1 m^3/sec. It was found that wetted perimeter decreases much less rapidly than volume of flow. Changes in maximum depth and area of cross section closely parallel wetted perimeter in percentage reduction, but mean velocity of water shows a very much greater percentage reduction.

F Delisle, G. E. and B. E. Eliason. 1961. Effects on fish and wildlife resources of proposed water development on Middle Fork Feather River. Calif. Dep. Fish. Game, Water Project Rep. No. 2. 55 pp.

The probable effects of the Rishvale irrigation and power project on the Middle Fork of the Feather River are discussed. Impoundment of stream habitat and reduced flows below impoundments destroy trout habitat and favor rough fish (carp, squawfish, and suckers) that compete with trout.

F Delisle, G. E. and T. W. Wooster. 1964. Changing the stream flow regime and its probable effects upon aquatic life and fishing - Middle Fork Feather River. Calif. Dep. Fish. Game, Water Proj. Br., Admin. Rep. 36 pp. (Mimeogr.)

This mimeographed report conveys the results of field studies to evaluate the suitability of specific flows in a section of the Middle Fork Feather River in California. Aquatic insect sampling was conducted to identify species and areas of use in relation to flows. A creel census and angler questionnaire were used in an attempt to evaluate effects of streamflows on fishing, wadeability, recreational enjoyment, and human safety. The report also relates the results of a literature review and provides a bibliography citing 105 references relating to water flows, rough fish control, and effects of water projects on trout and associated aquatic life. The results of the studies and analysis of the data are treated judgmentally in arriving at conclusions. The authors relate the changed flows to the biology of the river including treatment of problems involving food production, rough fish, wadeability, trout harvest, and fishing success. (Fraser 1972b.)

F,W Dendy, J. S. and R. H. Stroud. 1949. The dominating influence of Fontana Reservoir on temperature and dissolved oxygen in the Little Tennessee River and its impoundments. J. Tenn. Acad. Sci. 24(1):41-51.

Cold water from low levels in Fontana Reservoir has drastically altered fish environments in Cheoah and Calderwood Reservoirs and in the Little Tennessee River below. Once-productive warm-water fisheries existing in these waters were largely eliminated by this change.

Studies of temperature and dissolved oxygen concentrations of the waters suggest they may be suitable for brook and rainbow trout.

F,W Deppert, D. L. 1978. The effect of striped bass predation and water quality on the rainbow trout fishery of the lower Illinois River. M. S. thesis. Univ. Okla., Norman. 103 pp.

A creel survey was conducted on the lower Illinois River to determine the quality of the put-and-take trout fishery. The distribution and food habits of the striped bass were evaluated, along with environmental parameters at the three trout stocking sites on the lower river.

Predation by striped bass and low dissolved oxygen concentrations were the only factors found to be limiting to the survival of the rainbow trout.

Relative abundance of the striped bass was positively correlated to the flow rate; bass were significantly more abundant during water release periods from Tenkiller Ferry Dam. Predation by striped bass on rainbow trout was found only at one of the three sampling sites, and of the 111 stomach samples analyzed from striped bass, 22 stocked trout were found to be food items. Forty percent of the food items by number, and sixty-four percent by volume, taken from striped bass within 1 week after trout stocking were found to be trout. Gizzard shad were found to be the major food item throughout the year's study, and striped bass were not found to be selective as to type of food items. Peak abundance of striped bass occurred during the summer months.

Dissolved oxygen concentrations ranged from 0.8-14.0 mg/ℓ and were found to limit the survival of trout during late October and early November. Trout harvest showed a negative relationship to flow, although overall, 61.7 percent of the trout stocked were harvested. There were an estimated 75,000 man-hours of recreation provided by the trout fishery of the lower Illinois River. Neither temperature (range of 5.2°C-21°C) nor any of the selected chemical parameters were found harmful to trout survival.

F Dudley, R. B. and R. T. Golden. 1974. Effect of a hypolimnion discharge on growth of bluegill (Lepomis macrochirus) in the Savannah River, Georgia. Completion Report USDI/OWRR Proj. No. B-057 GA. Univ. Ga., Athens. 28 pp.

During 1972 and 1973 three northeast Georgia rivers were sampled to determine the effect of a hypolimnion discharge on growth and condition of bluegills (Lepomis macrochirus). Two stations on the Savannah River, 2.4 and 40 km below Hartwell Dam, were sampled. One station on the North Oconee River and one station on the Broad River were also sampled. The mean temperature of the Savannah River was about 5°C below the temperature of the control streams. Also temperature changes of as much as 11°C in 5 hours occurred in the Savannah River.

Growth increments of each fish, calculated from length and scale data, indicated that growth differences between the two control streams were greater than differences between the Savannah and the control streams. In general neither growth nor condition was significantly affected by the hypolimnion discharge. Apparently other differences among the four locations were great enough to mask the effect of temperature on growth. (Author abstract.)

F,W Edwards, R. J. 1978. The effect of hypolimnion reservoir releases of fish distribution and species diversity. Trans. Am. Fish. Soc. 107(1):71-77.

The fish faunas above and below Canyon Reservoir, Comal County, Texas, were surveyed to determine the effect of the impoundment upon the downstream community. Although 22 species were found above the reservoir, only 18 species were taken in the area downstream from the dam. Comparisons with preimpoundment surveys of this area, taken a quarter century earlier, indicate that seven species, which were once present in the downstream area, are now absent. Species diversity indices demonstrate reduced diversity below the impoundment. Changes in downstream water quality, especially water temperatures, due to hypolimnion water releases, seem to be the most likely causal factors associated with this disruption of the natural stream community. (Author abstract.)

F,I Elder, H. Y. 1966. Biological effects of water utilization by hydroelectric schemes in relation to fisheries, with special reference to Scotland. Proc. R. Soc. Edinb., 69 B:246-271.

Literature is reviewed in relation to particular Scottish problems. The individuality of waterbodies and methods of harnessing available power necessitates individual treatment. Some general conclusions can, however, be drawn.

The creation of impoundments and the raising of lake levels are considered in terms of the effects on agriculture, rare plant and animal species, lake plankton production, introductions, and the growth of fish.

The consequences of fluctuating lake levels are reviewed with reference to the productivity of shallow water communities, bottom animals, and the growth and reproduction of fish.

Pollution, changes in temperature and chemical factors, and alterations in the volume and stability of rivers are considered.

Anadromous fish conservation measures include guarantee of minimum river flow, provision of freshets, construction of fish passes, erection of smolt screens, passage of smolts through turbines, creation of artificial spawning gravels, use of hatcheries, and the opening up of previously unutilized natural spawning gravels.

In general, hydroelectric schemes have a depressing effect on biological productivity. This effect may be lessened through the application of gained knowledge and experience. Fundamental research into this branch of applied ecology is needed. (Author abstract.)

F Eliseev, A. I. and V. M. Chikova. 1968. Conditions of fish reproduction in the lower reach (downstream) of the V. I. Lenin Volga Hydroelectric Station. Pages 193-200 in B. S. Kuzin, ed. Biological and Hydrological Factors of Local Movements of Fish in Reservoirs. Academy of Sciences of the USSR. Institute of Biology in Inland Waters Trudy, No. 16 (19) (Transl. from Russian, U. S. Dep. Commerce, 1974).

The hydrological regime of the Volga has drastically changed over a distance of 200-250 km on the lower side of the dam after the creation of Kuibyshev Reservoir. The volume of the spring floods has decreased. Before the regulation of the river, the spawning temperatures were found to be on the increase before the high onset of spring floods, which favored a higher spawning rate. The temperature regime warming of the water is slower by 6-8 days in comparison with the natural warming from the river, and because of this, spawning takes place at the end of the floods. As a result of the drastic reduction in the water level, a large part of the spawn laid by ide, pike, perch, roach, zope, bream, white bream, and sandre perishes, while a large number of females survive. The spawning of sichel takes place most successfully in the lower underwater. In order to improve the conditions of spawning for bream and sandre in the dam part of the lower underwater, it is essential to create artificial spawning grounds of the nest type and to regulate the level regime during the spawning period of the fishes.

F Elser, H. J. 1960. Escape of fish over spillways: Maryland, 1958-1960. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 14:174-185.

A four-pond study in Maryland indicated a great difference between ponds in loss of fish over dams. There was a strong suggestion that shape of the spillway was the important factor. Dams with spillways having turbulent flow lost less fish than those with a smooth flow.

F,W England, R. H. and J. R. Fatora. 1976. Effect of low head impoundments on ambient trout stream temperatures. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 30:285-294.

Data from five northeast Georgia trout streams revealed significant alteration of ambient temperatures by impoundments. A 7.3-ha impoundment releasing water from a depth of 3.9 m warmed Anderson Creek a mean 2.2°C during August 1973 and reduced diurnal temperature variations by two-thirds. Surface release impoundments on Bean Creek and Chickamauga Creek warmed ambient temperatures a mean 4.2°C and 3.8°C, respectively, during the summer of 1974. Diurnal fluctuations were increased in these two streams. A 21-ha surface release impoundment on Smith Creek warmed ambient stream temperatures a mean 3.6°C during the summer of 1973 in spite of efforts to release water through the drain valve at 18 m below the surface. A multilevel release structure on Taylor Creek designed to closely duplicate ambient mean daily temperatures was not properly adjusted and elevated temperatures a mean 4.3°C during a 3-month period. (Author abstract.)

F Eschmeyer, R. W. 1944. Fish migration into the Clinch River below Norris Dam, Tennessee. J. Tenn. Acad. Sci. 19(1):31-41.

White bass, largemouth bass, and saugers moved into the Clinch River below Norris Dam in the fall and winter of 1942-1943; most were fast-growing young fish born in 1942. These fish migrated upstream from Watts Bar Reservoir during the first year of impoundment. The white bass had moved back to the reservoir by spring, but the other species remained in the tailwater.

F Eschmeyer, R. W. and D. E. Manges. 1945. Fish migrations into the Norris Dam tailwater in 1943. J. Tenn. Acad. Sci. 20(1):92-97.

Young-of-the-year fish movement is discussed between Watts Bar Reservoir and the tailwaters of Norris and Fort Loudoun Dams.

F Eschmeyer, R. W. and L. F. Miller. 1949. Fishing in TVA tailwaters. TVA Bull. 9 pp.

Creel data from the tailwaters of TVA main stem dams and Douglas Reservoir indicate 3/4 million fishing trips were taken and 1.8×10^6 kg of fish were harvested in 3 years. The authors state that the dams concentrate fish and create a fishery with no evidence of overharvest.

F,W Eschmeyer, R. W. and C. G. Smith. 1943. Fish spawning below Norris Dam. J. Tenn. Acad. Sci. 18(1):4-5.

The water immediately below Norris Dam generally has a temperature of less than 10°C. Fish are abundant in this area, but few if any are able to spawn here because of the cold temperatures.

I Fast, A. W. 1965. A report on the preliminary forage food studies in the Colorado River below Davis Dam. Calif. Dep. Fish Game. Fed. Aid Proj. F-4-D. 17 pp. (Mimeogr.)

The silt-sand substrate below the dam was degraded, resulting in exposure of a gravel-boulder bottom. Benthos standing crop was low (1 amphipod, 18 simuliidae, and 1 blackfly adult were captured in a limited sampling program). The presence of chironomid larvae in stomachs of trout taken near the dam was noted.

F,W Finnell, J. C. 1953. Dissolved oxygen and temperature profiles of Tenkiller Reservoir and tailwaters with consideration of these waters as a possible habitat for rainbow trout. Proc. Okla. Acad. Sci. 34:65-72.

Tenkiller Reservoir showed a characteristic and pronounced thermocline during the months of June and July 1953. The greatest ranges in temperatures observed occurred in the epilimnion and thermocline layers. The very stable hypolimnion had a dissolved oxygen concentration of less than 1.5 mg/ℓ from 10.7 to 39.7 m. Above 9.6 m the dissolved oxygen concentrations averaged upward from 4 to 8.1 mg/ℓ.

From the study of water temperature, the Illinois River appears suitable for the existence of rainbow trout for at least 11.3 km below Tenkiller Reservoir. During summer months when the oxygen tension of lake bottom waters is near zero, little aeration can be expected, and oxygen-deficient water will extend for a considerable distance downstream. From these limited observations it is believed that dissolved oxygen, not temperature or minimum streamflow, will be the factor limiting trout survival.

A total of 5,000 rainbow trout was stocked in the winter of 1952-1953. Of this number, 600 were from 36-41 cm long and the remainder 13-18 cm long. A few catches have since been reported, but only time will tell whether the introduction of this exotic species will be successful below Tenkiller Reservoir. Reproduction is not likely to occur due to constant water fluctuations, and future trout fishing will probably depend upon a program of continual replacement.

W Fish, F. F. 1959. Effects of impoundment on downstream water quality, Roanoke River, N. C. J. Am. Water Works Assoc. 51(1):47-50.

Impoundment of the Roanoke River has resulted in significantly reduced dissolved oxygen concentrations immediately downstream of dams during the summer months. There have also been wider variations in dissolved oxygen concentrations. Prior to the construction of the Roanoke Rapids Reservoir, waters released from the Kerr Reservoir were reaerated in the 70.8-km stretch from the dam to Highway 48 bridge.

With completion of the Roanoke Rapids project, the residual effects from deoxygenation in Kerr Reservoir extend 70.8 km through the Roanoke Rapids Reservoir and to Highway 48 bridge. With the heavy organic waste loading from paper, pulp, textile, and domestic sewage introduced below the Roanoke Rapids Dam, the river does not have the opportunity to recover from the degrading effects of impoundment.

I Fisher, S. G. and A. LaVoy. 1972. Differences in littoral fauna due to fluctuating water levels below a hydroelectric dam. J. Fish. Res. Board Can. 29(10):1472-1476.

Water level fluctuations below a hydroelectric dam on the Connecticut River produce a freshwater "intertidal" zone. Along a transect in this zone from high to low water mark benthic invertebrates increased markedly in density and taxonomic diversity. Community composition shifted from chironomid-oligochaete predominance on the most exposed sites to mollusc predominance on the least exposed sites. (Author abstract.)

F Fogle, N. E. and J. T. Shields. 1961. Tailwaters fishery survey 1961. S. D. Dep. Game, Fish Parks. Fed. Aid Proj. F-1-R-11. 9 pp. (Mimeogr.)

Data regarding 52 tailwater fisheries were obtained from questionnaires returned from 14 states. Predominantly trout fisheries were found to exist where maximum water temperatures do not exceed 70°F (21.1°C) and where the dam is over 150 ft (45.8 m) high and the outlet structure is at least 100 ft (30.5 m) below the maximum elevation of the reservoir. Dams not meeting these specifications provide warm water tailwater fisheries. Best fishing is experienced during periods of moderate flows with little or no fluctuation. Features causing eddies, swirls, and backwaters greatly improve angling. Fisherman facilities are of good quality but of insufficient quantity and variety. (Author abstract.)

F Forshage, A. 1976. Cost/benefit analysis of a catchable rainbow trout fishery in Texas. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 29:293-300.

An evaluation of stocking catchable rainbow trout, Salmo gairdneri, in a section of the Brazos River below Possum Kingdom Reservoir was made in 1972-1973 to determine if trout stocking was economically and recreationally justifiable. A creel survey to measure fishing pressure and harvest, gross annual expenditures, and net economic value of the fishery was made before and after trout introduction. Benefits, in terms of increased harvest and utilization, were found to be substantially higher than the cost of stocking catchable rainbow trout.

F Fortune, J. D., Jr., and K. E. Thompson. 1969. The fish and wildlife resources of the Owyhee Basin, Oregon, and their water requirements. Oreg. State Game Comm., Fed. Aid Proj. F-69-R-4. 50 pp. (Mimeogr.)

This report describes the fish and wildlife resources of the Owyhee Basin, their water requirements, and the water resources of the basin as they influence fish and wildlife. Its primary purpose is to provide the Oregon State Water Resources Board with information about these resources along with recommendations for minimum stream flows for fish.

An inventory of species present in the basin is included and their relative abundance and distribution are indicated; biological requirements of trout are discussed to point out the factors that are taken into account when recommendations are made for minimum stream flows. Problems within the basin that affect fish are listed and discussed. Management activities of the Oregon State Game Commission are outlined and the sport fisheries described.

F,I,W Fowler, J. A. 1978. Effects of a reservoir upon fish. Pages 51-64 in Environmental Effects of Large Dams. Report of the Committee on Environmental Effects of the United States Committee on Large Dams, American Society of Civil Engineers, New York.

The general effects of run-of-the-river hydroelectric dams and flood control dams on tailwater fishes is discussed. Major problems are defined as temperature reduction, fish loss from gas-bubble disease, turbine passage and predator concentration, blockage of migration, and water level fluctuations resulting in fish stranding and spawning ground desiccation.

Literature is reviewed which illustrates these problems and discusses possible solutions, including multiple outlet releases for temperature control and deflectors to prevent spillway passage.

F Foye, R. E., C. F. Ritzi, and R. P. Auclair. 1969. Fish management in the Kennebec River. Maine Dep. Fish. Game, Fish. Res. Bull. 8. 67 pp.

Dams constructed on the Kennebec and its tributaries since colonial times have destroyed the large runs of anadromous fish in the river.

Pollution in parts of the Kennebec has steadily worsened over the years. Recently enacted state laws will improve these waters to meet prescribed water quality standards.

The extensive pulpwood industry along the Kennebec has had a detrimental effect on fish and other aquatic life. Recent findings indicate that significant degradation in water quality can result from the materials leached from wood bark stockpiles on land or in watercourses.

Salmon and trout production is influenced by streamflow. Flows in the Kennebec River are regulated by several dams on the main river and its larger tributaries. Flows in sections of the upper Kennebec and some of its tributaries have undergone noticeable changes since 1940. Flow pattern alteration is apparently due to changes in power generation demands at some sites which now operate at peak load at certain hours only, followed by drastic streamflow cutbacks as turbines drop to lower generating rates. Since implementation of changes in flow pattern in upper reaches of the drainage, it appears that flows have been sufficiently low and variable to have had a direct adverse effect on fish populations. Changes in flow pattern have also resulted in greater seasonal variation in the concentrations of pollutants in the lower river.

Suggestions are made to improve the fisheries of the Kennebec by construction of fishways at dams, pollution abatement, and minimum flow recommendations.

I,W Fraley, J. J. 1978. Effects of elevated summer water temperatures below Ennis Reservoir on the macroinvertebrates of the Madison River, Montana. M. S. thesis, Mont. State Univ., Bozeman. 120 pp.

The effects of Ennis Reservoir on the chemistry, thermal regime, and aquatic macroinvertebrates of the Madison River were studied during 1976 and 1977. Only small differences in pH, total alkalinity, hardness, conductivity, dissolved oxygen, turbidity, ammonia, nitrate, nitrite, orthophosphate, and total phosphorus were measured at the five stations. Mean water temperatures from June through August 1977 at stations below the reservoir averaged 3.5°C higher than at stations above the reservoir. Water temperatures were above 17°C at least 31 percent more of the time at stations below the reservoir.

A total of 56 taxa of aquatic macroinvertebrates were collected on artificial substrate samplers. The average number of taxa per sampler was significantly lower at the station immediately below the reservoir than all other stations ($p<.01$). The average total numbers collected at stations below the reservoir were significantly greater than at stations above ($p<.01$). A greater composition of Trichoptera and a lower composition of Plecoptera were found on artificial substrates immediately below the reservoir. Weights of invertebrates on artificial substrate samplers averaged about 100 percent higher at stations below the reservoir than at stations above. A total of 54 taxa were collected in bottom samples. The average number of taxa per bottom sampler was significantly lower ($p<.01$) at the station immediately below the reservoir than at all other stations. The numerical composition of Trichoptera was larger and Plecoptera smaller immediately below the reservoir than at all other stations.

Biotic index values indicated stress on macroinvertebrate communities at stations below the reservoir. Coefficients of similarity indicated distinct invertebrate communities at stations above the reservoir, immediately below the reservoir, and at stations further downstream. Some species of adult aquatic insects appeared 2 weeks to 1 month earlier at stations below the reservoir than at stations above. (Author abstract.)

F Frankenberger, L. 1967. Evaluation of brown trout fingerling stocking programs in the lower Willow River and the economics thereof. Wis. Dep. Nat. Resour., Fish Mgt. Rep. 24. 17 pp. (Mimeogr.)

Fingerling stocking of brown trout in a tailwater below a hydroelectric dam on the lower Willow River was evaluated at two different stocking densities over a 6-year period. Under present stocking practices and policies, it was found that the stocking of legal-size trout each spring will provide more and larger fish per dollar to the sportmen's creel than will a fall fingerling program.

F Fraser, J. C. 1972a. Regulated discharge and the stream environment. Pages 263-285 in R. T. Oglesby, C. A. Carlson, and J. A. McCann, ed. River Ecology and Man. Academic Press, New York and London.

This report constitutes a review of the effects of discharge on stream environments. Emphasis is placed upon the effects of regulated or changed discharge (streamflow) on the current oriented biotic community, particularly the salmonid fishes. Discharge effects relate to food production, stimulus for migration, success of migration, spawning, survival of eggs and juveniles, spatial requirements, and shelter needs. Excessively high and low flows have caused major changes in fish populations.

Present approaches to preproject determination of regulated streamflows frequently fail to relate physical stream data to actual discharge needs of the biotic community. Greater emphasis should be placed on quantifying such needs. A major obstacle to maintaining the ecology and in-place values of streams is the emphasis of many water laws on diversion of water for off-stream uses and strong reliance on private ownership of water rights. The absence of statutory mechanisms to provide and protect water supplies for in-stream uses is also an obstacle.

F Fraser, J. C. 1972b. Regulated stream discharge for fish and other aquatic resources - an annotated bibliography. FAO Fish. Tech. Pap. 112. 103 pp. Rome.

This report is a collection of abstracts and references on the effects of regulated stream discharge on aquatic resources. According to the author it is not a complete review. The purpose was to present available literature on how to establish or select adequate minimum flows in streams which have been brought under partial or complete control by dams and diversions. Most of the references concern the salmonids because of the extensive work completed on these fishes.

F Fraser, J. C. 1975. Determining discharges for fluvial resources. FAO Fish. Tech. Pap. 143. 103 pp. Rome.

This is a review of the methods and approaches currently in use to determine adequately controlled discharges (streamflows) for maintenance of fishery resources. The many factors influenced by or influencing streamflows in relation to fluvial resources and activities are outlined. Methods of determining streamflows for Pacific salmon in the states of California, Oregon, and Washington are presented as examples of the quantification of streamflow needs of fish. Various "rules of thumb" currently in use for salmon and trout streams are reviewed, as well as approaches which involve geomorphology, rate of flow change, and the relation of past flows to year-class success. A check chart provides a basic means of ensuring consideration of the conditions and factors influenced by various streamflows for each month of the year. (Author abstract.)

F Friberg, D. V. 1972. Paddlefish abundance and harvest within a population lacking recruitment, Big Bend Dam tailwaters, 1969-1971, South Dakota. S. D. Dep. Game, Fish Parks, NMFS, Comm. Fish. Invst., 4-61-R. 16 pp. (Mimeogr.)

Reservoirs on the Missouri River in South Dakota have eliminated nearly all suitable paddlefish spawning areas. The quantity of paddlefish harvested from Lake Francis Case and the effects of harvest on the existing population were relatively unknown before 1969 and incidental harvest by contract fishermen became the target of much criticism from sport fishermen. Mark and recovery and creel census programs were conducted from mid-1969 through October 1971 to determine population size and harvest. Incidental harvest by contract fishermen and angler harvest were not considered excessive during the study period, but recommendations were advanced to preclude that possibility if more favorable harvest conditions develop. Angler harvest of paddlefish from Lake Francis Case and the Big Bend Dam tailwaters in 1972 will be limited to 2,000. Snagging will be prohibited when this quota has been attained. (Author abstract.)

F Fritz, A. W. 1969. 1968 Carlyle Reservoir and tailwater sport fishing creel census. Ill. Dep. Conserv. Div. Fish, Fish. Rep. 28. 34 pp. (Mimeogr.)

Projected tailwater data disclosed that 1,493 boat fishermen and 64,326 bank fishermen fished 344,574 hours and caught 425,461 fishes weighing 169,240 kg. Tailwater boat fishermen fished an average of 4.47 hours per fishing trip and had a catch rate of 1.37 fish per hour. Tailwater bank fishermen fished an average of 5.25 hours per trip and caught 0.83 fish per hour.

Thirty-one species were creeled by tailwater boat and bank fishermen. Carp, the most abundant species, comprised 57.3 percent of the total number caught and 71.9 percent of the total weight. Seven other species or groups of fishes in order of percent of total catch were: freshwater drum, crappies, bullheads, channel catfish, bluegills, green sunfish, and largemouth bass.

Projected reservoir data indicated there were 23,330 boat and 33,615 bank fishermen who fished a total of 272,522 hours and caught 281,945 fish weighing a total of 93,424 kg. Boat fishermen fished an average of 4.96 hours per fishing trip and caught

0.98 fish per hour. Bank fishermen fished 4.88 hours per trip and caught 1.12 fish per hour.

A total of 18 species were identified in the reservoir angler's creel. Bullheads ranked number one in total catch, comprising 37.1 percent of the total number and 21.8 percent of the total weight. Second in abundance but first in total poundage was carp with 16.8 percent of the total catch and 43.1 percent of the total weight. Other fishes commonly seen in the anglers' catches were crappies, bluegills, largemouth bass, green sunfish, and freshwater drum.

Detailed information pertaining to the total and percentages of the projected catch and poundage, species composition, catch rates, fishing bait success, fishing tackle used, methods of fishing, distances traveled, hours per completed fishing trip, and the sport fishery recreational value is also included.

W Fry, J. P. 1962. Water quality of Lake Taneycomo and its tailwaters. Mo. Conserv. Comm. Fed. Aid Proj. F-1-R-11. 19 pp. (Mimeogr.)

This study concerns the thermal and chemical effects cool hypolimnion discharge from Table Rock Reservoir has on the downstream impoundments, Lake Taneycomo and Bull Shoals Reservoirs. Lake Taneycomo lies almost immediately downstream from Table Rock Reservoir. Bull Shoals Reservoir extends nearly to the base of Powerslide Dam which impounds Lake Taneycomo. The cool hypolimnion discharge has drastically changed the physical, chemical, and biological aspects of Lake Taneycomo and the upper reaches of Bull Shoals Reservoir.

Stratification of Table Rock Reservoir became pronounced in June and a low oxygen tension was observed throughout the period of summer stratification. Specific conductance readings generally were lower from samples procured near the thermocline.

Water discharged into Lake Taneycomo varied between 7.2 and 15.6°C. The cool water flowed beneath a 10-ft-deep warmer surface layer through Lake Taneycomo, maintaining distinct thermal and sometimes observably distinct chemical identity. Water from this cool subsurface layer was discharged into Bull Shoals Reservoir headwaters and maintained its identity 59.5 km from the original discharge from Table Rock Dam.

F Fry. J. P. 1965. Harvest of fish from tailwaters of three large impoundments in Missouri. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 16:405-411.

A creel census on tailwaters below Table Rock and Taneycomo Reservoirs on the White River and below Clearwater Reservoir on the Black River was conducted in 1961.

Estimated fishing pressure on Table Rock tailwater was 1502 hr/ha and the rate of catch was 0.62 fish per hour. The yield per hectare was about 939 fish, weighing 215 kg. Hatchery-reared rainbow trout comprised nearly 90 percent of the yield by number.

Taneycomo tailwater supported an estimated 1504 hours of fishing per hectare. Rate of catch was 0.55 fish per hour; the yield per hectare was 847 fish, weighing 457 kg. White bass made up more than 37 percent of the total creel, followed by drum, crappies, channel catfish, and bluegills.

Estimated fishing pressure on Clearwater tailwater was 3969 hr/ha, with a catch rate of 0.55 per hour. The yield per hectare was 2297 fish, weighing 946 kg. Numerically, crappies comprised about 35 percent of the total catch, followed by carp, bluegills, channel catfish, and buffalo. Carp provided about one-third of the total weight.

The tailwaters of Table Rock, Taneycomo, and Clearwater Reservoirs received respectively 7, 10, and 16 times more fishing pressure per hectare than the reservoirs themselves. Taneycomo tailwater had more fishermen than Lake Taneycomo. Taneycomo and Clearwater tailwaters provided greater total harvests by weight than did their respective reservoirs.

F Fry, J. P. and W. D. Hanson. 1963. Lake Taneycomo: A cold-water reservoir in Missouri. Trans. Am. Fish. Soc. 97(2):138-145.

Significant changes in fishery of 1,730-acre (700-ha) Lake Taneycomo resulted from the construction of Table Rock Dam immediately upstream on White River because water, released through the dam from a relatively low level, is consequently quite cool. Discharge temperatures range from 40 to 60°F (4.4-15.6°C), and the cold water influences a large portion of Lake Taneycomo.

Netting indicated an excellent population of warm-water fishes prior to the cold discharge from Table Rock Dam. Since the change to a cold-water environment, only bluegills remain in significant numbers. Growth rates of warm-water species slowed markedly.

Fishing pressure on the lower two-thirds of the reservoir was as high as 133 hours per acre (329 hr/ha) annually before the change, with catch rates of over 1.0 fish per hour. White crappies made up half of the catch, by number, with bluegills and largemouth bass next. Low fishing pressure was observed on the upper one-third of the reservoir.

About 1,600,000 rainbow trout were stocked to sustain the fishery, following the release of cold water from Table Rock Dam. Fishing pressure on the upper portion of Lake Taneycomo increased to 528 hours per acre (1,304 hr/ha) with a catch rate of about 0.5 fish per hour. Relative numbers of rainbow trout in the creels increased steadily until they accounted for 99 percent in 1962 and

1963. Fishing pressure on the lower portion did not increase spectacularly; it was 87 hours per acre (215 hr/ha) in 1963. Catch rate was 0.7 fish per hour, with rainbow trout comprising half the catch. Bluegills, white crappies, and largemouth bass were still taken in limited numbers.

Tag returns revealed that the majority of the trout moved upstream, although some were captured as far as 95 miles (153 km) downstream. Growth of trout tagged, when about 10 in. (25.4 m) in length, averaged 0.4 in. (1.0 cm) per month. Those tagged at 6 in. (15.2 cm) averaged 0.6 in. (1.5 cm) per month. Tag returns were 22 percent of the larger size-group, but only 3 percent of the smaller size-group. (Author abstract.)

F Geen, G. H. 1974. Effects of hydroelectric development in western Canada aquatic ecosystems. J. Fish. Res. Board Can. 31(5):913-927.

The effects of some existing and proposed hydroelectric developments on lakes and rivers of western Canada are considered. There are few pre- and postimpoundment studies from this region on which to base generalization. Although the changes in species composition and water chemistry following impoundment of rivers and lakes reported thus far are comparable to those observed in other areas at similar latitudes, few data are available which permit prediction of thermal regimes in newly formed reservoirs, particularly in view of the turbid nature of some inflows to reservoirs. Several hydroelectric developments have blocked or impeded migrations of economically important fish and appear likely to produce a number of downstream changes in water temperature or composition, the effects of which are often speculative. More studies of the effects of altered temperature and flow regimes, reduced turbidity, and gas supersaturation are required. (Author abstract.)

F Geiger, W., H. J. Meng and C. Ruhle. 1975. Effects of simulated pumped storage operation on northern pike fry (in German, English summary). Schweiz. Z. Hydrol. 37(2):225-232.

The effects of periodic, simulated water levels fluctuations on northern pike fry produced by pumped-storage operations were examined. Daily fluctuations of 10 cm caused a significant increase in the daily mortality rate. Waves reduced the detrimental effect of water level fluctuations, at least during the adhesive phase of fry. (Author abstract.)

F Gengerke, T. W. 1978. Paddlefish investigations. Iowa Conserv. Comm., Commer. Fish. Invst., NMFS 2-255-R. 86 pp. (Mimeogr.)

Mississippi River paddlefish investigations were initiated to determine exploitation, characterize the harvest, and obtain basic life history information necessary for management of the species. Over 3,000 paddlefish were examined during the study. One thousand, five hundred sixty-two were tagged and released in Pool 13. Four hundred fifty were tagged and released in other pools bordering Iowa. Estimated numerical population size was 10,807. Movement to and from the tailwater area was measured through stochastic inference and estimated to be 10-80 percent of the pool population. Seasonal vulnerability was related to temperature, turbidity, and discharge. Temperature accounted for 46 percent of the variation in catch per effort. Discharge and turbidity were significantly intraclass correlated ($p<.01$). Mean size of fish in the sport harvest declined 150 mm (5.9 in.) and 2.33 kg (5.1 lb). Age frequency distributions were constructed from jaw samples removed from 603 fish. Survival over the study period, sexes combined, was 68 percent. Recommendations for management related to existing and projected survival and exploitation rates are included. (Author abstract.)

F,I,W Giger, R. D. 1973. Streamflow requirements of salmonids. Oreg. Wildl. Comm., Res. Div. Final Rep. AFS-62-1. 117 pp.

This report summarizes the streamflow requirements of juvenile salmonid fishes and relates current methodologies for recommending minimum summer streamflows. The objective of the review is to stimulate thought about ecological concepts important to the development of methods for determining minimum flows, rather than to recommend particular techniques.

Alteration in the flow regime of a stream initiates a complicated set of changes in environmental conditions that ultimately affects fish populations. Shelter, an essential and complex element of fish habitat, can be influenced significantly by streamflow. Aquatic and terrestrial invertebrates are of paramount importance as food for salmonids, and the manner in which streamflow affects these resources is of considerable significance. Substrate and water velocity are principal factors controlling the types and abundance of benthic invertebrates.

Salmonid feeding activity, like food supply, is linked with discharge level and particularly with water velocity. Much of the distribution of fish in stream channels is associated with feeding opportunity, yet much of it is also controlled by the physical environment. In determining the effects of streamflow on salmonid feeding, consideration might also be given to possible relationships between diurnal and seasonal feeding patterns and schedules for release of water below dams.

Requirements of young salmonids for space, shelter, water velocity, or other habitat characteristics can be appraised in a more comprehensive and interactive manner through such concepts as territory or microhabitat. These concepts and some of the more obvious habitat interactions are discussed in this report. In a general way, it is fairly evident how conditions such as fluctuating discharge below hydroelectric installations might be highly disruptive to microhabitats or to territorial behavior of salmonids, thereby affecting productivity.

Current methodologies for making minimum flow recommendations are limited by the level of understanding of stream ecology. In developing methods for determining flows for salmonids under conditions of limited understanding, consideration should be given to achievement of an optimal balance between as many important needs of fish as possible. Improved understanding of the stream ecology of juvenile salmonids is seen as a more important immediate goal, however, than efforts to develop procedures for making streamflow recommendations.

F,I Goodno, E. J. 1975. Post-impoundment limnology of the East Lynn Lake tailwater, West Virginia. W. Va. Acad. Sci. 47(3-4):170-176.

A post-impoundment tailwater limnological investigation was conducted from June 1973 through August 1974 at East Lynn Lake. Tailwater benthos populations were low and dominated by dipterans; 10 genera were collected. Thirty-eight genera of outflow plankton were collected. Golden brown algae and copepods, respectively, were the most numerous phyto- and zooplankton organisms. A total of 1,131 fish were collected. Game, forage, and rough fish comprised 19.63, 2.48, and 77.89 percent, respectively, of the total number of fishes and 50.13, 4.29, and 45.58 percent, respectively, of the total weight. The average annual outflow temperature was 16.6°C and the tailwater can be classified as a warm-water stream. (Author abstract.)

F Gordon, R. N. 1965. Fisheries problems associated with hydroelectric development. Can. Fish Cult., 35 (Oct.):17-36.

This paper reviews the current state of knowledge on salmon-hydro problems. The effects of large reservoirs on passage of juvenile salmon migrating seaward is not yet fully understood.

If migrants continue to behave as they do in natural river current, any reduction of normal velocities as might result from creation of reservoirs, would slow rate of migration accordingly. Flow reductions can produce delays. Sudden changes in discharge can cause a cessation of migration while the fish await return to stabilized conditions. Since salmon hold closely to the river margins during migration, sudden reductions in flow, as might be expected below a peaking plant, can cause them to become stranded in isolated pockets when the water recedes.

Powerhouse tailraces attract salmon away from normal safe routes up the river. Reductions in discharge are frequently accompanied by rising water temperatures.

While there undoubtedly is a minimum to which the natural flows can be reduced without harming the salmon stocks, local conditions vary so much with each stream that the only way of ensuring that altered flow patterns will not be detrimental is to provide continuous flows of approximately the same magnitude as those which occur in nature during the same period.

I Gore, J. A. 1977. Reservoir manipulations and benthic macroinvertebrates in a prairie river. Hydrobiologia. 55(2):113-123.

Samples were taken on the Tongue River, Montana, during 1974 and 1975 to determine the distributions and abundances of the benthic fauna after various reservoir manipulations. The upper cold-water section, influenced by hypolimnial discharge from the Tongue River Reservoir, was impoverished in insect fauna and dominated by the molluscs Physa and Sphaerium. The lower warm-water sections of the river contained two communities determined primarily by turbidity and periphyton cover. The upper warm-water area was dominated by Strophopteryx and hydropsychid caddis larvae. The lower river was dominated by Cheumatopsyche. The summer fauna, in the warm-water area, was dominated by short-lived mayfly species. During the summer, 1975, the cold-water section was invaded by many insects due to warming of the area when no hypolimnion was formed in the reservoir. Invasion was apparently due to increased thermal fluctuations which caused diapause eggs to hatch and influenced the upstream migration of older nymphs and larvae.

Results of drift and distributional samples after closure of the Tongue River Reservoir Dam for repairs showed that massive drift of all invertebrates began at a discharge of 130 c.f.s. (3.68 m^3/sec), a drop from 190 c.f.s. (5.38 m^3/sec) over a period of 3 days. Community composition was radically altered by reduced discharge. (Author abstract.)

F Graves, E. and B. Haines. 1969. Fishery survey of Navajo Tailwaters. N. Mex. Dep. Game Fish, Fed. Aid Proj. Sec. 8-A-66. pp. 60-91 (Mimeogr.)

This is the sixth and final annual report on this tailwater. The study objective was to develop a fish management program for the San Juan River below Navajo Dam. A deep outlet in the dam releases cool, clear water which makes an excellent trout stream for 12.9 km below the dam. Downstream the river becomes increasingly turbid and approximately 29 km below the dam it is unsuitable for trout, although there is limited channel catfish production.

In the first 12.9 km below the dam, the stream bottom is composed of rubble and rock. Invertebrates area abundant; Diptera, Ephemeroptera, Trichoptera, Gastropoda, and filamentous algae make up the bulk of trout diet.

The tailwater section from 12.9 to 29 km below the dam is characterized by cool and clear water most of the time with occasional high turbidities after rainstorms. Invertebrates occur only in moderate numbers because much of their habitat is covered with silt. Rainbow and brown trout occur here in only moderate numbers.

From 29 km below the dam to the New Mexico-Colorado state line, the tailwater is characterized by high turbidities, silt-laden stream bottom, and summer temperatures in the low 20's (C°). Invertebrates occur in small numbers.

I Gray, J. S. 1971. Seasonal cycles of net plankton in a cold-tailwater and a natural stream in the state of Arkansas. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 24:608-621.

Midwinter blooms of Chrysophyta at the Beaver Dam stations were preceded by an increase in average monthly temperatures and followed by a decrease in silica concentrations. Downstream from Beaver Dam, later summer blooms of Cyanophyta were recorded. Most of these increases occurred in conjunction with high average dissolved oxygen concentrations and temperatures. At the Kings River, winter blooms of Chlorophyta coincided with maximum dissolved oxygen concentrations. Summer blooms appeared to show a positive correlation with increases in temperature and dissolved oxygen concentrations.

Zooplankters were most abundant during the winter months at the Beaver Dam stations. Consequently, net zooplankton decreases appeared to be inversely proportional to the average seasonal temperature. From July to October 1968, the Kings River stations showed a positive correlation of zooplankton number with seasonal increases in temperatures and decreases in average riffle speeds.

Annual trout stockings have occurred in the first 29 km of tailwaters. It was recommended that rainbow fingerlings be stocked in the first 12.9 km, brown trout fry in the next 16 km. The stocking rate of maximum benefit to the fishery is unknown at this time. Another unresolved problem is the effect different reservoir releases have on the fishery. (Taken from author abstract.)

F Hall, G. E. 1949. Fish population of the stilling basin below Wister Dam. Proc. Okla. Acad. Sci. 30:59-62.

This study was a preimpoundment survey of the fish population in the stilling basin below Wister Reservoir. A large fish population was found below the dam in August, long after the spring spawning period. It was not known whether fish abundance would remain high in the stilling basin at all times of the year.

F Hall, G. E. and W. C. Latta. 1951. Pre- and post-impoundment fish populations in the stilling basin below Wister Dam. Proc. Okla. Acad. Sci. 32:1-6.

Fish collected in 1951 were compared with those taken in 1949. Changes in species composition and standing crops suggested the fish population was progressing from that native to the river to one more commonly associated with Oklahoma reservoirs.

W Hannan, H. H. 1979. Chemical modifications in reservoir-regulated streams. Pages 75-94 in J. V. Ward and J. A. Stanford, eds. The Ecology of Regulated Streams. Plenum Press, New York and London.

This paper is a review dealing with deep-storage reservoirs that thermally stratify during the summer. The author provides a generalized understanding of the limnological and hydrological factors associated with impoundment behavior that results in changes in the chemical conditions downstream from the reservoir.

W Hannan, H. H. and W. J. Young. 1974. The influence of a deep-storage reservoir on the physicochemical limnology of a central Texas river. Hydrobiologia 44(2-3):177-207.

A study was conducted to determine a physicochemical profile of a new deep-storage reservoir and to determine the influence of impoundment and thermal stratification in the reservoir on the physicochemical limnology of the parent river. The presence of thermal stratification from May through November caused the most significant change in water conditions. Of 24 parameters studied, 12 remained unchanged, 10 improved, and 2 deteriorated.

The greatest downstream changes in water conditions from those upstream from the reservoir were a decrease in temperature, an increase of ammonia, and the presence of hydrogen sulfide during the period of thermal stratification. Ammonia did not increase to a level considered to be toxic to aquatic species. It could, however, serve as a nutrient for certain species of plants and result in a change in community structure.

Water temperature downstream from the reservoir was always within the annual temperature range of the river upstream from the reservoir; however, the summer maximum in the tailrace was decreased to a temperature that could interfere with the normal life cycle of many species. (Author abstract.)

F Hanson, W. D. 1969. Fishery of Lake Taneycomo tailwater. Mo. Dep. Conser., Fed. Aid Proj. F-1-R-18. 18 pp. (Mimeogr.)

Studies conducted from 1961-68 indicate that the tailwater fishery is considerably influenced by the water level in Bull Shoals, the immediate downstream reservoir. Sportfishing was most successful in years with intermediate water levels. In years when water levels were low some species, particularly white bass, did not immigrate into the tailwaters from the reservoir and fishing success was poor. Fishing was also poor in years when reservoir water levels were high. Numbers of rainbow trout taken by anglers generally increased each year and were dependent on the number stocked and their escapement from Lake Taneycomo.

A variety of fishes occur in the tailwater and many interrelated factors contribute to their abundance.

F Hanson, W. D. 1977. The tailwater fisheries of Lake of the Ozarks and Pomme de Terre Lake, Missouri. Mo. Dep. Conserv., Fed. Aid Proj. F-1-R-25. 29 pp. (Mimeogr.)

The tailwater fisheries of Lake of the Ozarks, a 60,000 acre (24,280 ha) mainstem, power producing reservoir, and Pomme de Terre Lake, a 7,820 acre (3,165 ha) tributary stream, flood control reservoir, were measured by a part-time roving creel survey from 1965 through 1974. Catch rates of fishes were compared with temperature, conductivity, and dissolved oxygen, but no statistically valid correlations were found. However, high positive correlations existed at Lake of the Ozarks tailwater between annual average catch rates and the annual average discharge of water and also between preceding mean monthly discharges and following monthly catch rates. There was a high positive correlation between estimated number of fishes caught in this tailwater and the number of days per year that the floodgates were open. At Pomme de Terre tailwater, there was a high positive correlation between discharge and catch rate for monthly, seasonal, and annual periods. For some years, there was a high daily positive correlation. Anglers at the Lake of the Ozarks tailwater had short periods of outstanding angling, longer periods of good fishing and intermittent periods of poor fishing, while those at Pomme de Terre tailwater had shorter periods of good success and much longer periods of poor fishing. Manipulation of discharges, commensurate with safety, might be utilized to prolong and enhance fishing success below dams. Structures that cause deepening of tailwater pools and water current eddies also benefit the angler's success. (Author abstract.)

I Hartman, R. T. and C. L. Himes. 1961. Phytoplankton from Pymatuning Reservoir in downstream areas of the Shenango River. Ecology 42(1):180-183.

The author cited literature indicating that phytoplankton productivity was less in Missouri River reservoirs than in the river below and attributed this phenomenon to the clarification and enrichment of the stream from the reservoir above.

In Pymatuning Reservoir the species composition of the phytoplankton immediately below the dam was similar to that in the reservoir, but due to the depth (4.6-6.1 m) of withdrawal and mechanical distribution of some forms when forced through the effluent, numbers of phytoplankton immediately below the dam were lower. At a station further downstream (2.5 km), the streambed widened, water slowed, and phytoplankton numbers increased. Downstream from that section nutrient depletion, mechanical destruction, increased silt load, and increased current speed resulted in lowered standing crops. Diatoms increasingly comprised a larger proportion of the community in downstream areas.

F Henley, J. P. 1967. Coldwater investigations. Ky. Dep. Fish. Wildl. Resour., Fed. Aid Proj. F-27-R. 45 pp. (Mimeogr.)

Catch statistics and fish population parameters were presented on four Kentucky streams and three tailwaters. Catch rates for trout varied from 0.09 to 0.23 fish/hour on the tailwaters. Fish populations in the streams were rainbow trout-cyprinid associations or smallmouth bass-cyprinid-sculpin-sucker associations. Tailwaters were primarily Lepomis-Pomoxis-rainbow trout associations.

F,W Hicks, D. E. 1964. Limnological investigations of the Illinois River below Tenkiller Dam. Walleye investigations in Oklahoma. Okla. Wildl.Conserv. Dep., Fed. Aid Proj. F-7-R-3. 10 pp. (Mimeogr.)

Limnological studies were conducted from June through January to determine the feasibility of introducing walleyes into the Tenkiller Dam tailwaters. Low oxygen values occurred immediately below the dam because of lack of aeration within the penstock tunnels of the power plant. Oxygen values were adequate further downstream as were water temperature and bottom fauna. Walleye fingerlings were recommended for the stocking.

F Hicks, D. F. 1968. Determination of how to manage possible trout fishery below Tenkiller Ferry Reservoir. Okla. Wildl. Conserv. Dep., Fed. Aid Proj. F-15-R-3. 4 pp. (Mimeogr.)

A total of 12,429 kg of trout, ranging in size from 20.3-25.4 cm, were stocked at various intervals during 1967. Estimates of utilization and survival suggest that trout be stocked at two-week intervals and only in deep pools. Trout stocked in shallow pools were stranded and died when power peaking decreased water levels.

I,W Hill, D. M. 1978. Characteristics and determinants of the fisheries resources of three cold tailwaters in Tennessee. Div. for Fish. Wildl. Dev. TVA. 10 pp. (Manuscript.)

This investigation confirms that tailwater biota are governed by the interaction of a number of complex ecological relationships. It further proposes that dissolved oxygen is the factor most limiting to the maintenance of diverse tailwater faunal assemblages. Other biological differences such as standing crops and seasonal abundances of fish and bottom fauna are more directly influenced by temperature, mineral quality, flow regimes, and substrate composition.

I Hilsenhoff, W. L. 1971. Changes in the downstream insect and amphipod fauna caused by an impoundment with a hypolimnion drain. Ann. Entomol. Soc. Am. 64(3):743-746.

Mill Creek, a small stream in southwestern Wisconsin, was impounded to create a 150-acre (60.7-ha) recreational lake. This action had a pronounced effect on the insect and amphipod fauna of a riffle 600 ft (182.9 m) below the dam and also affected the fauna of a riffle 2 miles (3.2 km) downstream. Prior to impoundment both riffles were inhabited by a diverse insect fauna that included mostly Ephemeroptera, Trichoptera, Diptera, and Coleoptera.

After impoundment the reduction of the number of species in the upstream riffle was highly significant and previously dominant families such as Baetidae (Ephemeroptera), Hydropsychidae (Trichoptera), and Elimidae (Coleoptera) were replaced mostly by increased populations of <u>Simulium</u> <u>vittatum</u> Zetterstedt (Diptera), <u>Gammarus</u> <u>psuedolimnaeus</u> Bousfield (Amphipoda), and <u>Chironomus</u> and other genera of Chironomidae (Diptera). The impoundment affects the downstream riffle similarly but to a lesser degree. Large increases in phosphorus and nitrogen concentrations and increased siltation as a result of impoundment were probably the most important factors in altering the insect and amphipod populations. (Author abstract.)

F,I,W Hoffman, C. E. and R. V. Kilambi. 1970. Environment changes produced by coldwater outlets from three Arkansas reservoirs. Univ. Ark., Water Resour. Res. Cent., Publ. No. 5, 169 pp.

Water quality of two natural streams (Buffalo and Kings Rivers), one new cold-tailwater (Beaver), and two old cold-tailwaters (Norfork and Bull Shoals) in northwestern Arkansas were studied from July 1965 through October 1968.

The essential difference between the old cold-tailwaters and natural streams is a change in water quality which allows the development of a new productive ecological environment. Features which typify the old tailwaters are as follows: (1) relatively homeothermous temperatures; (2) stream beds scoured by strong hydroelectric power generation currents; (3) abundant phytoplankton and benthic macroinvertebrates; and (4) absence of warm-water game fishes.

Environmental factors characterizing natural streams are as follows: (1) high summer temperatures; (2) seasonal and individual current fluctuations at the various stations; (3) a greater variety of benthic macroinvertebrates and ichthyofauna; (4) abundant zooplankters; and (5) a tendency toward an equal distribution of the phyla Chrysophyta, Cyanophyta, and Chlorophyta.

By October 1968, the new Beaver cold-tailwater had lost all of its warm-water characteristics but had not developed the biotic features of the old tailwaters. (Author abstract.)

F Holden, P. B. 1979. Ecology of riverine fishes in regulated stream systems with emphasis on the Colorado River. Pages 57-74 in J. V. Ward and J. A. Stanford, eds. The Ecology of Regulated Streams. Plenum Press, New York and London.

Whether a factor is immediate or delayed, the ultimate impact of regulation on obligate riverine fishes depends on the degree of change and the tolerance level of the fish to that change. In general, the least tolerant (most highly adapted) species tend to sustain the greatest impact of regulation. In warm-water areas in the eastern and southern United States, where diverse fish faunas are common, tailwater species are usually replaced by other native species where changes are not drastic. Drastic changes, such as a reduction in summer temperature from warm to cold, usually displace all native fishes, and exotic species such as planted rainbow trout usually predominate. In the more arid Southwest, with its relatively depauperate but highly specialized fish fauna, regulation tends to replace native fishes with exotic species. (Author summary.)

F,I Hooper, D. R. 1973. Evaluation of the effects of flows on trout stream ecology. Pacific Gas and Electric Company, Dep. Eng. Res., Emeryville, California. 97 pp.

This paper deals with methods of evaluating the relationships between water flows and trout production in controlled streams. The paper reviews various techniques that have been used in stream ecology investigations and suggests methods which are applicable to determining flows which will optimize productivity with a given or minimum amount of water.

Computer analysis appears to be the most practical and meaningful method of analysis of the extensive transect data which have been collected in California studies. Such an approach would evaluate environmental changes affecting fish and invertebrates in a stream under various flow conditions. Recent refinements in our knowledge of the microhabitat requirements and tolerances of stream organisms would form the basis of such a computer program. (Author abstract.)

W Hubbs, C. 1972. Some thermal consequences of environmental manipulations of water. Biol. Conserv. 4(3):185-188.

Environmental manipulations can alter thermal regimes, upset the delicate adaptations of natural populations, and have adverse effects on the native biota. The resulting problems can be exacerbated by reducing 24-hourly oscillations, increasing potentiality for thermal shock, and causing reproduction to occur at adverse temperatures. (Author abstract.)

W Hull, C. H. J. 1965. Bibliography on the effects of impoundments and flow regulations on water quality. Preliminary draft prepared by the Committee on Research of the Sanitary Engineering Division, American Society of Civil Engineers, Technical Publications Department, New York. 119 pp.

The effects of impoundments and flow regulations on water quality are covered in a bibliography of available literature through 1962. An author and subject index for cross referencing is presented.

F Hulsey, A. H. 1959. An analysis of the fishery benefits to be derived from a warm-water tailwater vs. a cold-water tailwater. Ark. Game Fish Comm. 4 pp. (Mimeogr.)

This report discussed (1) the benefits of a warm-water tailwater to the native warm-water fishery; (2) the possible utility of a cold tailwater for a put-and-take trout fishery; and (3) known harmful effects of a cold tailwater on the native warm-water fishery.

F Hutchinson, J. M. and W. W. Aney. 1964. The fish and wildlife resources of the Lower Willamette Basin, Oregon, and their water use requirements. Oreg. Game Comm., Fed. Aid Proj. F-69-R-1. 76 pp. (mimeogr.)

Studies were conducted to define the water problems and needs associated with the basin's fish and wildlife resources. Resume's of the resources including abundance, distribution, and value of various species are included.

The recommended flows are based primarily upon biological requirements of salmonids. Most recommended flows are below the average stream discharges for the periods listed.

Flow studies conducted in the South Coast Basin showed that to satisfy the basic rearing requirements of adequate food and shelter, and a suitable medium in which to live, it was necessary that each stream possess a particular "live" flow over its entire length. This live flow should have a minimum depth of between one and two-tenths of a foot (3.0 and 6.1 cm) over a substantial portion of each riffle regardless of stream size.

It was found that this flow is not always adequate to provide acceptable water quality.

To determine stream flows necessary for anadromous fish spawning, sections of major spawning areas were examined in each stream studied. Investigations were conducted whenever possible at time of actual spawning. Minimum water depth for chinook salmon (Oncorhynchus tshawytscha) spawning was considered to be 0.8 of a foot (24.4 cm) while coho salmon (O. kisutch) and steelhead trout (Salmo gairdneri) require at least 0.6 of a foot (18.3 cm) of water. Proper spawning velocities for all these species were considered to range between 1.0 and 2.5 feet per second (0.3 and 0.8 m/sec) as measured 0.4 of a foot (12.2 cm) from the stream bottom.

In determining recommended minimum spawning flows, the desirable depths and velocities described above were required over substantial portions of each stream's spawning areas. (Fraser 1972b.)

F Hutchinson, J. M. and J. D. Fortune, Jr. 1967. The fish and wildlife resources of the Powder Basin and their water requirements. Oreg. State Game Comm., Fed. Aid Proj. F-69-R-5. 30 pp. (Mimeogr.)

This report describes the fish and wildlife resources of the Powder Basin, their water requirements, and the water resources of the basin as they influence fish and wildlife. Its primary purpose is to provide the Oregon State Water Resources Board with information about these resources along with recommendations for minimum stream flows for fish.

An inventory of species present in the basin is included and their relative abundance and distribution are indicated. Biological requirements of trout are discussed to point out the factors that are taken into account (e.g., spawning, rearing, water quality, and passage) when recommendations are made for minimum stream flows. Problems within the basin that affect fish are listed and discussed. Management activities of the Oregon State Game Commission are outlined and the sport fisheries described. Flow recommendations are made for 62 streams and sections of streams.

F Hutchinson, J. M., K. E. Thompson, and J. D. Fortune, Jr. 1966. The fish and wildlife resources of the Upper Willamette Basin, Oregon, and their water requirements. Oreg. Game Comm., Fed. Aid Proj. F-69-R-3. 55 pp. (Mimeogr.)

Primary objectives of the study were to define water problems and needs associated with the basin's fish and wildlife resources and to submit findings and recommendations for minimum flows to the State Water Resources Control Board.

A review is made of the status of the fish and wildlife resources of the basin including abundance, distribution, and value of the various species. Water developments in the basin are described. These have disrupted the fish distribution pattern from an original anadromous fish area to warmwater fish, trout, and anadromous fish. Dams have adversely affected game fish, their habitat, and their harvest. In excess of 346 km of stream environment are closed to Pacific salmon and steelhead trout (Salmo gairdneri) by Dexter Dam. Fish hatcheries provided as mitigation for losses resulting from Corps of Engineers dam construction are not capable of rearing the number of juvenile salmon and steelhead that could be produced in the streams isolated by the barriers. Developments beneficial to the fish resources are also described for each stream in the basin.

In the stream flow study, emphasis was placed on determining the minimum spawning and rearing flows necessary to maintain present levels of both resident and anadromous species. Recommended flows are based primarily upon biological requirements of fish life. Most recommended flows are at or below the average stream discharge for the periods listed. Some exception occurs for low elevation streams in the late summer and fall months of adverse years when recommendations are often above existing flows. Reduction of flows below those listed, whether caused by hydrological conditions or withdrawal, would diminish fish production.

F Idaho Fish and Game Department. 1969. Aquatic life water needs in Idaho streams. Prepared for Idaho Water Resour. Bd., Plan. Rep. 3. 39 pp.

This study was conducted by the Idaho Fish and Game Division to recommend minimum sustained flows to maintain coldwater aquatic life populations in 6 major Idaho streams. The following biological requirements necessary to maintain coldwater game fish populations were the basis for determining needed minimum flows.

(1) Water quality--Dissolved oxygen (D.O.) and water temperature are two factors most influenced by minimum flows. Suitable water for spawning and survival of eggs and fry in the gravel should range between 8-10 mg/ℓ D.O. and from 5.6-12.8°C. Temperatures for rearing juveniles and to maintain adult fish should not exceed 18.3°C over an extended period, and D.O. should not drop below 5 mg/ℓ.

(2) Food--Aquatic insects are the primary food of stream dwelling coldwater fish. This food is produced mostly in the riffle areas which must be maintained by minimum flows. Water quality suitable for fish is generally favorable for food organisms.

(3) Escape cover--Adequate flows should maintain deep riffles, pools, cutbanks, brush and grass, and other areas in which fish can avoid predators.

(4) Reproduction--Minimum water depth for spawning steelhead and large trout and char is 18.3 cm. Proper velocities for spawning

range between 0.3 and 0.8 m/sec as measured 12.2 cm above the stream bottom.

(5) Fish passage--Streamflow should be sufficient to allow migration and movement without blockage or stress.

In stock and take fisheries the depth and velocities should be such that the stocked fish remain congregated, thus insuring angler success. Few stocked fish survive beyond one year.

F,I,W Irving, R. B. and P. Cuplin. 1956. The effect of hydroelectric developments on the fishery resources of Snake River. Idaho Dep. Fish. Game, Fed. Aid Proj. Final Rep. F-8-R. 169 pp. (Mineogr.)

An investigation was made during periods of two successive years to determine the reasons for an apparent decline in fishing success in a section of the Snake River below the Idaho Power Company's Lower Salmon Falls hydroelectric installation which is operated for power-peaking. Average daily flows ranged from 7,000 cfs (198.2 m^3/sec) to almost 12,000 cfs (339.8 m^3/sec) below the dam. Water flows, turbidity, bottom organisms, temperatures, water chemistry, drift organisms, plankton, fish, fishing pressures, and fishing success were studied including the influence of four other hydroelectric dams located on the river. The effects of reservoir fluctuation and the productivity of the five reservoirs are discussed. Conclusions relate to the adverse effects of reservoir and tailwater fluctuations. (Fraser 1972b.)

I Isom, B. G. 1971. Effects of storage and mainstream reservoirs on benthic macroinvertebrates in the Tennessee Valley. Pages 179-191 in G. E. Hall, ed. Reservoir Fisheries and Limnology. Am. Fish. Soc. Spec. Publ. 8.

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. (Author abstract.)

F Jankovic, D. 1975. The fish fauna of the Djerdap impoundment in the first year after formation (in German, English summary). Arch. Hydrogiol. Supplement. 44:364-371.

The study and the survey of the changes occurring in the reservoir formed by damming the River Danube at the Iron Gates are not only of scientific but also of practical importance. The migration of anadromous fish species from downstream is obstructed, those in the lake migrate into the upper part with faster flow or into the mouths of tributaries, whereas the cyprinid fish species become adapted successfully to the newly created conditions. (Author abstract.)

F,I,W Jassby, A. D. 1976. Environmental effects of hydroelectric power development. U. S. Dept. of Commerce, Nat. Tech. Inf. Ser. LBL-5296. 24 pp.

Water discharged from the hypolimnion may contain large amounts of plant nutrients as well as other materials toxic to life downstream. Sulfur, iron, and manganese may be reduced to the extent that they may be toxic in high concentrations. Increased evaporation in the reservoir leads to increased total dissolved solids which could be seen in the discharge as well.

Mixtures of epilimnion and hypolimnion discharge may result in high concentrations of phytoplankton growth due to a combination of nutrient input and well-oxygenated clear water. Irregular discharges can discourage downstream benthic development. Cold hypolimnetic discharge and reduced dissolved oxygen with accompanying toxic substances affect downstream benthos.

F Jeffries, P. O., Jr. 1974. Food habits of selected game fishes related to composition and distribution of resident and anadromous fish populations in the Connecticut River below Holyoke Dam, Massachusetts. M. S. Thesis, Univ. Mass., Amherst. 89 pp.

The fish population and food habits of several species were investigated on the Connecticut River below Holyoke Dam, a run-of-the-river hydropower facility. Fish populations were stable in 1972 when compared to 1960 and 1966 studies. Food habit studies on largemouth bass and black crappies showed selectivity toward spottail shiners and away from Alosa spp.

W Johnson, M. G. and A. H. Berst. 1965. The effect of low-level discharge on the summer temperature and oxygen content of a southern Ontario reservoir. Can. Fish. Cult. 35(Oct):59-66.

Fanshawe Lake, a 261-ha multipurpose reservoir, is located on the north branch of the Thames River five miles upstream from London, Ontario. After 10 years of surface discharge, there was a noticeable deterioration of water quality within the reservoir because of the constant addition of dissolved and suspended nutrients from the watershed. From June through November 1963, water was released from near the lake bottom to determine the relation between low-level discharge and summer temperature and oxygen content.

With low-level discharge, water temperature of the hypolimnion was warmer than in previous years and deoxygenated water was eliminated for most of the reservoir. The cool effluent from the lake warmed rapidly in the tailwaters reaching air temperature equilibrium 610-1219 m from the dam depending on discharge. Oxygen concentration increased rapidly following release of water from the reservoir. Satisfactory recovery (60 to 75 percent saturation) usually occurred in the stilling basin.

F Johnson, Richardson, Johnson, Jackson, Helms, Wiley, and Baldes. (First names not shown.) 1964. An evaluation of data and observations on trial flow-releases in the Green River below Fontenelle Dam. Wyo. Game Fish Comm., Fish Div., Admin. Rep. 1964. 14 pp. (Mimeogr.)

A series of water-flow studies were carried out on a 32.2-km section of the Green River from Fontenelle Dam to the mouth of the Big Sandy River to determine a river flow optimum for sport fishery maintenance and also compatible with probable minimum releases from the dam. The study plan proposed to make observations on water flows of approximately 11.3, 8.5, and 5.7 m^3/sec in relation to their effect on the stream bottom and channel conditions. Five observation stations were located about 8.1 km apart. Comparative photographic records were made for the three flow rates.

On the basis of the photos and "general observations" by all personnel, the change in river condition between flows of 11.8 and 8.5 m^3/sec appeared to produce relatively unimportant differences in aquatic habitat. At 8.5 m^3/sec most shoal areas remained adequately covered with water for good fauna survival, and the channel conditions appeared little changed from those at 11.8 m^3/sec.

The drop from 8.5 to 5.7 m^3/sec, however, had many drastic effects. Channel areas became riffles and many square feet of shoreline shallows and midstream shoals were largely or completely dewatered, resulting in the destruction of much bottom fauna habitat and considerable reduction in fish habitat.

On the basis of this study, the report states that it seems logical to recommend that nothing less than 8.5 m^3/sec should be considered as providing adequate minimum conditions for the maintenance of a sport fishery.

F Kelley, D. W., A. J. Cordone, and G. Delisle. 1960. A method to determine the volume of flow required by trout below dams, a proposal for investigation. Calif. Dep. Fish Game Reg. 11. 13 pp. (Mimeogr.)

This report describes a method of measuring how well a given streamflow meets the needs of a fish population. Hypotheses were developed that certain of these flows will maintain or enhance the existing fishery. An investigation is proposed to validate methods and test hypotheses.

F Kent, R. 1963. North Platte River fish loss investigations. Wyo. Game Fish Comm., Fed. Aid Proj. 763-6-1. 62 pp. (Mimeogr.)

In 1946 the U. S. Fish and Wildlife Service recommended a minimum flow of not less than 5.7 m^3/sec below Kortes Dam and that changes in rate of flow be gradual. These recommendations were not made a part of the operating plan for the Kortes project. Fish losses, attributed to dewatering of the river during days of no power generation at Kortes Dam, occurred in the North Platte River during the summers of 1961, 1962, and 1963. Studies in 1961 and 1962 showed that high water temperatures, brought about by the combination of high air temperatures and low water flows, were responsible for the trout losses.

Studies were conducted in 1963 for the purpose of assessing a series of water flows designed to prevent further fish losses and to maintain the aquatic habitat and trout population at a level commensurate with at least the 1955 dry-year minimum. Six water-release patterns ranging from 1.0 to 22.4 m^3/sec were tested at five stations in a 10.5-km section of the river below the dam. Each station was chosen because of its (1) accessibility, (2) similarity to the river as a whole, and (3) relatively equal spacing within the 8-mile length.

The report concludes that a flow of 5.9 m^3/sec barely approaches the minimum constant release which will maintain the trout fishery. Flows of 14.2 m^3/sec and 22.6 m^3/sec are considered as optimum and maximum, respectively, for fisherman utilization and maintaining a proper trout fishery habitat.

The report makes an analysis of the effects of low flows and fluctuations of flows on the trout population of the North Platte River and finally recommends a constant minimum flow of 14.2 m^3/sec be released from Kortes Power Plant at all times.

F Kinnear, B. S. 1967. Fishes and fish habitats in Black Canyon of the Gunnison National Monument. M. S. Thesis, Colo. State Univ., Fort Collins. 45 pp.

The condition factor of rainbow trout increased following closure of the Blue Mesa Dam on the Gunnison River, Colorado. Control of Blue Mesa Dam reduced maximum flow and increased minimum flows; these conditions caused less stress on fish. High runoff periods (spring) still reduced habitat for native and introduced fishes.

W Kittrell, F. W. 1959. Effect of impoundments on dissolved oxygen resources. Sewage Ind. Wastes 31(9):1065-1078.

The effect of thermal stratification on reaeration characteristics of both storage and mainstream reservoirs is considered, and data are presented for a number of field situations. Corrective measures to overcome the effects of reduced oxygen content in the hypolimnion are discussed, including: use of multilevel penstock intakes, high-level penstock weirs, special tailrace design, compressed air reaeration, and circulator of reservoir contents by pumping. Research on the latter method is recommended. Forty-two references are appended.

F,I,W Krenkel, P. A., G. F. Lee, and R. A. Jones. 1979. Effects of TVA impoundments on downstream water quality and biota. Pages 289-306 in J. V. Ward and J. A. Stanford, eds. The Ecology of Regulated Streams. Plenum Press, New York and London.

It has been shown that reservoir construction and operation have significant effects on aquatic life, which vary depending upon the project objectives and the specific requirements of tailwater biota. The large variations in flow and associated water quality parameters may adversely affect downstream fisheries, influence the benthos, and, in general, lessen recreational opportunities.

Water quality parameters, such as temperature and dissolved oxygen, can greatly influence downstream aquatic life, particularly when adverse water quality conditions are combined with peaking power operations to yield periods of low flow, then sudden increases in cold water flow.

Additional information is needed to more clearly define the role of reservoir operation in maintaining downstream fisheries. Also, it is apparent that before meaningful biological studies can be pursued in reservoirs and tailwaters, the hydrodynamics of the systems must be delineated. (Author summary.)

F Kroger. R. L. 1973. Biological effects of fluctuating water levels in the Snake River, Grand Teton National Park, Wyoming. Am. Midl. Nat. 89(2):478-481.

The effects of fluctuating water levels--which result from variation in demand for irrigation water released through Jackson Lake Dam--on aquatic biota in the Snake River in Grand Teton National Park were observed. Unnaturally low water levels and sudden decreases in water flow exposed the streambed and destroyed algae, invertebrates and some fish, and probably limited the production of other fish occupying high trophic levels. This is evidently the first published report which shows that rapid changes in water levels leave aquatic invertebrates and some fish stranded on the exposed streambed. (Author abstract.)

F Kuznetsov, V. A. 1971. The effect of regulation of the discharge of the Volga on the reproduction of asp, zope, white bream, and bleak in Sviyaga Bay, Kuybyshev Reservoir. J. Ichthyol. 11(2):186-192.

The alteration of the hydrologic regime of the Middle Volga as a result of construction of the Kuybyshev Power Station has had some effect on the reproduction of fishes. The asp has adapted itself to new spawning grounds and substrates. It lays its eggs on the stony bottom, on plants, and exposed roots in the bank zone and the flooded zone. The bleak spawns in the shallows and in open flooded areas. The zope breeds only in bank areas where there is profuse aquatic vegetation, and when water level fluctuates during the spawning period its eggs perish. The white bream lays its eggs in the shallow-water zone. Because there is repeated addition of water at this time, the effectiveness of its reproduction is relatively high. (Author abstract.)

I Lehmkuhl, D. M. 1972. Change in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish Res. Board Can. 29(9):1329-1332.

The kinds and numbers of Ephemeroptera and other insects in the Saskatchewan River are greatly reduced downstream of a dam. This is attributed to changes in river temperatures caused by the reservoir. The river is warmed in winter and cooled in summer. Consequently, mayflies and other insects with strict thermal requirements cannot hatch and grow successfully. The effect is evident 70 miles (112.7 km) downstream. (Author abstract.)

I Lehmkuhl, D. M. 1979. Environmental disturbance and life histories: principles and examples. J. Fish. Res. Board Can. 36(3):329-334.

Drastic changes in physical features of a stream can eliminate sensitive species and allow tolerants to thrive. Nutrients and pH are apparently tolerated by organisms over a wide range. Minor alterations of temperature can cause drastic effects on the animal community and it is the critical triggering mechanism for various life stages. Temperature can affect faunal quantity and quality up to 100 km downstream from a hypolimnial release.

While many environmental disturbances have no readily detectable effect on aquatic invertebrates in the short term, they may prevent normal reproduction and cause eventual local extinction of species. (Taken from author abstract.)

F Little, J. D. 1967. Dale Hollow tailwater investigations. Tenn. Game Fish Com., Fed. Aid Proj. F-30-R-2. 18 pp. (Mimeogr.)

This report presents data collected from Dale Hollow tailwater before its partial impoundment by Cordell Hull Reservoir. When studied, this tailwater was one of the most popular trout fishing areas in the State of Tennessee. After impoundment of Cordell Hull, however, the tailwater length will be reduced from 11.7 to 4.8 km. Twenty species were found; all except trout occurred in small numbers. Data are also presented on trout growth rates, food habits, plus available food and water quality.

F Louder, D. 1958. Escape of fish over spillways. Prog. Fish-Cult. 20(1):38-41.

Heavy loss of fish over spillways appeared to be correlated with season rather than with magnitude of overflow. Losses occurred over short periods of time.

I,W Lowe, R. L. 1979. Phytobenthic ecology and regulated streams. Pages 25-34 in J. V. Ward and J. A. Stanford, eds. The Ecology of Regulated Streams. Plenum Press, New York and London.

Most of the chemical and physical parameters characteristic of regulated streams flowing from deep-release reservoirs have a positive impact on the density of phytobenthos. Reduced temperature fluctuation, reduced flow fluctuation, increased transparency, and increased nutrient concentrations all tend to stimulate growth of periphyton and aquatic vascular plants. Simulated species are, for the most part, cool-water stenotherms characteristic of nutrient-rich aquatic habitats. (Author summary.)

W MacDonald, J. R. and R. A. Hyatt. 1973. Supersaturation of nitrogen in water during passage through hydroelectric turbines at Mactaquac Dam. J. Fish Res. Board Can. 30(9):1392-1394.

Two fish kills occurred at the Saint John River, New Brunswick, below the Mactaquac Hydroelectric Station in the summer of 1968. Gas bubbles, commonly associated with nitrogen supersaturation, were observed on dead and dying salmon (Salmo salar) and eels

(Anguilla rostrata). Tests showed that the concentrations of dissolved oxygen and nitrogen gases were substantially increased when water passed through the turbine generating system at low generating levels. Concentrations of dissolved nitrogen gas increased by as much as 20 percent above atmospheric equilibrium. (Author abstract.)

I,W MacPhee, C. and M. A. Brusven. 1973. The effects of river fluctuation resulting from hydroelectric peaking on selected aquatic invertebrates. Water Resour. Res. Inst., Univ. Idaho, Moscow. 21 pp.

Near-shore variation in number and weight of riffle insects was shown to be affected by changes in depth (15, 30, and 45 cm) and current velocity, interacting with date and station of sampling. This differential littoral distribution of riffle insects resulted in variation of the littoral community structure. In the nonfluctuating system, community diversity and diversity per individual decrease with increasing depth to 45 cm and current velocity to 1.1 m/sec. Fluctuating flows appear to reverse the order of the community structure, i.e., community diversity and diversity per individual increase with increasing depth to 45 cm and current velocity to 1.1 m/sec. A flow reduction exponentially increased the number of drifting insects in zones adjacent to the exposed substrate in the shoreline. Insects tested in the laboratory demonstrated variability in temperature-exposure tolerances. The case-bearing caddisfly, Dicosmoecus sp., was generally more tolerant than the stonefly, Pteronarcys californica, at most temperature regimes.

Older age-class nymphs of the latter were more tolerant than younger nymphs. Shore migration studies indicated stoneflies were much more successful in maintaining contact with the water column during flow reductions than caddisflies and mayflies; mayflies were most vulnerable. (Author abstract.)

W Maddock, T. 1976. A primer on floodplain dynamics. J. Soil. Water Conserv. 31(2):44-47.

The principal purposes of reservoirs are the reduction of high discharge with subsequent lowered discharges for longer periods of time and for the elimination of sediment transport immediately below the dam. Elimination of flooding results in stream width reduction, allowing for vegetation encroachment and increased slope.

Channels below dams have several resulting physical modifications: vegetative encroachment reducing channel capacity, degradation, aggradation below tributaries, armored streambeds, and a widened streambed. The effect of these factors depends on the original existing conditions.

A streambed of fine sand is extremely unproductive because of its instability.

I,W Martin, D. B. and R. D. Arneson. 1978. Comparative limnology of a deep-discharge reservoir and a surface-discharge lake on the Madison River, Montana. Freshwater Biol. 8:33-42.

Phytoplankton standing crop, primary production, light penetration, temperature, and various chemical concentrations were measured in a man-made, deep-discharge reservoir and in a natural, surface-discharge lake in order to relate limnological conditions in the two bodies of water to their depth of outflow. The quantity and depth distribution of heat stored during the summer varied markedly. The reservoir functioned as a heat trap, whereas heat was readily dissipated from the lake. Salinity increased more in the lower layer of the lake. Throughout the summer, nutrient-rich water was discharged from the reservoir whereas nutrient-poor water was discharged from the lake. Phytoplankton standing crops were greater in the lake and were dominated by flagellates and diatoms. In the reservoir, blue-green algae were predominant. Rates of primary production and respiration were higher in the lake, but estimated algal turnover times were faster in the reservoir. It was concluded that depth of outflow was a direct and predictable effect on certain physical and chemical conditions within these two bodies of water; but effects of discharge depth on phytoplankton were secondary and thus difficult to ascertain. (Author abstract.)

I Martin, D. B. and J. F. Novotny. 1977. Zooplankton standing crops in the discharge of Lake Francis Case, 1966-1972. Am. Midl. Nat. 98(2):296-307.

An automatic plankton sampler was used for 7 years (1966-1972) to monitor zooplankton standing crops in the discharge of Lake Francis Case, a Missouri River reservoir. Cyclops, the most abundant taxon, had a strongly bimodal annual distribution, with maxima in late spring and early winter. Diaptomus, the second most abundant taxon, exhibited a unimodal annual distribution, with the maximum extending from early spring to midsummer. The annual cycle of Daphnia, the only other frequently encountered taxon, was weakly bimodal, with the primary maximum in late spring and a secondary maximum in early winter. Cyclops standing crops decreased during the 7-year study, while Diaptomus standing crops increased slightly. Daphnia standing crops fluctuated at relatively low levels from year to year, and no long-term trend was discernible. Year-to-year fluctuations in the standing crop of each major taxon were not correlated with young-of-the-year fish abundance or average hydrographic conditions. The long-term changes in the zooplankton standing crops in Lake Francis Case may be related to events in the history of Lake Oahe, a newer and much larger reservoir located about 140 km upstream on the Missouri River. (Author abstract.)

F,I,W Martin, R. G. and R. H. Stroud. 1973. Influence of reservoir discharge location on water quality, biology, and sport fisheries of reservoirs and tailwaters. U. S. Army Corps of Engineers Sport Fishing Institute, Washington, D.C. 128 pp. Contract No. DACW31-67-C-0083.

A 4-year study was conducted to compare the effects of epilimnial and hypolimnial discharge regimes on the biota of reservoirs and tailwaters. Biological and physicochemical field investigations were conducted on two flood-control reservoirs located on the Green River watershed in south-central Kentucky--Barren River Reservoir of 4,047 ha and Nolin Reservoir of 2,347 ha. Supplementary studies were made at Lake Russell, a 36.4-ha drainable recreational reservoir located within the Chattahoochee National Forest, Georgia.

Water quality investigations conducted at Lake Russell revealed that hypolimnial discharge reduced the severity of reservoir stratification, increased average reservoir water temperatures, and promoted substantially higher dissolved oxygen values throughout the deeper reservoir strata.

The precise relationships existing between outlet location and reservoir dissolved oxygen distribution at both Barren River Reservoir and Nolin Reservoir were obscured by inadequate capacity of the epilimnial discharge facilities available at each reservoir. Collective findings suggest, however, that hypolimnial discharge tends to enhance the vertical distribution in the water column of significant quantities of dissolved oxygen in reservoirs and, therefore, water quality, particularly those constructed in climatic regions characterized by a pattern of frequent and extensive summer precipitation.

Reservoir-outlet location did not appear to affect significantly either sport fish catch or any of the various biological parameters monitored during the field investigation at the three reservoirs. Levels of abundance of plankton, aufwuchs, benthos communities, and fish populations fluctuated considerably over the 4-year period of field studies, seemingly independent of either prevailing discharge regime--hypolimnial or epilimnial.

Automatic plankton samplers installed in the tailrace of both Barron River and Nolin Reservoirs indicated substantially higher losses of crustacean plankton and other fish food organisms during epilimnial discharge. However, there was no corollary evidence that the high rate of evacuation from the reservoirs was reflected by reduced standing crops within the reservoirs.

F,W May, B. and J. Huston. 1979. Status of fish populations in the Kootenai River below Libby Dam following regulation of the river. Completion Report. Cont. No. DACW67-76-C-055. Mont. Dep. Fish and Game. 57 pp.

The impoundment of the Kootenai River in 1972 altered downstream flow regimes, temperature patterns, and water quality. The aquatic insect population has changed from a stonefly, mayfly, caddisfly, dipteran complex to one dominated by a few mayfly and dipteran taxa.

Spawning and nursery areas available in the tributaries from the Regulation Dam Site to Kootenai Falls are sufficient to maintain high levels of fishing success in the river. Pipe, Libby, and Bobtail Creeks support the largest runs. The spawning runs of rainbow into Bobtail Creek increased over 200 percent from 1975 to 1979.

Fishing pressure has increased from about 116 angler-days per mile (72/km) in 1968 to about 1,600 per mile (944/km) in 1978. The catch rates (.36 to .64 fish per hour) and average size of the rainbow trout creeled (11.4 inches total length) rank the Kootenai as one of the better wild trout fisheries in Montana.

The marked improvement in rainbow trout and mountain whitefish populations downstream of Libby Dam has been a result of the interaction of several environmental factors. These include: (1) improved water temperatures for trout growth, (2) reduction of sediment loads below Libby Dam and sediment pollution from a mine-mill operation on Rainy Creek, (3) higher flows from August through March, and (4) reduction of fluoride and ammonia pollution from a Canadian fertilizer plant. (Taken from author abstract.)

I McGary, J. L. and G. L. Harp. 1973. The benthic macroinvertebrate community of the Greer's Ferry Reservoir cold tailwater, Little Red River, Arkansas. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 26:490-495.

This study provides an evaluation of the benthic faunal characteristics of the cold tailwater of Greer's Ferry Reservoir on Little Red River. This Ozark stream is characterized by cold and nonturbid water, and periodic drastic vacillation of water level, the results of a deepwater discharge for hydroelectric generation. For these reasons the benthic macroinvertebrate community is qualitatively limited.

Pool and riffle habitats were sampled at 6-week intervals at each of three stations established between .5 and .23 km below the dam. Most physicochemical characteristics measured were found not limiting, except water temperature and current velocity. Benthic organisms were limited to 59 taxa. Longitudinal zonation was characterized by an increase in diversity downstream with 15, 32, and 41 taxa collected at Stations 1, 2, and 3, respectively.

Overall dominant organisms numerically were oligochaetes, chironomids, and isopods. Oligochaetes composed 62-79 percent of pool organisms collected. Isopods dominated riffles with 37-81 percent of organisms collected. Chironomids were usually the second most abundant in riffles and pools. The mean numerical standing crop was greatest at Station 1 with 1,241 organisms/m^2 and lowest at Station 2 with 437 organisms/m^2. (Author abstract.)

F McMaster, K. M., R. G. White, R. R. Ringe, and T. C. Bjornn. 1977. Effects of reduced nighttime flows on upstream migration of adult chinook salmon and steelhead trout in the lower Snake River. U. S. Army Corps of Engineers, Contract No. DACW8-76-C-0016. Idaho Water Resour. Res. Instit., Univ. Idaho, Moscow. 64 pp.

Storage of water at night and discharge through turbines at lower Snake River dams during the day would best meet demands for power production. However, fisheries managers were concerned that such flow regulations would interfere with upstream migration of anadromous salmonids. During 1975 and 1976, the effects of reduced nighttime flows on the upstream migration of adult chinook salmon and steelhead trout were assessed. During the summer and fall, reducing discharge from the dams to zero at night (2300-0700 hours) had no observable effect on migration of adult fish.

F McMynn, R. G. and P. A. Larkin. 1953. The effects of fisheries of present and future water utilization in the Campbell River drainage area. B. C. Game Comm., Management Publ. 2, 61 pp. (Mimeogr.)

The Ladore Dam and Main Dam tailwaters on the Campbell River, B. C., were examined for their effect on spawning and migration of sport fishes. Ladore Dam tailwaters will not provide spawning habitat due to rapid flow and rocky substrate. The Main Dam will alter migration, but little loss is expected in tailwater spawning area for anadromous fishes.

W Middleton, J. B. 1968. Control of temperatures of water discharged from a multiple-purpose reservoir. Pages 37-46 in Reservoir Fishery Resources Symposium. Southern Division, American Fisheries Society.

The control of temperatures of water discharged from multiple-purpose reservoirs is now accepted as one of the goals of the reservoir planner in those cases where this is necessary to avoid damage to downstream fisheries. The planning and design of DeGray Reservoir on the Caddo River in south-central Arkansas was coordinated with interested agencies from the earliest stages.

From this planning has evolved a design of an intake structure which may be utilized to control, within a wide range, the elevations from which discharges are withdrawn. This feature, together with a downstream regulating dam, is expected to make practical the preservation of the existing downstream fishery. (Author abstract.)

F Miller, L. F. and C. J. Chance. 1954. Fishing in the tailwaters of TVA dams. Prog. Fish-Cult. 16(1):3-9.

Tailwaters of dams in the main Tennessee River provide the most sportfishing in TVA waters. Thirty-five percent of the fishing trips and 52 percent of the harvest came from these waters during 1947-1953. Tributary tailwaters provided only a limited amount of fishing because they discharge relatively cold water which reduces the concentration of warmwater fish.

F Moen, T. E. and M. R. Dewey. 1978. Loss of larval fish by epilimnial discharge from DeGray Lake, Arkansas. Arkansas Acad. Sci. Proc. 32:65-67.

Weekly samples of larval fish were collected from water discharged from the epilimnion of DeGray Lake into the tailwaters, for power generation, from April through August, 1976 and 1977. Peak rates of loss measured were 1.4 larvae/m^3 in May 1976 and 2.7/m^3 in April 1977. Sunfish, shad, and crappie made up 97 percent of an estimated 83.3 million fish lost in 1976, and 98 percent of 122.4 million lost in 1977. The most critical period for larval fish loss extended from the last week of April to the first week of June. No definite relationships were noted between length of the power generation period or power generation rate, and rate of larval fish discharge. Diel collections showed the rate of larval fish discharge to be lower and more uniform during darkness than during daylight. (Author abstract.)

F Moffett, J. W. 1942. A fishery survey of the Colorado River below Boulder Dam. Calif. Fish Game. 28(2):76-86.

Construction of Boulder Dam formed a body of water of great magnitude in the arid desert region and changed the river itself below the dam. Water from the dam can be discharged from 3 levels. Water discharged from the lower levels is cold. Because of the fairly constant low temperature and clarity of the water released from the dam, the river for a distance of 40.2 km has been transformed into good trout water. The chemical nature of the river is not detrimental to biological productivity. Rainbow trout growth was good, suggesting that the food supply is ample. There was considerable fluctuation in water releases from the dam and the effect on trout reproduction is unknown. Recommendations were made for trout stocking.

F Moffett, J. W. 1949. The first 4 years of king salmon maintenance below Shasta Dam, Sacramento River, California. Calif. Fish Game. 35(2):77-102.

The construction of Shasta and Keswick Dams across the Sacramento River created a problem of salmon and trout maintenance in the river below Keswick Dam. This construction permanently removed from access approximately 50 percent of the natural spawning and nursery ground available to these anadromous fishes.

A maintenance plan for this important fishery was selected from several plans presented by State and Federal biologists. This involved transfer of certain runs to fish hatcheries and the holding of other runs between the dams for natural spawning.

On the basis of operations to date and the meager positive evidence now available, it was concluded that: (1) present ecological conditions in the Sacramento River below Shasta Dam are greatly improved for the natural production of salmonid fishes; (2) the main river spawning plan is producing large numbers of seaward migrant salmon and presumably adult salmon in some measure of abundance; (3) the improvement in river conditions has compensated, as nearly as can be determined at present, for the loss of spawning grounds above Shasta Dam; (4) racks in Sacramento River similar to those used are not satisfactory as a means of blocking or controlling salmon migrations; (5) the main river has not been overcrowded with spawning salmon; (6) the numbers of salmon accommodated in the Shasta Salmon Maintenance Plan were far in excess of expectations; (7) the spring run of salmon is more likely to be perpetuated if left undisturbed in Sacramento River; (8) ultimate success of the program depends on the maintenance of presently favorable river conditions; (9) hatchery operations have been successful except for the problem of holding adult salmon, especially the spring run, until ready for spawning; (10) the Deer Creek program offers little hope of ultimate success without some changes in present conditions; and (11) experience has been insufficient to establish definitely the success or failure of the salmon maintenance work and observations and studies need to be continued. Criteria for Shasta Dam operation will change as new units for both control and storage of water in Sacramento River and the Sacramento Valley are built and integrated into the Central Valley Project. Constant evaluation of the effects on the fishery will be necessary as long as changing conditions may be anticipated.

I Morris, L. A., R. N. Langemeier, T. R. Russell, and A. Witt, Jr. 1968. Effects of main stem impoundments and channelization upon the limnology of the Missouri River, Nebraska. Trans. Am. Fish. Soc. 97(4):380-388.

Rigid control has been imposed upon the Missouri River by impounding over one-half of the upper 1,500 miles (2,414 km) and by channeling most of the remaining river within permanent, narrow banks. These controls have caused environmental changes in the lower Missouri River, as shown by this study, of adjacent unchannelized and channelized sections of river below the main stem impoundments. Impoundments have regulated flow by evening maximum and minimum discharges and improved downstream water quality by decreasing turbidity and indirectly raising the dissolved oxygen. In addition the impoundments have contributed a limnetic cladoceran, Leptodora kindtii, to the drift and have affected the distribution of benthos through the modification of turbidity. Channelization of the river has reduced both the size and variety of aquatic habitat by destroying key productive areas. Average standing crops of benthos were similar in unchannelized and channelized river (0.63 and 0.67 lb/acre (0.71 and 0.75 kg/ha), respectively), but the benthic area has been reduced 67 percent by channelization. In the channelized river the average standing crop of drift was 8 g/acre-ft (.0065 g/m^3). There was little similarity between the organisms of the drift and benthos; however, there was similarity between the organisms in the drift and the aufwuchs. (Author abstract.)

F Moser, B. B. and D. Hicks. 1970. Fish population of the stilling basin below Canton Reservoir. Proc. Okla. Acad. Sci. 50:69-74.

The stilling basin below Canton Reservoir was drained and fishes were collected, identified, and measured. This catch was compared to several cove rotenone samples taken in the reservoir. The fish population structure in the stilling basin was similar to that of the reservoir. The marked similarities between the two populations suggest that the stilling basin population is influenced more by the reservoir population than the river population. The large concentration of fish in the stilling basin suggests that it is a concentrator of fish; fish standing crop was 10 times greater in the stilling basin than in the reservoir.

F Mullan, J. W., V. J. Starostka, J. L. Stone, R. W. Wiley, and W. J. Wiltzius. 1976. Factors affecting upper Colorado River Reservoir tailwater trout fisheries. Pages 405-427 in J. F. Orsborn and C. H. Allman, eds. Instream Flow Needs. Vol 2. American Fisheries Society, Washington, DC.

Each tailwater presents its own set of factors influencing trout abundance, but within the following premise. Productivity of the water is substantial and limiting factors do not include nutrients, lethal chemical conditions, or failure of nature reproduction, with the latter circumscribed by stocking. Tailwater rearing habitat primarily involves considerations of flow, shelter, temperature, and food, but with sequential deferment to the pervasive influence of increasing downstream turbidity. Purge of sediment, by arrest in the reservoirs, resulted in four of the tailwaters temporal discontinuities of clear river which revert to turbid river. Less than optimum minimum flow appeared to be a major limiting factor only in the Gunnison River tailwaters. In Glen Canyon and Fontenelle tailwaters, discharge resulted in excessive water velocities in relation to available shelter as reflected in modest standing crop (25-38 lb/acre, 28-42.6 kg/ha), low yield (6.9 and 7.4 lb/acre, 7.7 and 8.3 kg/ha), and use (21 and 23 hr/acre (52 and 57 hr/ha)), but with the catch favoring trout 12 inches or over capable of coping with strong currents. Discharge and shelter components of the Navajo and Flaming Gorge tailwaters, by contrast, apparently approached the ideal as denoted by exceptional trout yield (inherent production of 169 and 93 lb/acre (189.4 and 104.2 kg/ha)), prior to dysfunction by low water temperatures.

Water temperatures were reduced in all the tailwaters to varying extents by reservoir operations. Fontenelle tailwater was least affected with water temperatures remaining near freezing in winter and approaching the maxima for trout in summer. As the much larger Flaming Gorge and Navajo Reservoirs filled over a number of years, a more regular hydroelectric operation produced stable flows of water from deeper and colder strata, reducing water temperatures most. At 39.0-49.0°F (3.9-9.4°C) harvest no longer even equaled the weight of trout stocked. Availability of insect food to rainbow trout, not the total that occurred, declined drastically at the lower water temperatures. (Author abstract.)

I,W Müller, K. 1962. Studies on limnology and fish biology in regulated waters of Swedish Lapland. Oikos, 13:125-154.

The author discusses the effect of river regulations on the aquatic fauna in the Stora Lule River, Sweden, which has been affected by the operation of the Suorva Reservoir since 1927, and compares it with conditions in the natural river system of the Lilla Lule. The damming up of snow and melting glacier waters affects the temperature of the river, interfering with the normal life of the organisms. Studies at the power dam at Selsforsen showed that by taking plankton-rich surface water below such dams, a rich bottom fauna can live in the river. (Author abstract.)

I,W Mullican, H. N., H. T. Sansing, and J. R. Shraber, Jr. 1967. A biological evaluation of the Caney Fork River in the tailwaters of Center Hill Reservoir. Tenn. Stream Pollution Control Bd., Tenn. Dep. of Public Health, Nashville, Tenn. 19 pp.

A biological study was conducted on the Caney Fork River from the

Center Hill Reservoir to a point 18.8 km downstream. These tailwaters were profoundly affected by the intermittent discharge of Center Hill Dam. Often hypolimnial releases result in riffle areas which are alternately inundated and exposed to drying as the discharge rate fluctuates. Also the cold release waters have the overall effect of delaying spring water temperature increases and autumn declines. It also allows for a trout fishery in the tailwaters during warm summer months. However, it sometimes has detrimental effects on aquatic insect and warmwater fish communities in that the colder temperatures inhibit the spawning, hatching, and development of various life stages. Also high concentrations of dissolved minerals are released, resulting in enriched tailwaters for algae and aquatic plant growth. Turbidity is generally negligible in released hypolimnial waters.

Biological activity greatly increased on the Caney Fork River with increasing distance from the dam. Station 1, located in the first riffle area below the dam, had an abundant growth of the attached algae, *Ulothrix* sp.; whereas at Station 9, 18.8 km downstream, attached filamentous algae were not common due to the scoured, irregular channeled bottom, at Station 1. Temperature, dissolved oxygen, and carbon dioxide values at the time of the study were 10°C, 9.2 mg/ℓ, and 0.4 mg/ℓ, respectively. Only 8 species of organisms were recovered, the most abundant of which were the midge larvae, *Cricotopus* sp., *Hydra* sp., the Isopid, *Lirceus* sp., and the amphipod, *Gammarus* sp. A normal diverse benthic community was established at Station 9. Twenty-one different species were collected with Plecoptera, Trichoptera, Ephemeroptera, Tendipedidae, and Elmidae beetles being the most common.

F Nelson, F. A. 1977. Fishery and flow relationships in the Beaverhead River below Clark Canyon Reservoir. U. S. Bureau of Reclamation, Contract No. 14-06-600-8790. Mont. Dep. Fish. Game. 118 pp. (Mimeogr.)

The effects of varied flow patterns on a trout population and the physical and hydraulic characteristics in a 6,455 ft (1,867.5 m) section of the upper Beaverhead River below Clark Canyon Reservoir, Montana, were measured between 1966 and 1976. Population estimates were made using electrofishing techniques. The WSP (Water Surface Profile) computer program of the Bureau of Reclamation was used to predict physical and hydraulic values at various flows.

The survival of age III and older rainbow trout was directly related to the magnitude of flows during the nonirrigation season (approximately October 15 to April 15). During this period, water for irrigation is being stored in the reservoir and releases into the river are minimal. Results of this study suggest that average daily flows greater than approximately 250 cfs

(7.1 m^3/sec) are needed to provide a high quality, trophy rainbow trout fishery. Flows during this study were not sufficiently reduced to adversely affect the survival of older brown trout.

Poor reproductive success was the major factor limiting the total numbers and biomass of trout throughout much of this study. Reproductive success, as measured by the estimated numbers of age I trout, appears to be related to flow patterns during the brown and rainbow trout spawning periods. With flow releases favorable to both reproduction and the survival of older trout, the upper Beaverhead River is capable of supporting greater numbers and biomass of trout of all age groups than those which existed throughout much of this study.

The physical and hydraulic characteristics most affected by flow reductions were cross-sectional area and current velocity. Top width and wetted perimeter were least affected. The rate of loss for all six of the measured characteristics was greatly accelerated at flow less than approximately 200 cfs (5.7 m^3/sec).

An evaluation of biological, chemical, discharge, and habitat data for a series of nine study sections suggests that other factors are operating in conjunction with flows to limit numbers and biomass of trout in much of the Beaverhead River below the confluence of Grasshopper Creek. (Author abstract.)

F Nelson, J. S. 1965. Effects of fish introductions and hydroelectric development on fishes in Kananaskis River System, Alberta. J. Fish. Res. Board Can. 22(3):721-753.

After closure of Lake Kananaskis Dam, the river below showed a change in fish species composition due to loss of spawning areas, competition, and a destabilized environment due to fluctuating water levels. Dolly Varden, cutthroat trout, rainbow trout, and longnose suckers were reduced, while white suckers and brown trout increased. Invader species enjoyed a competitive edge in the simple and unstable environment.

F Nelson, W. R. 1968. Reproduction and early life history of sauger, <u>Stizostedion canadense</u>, in Lewis and Clark Lake. Trans. Am. Fish. Soc. 97(2):159-166.

Sauger (<u>Stizostedion canadense</u>) reproduction and early life history have been studed to determine factors affecting year-class strength in Lewis and Clark Lake, a 28,000-acre (11,330 ha) reservoir on the South Dakota-Nebraska border. Saugers spawn over a rubble substrate in the Missouri River below Fort Randall Dam. Spawning is initiated at a water temperature of 43°F (6.1°C) and is complete in approximately 2 weeks. Maximum egg survival occurs 4 ft (1.2 m) below minimum river water level. Eggs hatch in 21 days at an average temperature of 47°F (8.3°C) and larvae drift down the Missouri River and into Lewis and Clark Lake. The yolk sac is absorbed in 7 to 9 days and larvae feed primarily upon Cyclops. Larger size larvae feed on Daphnia and Diaptomus. Fish are a major food after saugers reach 70 to 110 mm lengths. Adult year-class strength was inversely related to water level fluctuations over the spawning grounds. Abundance of larvae was 15 times greater in 1965 when water levels fluctuated 2.67 ft/day (0.81 m/day) than in 1963 when water levels fluctuated 4.44 ft/day (1.35 m/day). Apparently, year-class strength is dependent upon water level fluctuation during the incubation period and is determined before young-of-the-year enter Lewis and Clark Lake. (Author abstract.)

W Nilsson, C. 1978. Changes in the aquatic flora along a stretch of the River Umealven, N. Sweden, following hydroelectric exploitation. Hydrobiologia. 61(3):229-236.

The lower limit of vegetation in naturally flowing rivers is determined by a combination of decreasing illumination and increasing hydrostatic pressure. The upper vegetational limit is dependent on wave action, frost effects, and the substrate present. High water periods in early summer and autumn force the lower vegetation limit upwards while low water periods force upper limits downward.

F Orlova, E. L. and O. A. Popova. 1976. The feeding of predatory fish, the sheatfish, Silurus glanis, and the pike, Esox lucius, in the Volga Delta following regulation of the discharge of the river. J. Ichthyol. 16(1):75-87.

Changes in the ecology of two of the most abundant predatory fish in the Volga Delta, the sheatfish, Silurus glanis, and the pike, Esox lucius, are shown in connection with the change in the hydrologic regime of the delta with the regulation of the discharge of the river. Over a period of twenty-five years, spawning and feeding conditions of the predators changed. A redistribution of predators occurred in the zones of the delta, and there was a change in the species composition of their prey, feeding rhythm, size of annual ration, which in turn, influenced the abundance of predators. In the spring-spawning predator, the pike, these changes caused a decrease in abundance, while in the sheatfish, a summer-spawning species abundance increased. (Author abstract.)

F Parsons, J. W. 1957. The trout fishery of the tailwater below Dale Hollow Reservoir. Trans. Am. Fish. Soc. 85:75-92.

The 7.3 miles (11.7 km) of tailwater below Dale Hollow Dam were initially stocked with rainbow trout (Salmo gairdneri) in 1950. In 1953, creel records indicated that a minimum of 16 percent of the 16,500 fingerling-stocked fish were captured by anglers within 12 months after stocking. The rainbow trout creeled averaged 9.4 inches (23.9 cm) long, and had grown at a monthly rate of 15 millimetres in length and 26 grams in weight. On the basis of growth rates it was decided that an annual stocking of approximately 25,000 fingerling rainbow trout would most benefit the fishery. To maintain suitable water temperatures throughout the tailwater in the summer, a minimum cold-water discharge below the dam was established. Threadfin shad (Signalosa petenensis) were stocked in the reservoir in an attempt to establish a supplemental food supply for trout in the tailwater. The stocking of brown trout (Salmo trutta), brook trout (Salvelinus fontinalis), and cutthroat trout (Salmo clarki) in the tailwater has been only slightly successful. The Dale Hollow tailwater presently supports 7,000 put-and-take trout-fishing trips per year at a cost to the Tennessee Game and Fish Commission of less than 20 cents per trip. (Author abstract.)

F Parsons, J. W. 1958. Fishery management problems and possibilities on large Southeastern Reservoirs. Trans. Am. Fish. Soc. 87:333-355.

Principal problems concerning the fisheries of large reservoirs in the Southeast are: inefficient and highly selective exploitation of fish stocks and protection and reclamation of damaged or threatened fisheries in tailwaters and tributary streams. Seven mainstream reservoirs on which data are available support an average angling pressure of 4.9 trips per acre per year (12.1 trips/ha/yr), and an average catch of 16 pounds (17.9 kg) of sport fish and 6 pounds (6.7 kg) of food fish. Commercial take is 7 lb/acre (7.8 kg/ha). The rate of catch of sport fish, based upon tag returns, is only 3 percent. Sixteen storage reservoirs support an average angling pressure of 5.0 trips per acre per year (12.4 trips/kg/yr) and an average catch of 13 pounds (14.6 kg) of sport fish and 1 pound (1.1 kg) of food fish.

Commercial catch is of no significance. Average rate of catch of sport fish is 17 percent of the catchable population. Fish population studies indicate that there are twice as many sport fish and four times as many food fish in mainstream than there are in storage reservoirs.

Some reservoirs produce harmful effects downstream. Discharges of cold water may seriously reduce fishery values in tailwaters and downstream impoundments. Furthermore, migration of nonsport fish from reservoirs into tributary streams may reduce fishery values there.

In recognition of these problems, the development and application of sound management procedures may be accomplished by controlling species composition and availability of fish through water level control, timber clearing, application of selective toxicants, commercial fishing, introduction of new fish species, and the management of tailwaters and tributaries. Extended research and interagency cooperation are necessary to properly develop and apply sound management. Promotion of angling and regulation of the fishery may best be realized by providing adequate fishing facilities, elimination of certain restricted areas, and in some cases revision of laws and regulations. Biologists must not only meet the present demands for improved sport fishing but must also balance fish yield by increasing the use of food fish by sport and commercial operations. (Author abstract.)

F Pasch, R. W., P. A. Hackney, and J. A. Holbrook II. 1980. Ecology of paddlefish in Old Hickory Reservoir, Tennessee, with emphasis on first-year life history. Trans. Am. Fish. Soc. 109(2):157-167.

Paddlefish, Polyodon spathula, moved to the upper reaches of Old Hickory Reservoir (a main stem reservoir on the Cumberland River in north-central Tennessee) during the March-May spawning period and concentrated in the tailwaters of Cordell Hull Dam (Cumberland River) and Center Hill Dam (Caney Fork River). Paddlefish eggs were collected 5.6 km downstream from Cordell Hull Dam beginning 13 April, and larvae were found beginning 21 April 1977. No paddlefish eggs or larvae were collected in the Caney Fork River, presumably because the low temperature (11-11.5°C) of the Center Hill Dam discharge prevented spawning there. No paddlefish greater than 18 mm total length were taken by larvae sampling gear, and gill nets were ineffective in capturing young of year and yearlings. Paddlefish from 50 mm to 400 mm total length, however, were impinged on the intake screens at the Gallatin Stream Electric Plant on Old Hickory Reservoir in large numbers (approximately 9,000 from August 1975 to May 1976). Comparisons of lengths on capture dates with similar data reported in the literature demonstrated that the impinged paddlefish were young of the year which attained approximately 300 mm total length by age I. (Author abstract.)

I,W Pearson, W. D., R. H. Kramer, and D. R. Franklin. 1968. Macroinvertebrates in the Green River below Flaming Gorge Dam, 1964-65 and 1967. Proc. Utah Acad. Sci., Arts and Lett. 45(1):148-167.

The installation and operation of Flaming Gorge Dam has affected the river environment for at least 150 km downstream. Seasonal variations in flow have been reduced and stabilized, but due to power demands daily flows fluctuate widely. The general effect of the dam on temperature downstream has been warmer water during the winter and cooler water during the summer. Invertebrate communities between the dam and Carr Ranch have been altered, probably as a response to lower summer water temperatures. Baetis sp. responded well to low water temperatures in 1967 and practically disappeared from the first 9.5 km below the dam. Dissolved oxygen concentrations were 6.0 mg/ℓ or higher at all stations with highest values occurring when summer water temperatures were low, the water clear, and algal growths on the bottom were extensive. The pH at all stations ranged from 7.7 to 8.9 with no seasonal trends. Total alkalinity was 125-180 ppm between the dam and Echo Park during 1964-1965. With increasing distance below the dam, atmospheric influences and the addition of tributary flow into the tailwaters return the Green River toward a semblance of its preimpoundment state. Species composition below Lodore Canyon in 1964-1965 appeared to be much the same as that reported in preimpoundment studies with the exception of Claassenia sabulosa, which has apparently disappeared from the fauna. With continuing operation, the invertebrate community, particularly in the first 20 km below the dam, may never stabilize and will continually be in stages of succession as varying conditions favor some groups over others.

F,I Penaz, M., F. Kubicek, P. Marvan, and M. Zelinka. 1963. Influence of the Vir River Valley Reservoir on the hydrobiological and ichthyological conditions in the River Svratka. Acta Sc. Nat. Brno, 2(1):3-60.

The paper brings original results of several years' investigation on the influence of the construction and operation of a new, deep river valley reservoir on the Svrakta River near Vir, Czechoslovakia, on the hydrobiological and ichthyological conditions in the river, being particularly marked in the section below the dam and, to a smaller extent, also above the latter.

Detailed analyses are made of the changes that had occurred in the main abiotic factors of the environement, i.e., chiefly in the discharge regime, water temperature, chemical properties of water, and some additional associated factors, as well as in the specific structure of the biocoenosis, the main attention being directed to the ichthyofauna and such communities that serve as direct or indirect sources of food of the fish.

In evaluating the causes for the favorable changes in the specific structure of the biocoenosis, emphasis is placed on the balanced discharge regime and decreased detrimental effects of floods due to the effective auxiliary equipment of the Valley Reservoir; in the authors' opinion such auxiliary dams should be erected in all reservoirs operating during peak consumption of electric energy. (Author abstract.)

F,W Peterson, L. W. and T. H. Leik. 1958. A fisheries evaluation of North Platte River water flows resulting from releases at Alcova Reservoir. Wyo. Game Fish Comm. Proj. 255-5-2. 31 pp. (Mimeogr.)

This report relates the findings of a series of test water releases into the North Platte River from the Alcova Dam in the spring of 1958 for the purpose of evaluating a proposed new water project designed to regulate river flows just below Alcova Reservoir. Flows of 300, 800, 1,300, 2,800, and 3,800 cfs (8.5, 22.6, 36.8, 79.2, and 107.5 m^3/sec) were tested on five separate days in March and April.

A series of semitransparent overlay sheets are included in the report, each representing the actual shape of stream channel (water areas) at various flows at a particular station. The lowermost, or base sheet, in each case represents the river section with no water release at Alcova Dam, merely the flow from springs and seepage. Brief interpretations of the overlays and photographs are given for each of the five stations in relation to area covered and some of the fish habitat implications. The main thrust of analysis is toward the area of water coverage at the various flows. On the basis of this analysis the authors recommend a minimum flow of 300 cfs (8.5 m^3/sec).

Tables of surface area of the river at various test flows are provided for pool, riffle, and combined pool-riffle areas. Potential pounds of fish and potential values for the various flows are also shown in tables. (Fraser 1972b.)

F Pettit, S. W. 1977. Evaluation of game and rough fish populations below Dworshak Dam and relationship to changes in water quality. Idaho Dep. Fish. Game, Fed. Aid Proj. DSS-29. pp. 11-38. (Mimeogr.)

Anglers fished an estimated 12,600 hours and harvested an estimated 650 smallmouth bass, 5,050 rainbow trout-juvenile steelhead, and 208 cutthroat trout on the lower Clearwater River during the summer of 1976.

Cooler than normal discharge from Dworshak Dam during the summer reduced lower Clearwater River temperatures during July and August. Discharge temperatures were reduced to provide favorable water quality criteria at Dworshak National Fish Hatchery.

The trend toward oligotrophy on the lower river continued in 1976. Total alkalinity ($CaCO_3$) ranged between 14 and 28 mg/ℓ at the Spalding sampling site. North Fork water remained at near "distilled water" standards. Total alkalinity measured at Dworshak National Fish Hatchery ranged between 11 and 15 mg/ℓ.

Approximately 40 percent of the adult hatchery steelhead tagged and released by anglers during the 1975 steelhead season returned to Dworshak National Fish Hatchery in spring 1976.

A total of 1,858 adult steelhead were handled at Dworshak National Fish Hatchery during the 1976 spawning operation. Of the 1,726 adults sampled, 62.6 percent were females and 37.4 percent males.

F,I,W Pfitzer, D. W. 1954. Investigations of waters below storage reservoirs in Tennessee. Trans. N. Am. Wildl. Conf. 19:271-282.

The construction of large dams in the Tennessee Valley has caused major changes in the ecology of the waters below them.

A lower average temperature, 50° to 53°F (10.0-11.7°C), a reduction of the extreme temperatures, 39° to 65°F (3.9-18.3°C), and an erratic seasonal dissolved oxygen pattern has resulted.

Great daily fluctuations in water velocity and volume take place. These changes in water have brought about great changes in the plant and animal populations. Many of the minnow species have disappeared. Only a few species of those remaining are successfully reproducing. The bottom faunal pattern has changed from large warm-water species to small cold-water species. The most abundant groups are members of the insect families Tendipedidae, Simuliidae, and Hydropsychidae along with the scud, Gammarus, and snails. The plant populations are dominated entirely by algae of several species. These plants attain tremendous growths in some areas.

Experimental planting of rainbow trout fingerlings has shown that this species is very well suited for continued management. Brook trout have not survived tailwater conditions. (Author abstract.)

F Pfitzer, D. W. 1958. Some problems in tailwater fishery management. Southeastern Association of Game and Fish Commissioners Meeting, Louisville, Kentucky. 23 pp. (Unpubl. ms.)

Tailwaters in southeastern United States can be classified into two major groups by temperatures of the discharge water--warm and cold. Three general types of dams discharge warm waters: those constructed on main streams for the multiple-purpose of flood control, navigation, and power; the low level, single-purpose flood control dams constructed on tributary streams; and the older dams of varying heights constructed prior to 1935 for the single purpose of hydroelectric power, which take water from the upper levels of the reservoir. Dams discharging cold water are high, tributary-stream dams constructed for the purposes of flood control, navigation and hydroelectric power and usually have a depth greater than 100 ft (30.5 m), do not contain navigation locks, and take power production water from the lowest levels in the reservoir.

In all cases the streams, prior to dam construction, were warm-water streams supporting a varied population of sport and commercial fishes generally of high value. Most warm-water tailwaters have good fish populations, but the cold-water tailwaters have caused an almost complete loss of these fish. Attempts have been made to establish trout in approximately 15 of these cold tailwaters, but only nine are known to be successful put-and-take fisheries. Even in these nine, more than 50 percent of the

320 miles (515 km) supports neither an adequate trout fishery nor a warm-water fishery.

Before some of the problems can be rectified, new water release schedules providing for minimum flows will need to be adopted. To prevent continued loss of valuable warm-water streams, present plans for dams designed to release water from only one level will have to be altered to permit variable releases to obtain desired water temperature and oxygen concentrations as well as appropriate minimum releases for downstream flow. (Taken from Fraser 1972b.)

F,I,W Pfitzer, D. W. (1962?). Investigation of waters below large storage reservoirs in Tennessee. Tenn. Game Fish Comm., Fed. Aid Proj. Final Rep. F-1-R. 233 pp.

This is a report on the water quality characteristics, water flow, fish population studies, insect and other invertebrate populations, food habits of tailwater fish, drift material as available food for trout, plant populations, creel censuses, fishery management, and recommendations for tailwaters below eight major reservoirs on the Tennessee River system in eastern Tennessee. (This review will focus only on matters related to flow.)

Maximum design power discharge for tailwaters of seven reservoirs ranged from 2,300 to 9,500 cfs (65.1-169.0 m^3/sec). The lowest discharges usually occur during the cool months and have less effect on increases in temperature detrimental to trout. Exceptions to this occurred below Norris and Cherokee Reservoirs where the lowest flows occurred during May, June, and July; and June, May, and March, respectively. The warming effect of these low flows were quite detrimental to the habitat and resulted in temperatures in the high 70's and low 80's °F (mid to upper 20's °C) during the summer months as near the dam as about 3 miles (4.8 km). These low flows resulted from periods of 2 or more days of no dam discharge, which account for the warming of the water remaining in the stream. During the periods of normal power discharge, the temperatures below Norris Dam return to those tolerable for trout. Below Cherokee Reservoir high temperatures occur during the late summer resulting in a condition which was detrimental to both warm- and cold-water fish. This is especially significant when more than 2 consecutive days of zero discharge occur. When this happens the water temperatures approach air temperatures and if this occurs in the summer, the effect can be serious. Where there are enough deep pools to serve as cover and a deterrent to warming the water, trout can usually survive a 2- or 3-day nonflow. The increase in temperature is also accompanied by a decrease in dissolved oxygen, which also results in adverse conditions for trout.

The effects of no-flow periods are two-fold. First, if the no-flow period occurs during the warm months the water begins to warm beyond the limits of trout. Secondly, stream bottom areas are exposed, which reduces or eliminates the productivity of the area. Unfortunately, the riffle and shoal areas are the first to be exposed and are potentially the most productive of important bottom organisms.

Correction of this no-flow condition in the tailwaters would seriously interfere with the economics of hydroelectric power production. A compromise-type minimum flow based on time and water volume is practical and can greatly improve the conditions for trout.

Stream gradient has a very apparent significance to the effectiveness of trout management in tailwaters, although the reasons are not fully known. Trout distribution is related to fall per mile as well as bottom organism production.

The greatest concentrations of trout were in the areas of greatest fall per mile. As the gradient went below 2.5 ft per mile (0.47 m/km), the numbers of fish decreased and the catch success was correspondingly low. In flat or low gradient tailwater segments, there are fewer deep pools separated by riffles. The pools are shallower and indistinctly divided. As the no-flow periods occur, the long flat pools are very shallow, provide very little cover, and tend to warm rapidly.

Food production in the low gradient areas is very low unless, as in Norris tailwater, there is a heavy algal growth on the stream bottom. Even in this case, the quality of the food produced is low, being limited to aquatic isopods (sow bugs) and chironomids. A greater variety and quality of bottom organisms are produced in the steeper gradients. (Condensed from Fraser 1972b.)

F Pfitzer, D. W. 1968. Evaluation of tailwater fishery resources resulting from high dams. Pages 477-488 in Reservoir Fishery Resources Symposium. Southern Division, American Fisheries Society.

High dams have caused great ecological changes in streams. More than 260 dams have been constructed by public agencies in the southeastern United States. Tailwater areas can provide important habitat for recreational fishing. Most warm-water tailwaters produce very valuable fisheries without management. This study discusses the cold tailwaters which may or may not produce a good trout fishery.

Information was compiled on 32 projects, 27 predominately trout, with a total river length of 461 miles (742 km). It was found that dam design and operation have significant effects on quantity and quality of the fishery. Structural modification of dams has been employed to enhance downstream fisheries. After a project is completed, changes in operation can improve a tailwater fishery. Stocking is currently the most flexible tool for tailwater management. In four projects alone, more than 160 miles (257.5 km) of recreationally important streams have been modified to such an extent that the fishery values have been lost. Advanced planning in design and operation of hydroelectric and flood control projects must take into account the value of tailwater areas if we are to realize the full potential of the resource. (Author abstract.)

F Pfitzer, D. 1975. Tailwater trout fisheries with special reference to the Southeastern states. Pages 23-27 in Proceedings of the Wild Trout Management Symposium, Yellowstone National Park, 1974. Trout Unlimited, Inc.

More than 260 dams have been constructed by Federal agencies in the Southeastern states. Fishing success has generally been good below most warmwater or low-head dams. The purpose of this report is to look at trout fisheries that have developed below some of the high-head dams and the reasons for the wide variation in quality of fishing.

Factors important for a successful tailwater trout fishery are reservoir depth, storage volume, penstock level, water release pattern, river profile, and stream bottom. A major problem in trout management in tailwaters below hydroelectric projects is the erratic flow of water. Large variations result in a harsh environment. No or low flow periods result in summer warming of water beyond limits tolerable to trout. During these same periods, stream bottoms are exposed which severely reduces available food. To overcome this problem, a minimum downstream flow must be incorporated into the reservoir operation schedule.

Water quality is another factor important to tailwater trout fisheries. Desired water temperatures and oxygen concentrations must be available to trout at all times. This is especially important during late summer and early fall when the supply of cold hypolimnetic water can become exhausted. Multilevel water discharge ports in dams are suggested to improve water quality.

Because of poor design, some reservoir tailwaters are suitable for neither cold- nor warm-water fishes.

F,I Phillips, R. W. 1969. Effect of unusually low discharge from Pelton Regulating Reservoir, Deschutes River on fish and other aquatic organisms. Oreg. Game Comm., Basin Invest. Sec., Spec. Rep. 1. 39 pp. (Mimeogr.)

It became necessary for the operators of the Pelton Regulating Dam to inspect the stilling basin which required a severe reduction of river flow releases. This paper reports a study conducted during the 2 hours and 40 minutes of reduced flow. The purpose was to determine whether it would be better to reduce and resume flow releases as quickly as possible or to do it gradually (in relation to downstream aquatic resources). Data were gathered on stranded fish, fish food, exposed streambed, etc. It was concluded that the flow reduction was destructive of fish life because of the dead fish found on exposed gravel bars. Mortality was greatest to chinook salmon, steelhead, and rainbow trout of less than 1 year of age. The author recommends higher minimum flows be maintained if future inspections become necessary. He also concludes that the stranding of fish in the areas within a few miles of the dam might have been somewhat less if the flow had been reduced over, say a 30-minute period instead of the abrupt drop. (Author abstract.)

F,W Pierce, B. E. 1969. Tailwater study. W. Va. Dep. Nat. Res., Fed. Aid Proj. F-11-R-7. 12 pp. (Mimeogr.)

Comparisons were made between pre- and post-dam stream conditions, below Sutton and Summersville Dams, to determine specific changes that have occurred.

Regulation of Elk River through Sutton Dam has reduced the extremes in streamflow. Average maximum flows have been reduced and average minimum flows have increased through regulation. Average maximum temperatures have been reduced and generally occur later in the year. Flow regulation through Sutton Dam has provided an increase of 3 weeks of good fishing conditions.

Engineering difficulties and abnormal releases through Summersville Dam have precluded stabilization of Gauley River stream conditions, although extremes in fluctuations have been reduced. Fish population data reflect a considerable decrease in standing crop since construction of Summersville Dam. (Author abstract.)

F,I,W Powell, G. C. 1958. Evaluation of the effects of a power dam water release pattern upon the downstream fishery. M. S. thesis, Colo. State Univ., Fort Collins. 149 pp.

Investigations during the summer of 1957 revealed that the effects of water discharges from Green Mountain Power Dam in north central Colorado reduced bottom fauna populations, trout feeding success, and trout growth.

Effects of water releases were determined by comparing biological data collected in the Blue River below the dam with those collected from the undisturbed Blue River above Green Mountain Reservoir. Insect weights per square foot above the reservoir were over 32 times greater and never less than 2.5 times greater than the weights per square foot below the dam.

Effects were also determined by analyzing the severity of the bottom fauna reductions at various distances below the dam. Insect populations increased further from the dam.

Power dam water releases are detrimental to the downstream fishery because they produce reduced minimum flows, chemical, and temperature changes depending on seasonal weather conditions, severe water fluctuations, and great flushing action. (Author abstract.)

F,I Radford, D. S. 1972. Some effects of hydroelectric power installations on aquatic invertebrates and fish in the Kananaskis River system. Alberta Cons. Summer. 1972:19-21.

The regulation of flow of the Kananaskis River for hydroelectric purposes results in unusually low numbers of stream insects and of usually high rates of drift of such organisms. Drift organisms are carried into Barrier Reservoir--an unfavorable environment--where they perish. Consequently, the numbers of insects available for fish food have been reduced.

Fishes native to the Kananaskis River system have been severely reduced because of flooding of spawning areas by reservoir construction or competition by introduced species.

Future hydroelectric developments should recognize the considerable environmental impairment caused by such programs.

I Radford, D. S. and R. Hartland-Rowe. 1971. A preliminary investigation of bottom fauna and invertebrate drift in an unregulated and a regulated stream in Alberta. J. Appl. Ecol. 8:883-903.

Sedentary forms of invertebrates do not survive well in fluctuating conditions, but most insects, especially those with long mating and egg-laying flights, are able to cope with the water level variations. Normal annual temperature cycles can be disrupted since reservoirs delay the rise in tailwater temperatures in the spring and delay the temperature decline in the fall.

In this Alberta reservoir standing crops were uniformly low below the dam and certain benthic species were completely eliminated due to the extreme nature of the releases. Lake plankton was associated with reservoir releases in the tailwater area. Other nonriverine species were introduced into the drift from adjacent pools and backwater areas during reservoir releases. High drift rates occurred at night and fluctuating flows caused corresponding reactions in the drift. Torrential species were found to drift less than other species.

The periodic releases from the reservoir kept the stream bottom swept clean downstream, thus denying the system of allochthonous matter which is the most common source of energy in natural streams. The fluctuating effects of the releases resulted in the exposure of much of the substrate and subsequent desiccation of potential invertebrate habitats and production areas.

I Radford, D. S. and R. Hartland-Rowe. 1972. Some conservational problems posed by hydroelectric power installations in Alberta. Biol. Conserv. 4(3):166-168.

The regulation of flow of the Kananaskis River, Alberta, for hydroelectric purposes, results in unusually low standing crops of benthic invertebrates and in unusually high rates of drift of such organisms. Although the regulation of flow offers various benefits, including protection from spring floods, dilution of pollutants, and the provision of electric power for peak demand periods, the recreational and ecological impairment of the environment is considerable and should be taken into account in planning future hydroelectric developments. (Author abstract.)

F Reid, K. A. 1955. Increasing summer streamflow. Trans. N. A. Wildl. Conf. 20:229-241.

Studies reported here were conducted on streams below ponds and small lakes in Adirondack Park in northern New York. Low water and high temperature during summers were detrimental to trout growth and production. Summer stream volumes can be increased by using natural lakes and ponds and other depressions for moderate storage. Shoreline timber is not impaired when impoundage is under 0.6 m for only part of the year. A small opening in the bottom of dams will draw off cool bottom water. An open wood baffle dam in front of a conventional reservoir spillway will draw off cool bottom water. A series of low dams in streams with high banks and low gradients is a useful auxiliary measure. Three low dams on natural lakes with bottom valve outlets have multipled drought flows by 6, 8, and 15 times normal volume. Increased and more even summer streamflow benefits the whole public in many ways besides fishing. Development of one watershed of 170.9 km^2 will be completed this year and the first two major installations on a watershed of 468.8 km^2 will be operating. Three years' observation of the first major development shows great increase in resident trout populations of streams. This study concludes that careful planning of water development projects should allow for maintenance of relatively constant streamflow.

I Rhame, R. E. and K. W. Stewart. 1976. Life cycles and food habits of three Hydropsychidae (Trichoptera) species in the Brazos River, Texas. Trans. Am. Entomol. Soc. (Phila.). 102-65-99.

Other authors have indicated that net-spinning Trichoptera are usually abundant below some reservoirs, possibly due to the abundance of plankton. It is suggested that Hydropsyche simulans is a bivoltine species that undergoes an overwintering generation period from August to March. The summer generation is present from April to August. Macrocrustaceans dominated the diet of Hydropsyche during April to July, but diet shifted toward diatoms and filamentous algae during the cooler months. Cheumatopsyche preferred diatoms and filamentous algae during all months except April.

F Richards, J. S. 1976. Changes in fish species composition in the Au Sable River, Michigan, from the 1920's to 1972. Trans. Am. Fish. Soc. 105 (1):32-40.

Fish collections taken in the 1920's from the Au Sable River, Michigan, were replicated in 1972. The Au Sable system as a whole has remained a nonrigorous, predictable environment for fish species. Substantial changes in fish species lists have occurred at most stations. The percentage of cold-water species present in the cold-water, moderate flow areas has increased, while species diversity, evenness, and numbers of species have remained constant. The warm headwater areas remain unchanged. Below the impoundments and in the large river areas, water quality has changed with subsequent reductions in species diversity and evenness, and large changes in species lists. (Author abstract.)

F Ruggles, C. P. and W. D. Watt. 1975. Ecological changes due to hydroelectric development on the Saint John River. J. Fish. Res. Board Can. 32(1):161-170.

Most of the available head of the Saint John River is utilized for hydroelectric development by a series of dams located from the headwaters almost to tidewater. Seven of these hydroelectric dams are described in terms of location, power generation, size of impoundment, operating schedule, and fish passage facilities. Access to upstream spawning areas by Atlantic salmon (Salmo salar) and other anadromous species has been impeded, while ecological changes in the impoundments have favored such species as the alewife (Alosa pseudoharengus) and the white sucker (Catostomus commersoni). Hydroelectric developments on the mainstem of the river have reduced the capacity of the river to assimilate organic wastes and have resulted in a reduction of dissolved oxygen content. Fish kills have occurred due to low dissolved oxygen in the headponds and to supersaturation of nitrogen below the lowermost dam. The combination of impoundments and high pollution load results in the heterotrophic food chain dominating the biological carbon flow. (Author abstract.)

F Schmidt, A. and S. F. Robards. 1976. Determine the impact of any future flow variation from the Blue Lake Dam and hydroelectric facility on the downstream sport fishery of Medvetcha River. Alaska Dep. Fish. Game, Fed. Aid Proj. F-9-8. pp. 55-63. (Mimeogr.)

Increased demand for water stored in Blue Lake Reservoir for hydroelectric power, industrial use, and streamflow volumes necessary for salmonids has exceeded the storage capacity of the reservoir. A study was conducted to evaluate the impact of future flow variations on the stream's fishery.

Salmonid spawning and rearing areas of Sawmill Creek were identified by observation and minnow trapping. Sawmill Creek was found to receive significant resident and visitor use in angling for rainbow trout.

Available literature was searched and studies discussed to outline the effects of future flow variations upon the downstream habitat and fish behavior. The stream was surveyed, and flow measurements were recorded at selected locations.

It is recommended that the stream's historical base flow pattern be reestablished to support the stream's salmonid population at its previous level. Based upon the daily water discharge records for 1945 through 1957, 0.6 m^3/sec streamflow discharge should be maintained January through April, 1.4 m^3/sec during May through November, and 1.0 m^3/sec during December to provide adequate habitat for salmonids downstream of the controlled diversion valve.

F Schoeneman, D. E., R. T. Pressey, and C. O. Junge. 1961. Mortalities of downstream migrant salmon at McNary Dam. Trans. Am. Fish. Soc. 90(1):58-72.

A 3-year study was conducted to determine mortality rates for downstream migrant salmonids passing through spillways or turbines at McNary Dam. Mortalities were determined by releasing marked fish into the exit under study (spillway or turbine) and marked control groups immediately below the dam. Samples of released fish were recovered at stations below the dam, and survival rates were computed from the ratio of the number of experimental to control recoveries. Detailed techniques were devised to test assumptions involved in the estimating procedure. In 1955 and 1956, estimates were obtained for fingerling chinook salmon (Oncorhynchus tshawytscha) at McNary Dam. In 1957, yearling chinook were tested at Big Cliff Dam, a structure on the Santiam River with a turbine and spillway similar to those at McNary Dam. As a control measure, fingerling chinook were also tested in 1957. In all experiments the turbine was the major source of mortality. For each exit, no significant difference was found between mortalities at McNary Dam and Big Cliff Dam on fingerling chinook or between mortality rates for fingerling and yearling chinook. Estimated mortality rate of salmon passing over the spillway was 2 percent with a 95 percent confidence interval from 0 to 4 percent. Estimated mortality rate of salmon passing through the turbines was 11 percent with a confidence interval from 9 to 13 percent. The consistency of the results of the studies indicated that the estimates were valid representations of the mortalities experienced under the tested conditions. (Author abstract.)

F Sharonov, I. V. 1963. Habitat conditions and the behavior of fish in the tailwater of the Volga Hydroelectric Power Station.

Tr. Inst. Biol. Vnutr. Vod. Akad. Nauk. SSR 6(9):195-200 (Transl. from Russian, U. S. Dep. Commerce, 1968.)

Ecological conditions in the Volga River below Kuibyshev Reservoir have changed since dam construction. Fluctuations in current velocity and water level have been most notable. Temperature changes have also occurred. Summer temperatures are colder and the remainder of the year they are warmer. Favorable feeding conditions for planktivorous, benthophagous, and predatory fish are created due to the transport of plankton, benthic fauna, and young fish out of the reservoir.

Large fish concentrations occur in the tailwaters. Abundance of some species is dependent on their abundance in the reservoir from which they come. Abundance of other species is dependent on spawning conditions in the tailwater and movement from downriver areas. Increased discharge resulted in fish moving away from the dam, while with decreased discharge they approached the dam. Water level fluctuations in the tailwater had a detrimental effect on the spawning success of some species.

W Soltero, R. A., J. C. Wright, and A. A. Horpestad. 1973. Effect of impoundment on the water quality of the Bighorn River. Water Res. 7(3):343-354.

Water flowing through Bighorn Lake, a new impoundment on the Bighorn River, underwent certain physical and chemical changes. Turbidity was greatly reduced and most dissolved constituents lost concentration. Potassium was unchanged over 2 years and magnesium, sodium, and sulfate diminished 1 year and increased the next. Nitrate was augmented in the reservoir but other nitrogen compounds suffered reduction. Photosynthetic reduction of alkalinity was not detected and alkalinity decrease is assumed to reflect dilution. Passage through the reservoir delayed conductivity changes evident in the river above, and the mass of stored water was much more resistant to seasonal temperature changes. (Author abstract.)

F Spence, J. A. and H. B. N. Hynes. 1971. Differences in fish populations upstream and downstream of a mainstream impoundment. J. Fish. Res. Board Can. 28(1):45-46.

Four species of cyprinid fishes, Hybopsis biguttata, H. micropogon, Pimephales notatus, and Notropis spilopterus, found in a river upstream of a flood control dam are absent downstream. With the release downstream of cold hypolimnial waters from the dam there was a lag of about 4 weeks in the spring rise of water temperatures and a maximum summer temperature 7°C lower than upstream. Of the fish present in the river these four species had the most southerly distributions, all south of the 64°F (17.8°C) July isotherm, and it is concluded that the lower water temperatures are mainly responsible for their absence downstream of the dam. (Author abstract.)

I Spence, J. A. and H. B. N. Hynes. 1971. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Board Can. 28(1):35-43.

Pronounced differences were found in the macroinvertebrate riffle fauna upstream and downstream of a flood control impoundment. Downstream differences were comparable with those occurring after mild organic enrichment. Plecoptera were absent, but numbers of Baetis and Caenis (Ephemeroptera) increased, and the abundance and number of species of Stenonema were considerably reduced. Numbers of Chironomidae, Simuliidae, Optioservus (Coleoptera), Hydropsychidae, and Hyalella azteca (Amphipoda) increased downstream. These changes are associated with downstream increase in the availability of detritus, a lag of about 4 weeks in the early summer rise in water temperature and a maximum temperature more than 6°C lower than upstream, and alteration of other environmental factors.

F,W Stevenson, H. R. 1975. The trout fishery of the Bighorn River below Yellowtail Dam, Montana. M. S. thesis. Mont. State Univ., Bozeman. 67 pp.

The construction of Yellowtail Dam and a deepwater release from Bighorn Lake have allowed a trout fishery to develop in the Bighorn River below the dam. The purpose of this study was to determine the importance of the fishery by estimating fishing intensity, catch, and trout growth rate in the 22.5 km of river below the dam in 1972 and 1973.

Catch rates during 1972 and 1973 and fishing intensity and yield during 1973 increased as the season progressed. During 1973, the estimated total number of fisherman days was 92.4 per surface hectare in the afterbay below the dam and 5,987 and 1,014 per stream kilometre in downstream stations. During 1973, the estimated total yield was 37,321 trout caught during 18,648 fisherman days for an average of 2.00 fish per fisherman day.

Rainbow trout made up 90.1 percent while hatchery rainbow made up at least 59.4 percent of the total yield. However, the percent of rainbow trout in the yield decreased with downstream progression while the percent of brown and cutthroat trout increased. Brown trout in the study area averaged 57.2 cm in total length at the fourth annulus. Wild brown and marked hatchery rainbow trout grew from approximately 17.8 to 33.0 and 15.2 to 30.5 cm, respectively, in a period of 5 months. Gas bubble disease, caused by nitrogen supersaturation, may affect fish populatons in the study area.

I,W Stober, Q. J. 1963. Some limnological effects of Tiber

Reservoir on the Marias River, Montana. Proc. Mont. Acad. Sci. 23:111-137.

Observations were made on the temperature, turbidity, and plankton in the Marias River above Tiber Reservoir, in the Tiber Reservoir, and in the Marias River below during the summers of 1960 and 1961.

Water temperatures in the river below the reservoir were influenced by the level and volume of release, as well as by atmospheric conditions. Daily water temperatures below the reservoir averaged 6.7°C cooler than those above in 1961. Maximum and minimum temperatures increased approximately 0.7°C per mile for 17.7 km downstream. The reservoir had a marked effect on temperatures at least 38.6 km below the dam. At stations below this, temperatures were approaching those of the river above.

The average turbidity immediately below the reservoir was 14.4 mg/ℓ less than above the reservoir in 1960 and 10.3 mg/ℓ less in 1961. Turbidity increased downstream during periods when large volumes of water were released from the dam. Runoff from a severe storm increased turbidity in the river below the dam to the maximum recorded (465 mg/ℓ).

Plankton numbers were extremely low in the reservoir, as well as in the river. The plankton in the river below the reservoir was largely indigenous and not contributed from the reservoir. Diatoms comprised over 90 percent and 85 percent of the total phytoplankton at each river station during 1960 and 1961. Cladophora was observed growing in dense mats in the riffle areas in the first 6 miles of river below the dam. Following high water and increased turbidity in 1961, the average total phytoplankton population was lower at all stations below the reservoir than in 1960. In general, the total average populations of zooplankton were greater below the reservoir than above, and a decrease in the population at successive downstream stations occurred.

F,I,W Stone, J. L. 1972. Tailwater fisheries investigations, creel census, and biological study of the Colorado River below Glen Canyon Dam. Ariz. Game Fish Dep. 21 pp. (Mimeogr.)

This report is the final segment of a 9-year study to investigate the fishery and fisheries potential created by Glen Canyon Dam.

A creel census was conducted at Lee's Ferry from July 1, 1971, to June 30, 1972. Lee's Ferry is located approximately 15 miles below Glen Canyon Dam and offers the only public vehicular access to the Colorado River from Glen Canyon Dam to Lake Mead. The fishable area from Lee's Ferry access point is approximately 25.7 km of river; 4.8 km accessible from the shore and 22.5 km accessible from boats. A total of 779 angler trips were interviewed and found to have produced 872 rainbow trout, 7 channel catfish, 3 carp, 1 coho salmon, and 16 largemouth bass in

3,865 hours of effort. Total pressure and harvest was estimated at 3,581 angler trips producing 4,415 fish in 16,595 hours of effort. Angler success was estimated at 0.53 fish per man-hour of effort. The average trout creeled was 37.1 cm long.

Bottom fauna populations continue to be low. The only location where benthic organisms were found was around the wet diversion tunnel of Glen Canyon Dam. Extreme water level fluctuations are believed responsible for the paucity of benthos.

No chemical characteristics were detected which would be detrimental to fish life. The average annual temperature of the tailwaters was calculated at 9.4°C. Mercury, lead, and pesticide levels were measured in fish flesh and water samples with no harmful levels detected.

F,I,W Summers, P. B. 1954. Some observations on limnology and fish distribution in the Illinois River below Tenkiller Reservoir. Proc. Okla. Acad. Sci. 35:15-20.

Summer water releases from Tenkiller Reservoir are low in dissolved oxygen; studies were conducted in August 1954 to determine fish species present in these tailwaters.

Nineteen species were taken from the Illinois River in water containing less than 3.0 mg/ℓ dissolved oxygen, 15 in less than 2.0 mg/ℓ, and 13 in less than 1.5 mg/ℓ. All fishes were in distress. The presence of these fish does not imply that the habitat is suitable for large populations of desirable species.

No rainbow trout were trapped, and there were no reports of trout in angler's catches during August. The low dissolved oxygen recorded render this species highly unlikely during the summer months throughout the greater portion of the river.

W Symons, J. M., S. R. Weibel, and G. G. Robeck. 1964. Influence of impoundments on water quality - A review of literature and statement of research needs. U. S. Public Health Service Publ. No. 999-WP-18. Revised January 1966. 78 pp.

This paper is a review of the literature on the influences of impoundments on water quality. Sufficient selected references are reviewed to accomplish three purposes: (1) to indicate to readers who are new to the field of impoundment behavior the enormous breadth of the field, (2) to discuss each topic in sufficient detail to give the reader insight into the current understanding of that topic, and (3) to indicate the major research needs in each area and to suggest possible avenues of study to satisfy these needs.

Also included in the report are sections on the influence of impoundment releases on downstream water quality and operations research for water quality management.

W Symons, J. M., S. R. Weibel, and G. G. Robeck. 1965. Impoundment influences on water quality. J. Am. Water Works Assoc. 57(1):51-75.

This paper reviews the necessity for research on water quality behavior and describes plans and early results in five research areas. These are (1) the simulation of stratified reservoirs on a laboratory scale, (2) the rate and extent of the dissolution of iron and manganese from bottom muds in stratified reservoirs, (3) the dissolved oxygen budget in reservoirs, (4) the possibility of artificial destratification of reservoirs, and (5) the biologic transformations of nitrogen in reservoirs. Of these five research areas, only area 2 was not carried to completion. (Author abstract.)

F Tennant, D. L. 1975. Instream flow regimes for fish, wildlife, recreation, and related environmental resources. U. S. Fish Wildl. Serv. Billings, Montana. 30 pp. (Mimeogr.)

Maximum flow releases of twice the average flow cause severe bank erosion and degradation in the downstream aquatic environment when prolonged.

It is recommended that 10 percent of the average flow is needed to sustain short-term survival habitat. This reduction will: expose the substrate, reduce side channels, diminish bank cover, limit fish movement, increase water temperature, reduce invertebrate drift, and concentrate fish in pools. With 30 percent of the average flow, most of the above factors are improved and it allows for good survival habitat for most aquatic species. At 60 percent of the average flow, an excellent to outstanding habitat is supplied for primary periods of growth.

F Tennant, D. L. 1976. Instream flow regimes for fish, wildlife, recreation, and related environmental resources. Fisheries 1(4):6-10.

A quick, easy methodology is described for determiming flows to protect the aquatic resources in both warmwater and coldwater streams, based on their average flow. Biologists do their analysis with aid of hydrological data provided the U. S. Geological Survey (USGS). Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974, testing the "Montana Method." This work involved physical, chemical, and biological analyses of 38 different flows at 58 cross-sections on 196 stream-miles (315 km), affecting both coldwater and warmwater fisheries. The studies, all planned, conducted, and analyzed with the help of state fisheries biologists, reveal that the condition of the aquatic habitat is remarkably similar on most of the streams carrying the same portion of the average flow. Similar analyses of hundreds of additional flow regimes near USGS gages in 21 different states during the past 17 years substantiated this correlation on a wide variety of streams. Ten percent of the average flow is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Thirty percent is recommended as a base flow to sustain good survival conditions for most aquatic life forms and general recreation. Sixty percent provides excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. (Author abstract.)

F,W Thompson, J. S. 1970. The effect of water flow regulation at Gorge Dam on stranding of salmon fry in the Skagit River 1969-1970. Wash. Dep. Fish. 46 pp. (Mimeogr.)

The stranding of salmon fry on gravel bars below Gorge Dam, Skagit River, Washington, was studied at flow regimes from 141.5 to 28.3 m^3/sec. The severity of salmon fry loss is a function of the number of fry, tributary inflow, flow reduction at the dam, and time of the flow reduction. Flow reduction at night caused more loss than flow reduction during the day. Flow reduction after power peaking trapped fry in pools and at low flows these pools slowly drain. Recommendations to reduce stranding of salmon fry are presented.

F,I Trotzky, H. M. 1971. Effects of water flow manipulation by a hydroelectric power dam on the bottom fauna and rainbow trout sport fishery of the upper Kennebec River, Maine. M. S. thesis, Univ. Maine, Bangor. 75 pp.

Daily fluctuations in water release from Wyman Dam were 8.5 to 170 m^3/sec. These flow changes dewatered much of the streambed and decreased potential bottom fauna production in downstream areas. Rainbow trout below Wyman Dam were examined by food habits and growth. Food habits differed directly below the dam and further downstream. Trichoptera (32 percent), Ephemeroptera (30 percent), and Diptera (27 percent) were the main diet items but food was most abundant immediately below the dam. Stocked trout grew faster than native trout. Age II stocked trout were 338 mm compared to 254 mm for native trout. Also, the largest trout, 448 mm, came from below Wyman Dam.

I Trotzky, H. M. and R. W. Gregory. 1974. The effects of water flow manipulation below a hydroelectric power dam on the bottom fauna of the upper Kennebec River, Maine. Trans. Am. Fish. Soc. 103(2):318-324.

We studied the effect of severe fluctuations in flow on the distribution of bottom fauna of the upper Kennebec River. During the years 1964-1970, discharges below Wyman Dam ranged from

8.5 m^3/sec to an average daily high of about 170 m^3/sec. Slow currents resulting from low flows appeared to limit the diversity and abundance of swiftwater aquatic insects on the river bottom below the dam. Sampling stations above the impoundment averaged 19 aquatic insect genera, while those below the dam averaged 11. About 19 genera were found at stations where the current near bottom fluctuated from 0.5 m/sec to 0.9 m/sec while only 4 genera were found at stations where the fluctuations were from 0.1 to 0.5 m/sec. Aquatic insects adapted for swift water such as Rhyacophila, Chimarra, Iron, Blepharicera, Acroneuria, and Paragnetina were more abundant above the impoundment than below, and were absent from those stations below the impoundment with the lowest current velocities. (Author abstract.)

F Tsai, C. 1972. Life history of the eastern johnny darter, Etheostoma olmstedi Storer, in cold tailwater and sewage-polluted water. Trans. Am. Fish. Soc. 101(1):80-88.

The life history of two populations of Etheostoma olmstedi Storer in the Patuxent River, Maryland, one in cold reservoir tailwater and the other in sewage-polluted water, was studied to determine the effects on this species of man-made modifications in the stream. The spawning season was in May and June with temperatures approximately 12.5-14.5°C in the cold tailwater and 16.0-18.5°C in the sewage-polluted water. In the sewage-polluted water, the fish grew faster in early summer of the first year than those in cold tailwater, but later on growth in length slowed down, even though the condition factor continued to increase. Fecundity in the sewage-polluted water population was larger than that in the cold tailwater population because of larger body weight. In the sewage-polluted water, there were fewer males with a lower condition factor than females and had a higher percentage of fish in the II-year class and a lower percentage in the I-year class than the cold tailwater population. Males did not grow as fast as females in the cold tailwater. (Author abstract.)

W U. S. Bureau of Reclamation. 1973. Gas supersaturation below Yellowtail Afterbay Dam, Montana. M.A.P.P. Environmental Monitoring Workshop. 11 pp. (Typw.)

Gas-bubble disease was observed in rainbow trout below a low-head reregulating dam. Air entrapped in the water on passage through the sluiceway is apparently not released due to a lack of turbulence in the river below the dam.

Tests conducted on rainbow trout placed in live cages below the dam found gas-bubble disease to be a minor problem.

F U. S. Bureau of Sport Fisheries and Wildlife. 1966. Kansas

River Basin - Republican River, Nebraska - fishery study of experimental flows. U. S. Fish. Wildl. Serv., Bur. Sport Fish. Wildl. Rep. 28 p.

This is a report on a study of desirable minimum flows for fish and wildlife in the Republican River Basin in Nebraska, where at several points below large storage reservoirs and below diversion dams the river is occasionally depleted of all its flow-causing fish kills.

The river supports a warmwater fishery, but fish abundance is dependent on volume of river flows. When the water developments were constructed, it was expected that sufficient water would be released into the river to ensure sanitary river conditions and maintenance of fish and wildlife resources downstream. These assumptions were in error as inadequate consideration has been given to fish and wildlife in operation of the structures. Detailed limnological studies were made at three typical reaches, each about 0.5 km long. Physical conditions were measured, photographs taken, and fishing use censused. Experimental flows ranging from 0.6 m^3/sec up to 2.3 m^3/sec were observed on four days in June and July.

The flow studies indicated that a minimum instantaneous flow of 1.4 m^3/sec would go far toward restoration and perpetuation of the river's fish population. It was found that there was a mean annual loss or waste of water from five irrigation canals in the system of 3.3 x 10^7 m^3 which was 1.4 m^3/sec for fisheries purposes below the diversion dams during the months of April through September. From the analysis made, there was sufficient water available to correct the fishery problem, but because several water project agencies are involved and because of legal questions the problem is more complex than a simple question of water availability.

F U. S. Bureau of Sport Fisheries and Wildlife. 1969. Fish and wildlife and the Boysen Unit, Wyoming - initial follow-up report. Minneapolis, Minnesota, U. S. Bureau of Sport Fisheries and Wildlife, North Central Region. 21 pp.

Follow-up studies consist of systematic reexamination of previously studied water projects which have progressed to the construction or operational stage. The Boysen Unit consists of Boysen Dam, Reservoir, and Power Plant on the Wind River which becomes the Bighorn River.

Minimum flows below Boysen Dam generally occur during February, with the monthly average being about 720 cfs (20.4 m^3/sec). Although operating criteria specify a minimum daily average release of 100 cfs (2.8 m^3/sec) for fish preservation, flows this low rarely occur. Monthly maximum flows, usually reached in March, July, or August range from 1,020 cfs (28.9 m^3/sec) to

9,260 cfs (262.1 m^3/sec). The original recommendation for a minimum flow of no less than 700 cfs (19.8 m^3/sec) has not been followed. Although a minimum flow of 700 cfs (19.8 m^3/sec) may be necessary to maintain the present fishery, it is likely that the minimum flow of 100 cfs (2.8 m^3/sec) now designated for fish preservation is not enough. A cooperative streamflow study was initiated to determine the flows necessary to maintain the high quality fishery in the face of increasing water use. Biologists observed and photographed flows of 250, 400, and 700 cfs (7.1, 11.3, and 19.8 m^3/sec) at 10 different stations in a 50-mile (80.5 km) reach of the river downstream from Boysen Dam. Judgemental appraisals were made of the sufficiency of each flow for trout spawning, incubation, winter survival, passage, and fishability. Although acceptable in the upper reaches, flows of 250 and 400 cfs (7.1 and 11.3 m^3/sec) resulted in substantially reduced stream widths and bank, shoal and island areas were still exposed in the lower reaches. A release of 700 cfs (19.8 m^3/sec) provided excellent conditions in all sections.

Based on these observations it was concluded that a minimum instantaneous release of from 250 to 400 cfs (7.1 to 11.3 m^3/sec) at Boysen Dam during the nonirrigation season would preserve the existing fishery. (Fraser 1972b.)

W Vanicek, C. D. 1967. Ecological studies of native Green River fishes below Flaming Gorge Dam, 1964-1966. Ph. D. thesis, Utah State Univ., Logan. 124 pp.

Investigations to study (1) the species composition and distribution of Green River fishes between Flaming Gorge Dam and Ouray, Utah, and (2) the ecology and life history of selected native species (Colorado squawfish, Ptychocheilus lucius; Colorado chub, Gila robusta; bluehead sucker, Pantosteus delphinus; and humpback sucker, Xyrauchen texanus) in Dinosaur National Monument were conducted from May 1964 to October 1966. A total of 23,735 fish consisting of 9 indigenous and 11 exotic species, were taken in 639 collections by electrofishing, gill nets, seines, and fry gear. Flaming Gorge Dam has caused a major change in the ecology of the downstream Green River by alteration of seasonal flow and water temperature patterns as far as the mouth of the Yampa River, 65 miles (104.6 km) below the dam. As a result, native fish populations, particularly in the first 26 miles (41.9 km) below the dam, have been largely replaced by introduced rainbow and brown trout (Salmo gairdneri and S. trutta). Below the Yampa River mouth, fish populations were similar to those reported here during the preimpoundment years. Age and growth determinations were made from scales from 167 Colorado squawfish and 333 Colorado chubs. Both species grew slower in the years after dam closure (1963-1965) than before (1955-1962). The bonytail form of the Colorado chub grew slightly faster than the roundtail form. Length-frequency analyses of young Colorado squawfish, Colorado chubs, and bluehead suckers described seasonal growth of the first three year-classes and provided evidence that these species reproduced successfully in Dinosaur National Monument every year since impoundment. During years of high summer discharge from the dam resultant lower water temperatures (1964 and 1966), no reproduction of any native fishes were found above the mouth of the Yampa River. No juvenile humpback suckers were collected during the study. The roundtail and bonytail forms of the Colorado chub had significantly different length-weight relationships. Squawfish over 200 mm total length were entirely piscivorous, while shorter squawfish consumed microcrustaceans and aquatic insects. The diet of the Colorado chub consisted largely of aquatic and terrestrial insects. (Author abstract.)

F,I,W Vanicek, C. D. and R. H. Kramer. 1969. Life history of the Colorado squawfish, Ptychocheilus lucius, and the Colorado chub, Gila robusta, in the Green River in Dinosaur National Monument, 1964-1966. Trans. Am. Fish. Soc. 98(2):193-208.

Investigations of the ecology and life history of the Colorado squawfish, Ptychocheilus lucius, and the Colorado chub, Gila robusta, in the Green River in Dinosaur National Monument, Colorado-Utah, were conducted from May 1964 to October 1966. A total of 1,469 squawfish and 2,393 chubs was collected with gill nets, seines, fry gear, and an electric shocker. The operation of Flaming Gorge Reservoir (46 miles (74 km) above the Monument) has reduced the range of these two species in this area. Age and growth determinations were made from scales from 182 squawfish and 333 chubs. Both species grew slower in years after reservoir operation began (1963-1965) than before (1955-1962); this reduction in growth rate was related to the alteration of seasonal stream-temperature pattern caused by these operations. The bonytail form of the Colorado chub grew faster than the roundtail form. Length-frequency analyses of young squawfish and chubs described seasonal growth of the first three year-classes and provided evidence that these species reproduced successfully in Dinosaur National Monument every year since impoundment, although reproduction apparently did not occur above the mouth of the Yampa River in 1964 and 1966, years of high summer discharge from the dam and resultant lower water temperatures. Time of spawning of the two species varied and was related to water temperature and receding water level. The roundtail and bonytail forms of the Colorado chub had significantly different length-weight relationships. Squawfish over 200 mm total length were entirely piscivorous, while shorter squawfish consumed microcrustaceans and aquatic insects. The diet of the Colorado chub consisted largely of aquatic and terrestrial insects. (Author abstract.)

F,I,W Vanicek, C. D., R. H., Kramer, and D. R. Franklin. 1970. Distribution of Green River fishes in Utah and Colorado following closure of Flaming Gorge Dam. Southwest Nat. 14(3):297-315.

Flaming Gorge Dam on the Green River, Utah, was closed in November, 1962. Studies of fish populations from the dam downstream to Ouray, Utah, were conducted from July 1963 to October 1966. The objectives of these studies were (1) to study changes in river environment associated with closure of the dam, (2) to determine species composition, distribution, and abundance of fishes in the study section, and (3) to compare 1963-1966 distribution of fishes with that reported in preimpoundment collections. A total of 24,040 fish consisting of 9 indigenous and 12 exotic species were taken in 667 collections by electrofishing, gill nets, sienes, and fry gear. Flaming Gorge Dam has caused a major change in the ecology of the downstream Green River by alteration of seasonal flows and water temperature patterns as far as the mouth of the Yampa River, 65 miles (104.6 km) below the dam. As a result, native fish populations, particularly in the first 26 miles (41.9 km) below the dam, have been largely replaced by introduced rainbow trout (Salmo gairdneri). Below the Yampa River mouth, fish populations were similar to those reported during the preimpoundment years. During years of high summer discharge from the dam with resultant low water temperatures (1964 and 1966), no reproduction of any native fishes was found in the Green River above the mouth of the Yampa River. (Author abstract.)

F Vincent, E. R. 1975. Effect of stocking catchable trout on wild trout populations. Pages 88-91 in Proceedings of the Wild Trout Management Symposium at Yellowstone National Park, Sept. 25-26, 1974. Trout Unlimited, Inc.

Before 1968, low spring flows occurred in the Madison River below Hebgen and Ennis Dams because of water storage in Hebgen Reservoir. Flows were increased during February to May, 1968 through 1971, and numbers of wild trout (brown and rainbow) increased 80 percent below Ennis Reservoir but only 21 percent below Hebgen. Studies suggest that the difference in wild trout abundance was caused by stocking hatchery trout. Stocking of hatchery trout depressed abundance of wild trout stocks.

F Walburg, C. H. 1971. Loss of young fish in reservoir discharge and year-class survival, Lewis and Clark Lake, Missouri River. Pages 441-448 in G. E. Hall, ed. Reservoir Fisheries and Limnology. Am. Fish. Soc. Spec. Publ. 8.

Many age 0 fish are lost in the discharge from 11,330-ha Lewis and Clark Lake each summer. Sixteen species were identified from June, July, and August collections in 1969-1970 and most fish were less than 25 mm long. Estimated peak 24-hour losses are 10 million freshwater drum, 800,000 emerald shiner, 700,000 sauger-walleye, and 170,000 channel catfish. Numbers of fish lost were related to summer flushing rates, and most were lost when flushing time was less than 7 days. Summer survival of age 0 freshwater drum in the reservoir was inversely related to the July-August flushing rate. Abundance of age 0 channel catfish, freshwater drum, gizzard shad, and emerald shiner in summer trawl and seine catches was associated with rate of reservoir flushing. (Author abstract.)

F Walburg, C. H. 1972. Some factors associated with fluctuations in year-class strength of sauger, Lewis and Clark Lake, South Dakota. Trans. Am. Fish. Soc. 101(2):311-316.

Benthos, drift plankton, and fish were studied in Lewis and Clark Lake tailwater between February 1968 and 1969 to determine seasonal occurrence and origin. Abundance of fish was studied in relation to feeding, temperature, and spawning. Organisms found in the tailwater originated from both above and below the dam. Bryozoans and some species of algae, chironomids, and fish were endemic to the tailwater, whereas zooplankton, Hexagenia nymphs, and some species of algae, chironomids, and fish were flushed from the reservoir above.

Our studies illustrated concentration of fish in the tailwater. Seasonal change in fish occurrence was related to food abundance, spawning activity, and water temperature. Recruitment to tailwater fish stocks was partially supplied from the reservoir. Fish growth in the tailwater was superior to that in the reservoir for all species except channel catfish. (Author abstract.)

F,I Walburg, C. H., G. L. Kaiser, and P. L. Hudson. 1971. Lewis and Clark Lake tailwater biota and some relations of the tailwater and reservoir fish populations. Pages 449-467 in C. E. Hall, ed. Reservoir Fisheries and Limnology. Am. Fish. Soc. Spec. Publ. 8.

The strength of sauger, Stizostedion canadense (Smith), year classes in Lewis and Clark Lake has fluctuated widely since formation of the reservoir in 1956. Our studies suggest that more than 80 percent of the variability in year-class strength measured from the catch of fish older than age 0 can be predicted from knowledge of water level change over the spawning ground, June reservoir water temperature, and reservoir water exchange rate. These factors were measured and probably function during the first 2 months of fish life. Sauger year classes of better than average strength can be expected in most years if both power-peaking operations at Fort Randall Dam during the fish spawning and incubation period, and the reservoir water exchange rate during June are minimized. (Author abstract.)

F,W Walker, C. R. 1960. Investigation of water quality in Table Rock Reservoir, its tailwaters, Lake Taneycomo, and the headwaters of Bull Shoals Reservoir. Mo. Dep. Conserv., Fed. Aid Proj. F-1-R-9. 9 pp. (Mimeogr.)

Studies to note the influence of altered water quality characteristics upon fish populations were conducted on three closely spaced impoundments on the upper White River of Missouri. The uppermost impoundment is Table Rock, a flood control and electrical production reservoir; the middle impoundment, Lake Taneycomo, is a small hydroelectric and flood control lake; and the lower impoundment, Bull Shoals Reservoir, is a 18,433-ha multiple purpose reservoir. These impoundments involve 129, 37, and 142 km of stream in their respective portions of White River.

Chemical analysis to determine the extent of thermal and chemical stratification in these impoundments revealed seasonal trends in the water quality of the lakes and in the discharge of Table Rock Dam. Thermal and chemical stratification which created anaerobic conditions existed throughout the summer months until the fall overturn. The period of fall turnover presented the most critical conditions for trout in upper Lake Taneycomo, because hydrogen sulfide which had accumulated in the hypolimnion of Table Rock Reservoir was then discharged. Lower dissolved oxygen saturation values were observed at all sampling stations. The coldwater discharge from Table Rock Dam retained its chemical identity through Lake Taneycomo and into Bull Shoals Reservoir.

I,W Ward, J. V. 1974. A temperature-stressed stream ecosystem below a hypolimnial release mountain reservoir. Arch. Hydrobiol. 74(2):247-275.

Biological, chemical, and physical parameters were measured over a 12-month period of 4 sampling sites on the South Platte River below a Colorado mountain reservoir. Owing to the hypolimnial source, the stream temperature was higher than normal in winter, lower in summer, fluctuated less diurnally and seasonally, and exhibited a seasonally displaced maximum. These effects decreased downstream, but still altered the temperature pattern 8.5 km below the dam. The number of species of macroinvertebrates progressively increased downstream, and it is thought that the temperature regime is responsible for the low diversity by failing to stimulate various developmental stages of the life cycle or by seasonally altering developmental patterns. It is postulated that the river below the dam is a temperature-stressed ecosystem, and that this is the major reason for the low diversity and large standing crop of macroinvertebrates. (Author abstract.)

I Ward, J. V. 1975. Downstream fate of zooplankton from a hypolimnial release mountain reservoir. Int. Assoc. Theor. Appl. Limnol. Proc. 19:1798-1804.

Zooplankton density was highest at a site immediately below the dam and progressively diminished downstream. In this study the discharge of hypolimnial plankton was not an apparent food source for downstream benthos as the filter feeders generally increased downstream. In some reported cases there has been an increase in tailwater benthos due to increased densities of discharged reservoir plankton.

Largest zooplankton species were most abundant in upstream areas, whereas in downstream areas, smaller zooplankton were more common. This phenomenon could be due to the larger organisms sinking more readily, becoming more easily entangled in downstream vegetative assemblages, or being more susceptible to fragmentation.

I,W Ward, J. V. 1976a. Comparative limnology of differentially regulated sections of a Colorado mountain river. Arch. Hydrobiol. 78(3):319-342.

One-year studies were conducted from 1972-75 on four sections of the South Platte River in the Colorado Mountains to elucidate the effects and extent of influence of deep-release dams on stream macroinvertebrates. Study sites represented a gradient from highly regulated to unregulated areas. Macroinvertebrates exhibited lower standing crop but much higher diversity at unregulated sites. Gammarus and gastropods were restricted to regulated sites, whereas filipalpian stoneflies, heptageniid mayflies, and certain dipterans were not found below the dam. Restriction of taxa to regulated or unregulated sites is explained by differences in (1) chemical limiting factors, (2) distribution and abundance of submerged angiosperms and epilithic algae, (3) diversity of organic matter inputs, (4) predation pressure and competitive interaction, (5) environmental stability and predictability, and (6) thermal signals.

Suspended matter below the reservoir was low (2.2 mg/ℓ) due to the reservoir's settling effect. Dissolved matter near the dam was higher (3759 mg/ℓ) than the downstream sites (141 mg/ℓ) due to the concentration of ions in the deep waters of the reservoir and subsequent uptake by downstream biota. Temperatures immediately below the dam fluctuated minimally daily. However, 8.5 km below the dam temperature, differences of as much as 6°C over a 24-hour period were noted.

I,W Ward, J. V. 1976b. Effects of thermal constancy and seasonal temperature displacement on community structure of stream macroinvertebrates. Pages 302-307 in G. W. Esch and R. W. McFarlane, eds. Thermal Ecology II. Proceedings of a Symposium Held at Augusta, Ga., April 25, 1975.

Diurnal and seasonal thermal constancy, a greatly delayed seasonal temperature maximum, and summer cool and winter warm conditions characterize the stream environment below a deep-release dam in

Colorado. Low diversity index and equitability values and changes in macroinvertebrate species composition may result from failure of the temperature regime to provide the thermal stimuli essential for various life-cycle phenomena. It is hypothesized that the following sublethal effects, directly or indirectly resulting from the modified temperature regime, may further alter macroinvertebrate community structure: (1) reduction of niche overlap and a shift toward an equilibrium community as a consequence of reduced environmental fluctuation, (2) more intense competition associated with greater productivity, (3) elimination of major invertebrate predators, and (4) failure of the limited temperature range to provide optimal temperatures for various physiological processes. Effects of the temperature regime on diversity patterns should be considered in dam construction and operation. (Author abstract.)

I Ward, J. V. 1976c. Effects of flow patterns below large dams on stream benthos: a review. Pages 235-253 in J. F. Orsborn and C. H. Allman, eds. Instream Flow, Vol. 2. American Fisheries Society, Washington, DC

The variously modified flow patterns below dams are considered in relationship to the effects on ecological factors of importance to the benthic communities of receiving streams. Species composition and diversity are considerably modified by upstream impoundments. Benthic standing crop may be enhanced or reduced, largely depending on the flow regime. Daily flow fluctuations, if not too severe, may be associated with dense benthic populations as long as a relatively constant seasonal flow pattern is maintained. Little is known regarding subtle, sublethal effects of dams on life-cycle phenomena and biotic interactions and more data are needed on current preferenda of important fish food species. Any flow regime which significantly reduces habitat diversity should be avoided. A diverse substrate with silt-free interstices will considerably reduce deleterious effects of periods of reduced flow, fluctuating flow, and high current velocity. In establishing flow criteria for benthos, each dam must be considered individually. (Author abstract.)

F,I,W Ward, J. V. and J. A. Stanford. 1979. Ecological factors controlling streams zoobenthos with emphasis on thermal modification of regulated streams. Pages 35-36 in J. V. Ward and J. A. Stanford, eds. The Ecology of Regulated Streams. Plenum Press, New York and London.

This paper presents an overview of the general effects of reservoirs on the receiving stream. This is followed with a review of the effects of thermal and flow phenomena on benthic macroinvertebrates in lotic reaches downstream from impoundments, with special emphasis on the influence of temperature regime alterations.

Discussion concentrates on results of comprehensive investigations of the zoobenthos of regulated streams in temperate latitudes.

F Warden, R. L., Jr., and W. A. Hubert. 1977. Spring stomach contents of Lepomis from Wilsom Dam tailwater. J. Ala. Acad. Sci. 48(4):179-183.

The stomach contents are described for 181 bluegills and 211 longear sunfish collected in the spring from the Wilsom Dam tailwater by electrofishing. Qualitative aspects of the fish's stomach contents were described from 25-mm length intervals. Observations indicated that fish eggs and insects were the major diet components.

F,I,W Weber, D. T. 1959. Effects of reduced stream flows on the trout fishery below Granby Dam, Colorado. M. S. thesis, Colo. State Univ., Fort Collins. 149 pp.

Construction of Granby Dam on the Colorado River reduced water temperature and flow in the tailwater to 11 percent of historic flow favoring brook trout and moving brown and rainbow trout downstream. At the time of the study interim water releases from the dam constituted the main flow of water in the study area. The release schedule was: 2.1 m^3/sec during May-July, 1.1 m^3/sec during August, and 0.6 m^3/sec during the remaining eight months of the year.

After construction, food habits of brown trout in the tailwater shifted from Ephemeroptera, Plecoptera, and Trichoptera to Diptera.

Calculations of the amount and quality of habitat present in the three study sections showed that at a flow of 2.8 m^3/sec, 59 percent of the habitat in the lower study sections was preserved. A flow of 0.6 m^3/sec only preserved 18 percent of the quality habitat present in the streambed. The most important element of quality habitat that determined trout distribution was bank cover. The author concludes that the reduction in the amount of quality habitat has seriously decreased the production potential of the Colorado River.

F,I Welch, E. B. 1961. Investigation of fish age and growth and food abundance in Tiber Reservoir and the river below. Mont. Fish Game Dep., Fed. Aid Proj. F-5-R-10. 18 pp. (Mimeogr.)

Fish collected in the river section below the dam were similar in size and condition to those from the reservoir. It was not possible to make any conclusions regarding fish growth and abundance due to our inability to sample the river effectively and the lack of information regarding migration.

For the most part, the quality of the water and quality and quantity of fish-food in the river below the dam were found to be much improved over the river above. An exception to this trend was a 4.8 to 8.1 km section of river immediately downstream from the dam which supported a somewhat different population of bottom fauna and periphyton. Stomach contents of trout taken at the various stations in the river corresponded well with fish-food taken in bottom samples. (Comments concern only the tailwaters).

F White, R. G. 1975. A proposed methodology for recommending stream resource maintenance flows for large rivers. Univ. Idaho Coop. Fish. Unit, Contrib. 4, 18 pp.

The author recommends that criteria for seasonal minimum flows be based on requirements of the most vulnerable fish species. Suggested flows in the Snake River, Idaho, were based on the ecological requirements of sturgeon, channel catfish, smallmouth bass, and anadromous fishes.

F White, R. L. 1969. Evaluation of catchable trout fishery. Tex. Parks Wildl. Dep., Fed. Aid Proj. F-2-R-16. 18 pp. (Mimeogr.)

Studies have shown that the tailwaters below Canyon Dam, Comal County, Texas, are suitable trout habitat. Approximately 32,000 catchable rainbows were stocked over 3 years beginning in 1966. Creel studies in 1967 indicated a harvest of 59 percent. Studies in 1968 indicated that only 35 percent of the fish stocked in the spring and only 30 percent of the fall plants were harvested.

Despite the percent harvest being lower in 1968 than 1967 (owing to high water releases from the reservoir hindering fishermen efforts) the fishery was still felt to be quite successful. Project personnel recommend that trout stocking be continued.

F Wiley, R. W. and D. J. Dufek. 1980. Standing crop of trout in the Fontenelle tailwater of the Green River. Trans. Am. Fish. Soc. 109(2):168-175.

The standing stocks and instantaneous rates of total, fishing, and natural mortalities of rainbow trout (Salmo gairdneri) and brown trout (S. trutta) in the Green River of southwestern Wyoming were estimated from creel-survey and catch-curve information. Six-year averages for rainbow and brown trout were, respectively: standing stock, 49.6 and 5.2 kg/ha; yield from the sport fishery, 5.8 and 1.5 kg/ha; instantaneous total mortality, 1.12 and 0.75; instantaneous fishing mortality, 0.20 and 0.44; instantaneous natural mortality, 0.92 and 0.31; rate of exploitation, 0.12 and 0.30. The primary factor limiting the standing stock is lack of instream cover. Fishing can probably be sustained at current levels by stocking rates of 200 or fewer trout/ha. (Author abstract).

F Wiley, R. W. and J. W. Mullan. 1975. Philosophy and management of the Fontenelle Green River tailwater trout fisheries. Pages 28-31 in Proceedings of the Wild Trout Management Symposium at Yellowstone National Park, 1974. Trout Unlimited, Inc.

A discussion of four management alternatives based on flow below Fontenelle Reservoir; higher flows favor large trout and adversely affect rough fish and small trout.

F,W Williams, H. J. 1950. The operation of Taylor Reservoir and its effect on Gunnison River fishing. Colo. Game Fish Dep., Fish Mgt. Div. 26 pp.

Parts of the Gunnison and Taylor Rivers and their tributaries were studied during the summer and fall of 1950, to determine effect of operation of Taylor Dam on trout fishing in the Gunnison River between Gunnison and Sapinero, Colo.

None of the data gathered indicated that Taylor Dam, as operated during the 1950 fishing season, noticeably affected fishing. However, greater volume changes made suddenly would present an entirely different picture.

The release of water from Taylor Reservoir by means of the outlet tubes was found to lower the temperature of the Gunnison River between Gunnison and Sapinero, but the temperature was still believed to be within a satisfactory range for trout.

The mean monthly volume of the Gunnison River near Gunnison during the fishing season was found to be less (except for the month of September) than before construction of Taylor Dam, although only part of the decrease can be attributed to the operation of the dam.

I Williams, R. D. and R. N. Winget. 1979. Macroinvertebrate response to flow manipulation in the Strawberry River, Utah. Pages 365-374 in J. V. Ward and J. A. Stanford, eds. The Ecology of Regulated Streams. Plenum Press, New York and London.

The short-term flow fluctuations below Soldier Creek Dam on the Strawberry River had negligible effects on the stream benthic community. Uniformly low flows over extended periods appeared to be the major cause of changes in the community. The elimination of high seasonal discharges allowed enhanced algal growth, beaver dams, and increased sedimentation, which reduced or changed habitat heterogeneity, including reducing the availability of hyporheic zone. The annual release of flows simulating normal runoff would do much to reduce the adverse effects of reduced flows on the habitat and biota of the Strawberry River. (Author conclusions.)

F,W Wiltzius, W. J. 1978. Some factors historically affecting the distribution and abundance of fishes in the Gunnison River. Colo. Div., Wildl. Final Report. 202 pp. (Typw.)

The effects of Taylor Dam on the Taylor and Gunnison Rivers and the Blue Mesa Dam, Morrow Point Dam, and Crystal Dam (Curecanti Unit) on the Gunnison River fishery are discussed.

Survival of rainbow trout in the dry years of the 1930's is believed due to flows from Taylor Dam. The shift from rainbow trout (1950's) to brown trout (1970's) in the 96.6-km stretch below Taylor Dam may be due to upstream migration from the recently filled Blue Mesa Reservoir.

The lowering of water temperatures and obstruction of migration, since the completion of the Curecanti Unit, has reduced Colorado squawfish, flannelmouth sucker, and bluehead sucker populations while increasing white and longnose suckers. Large numbers of kokanee salmon planted in Blue Mesa Reservoir have passed through the dam and now comprise nearly the entire fishery in Morrow Point Reservoir.

F,W Wirth, R. L., R. C. Dunst, P. D. Uttormark, and W. Hilsenhoff. 1970. Manipulation of reservoir waters for improved quality and fish population response. Wis. Dep. Nat. Resour., Res. Rep. 62. 23 pp.

Eutrophication prevention by continual bottom-water discharge was studied in newly formed Twin Valley Lake. The hypolimnion was anaerobic during the summer resulting in high chemical concentrations. Large amounts of N and P were released, exceeding the potential amount for an epilimnion discharge; however, eutrophication was soon exemplified in high plankton densities and overabundant rooted vegetation. By the second fall the fish population exhibited signs of developing into a lower quality fishery. In the downstream channel, warmer water in winter and colder water in summer benefited the growth and survival of stocked brown trout. Although the stream environment was still unsettled after three years it was improved greatly. (Author abstract.)

F Wood, R. K. and D. E. Whelan. 1965. Low-flow regulation as a means of improving stream fishing. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 16:375-386.

Studies by the U. S. Study Commission, Southeast River Basin, and cooperating agencies have disclosed that utilization of many streams in the study area is curtailed in part by excessively low stages and sometimes by excessively high stages during the fishing season. The U. S. Study Commission has considered the regulation of low flows by controlled discharge from upstream storage reservoirs as one means of improving such streams for fishing.

Concepts and methods employed in the determination of flow-storage relationships, flow-fishery relationships, storage required to regulate flows, and measurement of fishery benefits are described in this paper. Results of the study indicate that the utility of some streams may be increased from two to five times with low-flow regulation; however, a much better understanding is needed of flow-storage-fishing relationships on which to base more accurate determinations of desired stages and potential benefits. (Author abstract.)

W Wright, J. C. 1968. Effect of impoundments on productivity, water chemistry, and heat budgets of rivers. Pages 188-199 in Reservoir Fishery Resources Symposium. Southern Division, American Fisheries Society.

The practice of designing large deep multiple-purpose dams with deepwater penstocks appears to have many deleterious effects. Water is released during the irrigation season with a higher salinity than would be obtained from surface water withdrawal. Essential nutrients are lost from such reservoirs, thus tending to deplete the productive capacity of the reservoir and at the same time cause eutrophication downstream. Evaporative loss is increased as a result of storing warm incoming water and releasing cold hypolimnial water. Water too cold for satisfactory fish growth may also be released under certain conditions. Water with dissolved oxygen concentrations too low to handle downstream BOD may be released. In extreme cases hydrogen sulfide-laden water has been discharged, resulting in downstream fish-kills.

The interrelationships between fish populations and zooplankton production in reservoirs should be more carefully investigated. Since bottom fauna production is usually negligible in such reservoirs, excessive predation pressure on large zooplankton forms by fish may be responsible, in part, for decreased fish production. (Author abstract.)

I Young, C., D. H. Kent, and B. G. Whiteside. 1976. The influence of a deep storage reservoir on the species diversity of benthic macroinvertebrate communities of the Guadalupe River, Texas. Texas J. Sci. 27(1):213-224.

A comparison was made of the species diversity ($\bar{d}$) of the benthic macroinvertebrate communities during an annual cycle at 5 stations located in, above, and below Canyon Reservoir, a deep storage reservoir on the Guadalupe River in central Texas. New equations were derived for maximum diversity ($\bar{d}_{max}$) and minimum diversity ($\bar{d}_{min}$) which were utilized in calculating a new redundancy value ($\bar{r}$) which can be used for small sample sizes.

Pronounced differences were found in the structure of the faunal communities at the 5 stations as indicated by values of $\bar{d}$ and $\bar{r}$. The river above the reservoir had a community in which structural changes throughout the year resulted from the appearance and disappearance of taxa while there was no marked dominance of any one taxon. Such a condition normally exists in unpolluted shallow streams. The river immediately below the reservoir had a community with few taxa, each represented by numerous individuals, a condition characteristic of communities undergoing environmental stress. Apparently this stress was created by low water temperatures and the presence of hydrogen sulfide. Further downstream the community had wide seasonal fluctuations in diversity due primarily to changes in the dominance of certain taxa. The deep reservoir station had a community influenced mostly by low temperatures, low oxygen, and high hydrogen sulfide which resulted from thermal stratification. During stratification, $\bar{d}$ reached its theoretical minimum and $\bar{r}$ its theoretical maximum, indicating severe environmental stress. The station located in a shallow cove had a community structure indicating mild environmental stress. Detrimental effects of impoundment appear limited to the reservoir and the region immediately below the dam. (Author abstract.)

F Zalumi, S. G. 1970. The fish fauna of the lower reaches of the Dnieper, its present composition, and some features of its formation under conditions of regulated and reduced river discharge. J. Ichthyol. 10(5):587-596.

Hydraulic engineering works on the Dnieper have led to an alteration in the water regime of the lower reaches of this river and of the Dnieper-Bug Delta which, in turn, has caused an alteration in the composition of the fish fauna; some fish species have disappeared and new ones have appeared. The fishes of the lower reaches of the Dnieper and of the Delta are divided into 8 groups in relation to the reaction of alteration of environmental conditions. A table has been compiled of the fish species which have inhabited the lower reaches of the Don and Dnieper-Bug Delta or have periodically entered in before and after the regulation of river discharge. The water regime of the rivers of the Azov-Black Sea, Caspian, and Aral basins is being modified in the same direction under the influence of hydraulic engineering works. Given that the fish fauna of the lower reaches of the rivers is similar, changes similar to those which have taken place in the lower reaches of the Dnieper are to be expected. (Author abstract.)

F,W Adelman, I. R. and L. L. Smith, Jr. 1972. Toxicity of hydrogen sulfide to goldfish (Carassius auratus) as influenced by temperature, oxygen, and bioassay techniques. J. Fish. Res. Board Can. 29(9):1309-1317.

Bioassays were conducted to test the effect of temperature and oxygen on H_2S toxicity to goldfish (Carassius auratus L.) and to investigate some factors that influence bioassay results. Relation to H_2S toxicity to temperature is negatively logarithmic over the range of 6.5-25°C. The mean 96-hr TL50 at 6°C was 530 μg/ℓ and at 25°C was 4 μg/ℓ. At temperatures of 14, 20, and 25°C, most acute mortality from H_2S ended by 11 days and the 11-day TL50's at these temperatures were significantly different. In bioassays with and without prior oxygen acclimation, decreasing oxygen concentrations increased H_2S at oxygen concentrations of 6 and 1.5 mg/ℓ, respectively, and in the latter, 71 and 53 μg/ℓ H_2S at the same oxygen concentrations. Variability in bioassay results was not affected by test temperatures of 14, 20, and 26°C, and in most cases 1 week of temperature acclimation was adequate. Stocks of fish responded differently after 11 days of bioassay, although differences were not detected after 4 days of bioassay. (Author abstract.)

F,I Allen, K. R. 1951. The Horokiwi Stream. A study of a trout population. New Zealand Mar. Dep. Fish. Bull. 10. 238 pp.

The object of this work was to study factors affecting the production of trout in a typical stream by examining the relationship between trout production, quantity of food available and consumed, and quantity of trout taken by anglers. A significant relation was found between the food supply as represented by bottom fauna and the production of trout. Floods caused some reduction in the numbers of trout, but the balance between trout stock and food supply caused the growth rate of trout to decrease as a result of the destruction of the bottom fauna. It is probably that, while the bottom fauna and hence trout production may be limited by its food supply in times of continuous stability, the sudden decreases and slow recoveries caused by floods may also be an important controlling factor.

F Allen, W. R. and M. E. Clark. 1943. Bottom-preferences of fishes of Northeastern Kentucky streams. Trans. Ky. Acad. Sci. 2(2):26-30.

Nine hundred forty-five observations of particular fish species on specific bottom types are summarized. Examination by fish family showed an apparent preference for areas with sand and gravel bottoms. Habitat selection may actually have been determined by the water velocity at which these bottom types occur.

I Anderson, N. H. and K. W. Cummins. 1979. Influences of diet on the life histories of aquatic insects. J. Fish. Res. Board Can. 36(3):335-342.

Benthic species are partitioned into functional feeding groups based on food-acquiring mechanisms. Effects of food quality on voltinism, growth rate, and size at maturity are demonstrated for representatives of gougers and shredders, collectors, and scrapers. Food quality for predators is uniformly high, but food quantity (prey density) obviously influences their life histories. A food switch from herbivory to predation, or some ingestion of animal tissues in the later stages, is a feature of the life cycle of many aquatic insects. Temperature interacts with both food quality and quantity in effects on growth as well as having a direct effect on control of metabolism. Thus further elaboration of the role of food in life history phenomena will require controlled field or laboratory studies to partition the effects of temperature and food. (Author abstract.)

I Anderson, N. H. and D. M. Lehmkuhl. 1968. Catastrophic drift of insects in a woodland stream. Ecology 49(2):198-206.

Catastrophic drift in this small stream occurred in response to freshets resulting from heavy fall rains. Fall hatching insects increased benthic standing crops and drift may have been useful in dispersing aggregations of newly hatched larvae. The data indicated that increased flows did not increase drift density, but that insects per unit volume remained about the same. Removal of the allochthonous element in the stream could be more detrimental to benthic communities than catastrophic drift.

I Armitage, K. B. 1961. Distribution of riffle insects of the Firehole River, Wyoming. Hydrobiologia. 17:152-174.

Rubble substrate had 1.4 times more organisms and they weighed 2.5 times more than invertebrates from bedrock substrates. Some species have a current demand and are located in areas where they are more exposed such as in bedrock substrates. Insects in a stream are present in and along a continuously fluctuating environment making discrete communities difficult to describe.

I Baily, R. G. 1966. Observations on the nature and importance of organic drift in Devon River. Hydrobiologia. 27:353-367.

Drift can be generally separated into three categories: (1) organisms from the bottom fauna, (2) emerging imagos produced by the bottom fauna, and (3) terrestrial sources. Practically all species found in the bottom fauna occurred in the drift at some time and most abundant species in the bottom fauna were also the most abundant in the drift samples. Emergent and terrestrial insects were present throughout the year, but were most abundant during the spring. Terrestrial insects were more prevalent in areas with overhanging vegetation.

F Baldes, R. J. and R. E. Vincent. 1969. Physical parameters of microhabitats occupied by brown trout in an experimental flume. Trans. Am. Fish Soc. 98(2):230-238.

Physical parameters govern microhabitat characteristics. A resting microhabitat for fishes in streams becomes the focus for movement to other segments of the habitat.

Brown trout were observed in a flume at flows of 0.034, 0.102, and 0.192 m^3/sec (1.2, 3.6, and 6.8 cfs). Study fish occupied resting microhabitats within a velocity range of 12.2 to 21.3 cm/sec (0.4 to 0.7 ft/sec). Turbulence, light, water depth, spatial limits, direction of flow, and cover also influence selection.

Most microhabitats were above structures or along the edge of the shaded east side of the flume. Study fish occupied areas near the bottom and were positive rheotactic. A strong thigmotactic response substituted for lack of overhead cover. Areas less than 5.1 cm (2 inches) deep and less than 20.3 cm (8 inches) square within the suitable velocity range were avoided. (Author abstract.)

I Bane, C. A. and O. T. Lind. 1978. The benthic invertebrate standing crop and diversity of a small desert stream in the Big Bent National Park, Texas. Southwest. Nat. 23(2):215-226.

Due to scouring conditions and emerging insects the numerical standing crop was highly variable. Diversity was moderately high.

F Behmer, D. J. 1964. Movement and angler harvest of fishes in the Des Moines River, Boone County, Iowa. Iowa Acad. Sci. 71:259-263.

Fish tagging returns of the Iowa Cooperative Fishery Research Unit from 1955 to the end of 1963 are summarized. Tag returns give minimum estimates of angler harvest of 4.6 percent for channel catfish, Ictalurus punctatus, and 12 percent for walleye, Stizostedion vitreum. Very few flathead catfish, Phlodictis olivaris, and smallmouth bass, Micropterus dolomieui, were reported caught by anglers. Channel catfish showed greatest movement of the species studied with downstream movement predominating. Walleyes moved as far as 18 miles (29 km). Smallmouth bass showed very little movement, except for one individual that moved about 40 miles (64.4 km). (Taken from author abstract.)

F Berra, T. M. and G. E. Gunning. 1970. Repopulation of experimentally decimated sections of streams by longear sunfish, Lepomis megalotis megalotis (Rafinesque). Trans. Am. Fish. Soc. 99(4):776-781.

Repopulation by longear sunfish of stream segments decimated by electrofishing was studied in six areas on four streams in Louisiana. Lepomis megalotis megalotis (Rafinesque) repopulated the decimated areas to a level as great or greater (3.5 times) than the biomass of the decimation sample at four of the six areas within one year. Repopulation occurred between March and later summer and was accomplished by fish at least two years old. A principal factor allowing rapid repopulation of longear sunfish in the decimated segments may have been an apparent lack of repopulation by large predatory species. (Author abstract.)

F,W Bianchi, D. R. 1963. The effects of sedimentation on egg survival of rainbow trout and cutthroat trout. M. S. thesis. Mont. State Univ., Bozeman, 28 pp.

A study was conducted on Bluewater Creek during April, May, and June 1962 to determine the effects of various amounts of suspended sediment on egg survival of rainbow trout and cutthroat trout. Water temperature, stream discharge, and suspended sediment data were collected. A particle size analysis of the original material placed in the redds was compared with materials removed after the egg incubation periods. The apparent velocity and dissolved oxygen concentration of the groundwater within the redds were determined by means of Mark VI groundwater standpipe. When sediment settled into a redd the permeability of the gravel and consequently the apparent velocity of the groundwater was decreased. A total of 60 or more tons ($\geq$54 metric tons) of suspended sediment passed the redds before apparent velocity showed a perceptible decrease. Apparent velocity decreased as the total suspended sediment load increased beyond this level. Redds exposed to 290 or more tons ($\geq$263 metric tons) of suspended sediment had the highest egg mortality. Redds with the lower suspended sediment load, highest apparent velocity, and highest dissolved oxygen concentration had the greatest egg survival. Multiple regression analyses of the results showed apparent velocity, dissolved oxygen, suspended sediment load, and stream discharge were the important factors in determining rainbow trout and cutthroat trout egg survival. (Author abstract.)

I Bishop, J. E. and H. B. N. Hynes. 1969a. Upstream movements of the benthic invertebrates in the Speed River, Ontario. J. Fish.

Res. Board Can. 26(2):279-298.

Upstream movements of substantial numbers of invertebrates were detected. The mechanism for this was largely positive rheotaxis, but positive skototaxis and the release of phototactic control probably governed the distance covered. During the winter, statistically greater movement occurred in areas adjacent to the banks than in midstream, but in summer the midstream area contributed most of the migrants. Movements upstream counteracted 6.5 percent of downstream drift by numbers and 4 percent by weight, but no comparison of relative distance travelled was made. The upstream movement was of sufficient quantity and species diversity to account for recolonization of dried-out or erosion-denuded areas. (Taken from author abstract.)

I Bishop, J. E. and H. B. N. Hynes. 1969b. Downstream drift of the invertebrate fauna in a stream ecosystem. Arch. Hydrobiol. 66(1):56-90.

The density and biomass of the invertebrates in the Speed River drift vary temporally and with total discharge. Partial depression of nocturnal drift maxima by moonlight is evident. All benthic species (Pelecypoda excepted) occur, at least occasionally, in the drift, but the proportion of standing stock moving downstream at any time is low (0.0002-0.004 percent). Such losses result primarily from current forces acting on insects present in stone-top forage areas after the release of negative phototactic control. Reattachment by thigomotactic and rheotactic responses is normally rapid. All Ephemeroptera and Plecoptera and some Trichoptera are night-active, while Helicopsyche and the Hydracarina are predominantly day-active; the Diptera show no preference. The biomass drifting is sufficient to sustain the vertebrate population, but still accounts for only 15 percent of annual production. (Author abstract.)

F,I Bjornn, T. C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Trans. Am. Fish. Soc. 100(3):423-438.

Many juvenile salmon and trout migrated from the Lemhi River drainage each fall-winter-spring period. Seaward migration of anadromous trout and salmon normally occurred in the spring but presmolt anadromous and nonanadromous fishes also left the stream usually beginning in the fall. Compare data on temperature, food abundance, streamflow, cover, and population density with movements and conducted field and laboratory tests to determine reasons for the two types of movements.

Smolts of the anadromous species migrated for an obvious reason, but none of the factors examined appeared to "stimulate or release" their seaward migration. Movement frequently coincided with changes in water temperature and streamflow, but could not establish a consistent casual relationship and concluded that photoperiod and perhaps growth must initiate the physiological and behavioral changes associated with seaward migration.

Nonanadromous and presmolt anadromous species emigrated from the streams for different reasons than the smolts. I postulated that fish found the stream environment unsuitable during the winter. Stream temperature declined in the fall as fish began moving from the streams, but I could not induce more fish to stay in test troughs with 12°C water versus troughs with 0-10°C water. Fish emigrated before abundance of drift insects declined in winter. Emigration occurred in spite of the relatively stable flows in both streams. Population density modified the basic migration pattern by regulating the number and percentage of fish that emigrated and to a limited extent time of emigration.

Movements of nonsmolt trout and salmon correlated best with the amount of cover provided by large rubble substrate. Subyearling trout emigrated from Big Spring Creek which contained no rubble substrate but remained in the Lemhi River which did. In both field and laboratory tests, more fish remained in troughs or stream sections with large rubble substrate than in troughs or sections with gravel substrate. Trout and salmon in many Idaho streams enter the substrate when stream temperatures declined 4-6°C. A suitable substrate providing adequate interstices appears necessary or the fish leave. (Author abstract.)

F,I,W Bjornn, T. C., M. A. Brusven, M. P. Molnau, J. H. Milligan, R. A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho; Forest, Wildlife, and Range Experiment Station, Bull. 17. 43 pp.

We assessed the transport of granitic bedload sediment (<6.35 mm diameter) in streams flowing through central Idaho mountain valleys and the effects of the sediment on juvenile salmonids and aquatic insects. We measured bedload sediment tranported in the streams during the spring snowmelt runoff and the summer lowflow periods for 2 years. In both years the streams transported all the sediment available, including that under the armor layer of the stream bottom in the first year. The modified Meyer-Peter, Müller equation proved accurate in estimating the transport capacity of such streams using measurements of slope, hydraulic radius, and mean diameter of streambed material.

In artificial stream channels, benthic insect density in full sedimented riffles (<2/3 cobble imbeddedness) was one-half that in unsedimented riffles, but the abundance of drifting insects in the sedimented channels was not significantly smaller. In a natural stream riffle, benthic insects were 1.5 times more abundant in a plot cleaned of sediment, with mayflies and stoneflies 4 and 8 times more abundant, respectively. Riffle beetles (Elmidae) were more abundant in the uncleaned plot.

During both summer and winter, fewer fish remained in the artificial stream channels where sediment was added to the pools.

The interstices between the large rocks in the pools provided essential cover necessary to maintain large densities of fish. Fish in sedimented channels exhibited hierarchical behavior, while those in unsedimented channels were territorial in behavior. In small natural pools (100 to 200 m^2), a loss in pool volume or in area deeper than 0.3 m from additions of sediment resulted in a proportional decrease in fish numbers. The amounts of sediment in the two streams studied did not have an obvious adverse effect on the abundance of fish or the insect drift on which they feed. (Taken from author abstract.)

F Bjornn, T. C. and J. Mallet. 1964. Movements of planted and wild trout in an Idaho river system. Trans. Am. Fish. Soc. 93(1):70-76.

During 1959-61, 10,000 catchable-sized hatchery-reared rainbow trout were jaw-tagged and released in the upper Salmon River, Idaho, and 2,247, 619, and 539 wild cutthroat trout, Dolly Varden, and rainbow trout, respectively, were caught on hook and line, tagged, and released in the Middle Fork of the Salmon River. More than 1,500 of the tagged, hatchery-reared rainbow trout were recovered after being in the stream up to 1 year. Of those recovered the same season as released, more than 90 percent were taken within 2 miles (3.2 km) of the release site. Ninety percent of those recovered after having been in the river over winter were taken within 5 miles (8.0 km) of the release site. Of 253 tagged wild cutthroat trout recovered, 64 were recovered in release areas, and 189 were recaptured one or more miles (≥1.6 km) from their release sites (average for the latter, about 19 miles (30.6 km)). Of 95 tagged wild Dolly Varden recovered, 27 were recovered in the release areas, and 68 were recovered one or more miles (≥1.6 km) from release sites (average for the latter, 22.2 miles (35.7 km)). Twenty-seven tagged wild rainbow or steelhead trout were recovered; 14 in release areas and 13 downstream from the release sites. Only 25.3 percent of the cutthroat trout and 28.4 percent of the Dolly Varden were recovered within 1 mile (1.6 km) of release sites. (Author abstract.)

F Boussu, M. F. 1954. Relationship between trout populations and cover on a small stream. J. Wildl. Manage. 18(2):229-239.

A study was made of the relationship of eastern brook trout, rainbow trout, and brown trout populations to cover in fourteen sections of Trout Creek, Montana. Stream sections were inventoried by electroshocking before and after alteration, with fish classified in legal, sublegal, and fingerling groups.

Addition of brush cover resulted in an average increase of 0.7 kg of fish per inventory. Removal of brush cover resulted in a decrease of 0.8 kg of fish per inventory. The weight of fish per inventory was reduced by 0.1 kg following the removal of undercut banks. Control sections increased 0.10, 0.08, and 0.13 kg per inventory.

F,I,W Bovee, K. D. 1975. The determination, assessment, and design of "in-stream value" studies for the Northern Great Plains Regions. Northern Great Plains Resources Program, EPA Control #68-01-2413, Univ. Mont., Missoula. 205 pp.

An extensive literature review was conducted to determine the discharge requirements of various components of a warmwater fishery. Where exact hydrologic parameters were not measured directly in individual studies, they were estimated from inferred statements and knowledge of hydrologic variables leading to certain instream conditions. From this information it was possible to determine which components of the stream community would be most seriously affected by reduced discharges. In addition, a number of different methods used in the recommendation of minimum streamflows were reviewed. It was concluded that a method for recommending minimum discharges should not sacrifice reliability for expediency.

A methodology is proposed for the recommendation of minimum discharges for a warmwater fishery. This method utilizes field measurements of critical stream areas and biological criteria determined from the use of indicator species. A number of variables were identified which might require a greater amount of in-stream flow than the fishery, per se. These variables included streamflow needs for riparian and other subirrigated vegetation, water quality parameters, anchor ice formation, and the relationship between discharge and sediment yield.

Included are Appendices which cover a review of water quality, streamflow, the benthic community, and the habitat preferences and spawning requirements of various groups of fish.

F Bovee, K. D. 1978. The incremental method of assessing habitat potential for coolwater species, with management implications. Pages 340-346 in R. L. Kendall, ed. Selected Coolwater Fishes to North America. Am. Fish. Soc. Spec. Publ. 11.

The U. S. Fish and Wildlife Service Instream Flow Group (IFG) incremental method assesses the effects of streamflow regimes on fish communities. It utilizes one or more hydraulic simulation procedures to determine the distribution of depth, velocity, and substrate within a channel at different discharges. A composite probability of use for each combination of depth, velocity, and substrate is determined for each life stage of each species under study. A weighted usable area, roughly equivalent to the physical carrying capacity of the stream reach, is then determined for each month of the year. The weighted usable area may then be used to interpret changes in both standing crop and species composition due to changes in the hydraulic features of the stream. (Author abstract.)

F Bovee, K., J. Gore, and A. Silverman. 1978. Field testing and adaptation of a methodology to measure "in-stream" values in the Tongue River, Northern Great Plains Region. U. S. Environmental Protection Agency Contract 908/4-78-004A. Univ. Mont., Missoula. 465 pp.

A comprehensive, multicomponent in-stream flow methodology was developed and field tested in the Tongue River in southeastern Montana. The methodology incorporates a sensitivity for the flow requirements of a wide variety of in-stream uses, and the flexibility to accommodate seasonal and subseasonal changes in the flow requirements for different uses. In-stream flow requirements were determined by additive independent methodologies developed for: (1) fisheries, including spawning, rearing, and food production, (2) sediment transport, (3) mitigation of adverse impacts of ice, and (4) evapotranspiration losses. Consideration of a single in-stream flow requirement is inadequate since flow requirements for each use varied throughout the year. The methodology can be an effective water management tool.

I Bradt, P. T. 1977. Seasonal distribution of benthic macroinvertebrates in an eastern Pennsylvania trout stream. Proc. Pa. Acad. Sci. 51(2):109-111.

The highest biomass, the highest number of individuals, and the highest number of taxa were recorded during the summer months. The diversity index did not show any substantial seasonal fluctuation. Total numbers of macroinvertebrates, wet weight, and total number of taxa were negatively correlated with the amount of rain and positively correlated with temperature and percent of oxygen saturation. Members of the family Hydropsychidae comprised 38.6 percent of the macroinvertebrate population, family Chironomidae 18.6 percent, and order Ephemeroptera 16.0 percent. (Taken from author abstract.)

F Branson, B. A. 1977. Endangered fish and Kentucky streams. Nat. Hist. 86(2):64-69.

The twenty-three rare, threatened, and endangered fish species in the Daniel Boone National Forest are suffering from varying degrees of habitat deterioration. A wide range of human activities are responsible such as surface mining, road building, dam construction, bank clearing, and channel straightening. Siltation is the major cause for destruction of aquatic habitats followed by changes in water chemistry and flooding of streams by dam building.

F Brown, E. H., Jr. 1961. Movement of native and hatchery-reared game fish in a warm-water stream. Trans. Am. Fish. Soc. 90(4):449-456.

Movement of 248 marked and recaptured native smallmouth bass (Micropterus dolomieui), native rock bass (Ambloplites repestris), and hatchery smallmouth bass released in a headwater tributary of the Little Miami River in Ohio during 1953 through 1957 is described. More than 91 percent of the native fishes of both species reported by anglers were taken within 1/2 mile (0.8 km) of release points. Recaptures made with electric shocker and hoop nets indicated that appreciable numbers of native fish remained within limited areas of one to several pools between successive years. Considerable numbers of stocked smallmouth bass moved away from release points. A total of 35.7 percent of fish stocked in optimum habitat in 1953 and later recovered by anglers had moved distances greater than 1/2 mile (0.8 km). All fish stocked in submarginal habitat upstream in 1955 and later recovered by anglers moved more than 1/2 mile (0.8 km). Except for one recapture 6 miles (9.6 km) upstream from the release point, all returns of stocked fish were from dowmstream at distances ranging up to 70 miles (112.6 km). The proportion of fish stocked in optimum habitat in 1953 and recaptured 11 to 50 miles (17.7 to 80.5 km) downstream increased significantly from 1953 to 1954, suggesting a progressive downstream dispersal. Movement of hatchery smallmouth bass was independent of size at stocking in 1953. Rapid disappearance of the 1953-stocked fish may have resulted from higher mortality, as well as from movement. (Author abstract.)

F Brown, M. E. 1946. The growth of brown trout (Salmo trutta Linn.). III. The effect of temperature on the growth of two-year-old trout. J. Exp. Biol. 22(3-4):145-155.

The growth of two-year-old brown trout under controlled environmental conditions in water of different temperatures was examined. Specific growth rates of trout were high between 7 and 9°C and between 16 and 19°C and were low above, between, and below these temperatures. These two maxima are explained by a differential effect of temperature on the amount of food eaten, maximal between 10 and 19°C, and the activity of the fish, maximal between 10 and 12°C.

The maintenance requirements of trout of equal weight increased sigmoidally with an increase in temperature.

I Brusven, M. A. and K. V. Prather. 1974. Influence of stream sediments on distribution of macrobenthos. J. Entomol. Soc. B.C. 71(Oct.):25-32.

Studies were conducted in the laboratory and field to determine the substrate relationships of five species of stream insects representing the orders Ephemeroptera, Plecoptera, Trichoptera, and Diptera.

Various combinations of pebble and sand were tested in the presence or absence of cobbles. Substrates with cobble were generally preferred over substrates without cobble. The preference for cobble generally increased as the sediments around the cobble decreased in size. Substrates with unembedded cobble were slightly preferred over half-embedded cobble; completely embedded cobble in the sand proved unacceptable to most species. Three types of substrate distribution patterns are recognized: stream insects which inhabit substrate surfaces, interstices, and both substrate surfaces and interstices. (Author abstract.)

F Brynildson, O. M. 1967. Dispersal of stocked trout in five Wisconsin streams. Wis. Conserv. Dep., Res. Re. 26 (Fisheries). 51 pp.

Brook trout stocked as fingerlings during early summer and during the fall remained near the stocking sites or tended to disperse a short distance above the stocking sites by the following spring. Yearling brook trout released in winter were concentrated 3 to 4 miles (4.8 to 6.4 km) above the stocking site the following spring. Yearling brook trout released in March were distributed in a 1-mile (1.6-km) section below the stocking site within 10 days after release.

Brown trout stocked as fingerlings during early summer and during the fall remained near the stocking sites or dispersed upstream from the stocking sites by the following spring. Yearling brown trout released during January were distributed above and below the stocking sites, but were concentrated at the stocking sites the following April. Out of six stocks of yearling brown trout released during March, four had greater dispersal downstream than upstream from the area of release and two had greater dispersal upstream than downstream a week to a month after release.

Various strains of rainbow trout stocked as fingerlings during early summer and during the fall remained near the stocking sites the following spring. Yearling fall-hatched rainbow trout released in March were concentrated at the stocking sites and had only limited dispersal upstream and downstream from the stocking sites 3 to 4 weeks after release. (Author abstract.)

F,W Buck, D. H. 1956. Effects of turbidity on fish and fishing.

Okla. Fish. Res. Lab. Rep. 56. 62 pp.

The effects of turbidity on fish was studied on farm ponds, hatchery ponds, and two reservoirs in Oklahoma. Production of fish and fish food organisms was greater in clear waters, with the exception of channel catfish. The average total weight of fish in clear farm ponds was 1.7 times greater than in moderately turbid ponds and 5.5 times greater than in muddy ponds. Of the three species stocked (largemouth bass, bluegill, and channel catfish), largemouth bass were most affected.

Average volume of net plankton of clear ponds was 7 times greater than the intermediately turbid waters and 12.8 times greater than the muddy ponds. In hatchery ponds turbidity decreased growth and total yield of largemouth bass and bluegill, but increased channel catfish production. Growth of largemouth bass, crappie, and channel catfish was much slower in the turbid reservoir than in the nonturbid reservoir. Flathead catfish had the most favorable growth in the turbid reservoir. Scaled fish numbers were low in the turbid reservoir, apparently due to unsuccessful reproduction caused by the heavily silted waters. Also, growth was slow due to the lack of sufficient forage fish. The clear reservoir attracted more anglers and yielded greater returns per unit of fishing effort than did the turbid reservoir.

F,W Burdick, G. E., M. Lipschuetz, H. F. Dean, and E. F. Harris. 1954. Lethal oxygen concentrations for trout and smallmouth bass. N. Y. Fish Game J. 1(1):84-97.

Curves for the mean oxygen concentrations lethal to fish over short exposure periods have been constructed for brook, brown, and rainbow trout and smallmouth bass. Lethal oxygen concentrations were determined at several temperatures using complete loss of equilibrium by the fish as an end-point. The highest and lowest concentrations producing such an effect are noted for each temperature. Curves derived are believed to represent the lethal concentrations for certain hatchery trout and fish under natural stream conditions. (Taken from author abstract.)

F,W Burton, G. W. and E. P. Odum. 1945. The distribution of stream fish in the vicinity of Mountain Lake, Virginia. Ecology 25(2):182-194.

A detailed longitudinal survey of fish in five streams was conducted using seines and dip-nets. Marked longitudinal succession of fishes occurred in all streams but was more pronounced the greater the altitude change. Temperature, stream size, and gradient of flow appeared to be most important in determining distribution within the study streams. No correlation was observed between pH and fish distribution.

F Burton, R. A. and T. A. Wesche. 1974. Relationship of duration of flows and selected watershed parameters to the standing crop estimates of trout populations. Water Resour. Series 52. Water Resour. Inst., Univ. Wyoming. 86 pp.

The objectives of this study were twofold: to aid in determining suitable streamflow recommendations for trout through the use of flow duration values and to develop an index of potential trout productivity, utilizing watershed parameters that were found to be significantly related to standing crop estimates.

The 25 percent average daily flow level recommended by Wesche (1973) was equalled or exceeded an average 55 percent of the time during the summer months in streams with good trout populations, as compared to an average of 15.8 percent of the time in streams with poor populations.

Seven watershed parameters were found to be significantly related to standing crop estimates in small Wyoming streams. Four of the parameters, drainage area, total stream length, mean basin elevation, and forested area were utilized in development of an index equation for the potential trout productivity. Calculated results of the index were found to show a general relationship between geomorphic charactertistics and standing crop estimates. (Author abstract.)

I Buscemi, P. A. 1966. Importance of sedimentary organics in the distribution of benthic organisms. Pages 79-86 in K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman, eds. Organism - Substrate Relationships in Streams. Pymatuning Laboratory of Ecology, Spec. Publ. 4, Univ. Pittsburgh.

Flowing water has a high quantity of particulate detritus which is held in suspension and is most abundant during the spring. Greatest numbers and varieties of organisms were found in areas of the stream which contained the lowest total organic seston and sediment.

I Cairns, J., Jr., and K. L. Dickson. 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. J. Water Pollut. Control Fed. 43(5):755-772.

Short-term exposure to intolerable conditions results in alteration of the macrobenthic community structure. A specific stressful condition eliminates the organisms most sensitive to it and leaves the ones that are able to survive adverse conditions, thus reducing the complexity of the ecosystem. Species which are tolerant of the adverse conditions increase in numbers because of the lack of competition and predation until their limits of available space and food are reached. When conditions become unfavorable in a community with few species, one or more species may be completely eliminated, thus reducing a major portion of the benthic standing crop.

F Carlander, K. D., ed. 1957. Symposium on evaluation of fish populations in warm-water streams. Iowa Coop. Fish. Res. Unit., Iowa State Univ., Ames. 118 pp.

A compilation of papers on fish populations in warmwater streams presented at Iowa State College, 25 March 1957. Subjects discussed were distribution behavior of fishes, use of nets in sampling stream fish populations, electric shockers, and stream survey methods.

I Chandler, D. C. 1937. Fate of typical lake plankton in streams. Ecol. Monogr. 7(4):447-479.

Plankton present near outlets of lakes decreased in density as it progressed downstream. The degree of reduction in plankton density, 8 km downstream, varied between 99 percent in July and 40 percent in February. Plankton underwent greatest reduction downstream when aquatic vegetation was most abundant in the river and the river water level was the lowest. When water levels were high and vegetation absent, plankton densities were highest. The vegetation may have acted as a strainer, straining out the plankton which would either be permanently detained in the vegetation or eaten by predators. Heavy silt accumulation resulted in plankton adhering to the particles and subsequently sinking to the stream bottom. Water temperatures, tributary dilution, current speed, and changes in chemical components did not affect the plankton community.

F Chapman, D. W. 1966a. Food and space as regulators of salmonid populations in streams. Am. Nat. 100(913):345-357.

In summer each salmonid species appears to be regulated in density by a space-food, sometimes a space-shelter, mechanism. A minimal spatial requirement appears to be present regardless of food supply. Predation, cannibalism, pathogens, and parasites simply act as the agents of destruction in controlling densities.

Density regulation in winter, if present, is probably related to the space necessary to escape downstream displacement or current damage.

I Chapman, D. W. 1966b. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. Pages 116-130 in K. W. Cummins, C. A. Tryon, Jr., and

R. T. Hartman, eds. Organism - Substrate Relationships in Streams. Pymatuning Laboratory of Ecology, Spec. Publ. 4, Univ. Pittsburgh.

Light energy which is fixed by primary producers is made available to stream-dwelling consumers in three ways: (1) terrestrial dwellers may fall in and be utilized, (2) terrestrial plant detritus may be consumed by aquatic animals, and later fish, (3) stream-dwelling insects may utilize autochthonous detritus and aquatic plants and subsequently be consumed by fish. Algal production is inhibited by decreased photoperiod and closure of the overstory vegetation in the late summer and fall. Accumulated leaves in the fall on the stream bottom reduce algal production also but do provide sources of energy for the aquatic community.

Insect emergence is greatest in the spring and early summer. Their progeny are thus in very small life stages of development in the fall making them difficult for utilization by the fish. Stable streamflows in the fall fail to dislodge many insects for subsequent fish prey.

F Charles, J. R. 1958. Final report on population manipulation studies in three Kentucky streams. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 11:155-185.

Perhaps the most universal problem in many of Kentucky's streams, from the angler's viewpoint, is that of excessive numbers of rough fish in proportion to the numbers of game fish. This paper presents the findings of a Dingell-Johnson project that has been concerned since 1952 with the manipulation of populations in 3 streams typical of types found in the state. The upper 46 miles (74 km) of North Fork River in Mason County and 12 miles (19.3 km) of Whippoorwill Creek in Logan County were treated with 5 percent powdered rotenone in 1952 to eradicate their entire fish populations. Both streams were immediately restocked with game and panfish species. Annual sampling of the population of both streams revealed a gradual reversion to the original population composition in each stream. It was concluded that total population manipulation could be accomplished, and at no more prohibitive cost than other comparable management techniques, but that any benefit to the game fish species was of questionable value and of short duration. Similar findings resulted from removing undesirable species from 11.5 miles (18.5 km) of Floyd's Fork Creek (Bullitt County) with an electric seine during 1955.

All available evidence indicates that partial or total population manipulation along (without environmental alteration or improvement) holds little promise as a management tool for improving the population composition of the average Kentucky stream. (Author abstract.)

F,I Chaston, I. 1969. Seasonal activity and feeding pattern of brown trout (Salmo trutta) in a Dartmoor stream in relation to availability of food. J. Fish. Res. Board Can. 26(8):2165-2171.

In laboratory tests, brown trout were most active between dusk and dawn from spring to autumn, but the percentage of the total activity that occurred during daylight was higher in the summer than in the other two seasons. Analysis of the variation in the weight of stomach contents during 24 hours in the three seasons showed a higher peak in weight at noon in summer than in the other seasons. The difference was related to an increased consumption of material of terrestrial origin, which other work showed to be most available to the fish between 0900 and 1200 hour. No relationship was found between the times of maximum occurrence of benthic and emergent items in the stream and of their consumption by trout. The increase in daytime activity during the summer was also evidently related to increased consumption of terrestrial material. (Author abstract.)

I Ciborowski, J. J. H., P. M. Pointing, and L. D. Corkum. 1977. The effect of current velocity and sediment on the drift of the mayfly Ephemerella subvaria McDunnough. Freshwater Biol. 7:567-572.

Experiments conducted in an artificial stream showed that significantly more nymphs drifted from an inorganic substrate at a mean current velocity of 28.5 cms^{-1} than at 18.5 cms^{-1}. Drift density, however, was not affected. Disproportionately large numbers of nymphs drifted while current velocities were being increased from 18.5 to 28.5 cms^{-1}.

Both drift numbers and drift density were greater in turbid water after the addition of large amounts of inorganic sediment, than under clear-flowing conditions during dark periods but not in the light. The interaction of increasing current velocity and sediment levels resulted in a significantly greater number of drifting nymphs under lighted conditions.

Minor spates which do not seriously disturb the streambed may initiate significant increases in macroinvertebrate drift. (Author summary.)

F Cleary, R. E. and J. Greenbank. 1954. An analysis of techniques used in estimating fish populations in streams, with particular reference to large non-trout streams. J. Wild. Manag. 18(4):461-476.

This report is a critique of methods currently used to estimate fish populations in large streams and rivers. No fixed operating procedures are recommended due to inefficiencies in present known techniques.

F Clothier, W. D. 1954. Effect of water reductions on fish movement in irrigation diversions. J. Wildl. Manage. 18(2):150-160.

Movements of marked trout, whitefish, and suckers were studied in four irrigation canals from the West Gallatin River, Montana, following flow reductions. One period of flow reduction, before headgate closure in two streams, resulted in an upstream movement of 73 percent and 100 percent of marked fish, respectively. Large game fish concentrations were found immediately behind both headgates. Abrupt closure of the headgate with no prior reduction in flow resulted in the downstream movement of 51.4 percent of the marked fish. Only 12.1 percent of the game fish poundage was found immediately behind the headgate. In all cases, fish concentrations were widely separated in concealed areas of brush, undercut banks, and pools. This suggested that reduced flow caused a redistribution of the fish population.

I Cloud, T. J., Jr., and K. W. Stewart. 1974. The drift of mayflies (Ephemeroptera) in the Brazos River, Texas. J. Kans. Entomol. Soc. 47(3):379-396.

An investigation into the drift-ecology of the mayfly populations of the Brazos River, a Southwestern United States river, was conducted from April 1972 to February 1973. Bimonthly drift samples were used to delineate the nocturnal periodicities and seasonal fluctuations of six species, three of which are new and as yet undescribed. Highest levels of behavioral drift, expressed in drift density units, occurred during the night of the summer sample dates. The drift of exuviae seems to be an accurate indicator of mayfly emergence in the Brazos River. (Author abstract.)

I Coleman, M. J. and H. B. N. Hynes. 1970. The vertical distribution of the invertebrate fauna in the bed of a stream. Limnol. and Oceanogr. 15(1):31-40.

A type of sampler is described that permits the collection of benthic fauna to a depth of 30 cm in the beds of streams. It depends on the colonization of natural substratum placed into the streambed, and invasion can occur both horizontally and vertically downward. When fully colonized, these samplers collect many times the number of animals taken by vigorous stirring of the substratum upstream of a net.

Sets of samplers in which only one of four possible horizontal layers about 7.5 cm deep was available for colonization were implanted in an Ontario stream and lifted from 1 to 28 days later.

The total numbers of many types of animals increased steadily with time in all 4 layers; more than 28 days are probably needed for full colonization. When all the catches are considered together only about 20 percent of the total was in the top layer, about 26 percent was in the bottom layer, and the reset was about evenly distributed in the two middle layers. This type of distribution was found for all the groups of animals present. Only Simulium appeared to be normally confined to the surface of the substratum.

It is suggested that significant numbers of animals occur deep within the substrata of stony streams, and that even samples collected down to 30 cm do not adequately represent the fauna. (Author abstract).

F,W Cordone, A. J. and D. W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. Calif. Fish Game 47(2):189-228.

This report is essentially a review of investigations made of the effects of inorganic sediment on the aquatic life of streams. Almost all of these kinds of investigations have been made on streams inhabited by trout and salmon. Only historical changes are available to evaluate the warm waters.

There is abundant evidence that sediment is detrimental to aquatic life in salmon and trout streams. The adult fishes themselves can apparently stand normal high concentrations without harm, but deposition of sediments on the bottom of the stream will reduce the survival of eggs and alevins, reduce aquatic insect fauna, and destroy needed shelter. There can scarcely be any doubt that prolonged turbidity of any great degree is also harmful. It is not known how much sediment is harmful because most workers have failed to measure the amounts of sediment.

Most of the sediment problems reported in the literature are the result of large-scale discharges of sediment from gravel washing or mining operations. These are often spectacular but probably less important than the gradual deposition being caused by erosion.

The increasing activity of man especially in mountain watersheds is resulting in increased erosion and sediment deposition. Failure to recognize the harmful effects of even small amounts of sediment may result in gradual destruction of the majority of our streams.

I Cummins, K. W. 1966. A review of stream ecology with special emphasis on organism - substrate relationships. Pages 2-51 in K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman, eds. Organism - Substrate Relationships in Streams. Pymatuning Laboratory in Ecology, Spec. Publ. 4, Univ. Pittsburgh.

In waters with high streamflow velocity all but the coarse substrates are washed away. The resultant fauna and flora are adapted to attaching, clinging, and avoiding direct current contact. In areas of reduced current velocity, sediments are deposited resulting in organisms suited to burrowing and generally adapted to that particular substrate.

In erosional zones, production takes place primarily by the periphytic algal flora. However, in depositional areas allochthonous, and, to a lesser degree, autochthonous detritus are sources of primary production.

I Cummins, K. W. 1972. What is a river? - Zoological description. Pages 33-52 in R. T. Oglesby, C. A. Carlson, and J. A. McCann, eds. River Ecology and Man. Academic Press, New York.

Three general habitat types have developed in streams and all include a biota which has been typically adapted to living in each specific area. These areas are described as erosional, intermediate, and depositional zones.

The erosional zones include areas of rapid flow where most of the drifting components of the system originate. The intermediate zones include areas of moderate flow over sand-gravel substrates. Depositional zones are regions of slack water where deposition of fine sediment takes place and which include genera most often found in lakes and ponds.

Most lotic species are opportunistic feeders and food habits are related to the size of the organism rather than to the species. The food base for most engulfing and filter-feeding organisms is algae, but a great deal of detrital feeding takes place because of its high density. Detritus is an important component in the diet of early life-stages and small-sized insects.

I Cummins, K. W. 1973. Trophic relations of aquatic insects. Annu. Rev. Entomol. 18:183-206.

Freshwater ecosystems generally have a constant macrobenthic biomass which turns over at a rate primarily controlled by temperature. Aquatic insects must take in sufficient calories to meet their energy demands and must take in adequate amounts of protein for essential growth. Significant feeding and growth occur in the fall and winter.

I Cummins, K. W. 1974. Structure and function of stream ecosystems. Bio-Science. 24(1):631-641.

The majority of the energy supply in a stream system comes from the import of terrestrial matter from the stream's watershed. Much of this material is utilized in the fall and winter when water temperatures are lower.

Autochthonous production in a stream may contribute only about 1 percent to the total stream community energy supply. Autotrophic conditions may become prevalent as the system goes from a heterotrophic, diatom-moss community to one dominated by filamentous green algae and beds of rooted plants. Spates may prevent the establishment of filamentous algal systems and result in a reduction in invertebrate diversity.

I Cushing, C. E., Jr. 1963. Filter-feeding insect distribution and planktonic food in the Montreal River. Trans. Am. Fish. Soc. 92(3):216-219.

Bottom fauna and plankton populations at two physically similar locations on the Montreal River, Saskatchewan, were compared. Filter-feeding Trichoptera larvae were most abundant at the station below a series of productive lakes. This difference was related to the richer supply of suspended food in the water, rather than to differences in alkalinity. Ephemeroptera and Plecoptera distributions are also discussed. (Author abstract.)

F,I,W Davis, J. C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. J. Fish. Res. Board Can. 32(12):2295-2332.

This article reviews the sensitivity, responses, response thresholds, and minimum oxygen requirements of marine and freshwater organisms with strong emphasis on Canadian species. The analysis attempts to define low dissolved oxygen thresholds which produce some physiological, behavioral, or other response in different species. Oxygen availability is discussed with reference to seasonal, geographical, or spatial variation in dissolved oxygen. Factors affecting availability of dissolved oxygen include atmospheric exchange, mixing of water masses, upwelling, respiration, photosynthesis, ice cover, and physical factors such as temperature and salinity.

Incipient O_2 response thresholds are used in a statistical analysis to develop oxygen criteria for safeguarding various groups of freshwater and marine fish. These include mixed freshwater fish populations including or excluding salmonids, freshwater salmonid populations, salmonid larvae or mature salmonid eggs, marine and anadromous and nonanadromous species. Criteria are based on threshold oxygen levels which influence fish behavior, blood O_2 saturation, metabolic rate, swimming ability, viability and normal development of eggs and larvae, growth, circulatory dynamics, ventilation, gaseous exchange, and sensitivity to toxic stresses. The criteria provide three levels of protection for each fish group and are expressed as percentage oxygen saturation for a range of seasonal temperature maxima.

Oxygen tolerances and responses of aquatic invertebrates to low oxygen are reviewed for freshwater and marine species according to habitat. No invertebrate criteria are proposed owing to the capacity for many invertebrate species to adopt anaerobic metabolism during low O_2 stress. It is suggested that the criteria proposed for fish species will provide a reasonable safeguard to most invertebrate species. (Author abstract.)

F Deacon, J. E. 1961. Fish populations, following a drought, in the Neosho and Marais des Cygnes Rivers of Kansas. Univ. Kans., Publ. Mus. Nat. Hist. 13(9):359-427.

Marked environmental changes in two Kansas rivers resulted in a wide range of adjustment in the fish fauna. At low flows fishes characteristic of small tributaries and ponds predominated.

Resumption of permanent flow resulted in the rapid increase in numbers of the more mobile and generalized species. Species that occupy restricted habitats, especially riffle-dwellers were slowest to increase following drought.

Nearly all species found prior to the drought of 1952-1956 remained after the resumption of flow. However, some species that live in a restricted habitat may eventually be extirpated through flow reductions in these two rivers.

I DeMarch, B. G. E. 1976. Spatial and temporal patterns in macrobenthic stream diversity. J. Fish. Res. Board Can. 33(6):1261-1270.

The relationship between the characteristics of a stream community and sediments were studied for 1 year in a small unpolluted river with a morainal substrate. Recognizable faunal assemblages were associated with silt or silt fill, sand or sand fill, and large boulders. The fauna in sediments of mean particle sizes coarser than sand but finer than boulders was characterized by a high variability due largely to temporal successions of morphologically related species. It was found that the number of species was directly proportional to mean particle size (in ϕ units) in spring when the sediments were well sorted, but the relationship broke down as the sediment interstices filled in. In late fall when the sediments were badly sorted, the number of species is perhaps more related to the sorting coefficient of the sediments. The relevance of these findings to studies of pollution is discussed. (Author abstract.)

I Dimond, J. B. 1967. Evidence that drift of stream benthos is density related. Ecology 48(5):855-857.

Recovery of bottom fauna after treatment with DDT was rapid, but the recovery in the drift was delayed, suggesting that the drift is a density-related phenomenon. Drift became significant only after benthos recovery had occurred. Drift apparently provides a means of maintaining a balance between standing crop and available resources. Instream disturbances which negatively affect the benthic community can be expected to reduce drift.

F,W Doudoroff, P. and D. L. Shumway. 1967. Dissolved oxygen criteria for the protection of fish. Pages 13-19 in Symposium on Water Quality Criteria to Protect Aquatic Life. Am. Fish. Soc., Spec. Publ. 4.

The authors suggest that the only standard that would protect fishery resources under all circumstances is that there be virtually no reduction of dissolved oxygen below natural levels. They emphasize that the lack of good, unfavorable temperatures and other factors in the environment may produce stress requiring more oxygen in nature than in controlled laboratory conditions. Also noted are the adverse effects of wide diurnal fluctuations of dissolved oxygen on fish growth. The authors suggest that dissolved oxygen criteria should be expressed as concentrations (mg/ℓ) rather than as percent saturation.

Minimal levels of dissolved oxygen should be 5 mg/ℓ for warmwater species and 6 mg/ℓ for salmonids. Lower concentrations for brief periods of time can be tolerated, but the production and survival of eggs and fry may be impaired.

I Egglishaw, H. J. 1969. The distribution of benthic invertebrates on substrates in fast-flowing streams. J. Anim. Ecol. 38:19-33.

Benthic invertebrates in a stream riffle are dependent on three main sources of plant food: (1) plant detritus under stones in the bed of the stream, (2) clumps of moss growing on stones, and (3) algal coverings on the upper surfaces of stones.

The structure of the invertebrate community can shift with a change in amount of plant detritus present in the system. However, within the same habitat, different species have different patterns of distribution. Additionally, community structures differ a great deal between the 3 primary areas of food distribution.

I Elliott, J. M. 1965. Daily fluctuations of drift invertebrates in a Dartmoor stream. Nature 205:1127-1129.

Drift is an important phenomenon in trout feeding. Invertebrates were continually present in the streamflow with the greatest numbers occurring at night especially in the first three hours after sunset. The insect component in the midwater area was nearly all of aquatic origin, but terrestrial insects were common in the surface drift. The author tentatively suggests that drift might increase at night due to decreased light intensity and corresponding decreases in negative phototactic response by the insects.

I Elliott, J. M. 1967. Invertebrate drift in a Dartmoor stream. Arch. Hydrobiol. 63(2):202-237.

Aquatic, emerging, and terrestrial invertebrates were present in the drift during all seasons of the year. Aquatic invertebrates were the most important component of the drift and nearly all species taken in the bottom samples were also taken in the drift, the exceptions being Tricladia and Trichoptera larvae with stony cases. More aquatic invertebrates were taken in the drift at night than in the day, the greatest numbers being in the three-hour sample after sunset. The daily fluctuations were related to fluctuations in light intensity.

Only a small proportion of the benthos (under 0.01 percent) was in the drift at any instant in time. The detached animals were in the drift for a short period of time and travelled only a short distance if conditions allowed a quick return to the benthos.

It was concluded that most aquatic invertebrates are negatively phototactic, positively thigmotactic, and more active at night. The nocturnal movements are probably associated with foraging and occur on both the upper and lower surfaces of stones. It was suggested that the density of detached animals in the drift reflects both the number of animals moving over the exposed parts of stones and aquatic plants and the extent of the competition between these animals for food and space. (Taken from author summary.)

F,I Elliott, J. M. 1970. Diel changes in invertebrate drift and the food of trout <u>Salmo</u> <u>trutta</u> L. J. Fish Biol. 2(2):161-165.

Diel changes in the stomach content of 0^+, 1^+, and 2^+ or older trout were compared with diel changes in invertebrate drift. Peaks in mean numbers and biomass of invertebrates per fish stomach occurred in the midday (1000 to 1400 hour) and evening (1800 to 2200 hour) samples. The major peak was usually in the evening sample, but the major peak in biomass was in the midday sample for 2+ fish. There was a good correlation between diel changes of benthic invertebrates in the diet and drift, with the major peak in the evening. A similar relationship did not always exist for emerging and terrestrial invertebrates. Known non-drifting benthic invertebrates (e.g., large caddis larvae) were excluded from the comparisons, and were only taken by 2+ or older trout in which they contributed a large biomass to the day food. (Author abstract.)

I Elliott, J. M. 1971. The distances travelled by drifting invertebrates in a Lake District stream. Oecologia 5:350-379.

Drift is a normal feature in a lotic system and provides readily available food for fish, facilitates colonization of denuded areas of bottom, and acts as an input into secondary production. Drift distance may vary considerably between species, types of streams, and with streamflow conditions at time of drifting. Drift rates usually increased as velocity increased. As velocity reached very low levels, drift rates increased in response to avoid desiccation. Return to stream bottom by drifting insects was greatest in areas of dense stands of aquatic macrophytes.

F,I Elliott, J. M. 1973. The food of brown and rainbow trout (Salmo trutta and S. gairdneri) in relation to the abundance of drifting invertebrates in a mountain stream. Oecologia (Berl.). 12(4):329-347.

The diet of Salmo gairdneri and S. trutta in a Pyrenean stream was very similar, and was also similar to the percentage composition of the drift but not the benthos. There was a good correlation between diel changes in the amount of food (both numbers and biomass) in the stomachs and diel changes in the abundance of drifting invertebrates. The major feeding period was in the early hours of the night when the trout fed chiefly on benthic invertebrates in the drift. This was the only feeding period in experiments 1 and 2 (mean water temperatures 4.7 and 7.3°C) but in experiment 3 (10.8°C), there was a second feeding period in the day when terrestrial invertebrates and emerging aquatic insects formed a large proportion of the diet.

The weight of food consumed/trout/day increased with water temperature, and was close to the daily food requirements for resting metabolism in experiment 1, for twice resting metabolism (active metabolism) in experiment 2, and for four times resting metabolism in experiment 3. Therefore, the energy of the second meal in experiment 3 was available for growth.

The effect of temperature on rates of gastric evacuation was the chief factor which determined the number of meals/day; the availability of food organisms in the drift determined the time of feeding; and the requirements for metabolism (affected by temperature and body weight) determined the amount of energy left for growth. (Author summary.)

F,I Ellwood, J. W. and T. F. Waters. 1969. Effects of floods on food consumption and production rates of a stream brook trout population. Trans. Am. Fish. Soc. 98(2):253-262.

Food consumption and production rates were estimated for a stream population of brook trout, Salvelinus fontinalis Mitchill, over a two-year period (1965-1966) in which four severe floods occurred. Two-year classes were nearly eliminated as producing components of the population. Standing crops of older age groups were reduced as a result of a decrease in the stream's carrying capacity after sand and debris carried into the stream by floodwaters filled pools and blanketed riffle areas. Invertebrate populations were also severely damaged by floods, reducing the food supply and causing an apparent decrease in growth rates in 1965 when three of the four floods occurred. Results of laboratory feeding experiments at four different temperature-season combinations were used to estimate food consumption rates of the brook trout in their natural environment.

Maintenance requirement increased with increasing temperature in the spring and summer and decreased with decreasing temperature in the fall and winter. Net efficiency of food utilization increased with increasing temperature in the spring and summer and decreased in the fall and winter. The smaller fish (<63 g) had a greater percentage maintenance at all temperature-season combinations except in the fall when they had a lower percentage maintenance requirement than the larger fish ($\geq$63 g). Annual production rates in 1965 and 1966 were 61.4 kg and 43.5 kg/ha, respectively. Annual food consumption rates in the same two years were 855.6 and 370.1 kg/ha. The two-year classes entering the population during the study contributed only 7 percent to the total accumulated production during the two-year study period.

W Emerson, J., R. C. Russo, R. E. Lund, and R. V. Thurston. 1975. Aqueous ammonia equilibrium calculations: effect of pH and temperature. J. Fish. Res. Board Can. 32(12):2379-2383.

The toxicity of ammonia to fishes has been attributed to the unionized ammonia chemical species present in aqueous solution. Because the percent of total ammonia present as unionized ammonia (HN_3) is so dependent upon pH and temperature, an exact understanding of the aqueous ammonia equilibrium is important for toxicity studies. A critical evaluation of the literature data on the ammonia-water equilibrium system has been carried out. Results of calculations of values of pK_a at different temperatures and of percent of NH_3 in aqueous ammonia solutions of zero salinity as a function of pH and temperature are presented. (Author abstract.)

F Erman, D. C. and V. M. Hawthorne. 1976. The quantitative importance of an intermittent stream in the spawning of rainbow trout. Trans. Am. Fish. Soc. 105(6):675-681.

From 1972 to 1975, an estimated 39-47 percent of the adult rainbow trout (Salmo gairdneri) in Sagehen Creek spawned in an intermittent stream--Kiln Meadow Tributary--while several permanently flowing tributaries attracted only 10-15 percent of the run. The balance of the fish presumably spawn in the upper reaches of the main stream. Kiln Meadow Tributary drains a south-facing slope, and peak runoff from snow melt occurs early. This may be one factor that attracts spawning fish. The absence of competition from brook trout, which cannot spawn in Kiln Meadow Tributary in the fall, may enhance the value of this watercourse for rearing young rainbow trout.

The number of spawning rainbows in Kiln Meadow Tributary declined from 707 in 1972 to 254 in 1975. Two large-year classes were present in 1972 and 1973 following winter floods in preceding winters. Males matured a year earlier than females. Males outnumbered females in every year; the sex ratio in mature fish varied from 2.4:1 to 4.9:1. Repeat spawners to Kiln Meadow Tributary ranged from 25-28 percent of the run. (Author abstract.)

F Erman, D. C. and G. R. Leidy. 1975. Downstream movement of rainbow trout fry in a tributary of Sagehen Creek, under permanent and intermittent flow. Trans. Am. Fish. Soc. 104(3):467-473.

Rainbow trout fry spawned in an intermittent stream had a diel periodicity in downstream movement that was highly correlated with discharge. Shortly after fry emerged in mid-July 1973, Kiln Meadow Tributary of Sagehen Creek began to dry up and fry began to move downstream, primarily during the day. After rains, when the water level remained high (5 to 8 ℓ/s) without diel fluctuations, few fry were captured in the trap.

In 1974, the tributary was permanent and fry exhibited a nocturnal downstream emigration. Many fry remained in the tributary where they were almost the only fish occupants. (Author abstract.)

F Everest, F. H. and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Board Can. 29(1):91-100.

During summer, sympatric steelhead trout and summer chinook salmon segregated in Crooked Fork and Johnson Creeks. In short-term allopatry, each species occupied the same type of habitat as in sympatry. Most age 0 steelhead lived over rubble substrate in water velocities and depths of less than 0.15 m/sec and 0.15 m, respectively; most age 0 chinook lived over silt substrate in water velocities of less than 0.15 m/sec and depths of 0.15-0.3 m; most age 1 steelhead resided over large rubble substrate in water velocities of 0.15-0.3 m/sec (near bottom) and 0.75-0.9 m/sec (near surface), and in depths of 0.6-0.75 m. As fish of each species became larger they moved into faster, deeper water. Juvenile chinook and steelhead of the same size used the same physical space. But steelhead spawn in spring, chinook spawn in early fall, and disparate times of spawning create discrete intra- and inter-specific size groups of presmolts. The size differences minimize potential for social interaction, both intra- and interspecific. (Author abstract.)

F Fajen, O. F. 1962. The influence of stream stability on homing behavior of two smallmouth bass populations. Trans. Am. Fish. Soc. 91(4):346-349.

The homing behavior of smallmouth bass was studied in two small Ozark streams: Big Buffalo Creek with relatively permanent pools, and Little Saline Creek with many unstable pools continually altered by the shift of chert gravel. The smallmouth bass in both streams normally restrict their movements to limited sections of the streams, usually one distinct pool.

In Little Saline Creek, 39 to 97 tagged bass recaptured had deserted their home pools. Of these, 24 were forced to move because their home pools had been eliminated by disposition of chert gravel. It was concluded that the movement of smallmouth bass in Little Saline Creek was directly correlated with the physical stability of the stream.

The bass of Big Buffalo Creek moved somewhat more frequently than the bass in the stable pools of Little Saline Creek although the pools of Big Buffalo Creek were comparatively stable during the study period. Fifteen bass made voluntary trips of 100 to 2,845 feet (30.5 to 867.7 m) to other pools, and later returned to their home pools. Such voluntary straying and homing behavior has not been reported before for warmwater fish. (Author abstract.)

F Fajen, O. F. 1972. The standing crop of fish in Courtois Creek, Missouri. Mo. Dept. Conserv., Fed. Aid Proj. F-1-R-20. 29 pp. (Mimeogr.).

Estimates of fish standing crop in pounds per acre and total number were obtained in portions of Huzzah and Courtois Creeks during 1958-1964 and 1958-1968, respectively. Standing crops of suckers fluctuated more erratically than did centrarchids. Smallmouth bass standing crops seemed to follow long-term trends not subject to great annual change. Comparison of "virtual populations" of smallmouth bass year classes indicated that practically all adult mortality was caused by angling.

Tagged bluegills and green sunfish were extremely sedentary while smallmouth bass, rock bass, flathead catfish, and black redhorse were slightly more mobile. The majority of movement was downstream. (Taken from author abstract.)

I Fisher, S. G. 1977. Organic matter processing by a stream-segment ecosystem; Fort River, Massachusetts, U.S.A. Int. Rev. Ges. Hydrobiol. 62(6):701-727.

An annual organic matter budget for 1700 m segment of Fort River (Massachusetts) is presented. Primary production in this fourth order stream exceeds litter input annually; however, ecosystem

P:R is 0.5. Respiration in excess of gross primary production is supported by allochthonous organic matter imported from upstream reaches. The relative contribution of organic matter size fractions to stream consumers depends upon biologic liability, rate of input, and residence time in the ecosystem. Particles of seston size (1 µm to 1 mm) are most heavily used by consumers; however, dissolved organic matter represents the largest input component. Microorganisms are the predominant consumers in this soft-water, nutrient-poor stream ecosystem. A conceptual model for assessing the processing efficiency of stream ecosystems is presented and discussed in terms of several headwater to estuary gradients. (Author abstract.)

I Fisher, S. G. and S. R. Carpenter. 1976. Ecosystem and macrophyte primary production of the Fort River, Massachusetts. Hydrobiologia 47(2):175-187.

Primary production and ecosystem respiration of the Fort River ecosystem, a medium size (mean discharge 1.4 m^3/sec) lowland stream in central Massachusetts, were measured using diurnal oxygen techniques from May 1972 to November 1973. During the summer of 1973, vascular hydrophyte production was measured with a modified cropping technique. Whole ecosystem gross primary production ranged from 0.44 gO_2/m^2day in winter to 6.50 gO_2/m^2day in summer, and averaged 1.78 gO_2/m^2day for 12 months. Mean ecosystem respiration was 3.65 gO_2/m^2day for 12 months.

Macrophyte gross production (59.9 gO_2/m^2year) constitutes 9.2 percent of annual ecosystem productivity and 15.2 percent of summer primary production. Macrophytes were little grazed and entered food webs only after death as detritus. Decomposition occurred near the site of production at relatively rapid rates, thus transport of dead macrophyte material in stream water was low. Data from this and other stream ecosystems suggest that in general streams only moderately productive ecosystems which depend to varying degrees on watershed derived organic matter inputs. (Author abstract.)

I Fisher, S. G. and G. E. Likens. 1972. Stream ecosystem: organic energy budget. Bioscience 22(1):33-35.

Small canopied streams are dependent upon solar energy fixed elsewhere by the photosynthetic process and then transported to the stream in the form of organic matter. Around 99 percent of the energy flow in the stream is of allochthonous origin. Forested areas may act as "transducers," packaging solar energy in reduced carbon compounds which enter the stream as detritus.

Sixty-six percent of the energy entering the stream is exported through the system. The remainder is left over to be utilized in respiration by the consumers and is calculated as the net loss.

I Fisher, S. G. and G. E. Likens. 1973. Energy flow in Bear Brook, New Hampshire: an integrative approach to stream ecosystem metabolism. Ecol. Monogr. 43(4):421-439.

An annual energy budget is presented for Bear Brook, a small undisturbed second-order stream in the northeastern United States. The ecosystem approach, in which all input and output fluxes of potential energy as organic matter are considered, is used to describe the dynamics of energy flow in a 1,700 m segment of the stream. The annual input of energy to the stream is 6,039 kcal/m^2. Over 99 percent of this is allochthonous, from the surrounding forested watershed, or from upstream areas. Autochthonous primary production by mosses accounts for less than 1 percent of the total energy available to the ecosystem. Algae and vascular hydrophytes are absent from the stream. Meteorologic inputs (litter and throughfall) from the adjacent forest account for 44 percent of annual energy input. Most of this is particulate form. The remaining 56 percent of input enters by geologic vectors (inflowing surface and subsurface waters). Eighty-three percent of the geologic input and 47 percent of the total input of energy occur as dissolved organic matter.

Approximately 4,730 kcal/m^2 of organic detritus, nearly equally divided between leaves and branches, is stored within the system. The size of this detritus reservoir is stable from year to year. The turnover time of the branch compartment is about 4.2 years; the leaf compartment is about 1 year. Although much of the annual input of energy is in a dissolved state, dissolved organic matter does not tend to accumulate in the system and displays a very rapid rate of turnover. Sixty-six percent of annual energy input is exported to downstream areas in stream water. The remaining 34 percent is lost as heat through consumer activity. (Taken from author abstract.)

F,W Fry, F. E. J. 1960. Requirements for the aquatic habitat. Pulp and Paper Magazine of Canada. 61:61-66.

This paper presents the summary of Ellis' (1937) findings and enlarges these with reference to more recent work. The parameters considered are:

(1) Temperature--Fluctuating temperatures are more detrimental to life than stable temperatures and it is usually the lower extreme which is harmful, not the upper limit. Fish tend to become more hardy to higher temperatures and more sensitive to lower temperatures. Fish tend to congregate at a "preferred temperature" which is a range of temperatures subject to other conditions which influence fish, such as light intensity, food, etc. Preferred temperature of the following species are: bass and bluegill, 25.6-33.9°C; pike and perch, 22.8-25.6°C; and trout, 10.6-20.6°C.

(2) Oxygen--Generally good fish fauna is not limited to waters which are supersaturated; however, good fish fauna is not likely to occur where the oxygen concentration drops below 5 ppm for extended periods of time.

(3) Carbon dioxide--Good fish fauna is associated with low level concentrations of carbon dioxide. The primary cause of the absence of fish in high concentrations of CO_2 is the depletion of oxygen that accompanies the intense respiration which brings about high CO_2 values. A slight increase in CO_2 is unimportant when the oxygen level isn't affected; however, concentrations of 50 ppm are detrimental even in the presence of high oxygen concentrations.

(4) Hydrogen ion concentration--The pH of waters supporting good fish fauna is between 6.7-8.6. Changes in pH within this range and slightly below or above it have little effect on fish. It does, however, affect the toxicity of certain substances.

(5) Turbidity and siltation--The lethal concentrations which bring death to fish by clogging their gills were found to be somewhere between 175,000-200,000 mg/ℓ. Although this high range is generally not found in nature, lesser concentrations have a profound effect on the survival and growth of fish. Bass, bluegills, and redear are inhibited by turbid waters, with bass being the most sensitive. Channel catfish are relatively unaffected. Sedimentation covers the fish spawning sites and eggs, reducing the oxygen necessary for survival. Also the benthic community is reduced by siltation.

F Funk, J. L. 1957. Movement of stream fishes in Missouri. Trans. Am. Fish. Soc. 85:39-57.

Eight hundred forty-six reports of tagged fish caught by anglers were analyzed to determine the movement patterns of 14 species of native warm-water stream fishes. Each species included a sedentary group which remained near the release point and a mobile group which ranged more or less freely. The species could be classified according to the relative abundance of the two groups. Rock bass, smallmouth bass, longear sunfish, spotted bass, and yellow bullhead were classified as sedentary species; carp, flathead catfish, largemouth bass, golden redhorse, and black redhorse as semimobile; and channel catfish, freshwater drum, and white crappies as mobile.

When released in headwaters, sedentary species tended to be more sedentary, and semimobile species in their preferred habitat also tended to be more sedentary than the average. Mobile species and semimobile species not in their preferred habitat became more mobile. Most of the mobile fish released in headwaters moved downstream.

The concept that the native population of warm-water stream fish species consists of a sedentary and a mobile group provides a logical explanation of many observed phenomena and of contradictory results which have confused some investigators. It supplements recent findings concerning the home ranges of species if it is assumed that only the sedentary group was investigated. (Taken from author abstract.)

F Funk, J. L. 1975. Structure of fish communities in streams which contain bass. Pages 140-153 <u>in</u> R. H. Stroud and H. Clepper, eds. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

The structure of fish communities in streams which contain bass was examined by review of 99 papers which dealt with various aspects of the subject. Stream communities in which the smallmouth bass was predominant had a relatively high number of species (median 63). Stream communities in which spotted bass predominated had a median of 60 species while largemouth bass streams had a median of 53 species.

F,I,W Gammon, J. R. 1970. The effect of inorganic sediment on stream biota. E.P.A., Water Pollu. Control Res. Ser. 18050 - DWC 12/70, Washington, D.C.

Fish and macroinvertebrate populations fluctuated over a 4-year period in response to varying quantities of sediment produced by a crushed limestone quarry. Light inputs which increased the suspended solids loads less than 40 mg/ℓ resulted in a 25 percent reduction in macroinvertebrate density below the quarry. Heavy inputs caused increases of more than 120 mg/ℓ including some deposition of sediment and resulted in a 60 percent reduction in population density of macroinvertebrates. Population diversity indices were unaffected by changes in density because most taxa responded to the same degree. Experimental introductions of sediment caused immediate increases in the rate of invertebrate drift proportional to the concentration of additional suspended solids.

The standing crop of fish decreased drastically when heavy sediment input occurred in the spring, but fish remained in pools during the summer when the input was very heavy and vacated the pools only after deposits of sediment accumulated.

After winter floods removed sediment deposits, fish returned to the pools during spring months and achieved levels of 50 percent normal standing crop by early June. Slight additional gains were noted during the summer even with light sediment input. Only spotted bass (<u>Micropterus punctulatus</u>) was resistant to sediment, but its growth rate was lower below the quarry than above.

F 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.

The modal preferred temperatures of rainbow trout acclimated to 5°C, 10°C, 15°C, and 20°C were determined photographically to be 16°C, 15°C, and 13°C. The phenomenon of decreasing preferred temperature with increasing acclimation temperature has not been reported for any other species of fish. (Author abstract.)

I Gelroth, J. V. and F. R. Marzolf. 1978. Primary production and leaf-litter decomposition in natural and channelized portions of a Kansas stream. Am. Midl. Nat. 99(1):238-243.

The channelized portion of a second-order Kansas Flint Hills stream had higher photosynthetic rates in midsummer and lower leaf degradation rates in winter than the more natural portion of the stream. Photosynthesis/respiration ratios were less than one in the natural portion but greater than one in the channelized portion of the stream. Hackberry (Celtis occidentalis) leaves were degraded faster than chaniquapin oak (Quercus muehlenbergii) leaves, losing an average of 90 percent and 50 percent, respectively, after 16 weeks in the stream. Degradation was faster in the natural portion than in the channelized portion.

F Gerking, S. D. 1950. Stability of a stream fish population. J. Wildl. Manage. 14(2):193-202.

Stream fish population stability studies were conducted during the summer months on Richland Creek, Indiana. A flash flood which occurred during the study allowed an evaluation of the effects of a natural stress on the fish population. There was a tendency for fish to move upstream during the period of high water.

After the flood subsided, 75 percent of recaptured fish were found in their original location. Small fish were apparently no more affected than large fish. The data suggest that individuals of certain species occupy "homes" during the summer months.

F Gerking, S. D. 1953. Evidence for the concepts of home range and territory in stream fishes. Ecology 34(2):347-365.

Longear, green sunfish, and rock bass exhibit little movement, having home ranges of 30.5 to 61.0 m. Smallmouth and spotted bass, golden redhorse, and hog sucker had larger home ranges of 61 to 122 m. Riffle areas appeared to be respected as boundaries between home ranges. Larger fish of a species did tend to "stray" more than smaller fish.

F Gerking, S. D. 1959. The restricted movement of fish populations. Biol. Rev. (Camb.) 34:221-242.

This paper is a review of the literature involving restricted fish movements and homing activities. At least thirty-four species of fish have restricted movements if examined outside of their breeding season or when immature. Twenty-one species are known to "home," in the sense that they choose to return to a place formerly occupied.

F,I Gibson, R. J. and D. Galbraith. 1975. The relationships between invertebrate drift and salmonid populations in the Matamek River, Quebec, below a lake. Trans. Am. Fish. Soc. 104(3):529-535.

The amount of daily invertebrate drift in the Matamek River varied both seasonally and down the length of the river. From June to September 1973, the volume of drift was about eight times greater in June than in August. Filter feeding insects and planktonic Crustacea were more numerous at the upstream station near a lake than at a station 4 km downstream. Larvae of net-spinning Trichoptera were twice as abundant at the upstream station and simuliid larvae four times as abundant. Numbers of zooplankton closely followed changes in water level, and were highest in early summer and the fall, and were lowest in August. The salmonid biomass was at least four times greater at the upstream station than the lower one, most likely the results of a greater abundance of insect larvae suitable as food nearer the lake. (Author abstract.)

F Gorman, O. T. and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59(3):507-515.

Stream habitat complexity is correlated with fish species diversity in selected Indiana and Panama streams. Habitat diversity was measured along dimensions judged important to a wide range of fish groups and applicable to many stream conditions: stream depth, bottom type, and current. Increasing community and habitat diversity followed stream-order gradients. Natural streams supported fish communities of high species diversity which were seasonally more stable than the lower diversity communities of modified streams. After disturbances such as channelization, seasonal peaks in species diversity attain levels typical of undisturbed streams. Because seasonal changes in stream quality are high, the stability of the fish community is lower in modified than in natural streams. The general correlation between habitat characteristics and presence and absence of fish species suggests that most fish of small streams are habitat specific. (Author abstract.)

F,I Griffith, J. S., Jr. 1974. Utilization of invertebrate drift by brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in Idaho. Trans. Am. Fish. Soc. 103(3):440-447.

In four northern Idaho streams I assessed availability of invertebrate drift in the summer 1969. Brook and cutthroat trout inhabited two streams sympatrically and two allopatrically. I compared drift and diet components to assess proportion of drift cropped by trout and extent to which trout segregated into dietary niches.

Members of five insect orders (Ephemeroptera, Coleoptera, Diptera, Trichoptera, and Plecoptera) comprised 97 percent of the number of drift organisms and an average of 92 percent of the number of organisms eaten by both brook and cutthroat trout. The terrestrial component of both drift and diet was insignificant, and predation of fish and/or cannibalism was rare. Most Ephemeroptera, Plecoptera, and Coleoptera drifted between dusk and dawn when they may not have been available to trout.

Trout selected certain food items. Underyearling brook and cutthroat trout differed little in their food preferences or habits, whether they lived sympatrically or allopatrically, and consumed smaller organisms (mainly Diptera and Ephemeroptera). Older trout of each species living allopatrically differed in utilization of Diptera and Trichoptera, with cutthroat selecting the former and brook trout the latter. These differences were intensified in sympatry. (Author abstract.)

F Gunderson, D. R. 1968. Floodplain use related to stream morphology and fish populations. J. Wildl. Manage. 32(3):507-514.

For two continuous sections of a Montana stream, the agricultural use of the floodplain was related to cover, stream morphology, and fish populations. In one section the vegetation of the floodplain had been reduced by clearing and intensive livestock grazing; in the other section, which had received light use by livestock, vegetation was relatively unchanged. This ungrazed section had 76 percent more cover (undercut banks, debris, overhanging brush, and miscellaneous) per acre of stream than the grazed section. Brown trout (+6 in. (>15.2 cm)) were estimated to be 27 percent more numerous and to weigh 44 percent more per acre in the ungrazed section of the stream, although their rate of growth was similar in the two stream sections. (Author abstract.)

F Gunning, G. E. and T. M. Berra. 1969. Fish repopulation of experimentally decimated segments in the headwaters of two streams. Trans. Am. Fish. Soc. 98(2):305-308.

Fish repopulation of experimentally decimated segments in the headwaters of two Louisiana streams was studied over a period of

2 years. Fishes were decimated using an electrical shocking device. The sharpfin chubsucker, Erimyzon tenuis, was able to repopulate the decimated segment of Talisheek Creek in excess of the total weight of suckers that were collected when the section of stream was originally decimated.

The repopulation sample exceeded the decimation sample on a total weight basis for two successive years at Talisheek Creek. Repopulation did not occur to this extent at Bayou Lacombe where the repopulation sample was 52 percent of the decimation sample on a total weight basis. Decimation was accomplished without disturbing the environment to any significant degree; hence, fish were returning to the decimated area under the same conditions, for all practical purposes, that prevailed at the time of decimation. (Author abstract.)

F Gunning, G. E. and C. R. Shoop. 1963. Occupancy of home range by longear sunfish, Lepomis m. megalotis (Rafinesque), and bluegill, Lepomis m. macrochirus Rafinesque. Anim. Behav. 11(2-3):325-330.

The size of the home range in streams for longear sunfish is estimated at 21.3 m, while for bluegills it is approximately 38.1 m. Older longear sunfish and bluegills appear to have larger home ranges than younger individuals. The longer a sunfish is free subsequent to marking, the greater is its tendency to stray outside its home range. Bluegill strays have a tendency to move upstream.

F Gunning, G. E. and C. R. Shoop. 1964. Stability in a headwater stream population of the sharpfin chubsucker. Prog. Fish. Cult. 26(2):76-79.

Sharpfin chubsucker populations in Talisheek Creek, Louisiana, were relatively stable, with 93 percent of fin-clipped fish and 82 percent of tagged fish recaptured within 15.2 m of their release points. Long-term studies also indicated a stable population. Of 21 fish marked in 1961, six were recaptured in the same stream section in 1962, and eight were recaptured in 1963.

I Haddock, J. D. 1977. The effect of stream current velocity on the habitat preference of a net-spinning caddisfly larva, Hydropsyche oslari Banks. Pan-Pac. Entomol. 53(3):169-174.

Adequate current flow is necessary for the survival of this trichopteran species since it provides the vehicle for the transport of food to the stationary larva and is additionally important in maintaining a constant oxygen supply. Various species have different velocity requirements.

Larvae move out of areas with extremely high velocities during early spring or they are swept downstream. High and low velocities have varying effects on the larvae because the nets require a certain amount of flow to billow out, but not too much current, which may destroy them.

F Hall, C. A. S. 1972. Migration and metabolism in a temperate stream ecosystem. Ecology 53(4):585-604.

Fish migration, total stream metabolism, and phosphorus were studied in New Hope Creek, North Carolina, from April 1968 to June 1970. Upstream and downstream movement of fish was monitored using weirs with traps. Most of the 27 species had a consistent pattern of larger fish moving upstream and smaller fish moving downstream. Both upstream and downstream movements were greatest in the spring. For example, in the spring of 1969, a daily average of seven fish weighing a total of 1,081 g were caught moving upstream, and 17 fish weighing a total of 472 g were caught moving downstream. Although more moved downstream than up, the larger average size of the fish moving upstream resulted in a large transfer of fish mass upstream.

Diurnal oxygen series were run to measure the metabolism of the aquatic community. Gross photosynthesis at the principal sampling station ranged from 0.21 to almost 9 g O_2 m^{-2} day^{-1}, and community respiration from 0.4 to 13 g O_2 m^{-2} day^{-1} (mean of 290 and 479 g O_2 m^{-2} yr^{-1}). Both were highest in the spring. Area values of metabolism were often similar for different parts of the stream, but both production per volume and respiration per volume were always much larger near the headwaters than farther downstream. This was apparently due to the dilution effect of the deeper water downstream. Migration may allow populations to take advantage of such differences in productivity by maintaining young fish in areas of high productivity. Other effects of migration may include: prey control, recolonization of defaunated regions, genetic exchange, and mineral distribution.

An energy diagram was drawn comparing energies of insolation, leaf inputs, currents, total community respiration, fish populations, and migration. About 1 percent of the total respiration of the stream was from fish populations, and over 1 year about 0.04 percent of the total energy used by the ecosystem was used for the process of migration. If it is assumed that upstream migration is necessary to maintain upstream stocks which may be periodically decimated by droughts, each Calorie invested by a fish population in migration returns at least 25 Calories (kilocalories). Even without that assumption returns are three-fold.

Analysis of phosphorus entering and leaving the watershed studied indicated that flows were very small relative to storages and that this generally undisturbed ecosystem is in approximate phosphorus balance. Upstream migrating fish were important in maintaining phosphorus reserves in the headwaters of New Hope Creek. (Author abstract.)

F Hannuksela, P. R. 1969. Food habits of brown trout in the Anna River, Alger County, Michigan. Mich. Dep. Nat. Res., Res. Devel. Rep. 186:107-118.

Food habits of brown trout were studied in a small Lake Superior tributary during May-October 1968 to determine possible effects on production of juvenile rainbow trout. The rainbow in this stream is migratory, and thus a steelhead. Brown trout 1.3-11.8 inches (33-300 mm) long and 0, I, II, and III years of age, fed primarily on Trichoptera. Larger brown trout, 11.8-20.6 inches (300-522 mm) long (ages IV and V) ate mostly fish, but very few rainbow trout. Stocked coho salmon were the most frequently ingested fish during May, and slimy sculpins were eaten most frequently during June-October. Brown trout selected salmonids over sculpins to eat, even though sculpins were nine times more abundant than salmonids in the stream. (Author abstract.)

F Hanson, D. L. and T. F. Waters. 1974. Recovery of standing crop and production rate of a brook trout population in a flood-damaged stream. Trans. Am. Fish. Soc. 103(3):431-439.

The brook trout (Salvelinus fontinalis Mitchill) population in Valley Creek, Minnesota, recovered from heavy flood damage in 1965-66 in terms of standing crop, growth, and production rates over a period of 4 to 5 years. Standing crops of brook trout increased numerically by twenty-fold from a low of 498 kg/ha in 1966 to 10,882 kg/ha in 1969, and in biomass by six-fold from 25 kg/ha in 1966 to a maximum of 148 kg/ha in 1970. Growth rate early in the recovery period was high due to the low density of trout but decreased in successive years as fish density increased. Annual production was about 50 kg/ha during the flood years, but increased during the recovery years to a maximum of 167 kg/ha in 1969. Cohort production for the 1965 year class, the one most seriously affected by the floods, was about 15 kg/ha; whereas, cohort production for the 1968 year class, the last one that could be completely followed in this study, was about 190 kg/ha. After the floods, rainbow trout (Salmo gairdneri Richardson) immigrated into the study section from downstream; although variable in year class strength, the rainbow contributed substantially to total salmonid standing crop and annual production in some years. It has apparently become permanently established, even after total recovery of the brook trout population. (Author abstract.)

F Harrell, H. L. 1978. Response of the Devil's River (Texas) fish community to flooding. Copeia. 1978(1):60-68.

Flooding on the Devil's River, Texas, caused changes in both physical and biological structure of the river. Habitat types became less distinct and generally more rifflelike. Fish species diversity, evenness, and number of species decreased. Higher diversities were expressed nearer the river's terminus, indicating flood-resistance there. Prior to the flood 18 species associations existed; 13 existed after flooding, only three of which were present prior to flooding. Six species dominated both pre- and postflood community biomass and maintained the same rank-order dominance in both flood regimes. These (*Dionda episcopa*, *Notropis proserpinus*, *N. amabilis*, *Astyanax mexicanus*, *Notropis venustus*, and *Dionda diaboli*) occupied slightly different habitats or utilized different resources of the same habitat in the postflood regime. All are adapted to a flood-prone environment and may constitute the greatest degree of faunal stability in the ecosystem. (Author abstract.)

F Heidinger, R. C. 1975. Life history and biology of the largemouth bass. Pages 11-20 *in* R. H. Stroud and H. Clepper, eds. Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

The author reviews papers concerning largemouth bass life history. Types of forage organisms are well documented, while details of migration and movement are largely not understood. The strength of a bass year class depends largely on the survival of the young during the first few months of life.

I,W Herricks, E. E. and J. Cairns, Jr. 1974-76. The recovery of stream macrobenthos from low pH stress. Rev. Biol. (Lisb.) 10(1-4):1-11.

The effects of short-term low pH stress were studied in relation to recovery and restoration of aquatic macrobenthic communities. Experimental acid additions were made to a healthy productive stream, reducing pH for 15 minutes from 8.0 to 4.0. Diversity and density were decreased (d 3.91 and 74 organisms/ft^2 (797/m^2) before acid vs. d 279 and 43 organisms/ft^2 (463/m^2) after acid). Recovery was related to downstream drift of recolonizing organisms; full recovery occurred within 19 to 28 days with density and diversity equaling or exceeding prestress values. A second study was made to observe drift borne recolonizing organisms.

Baetis sp. dominated drift collections and was the most abundant taxon in bottom fauna collections indicating a relationship between drift and recovery.

Average drift rate was 10 organisms or less during one 15-minute drift sample; drift rates were calculated to be in excess of 5,000 organisms/day. (Author abstract.)

I Hildebrand, S. G. 1974. The relation of drift to benthos density and food level in an artificial stream. Limnol. Oceanogr. 19(6):951-957.

The relationship between drift rates, benthos density, and food level for select taxa of stream invertebrates was studied in an artificial stream system to determine if drift is independent of or dependent on population density, and if food level affects drift rates. Two taxa were introduced in a range of densities at a single level of periphyton food, and the drift from each density at each food level was measured. Four taxa were introduced in a range of densities at a single level of periphyton food and the drift from each density was measured. The drift of all taxa examined by simple linear regression analysis at each food level was judged, a density independent response to increasing population density. The drift of three taxa at a given density was significantly greater at the lower food level; it is suggested that increased activity in searching for food at the lower food level resulted in increased drift. (Author abstract.)

I,W Hilsenhoff, W. L. 1977. Use of arthropods to evaluate water quality of streams. Wis. Dep. Nat. Resour., Tech. Bull. 100, 15 pp.

Arthropods were used to evaluate the water quality of Wisconsin streams. The biotic index based upon arthropod samples is a sensitive and effective method for it yields information on present quality and past perturbations. Every species was assigned an index value on the basis of collections made previously and in this study for the purpose of calculating the biotic index. Water quality determinations were made for 53 Wisconsin streams based on these values.

A sampling procedure for evaluating all streams in an area is given. (Author abstract.)

F Holden, P. B. and C. B. Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. Trans. Am. Fish. Soc. 104(2):217-231.

Twenty-nine species of fishes were collected in the middle and upper Colorado River basins in 1967-1973. The native suckers, Catostomus latipinnis and C. discobolus, were the dominant species in the study area. Introduced species outnumbered native species 19 to 10. The introduced Ictalurus punctatus and Notropis lutrensis were abundant throughout most of the upper basin. The abundance of introduced species has increased steadily since 1900 as has the introductions of new species. Four endemic species, Ptychocheilus lucius, Gila elegans, Gila cyphas, and Xyrauchen texanus, are considered endangered. These rare forms reproduce in the lower Yampa River, Desolation Canyon of middle Green River, and the lower Green River in Canyonlands National Park. The major reasons for the decline of native fishes are considered to be alterations of habitat by high dams and introductions of exotic species. (Author abstract.)

I Hoskin, C. M. 1959. Studies of oxygen metabolism of streams of North Carolina. Publs. Inst. Mar. Sci., Univ. Texas. 6:186-192.

Diurnal measurements of dissolved oxygen were made in the Neuse River and eight other streams in the mountains, piedmont, and coastal plain of North Carolina. The data were used to estimate gross photosynthesis and total respiration of the streams. Production rates were 0.2 to 9.8 $gm/m^2/day$ oxygen; respiration rates were 0.7 to 21.5 $gm/m^2/day$. Respiration was much in excess of photosynthesis at all stations indicating the aquatic communities were deriving as much organic matter from the land drainage as from photosynthesis within the streams. Metabolism in riffles was greater than in pools. In the Eno River a tenfold range in metabolism was observed between low values of late winter and high values of late spring. Streams draining forest and agricultural lands of North Carolina are intermediate in fertility as compared to other aquatic environments. (Author abstract.)

F Huet, M. 1959. Profiles and biology of Western European streams as related to fish management. Trans. Am. Fish. Soc. 88(3):155-163.

In the running waters of temperate Western Europe there are four main biological zones, each of which is characterized by a distinctive fish fauna. These are designated (1) trout, (2) grayling, (3) barbel, and (4) bream zones. They are related basically to longitudinal section (slope of the streambed) and to the cross section of the stream and its valley. The physical and biological characteristics of these zones are discussed together with the concepts "slope-rule" and "slope-graph" which express these relationships, and which have proven useful for evaluating and comparing running waters and for estimating fisheries potentials of streams from topographic information. (Author abstract.)

I Hughes, D. A. 1966. The role of responses to light in the selection and maintenance of microhabitat by the nymphs of two species of mayfly. Anim. Behav. 14(1):17-33.

The response of two species of mayfly, Baetis harrisoni and Tricorythus discolor, to various light conditions was determined to be important in the selection and maintenance of their respective habitats. The activity level of T. discolor was found to be reduced in areas of low light intensity resulting in the accumulation of nymphs in these regions. Conversely, B. harrisoni was found to have a similar reaction in areas of high light intensity.

I Hughes, D. A. 1970. Some factors affecting drift and upstream movements of Gammarus pulex. Ecology 51(2):301-305.

Laboratory experiments, conducted within a current chamber, suggest that upstream movements of the amphipod Gammarus pulex, expecially in regions of slower current flow, are sufficient to compensate for the downstream displacements of animals by drift. They indicate also that drift was greater in slow-flowing than in faster water. (Author abstract.)

I Hynes, H. B. N. 1958. The effect of drought on the fauna of a small mountain stream in Wales. Verh. Internat. Ver. Limnol. 13:826-833.

This study found that worms, small Crustacea, Helmis maugei and at least one Diamesa species can survive prolonged drought. Most insect nymphs and larvae were killed, but the eggs of all except one species survived. It was also shown that the number of individuals surviving depended on whether or not the drought coincided in part with normal hatching periods. The effect of stream desiccation on the insect fauna ultimately depends on the season in which it occurs.

F,I Hynes, H. B. N. 1970a. The ecology of flowing waters in relation to management. J. Water Pollut. Control Fed. 42(3):418-424.

The author discusses the aspects of temperature, substrate food sources, and fish breeding to show how they may be related to subtle disturbances by man, and how they may have a bearing on management practices of running water environments.

Temperature--An unaltered stream in a temperate climate has a definite seasonal temperature regime. Most stream animals are geared to fit their breeding seasons and life cycles into annual temperature cycle changes. Small differences of a few degrees often have profound effects upon stream organisms.

Substrate--Some plants and animals are confined to certain types of substrate because of special needs of attachment. Alteration of stream bottoms may result in a reduction of desired aquatic organisms or in the development of nuisance weed or insect problems.

Food source--The main food source of streams is from the organic debris (leaf litter, etc.) which falls into the stream. Bacterial degradation of this organic matter provides food for aquatic invertebrates.

Fish breeding--Any interference with a water course is likely to alter breeding sites in such a way as to restrict or encourage the reproduction of certain species, and possibly eliminate some species altogether. Species that need shallow riffles cannot use channelized reaches, and Salmonidae cannot use gravel in which the interstices are blocked by silt. Also, water passages must be maintained for migration to and from spawning sites without blockage or stress.

I Hynes, H. B. N. 1970b. The ecology of stream insects. Annu. Rev. Entomol. 15:25-42.

This paper is a review of the literature on stream insect ecology. Included in the review are discussions of faunal distributions, food, life histories, drift, and methods of disaster avoidance.

I Hynes, H. B. N. 1974. Further studies on the distribution of stream animals within the substratum. Limnol. Oceanogr. 19(1):92-99.

A study to verify the vertical depth colonization of benthic invertebrates confirmed organisms were colonizing the substrate to a depth of at least 50 cm. Studies of lateral colonization in stream sides did not confirm studies suggesting that stream animals occur far from the water's edge under banks. Only a few truly aquatic animals were found 50 cm into the bank.

I Jaag, O. and H. Ambuhl. 1964. The effect of the current on the composition of biocoenoses in flowing water streams. Adv. Water Poll. Res. 1:31-49.

Most stream insects inhabit the areas of slow-moving water near the substrate-water interface or the dead water areas between cracks, rocks, and in dense algae mats, etc., which are actually removed from the water current. Most of the streambed consists of these dead water pockets when streamflow is reduced. This results in an increase in the availability of many different habitat types and locations producing a wide variety of insects and invertebrates with varying velocity requirements. Some organisms require very little current, whereas others prefer certain ranges of velocity and take advantage of both the slow-moving boundary areas and the full current.

F,I Jenkins, T. M., Jr., C. R. Feldmeth, and G. V. Elliott. 1970. Feeding of rainbow trout (Salmo gairdneri) in relation to abundance of drifting invertebrates in a mountain stream. J. Fish.

Res. Board Can. 27(12):2356-2361.

Hatchery-reared rainbow trout, deprived of food for 48 or 96 hours and released in a mountain stream for 5- or 10-hour periods, consumed aerial invertebrates in numbers loosely associated with their seasonal and hourly abundance in the drift. The same was generally true for benthic insects, except that on several days feeding was much poorer relative to drift from 3:00 a.m. to 8:00 a.m. than at other times of day.

In September and October tests, aerial forms were abundant during daylight, and benthic forms abundant at night, enabling trout to feed 24 hours a day. Day and night feeding in September were roughly equal in importance, but in October more food was taken during the day. Aerial invertebrates were so rare in December that benthic insects were the most important prey day and night. However, even benthics were not numerous enough to provide good feeding. (Author abstract.)

F Johnson, M. G. 1965. Estimates of fish populations in warmwater streams by the removal method. Trans. Am. Fish. Soc. 94(4):350-357.

The removal method was used to estimate the size and composition of fish populations in four warmwater streams in southern Ontario. The assumptions underlying the removal method and variability in the data were examined. Populations of 8,000 to 33,000 fish/acre (19,800 to 81,500/ha) weighing 32 to 174 lb/acre (36 to 195 kg/ha) were estimated. Four of 22 species of fish encountered comprised two thirds of the average standing crop of 120 lb/acre (134 kg/ha). These four, the white sucker, *Catostomus commersoni*, blacknose dace, *Rhinichthys atratulus*, creek chub, *Semotilus atromaculatus*, and common shiner, *Notropis cornutus*, appeared to be the best able of all species to utilize both pools and riffles. Other species were associated with either pools or riffles and, therefore, while locally abundant, had lower average standing crops in the characteristic pool-riffle habitat of the streams studied. (Author abstract.)

I Kimble, L. A. and T. A. Wesche. 1975. Relationships between selected physical parameters and benthic community structure in a small mountain stream. Water Resour. Series 55. Water Resour. Res. Inst., University of Wyoming. 64 pp.

The benthic community present in a stream is dependent upon or regulated by chemical, biological, and physical factors. Three important physical factors which can influence the composition of benthic organisms are substrate, water velocity, and water depth. In this study, four different substrates in a small Wyoming mountain stream were compared as to benthic community structure. The substrate types sampled were silt, sand, and fine gravel, coarse gravel, and rubble. Highest mean number and mean biomass were found in the samples taken in rubble. Point and mean velocities also were measured for each sample taken. Greatest mean number and mean biomass were found at mean velocities of 0.50 fps (0.152 m/sec) or higher. Mean depth data indicated a preference by benthic organisms for depths of less than 1 foot (0.305 metre). (Author abstract).

I Kovalak, W. P. 1978. Effects of a pool on stream invertebrate drift. Am. Midl. Nat. 99(1):119-127.

Drift rates out of the pool were greater than drift rates into the pool for most taxa on all dates. Increase in drift rate between the upstream and downstream ends of the pool (expressed as percent of number entering the pool) average 86.4 percent (range 3.3-707.7 percent) and decreases in drift rates average 24.4 percent (range 1.2-72.1 percent). The source of drifting organisms was a rheophilic fauna living on logs and twigs along the margins of the pool. Patterns of drift periodicity of most taxa were similar at the two sampling sites, but nocturnal peaks of drift rate of Ephemeroptea and Gammarus occurred earlier in the evening at the downstream site. Estimates of deposition rate suggested that the total number of organisms deposited in the pool per day was greater than the total number drifting into or out of the pool. Fish predation on drift probably was negligible, because the number of trout in the pool was small and the fish present were large. (Taken from author abstract.)

F Kraft, M. E. 1972. Effects of controlled flow reduction on a trout stream. J. Fish. Res. Board Can. 29(10):1405-1411.

The total number of brook trout age I and older in three runs of Blacktail Creek, Montana, was reduced approximately 63 percent when 90 percent of the normal flow was diverted for about 3 months, in comparison with 20 percent for runs in control sections. Both number and weight of trout in pools of the test sections generally increased, whereas those in control pools decreased. Recaptures of tagged trout also indicated movements from runs to pools in the test sections, but not in the control sections. When the flow was reduced 75 percent or less, there were no consistent changes in number or weight of trout in the test runs and pools, whereas those in the control sections were more marked though also inconsistent. Reduced flows had no consistent effect on the number of underyearlings. The changes in most physical characteristics after 90 percent flow reduction were considerably less than the degree of reduction, presumably because the stream flowed in a well-defined channel. Surface area and average depth were least affected (about 42 percent decrease) and current velocity (75 percent) the most. Fast-water portions (current velocity over 0.30 m/sec) comprised over 60 percent of the surface area at normal flows and slow water portions over 85 percent of the area when the flow was reduced 90 percent. A multiple linear regression with the physical characteristics as independent variables and the number of trout as the dependent variables accounted for over 75 percent of the variation in the number of age I and older trout in runs and pools. (Author abstract.)

I Kroger, R. L. 1974. Invertebrate drift in the Snake River, Wyoming. Hydrobiologia 44(4):369-380.

Drifting invertebrates were collected hourly during 24-hour sampling periods at two stations in the Snake River. The greatest number of invertebrates was collected on 8 and 15 July 1966 at Station 1 between 9:00 p.m. and 12 midnight, then the numbers gradually decreased until the low daylight drift rate was reached at dawn. On 26 and 27 August 1966, at Station 2, the diel periodicities of drifting invertebrates were different than at Station 1. Many species increased their drift rates slightly during the first hour of darkness but also exhibited a higher drift peak later in the night.

Drift indices for 25 taxonomic groups of invertebrates were established from the ratio of standing crop, estimated from Surver samples, to numbers drifting. There was more apparent correlation between species life cycle stage and numbers drifting than between species abundance and numbers drifting. (Author abstract.)

F Kuehne, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43(4):608-614.

Twenty-eight fish species, surveyed in Buckhorn Creek, Kentucky, were distributed in a way that clearly demonstrated longitudinal succession. The fish collections were found to fit the geological method of stream classification using increasing stream order numbers. Average numbers of species increased progressively as stream order increased.

F Larimore, R. W. 1955. Minnow productivity in a small Illinois stream. Trans. Am. Fish. Soc. 84:110-116.

As a means of evaluating the effects of harvesting minnows in a small stream, a study was made of the minnow population in a section of Jordan Creek in east-central Illinois. Nine collections of minnows were made with an electric fish shocker from August 1950 through October 1953. These collections represented a large proportion of the existing population. The yields for the corresponding months of each of the succeeding years increased progressively. The minnow population as a whole exhibited annual cycles of abundance and of average weights of individual fish. Each species responded differently to various environmental factors and to the continuous cropping. Shocking, which is a more effective method of harvesting minnows than seining, did not reduce the minnow population in the study section of Jordan Creek longer than a few months. The natural fluctuations of the minnow population made it difficult to measure the effects of cropping with the electric shocker. (Author abstract.)

I,W Larimore, R. W. 1974. Stream drift as an indication of water quality. Trans. Am. Fish. Soc. 103(3):507-517

Stream drift and benthos were collected from five stream locations having different levels of domestic and industrial pollution. The drift organisms from 100 m^3 of water during the diel period of peak drifting were compared with the benthos from 1 m^2 of stream bottom. Numbers and weights of both drift and benthos followed similar quantitative relations with water quality generally increasing with water degradation. The relative abundance of benthos greatly exceeded that of the drift at the most polluted station where tubificids, which infrequently drift, were abundant. A greater variety of organisms occurred in the drift than in the benthos. Drifting organisms came from a wider spectrum of habitats and were collected with less effort than benthic organisms but did not always include benthic forms that seldom leave the stream bottom.

F,I Larimore, R. W., W. F. Childers, and C. Heckrotte. 1959. Destructon and re-establishment of stream fish and invertebrates affected by drought. Trans. Am. Fish. Soc. 88(4):261-285.

In 1953 and 1954 a severe drought virtually destroyed the fish and invertebrate populations in Smiths Branch, a small warm-water stream in Vermilion County, Illinois, and presented an opportunity to study the adaptations, survival, and repopulation of aquatic organisms exposed to the critical conditions associated with low water levels.

Discontinuous flow reduced the aquatic habitat and exposed the fish and invertebrates to desiccation, stagnation, and predation. Stagnation was most detrimental during early fall months, in association with leaf accumulations and drastic temperature fluctuations, or during the winter when ice covered the pools. Most of the fishes withstood the extreme drought conditions in at least a few parts of the stream.

Reestablishment of the populations began as soon as the stream resumed its flow. The upstream ingression of fish was limited to the first few pools above the stream mouth until the full flow was resumed, and then during the following 2 weeks, 21 of the

29 regularly occurring species moved into most of the stream course.

Twenty-five of the regular species of fish had entered Smiths Branch by the end of the first summer after the population was destroyed in 1953. Only three species were significantly absent. The longear sunfish was not taken until the fall of 1955, and the black-stripe topminnow and hornyhead chub had not repopulated the stream when the final collections were made in September 1957.

Invertebrates displayed remarkable adaptations to drought conditions and repopulated the stream soon after normal flow resumed. The invertebrate population was established soon enough to serve as an adequate food base for ingressing fish. (Taken from author abstract.)

I Lehmkuhl, D. M. and N. H. Anderson. 1972. Microdistribution and density as factors affecting the downstream drift of mayflies. Ecology 53(4):661-667.

During high volume of flow in a stream that has considerable seasonal fluctuation, the microdistribution of five species of mayflies was determined by displacement of individuals by drift from rapid current areas to those with gentle or no current. The major effect of drift was dispersal, not depletion, of the mayfly population. Occurrence in drift is determined by a species-specific complex of interdependent factors including life cycle, microdistribution (both before and after the effect of spates), and the behavioral characteristic of individual species. (Author abstract.)

F,I Leonard, J. W. 1942. Some observations on the winter feeding habits of brook trout fingerlings in relation to natural food organisms present. Trans. Am. Fish. Soc. 71:219-227.

At the Hunt Creek Experiment Station near Lewiston, Michigan, water was first admitted to a newly-excavated stream channel on 16 October 1940, after adult aquatic insects had apparently disappeared. The first bottom organisms to invade the new habitat, blackfly larvae, were observed 1 week later. It is concluded that these and subsequent invaders were drift-borne from natural areas upstream. On 20 December, a square-foot bottom sample contained 187 organisms representing 8 species, with a volume of 0.20 cm^3. On 4 February 1941, a sample contained 21 species and 1,535 organisms, with a volume of 1,575 cm^3.

The section was first screened and drained down on 18 January 1941. At that time, 34 eastern brook trout (Salvelinus fontinalis) were removed, of which 22 were retained for stomach analysis. These fish had an average total length of 80.3 mm and an average weight of 5.0 grams. A comparison of stomach contents with bottom samples revealed that the percentage occurrences of food organisms in the brook trout stomachs and in the bottom fauna were not the same. For example, volumetrically, larvae and pupae of midges and blackflies made up 84.7 percent of the diet but only 56.9 percent of the bottom fauna; mayfly nymphs formed only 7.5 percent of the diet but 24.8 percent of the bottom fauna. The average number of food organisms per stomach was 252; the average volume of the contents of an individual stomach was 0.425 cm^3. The average square foot of bottom contained 1,114 organisms with a volume of 1.275 cm^3. (Author abstract.)

F Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Am. Fish. Soc. 98(1):14-19.

The relationship between fish populations and physical parameters of pools was studied in Little Prickly Pear Creek, Montana, during the summers of 1965 and 1966. The pools were mapped and their fish populations sampled. Surface area, volume, depth, current velocity, and cover accounted for 70 to 77 percent of the variation in numbers of trout over 6.9 inches (17.5 cm) total length. Most of the variation was the result of differences in current velocity and cover. Cover was the most important factor for brown trout, and current velocity for rainbow trout. The density of all trout per unit area of pool surface and cover increased significantly as current velocity became greater. Deep-slow pools with extensive cover had the most stable trout populations with brown trout showing greater stability than rainbow trout. The importance of cover to trout is discussed in terms of security and photonegative response and current velocity in terms of space-food relationships. (Author abstract.)

I Lewis, S. P. and R. C. Harrel. 1978. Physicochemical conditions and diversity of macrobenthos of Village Creek, Texas. Southwest. Nat. 23(2):263-272.

Physicochemical conditions varied seasonally, downstream and with discharge. A total of 143 taxa of macrobenthos were collected and the number at each station ranged from 44 to 98. Diversity was determined by Shannon's index ($\bar{d}$). Station $\bar{d}$ values for individual collections ranged from 0 to 4.50. Annual $\bar{d}$ values ranged from 3.21 to 4.93. The large number of taxa and high $\bar{d}$ values obtained in this unstable sand substrate environment may have been due to high discharge, carrying many taxa from small tributaries and other diverse habitats in the drainage basin. The concept of high diversity-high environmental stability was contradicted and high $\bar{d}$ values occurred during maximum discharge and stream scouring. Lowest $\bar{d}$ values occurred after return to near normal discharge conditions. (Taken from author abstract.)

F,I Logan, S. M. 1963. Winter observations on bottom organisms and trout in Bridger Creek, Montana. Trans. Am. Fish. Soc. 92(2):140-145.

Ninety-six bottom samples and 27 drift samples were studied. Limnephilidae were the most abundant aquatic organisms in the area. Surface ice cover had no effect on the abundance of bottom organisms except for the loss of a small number frozen in the ice at the stream edge. High flows during the spring reduced the number of bottom organisms in situ, and increased the number taken in drift sample. Floating surface ice did not appear to increase the number of organisms in drift samples.

Sixty-one percent of the trout captured and tagged in the study section were recaptured no more than 150 feet (46 m) from the original place of capture. More trout were recovered downstream than upstream during each month of study. Trout moved as far as 2 miles (3.2 km) upstream from the study section, and 55 miles (88.5 km) downstream. During the spring, summer, and autumn, trout were mainly found in pools; while in winter many were collected in riffle areas under surface ice. (Taken from author abstract.)

I Lose, E. D. and W. L. Mickley. 1963. Dispersion of macrofauna in a section of Muddy Fork, Jefferson County, Kentucky. Trans. Ky. Acad. Sci. 24:81-84.

Cladophora glomerata occurs as a characteristic stream community with associated diatoms Gomphonema, Diatoma, and Navicula, which require swift water, high light intensity, and solid substrate. Amphipods, isopods, and dipterans were the most abundant and all invertebrates preferred Cladophora beds in the channel and coarse rubble. The greatest densities occurred in the thicker beds of vegetation.

F,I Lotrich, V. A. 1973. Growth, production, and community composition of fishes inhabiting a first-, second-, and third-order stream of eastern Kentucky. Ecol. Monogr. 43(3):377-397.

Fish populations in a first-, second-, and a third-order stream were studied during the summers of 1967-68. The primary food of each fish species was determined. Available food sources included terrestrial invertebrates, aquatic primary production, aquatic invertebrates, aquatic vertebrates, and detritus. Average daily growth rates showed that age-group I fish of most species grew faster in early than in late summer. The growth rate of most age-group II fish varied little between these seasons. Total numbers, total standing crop, and gross production were estimated for each species in each order. Total production was compared among stream orders on a per linear meter basis. Production values were nearly equal in first-order (2.35 gram dry weight per linear meter) and second-order (2.36), but increased in third-order (3.29).

The relative importance of terrestrial invertebrates as an energy source decreased with increasing stream order. Aquatic primary production and aquatic invertebrates began to be utilized as energy sources in second-order. The aquatic vertebrates and detritus began to be utilized in third-order. The relative importance of aquatic primary production utilization increased in third-order, but the relative importance of aquatic invertebrate utilization was approximately the same as in second-order.

The community structure of the fish populations of each pool was analyzed with information theory and the ratio H/H. Community structure differed between third-order and second-order pools even when the same species complement was present. It is postulated that stream order in most cases represents a biological unit which can be subdivided into microhabitats based on riffle, pool, type of substrate, etc., and addition in most cases proceeds by discrete units of stream order. (Author abstract.)

I Luedtke, R. J. and M. A. Brusven. 1976. Effects of sand sediments on colonization of stream insects. J. Fish. Res. Board Can. 33(9):1881-1886.

Results of field and laboratory studies indicate that riffle insects are unable to move upstream in sandy substrates even at low current velocities. A combination of exposure to current and the instability of sand grains is thought to be the reason. Rubble substrates may be necessary for upstream movement.

I Luedtke, J. R., M. A. Brusven, and F. J. Watts. 1976. Benthic insect community changes in relation to in-stream alterations of a sediment-polluted stream. Melanderia 23:21-39.

Insect life in heavily sedimented streams was usually reduced, but recolonization following sediment removal was rapid. Insects are intermediates in the plant-fish food chain, thereby affecting the distribution and abundance of organisms at higher trophic levels. A "run" was considered an area between a riffle and a pool.

I Macan, T. T. 1957. The Ephemeroptera of a stony stream. J. Anim. Ecol. 26:317-342.

Generally, the ephemeropteran fauna fluctuates with varying habitat conditions. Species are habitat selective and are present or absent in accordance with their degree of selectivity.

Small stony streams are typically inhabited by: Baetis rhodani, Rhithrogena semicolorata, Ecdyonurus torrentis, Baetis pumilus, Heptagenia laturalis, Paraleptophlebia submarginata, and Ephemerella ignita.

Rivers contain a greater number of ephemeropteran species than small streams. Additional species found in larger streams and rivers would be: Baetis bioculatus, Baetis scambus, Heptagenia sulphurea, Centroptilum luteolum, Procloeon rufulum, and Centroptilum pennulatum.

F Machniak, K. 1975. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics) III. Yellow walleye Stizostedion vitreum vitreum (Mitchill). A literature review and bibliography. Environment Canada, Fish. Mar. Serv., Tech. Rep. 529, 68 pp.

The reproduction and early life of the yellow walleye, Stizostedion vitreum vitreum, is reviewed. Walleye commonly spawn in riffles of streams or along shorelines of lakes. Although they have been reported to spawn on a wide variety of substrate, it appears they prefer clean gravel bottoms at depths less than 1.5 metres. In impoundments, walleye are apparently less influenced by water levels during the spawning period than are other "shallow water" spawners. Nonetheless, fairly stable or slightly rising levels during spawning and incubation are recommended if spawning is to be successful. Among the many hazards to reproduction, the silting over of spawning beds due to erosion along lakeshores and flooded streams is probably the major cause of spawning failure in impoundments. Growth and numbers could increase, but will be dependent upon the availability of forage species and spawning habitat. (Author abstract.)

F,I Maciolek, J. A. and P. R. Needham. 1952. Ecological effects of winter conditions on trout and trout foods in Convict Creek, California, 1951. Trans. Am. Fish. Soc. 81:202-217.

In 1951, winter studies were conducted in the Sierra Nevada Mountains near Bishop, California. These were designed to extend knowledge of winter conditions in stream environments and to bring to light problems requiring further investigation at this season.

Snowfall was meager at Convict Creek in 1951, but freezing temperatures induced extensive ice formations. Surface ice immobilized screens and other objects protruded from the water, yet provided the trout with abundant shelter. Frazil and anchor ice had a more pronounced effect on stream life and water temperatures than surface ice. When subsurface ice was present the water was at or very close to the freezing point, regardless of weather conditions or time of day. Anchor ice formed and dispersed in a daily cycle that caused wide fluctuations in streamflow. Minimum water flow at night often left secondary channels empty, while morning peak flows scoured the stream with ice fragments, washing loose debris and bottom fauna. Trout were active in the freezing water and fed regularly throughout the winter. Trout were caught on bait when the water was 32°F (0°C).

Large numbers of aquatic organisms were dislodged by fluctuating flows and became available as food for trout. Adult stoneflies and dipterans emerged on warm days during the winter.

A comparison between the numbers of stream bottom organisms present, drift foods, and foods consumed by trout gave a positive correlation. In cold weather, trout consumed large numbers of mayfly and stonefly nymphs, while dipterans predominated in trout stomachs over the entire winter. Rainbow and brown trout of similar lengths and stomach volumes differed in the number of organisms eaten by each in that rainbow trout ingested larger quantities of small organisms than did brown trout.

Wild trout suffered an initial mortality in early January that was caused by heavy subsurface ice which blocked streamflow into side channels. Very few dead trout were found after this occurrence. The overwinter survival of marked trout approximated 50 percent in 1950-51. (Author abstract.)

I Mackay, R. J. and J. Kalff. 1969. Seasonal variation in standing crop and species diversity of insect communities in a small Quebec stream. Ecology 50(1):101-109.

The number of insects per unit area of each habitat was least in sand and increased through gravel, stones, leaves, and detritus. Biomass per unit area was least in gravel and increased through detritus, sand, leaves, and stones. The annual standing crop of the stream as a whole was approximately 3,000 insects/m^2 and 2 g/m^2 (dry weight). The number of insect species in any one habitat varied according to apparent spatial heterogeneity of the environment, to substrate stability, and to food resources. Leaves supported the highest number of species (92), sand the least (61). Species diversity was higher during summer and winter than during spring and autumn. When compared with other aquatic environments, the bottom fauna of the stream has oligotrophic features, including a large number of species and an annual standing crop of poor to intermediate richness. (Taken from author abstract.)

F,W Marcuson, P. 1969. Stream sediment investigations. Mont. Fish Game Dep., Fed. Aid Proj. F-20-R-13. 10 pp. (Mimeogr.)

Effects of sediment on trout abundance in streams were determined by comparing trout-rough fish ratios before and after completion of streambank improvement projects. In 1963, before streambank improvements, trout comprised 13 percent of the total fish weight sampled. In 1968, 2 years after improvement, trout represented 37 percent of the total.

F,I McClain, J. R. 1976. Food habits of brook trout in relation to the abundance of diel drift invertebrates in the Little Colorado River. M. S. thesis, Univ. Ariz., Tucson. 37 pp.

The diel feeding of brook trout (Salvelinus fontinalis) was examined in relation to invertebrate stream drift and benthos during seven 24-hour sampling periods from May to September 1975. Samples were taken in the East Fork of the Little Colorado River in the White Mountains of Arizona.

Diel differences were found in the feeding ability of brook trout. During the day trout fed efficiently on what was available, while at night their feeding efficiency decreased. These differences in feeding ability resulted in a high consumption rate of day-active invertebrates compared to a low consumption rate of night-active invertebrates. Trout were nonselective in their utilization of drifting invertebrates.

Different factors controlled the availability of aquatic and terrestrial invertebrates to trout. This has significant implications to trout stream management. It appears difficult to increase the availability of aquatic invertebrates since they apparently have developed escape mechanisms to avoid predation. Terrestrial invertebrate availability, however, depends largely on their abundance near the stream. The relationship of land management practices along streams to terrestrial invertebrate availability for trout food is discussed. (Author abstract.)

I McClay, W. 1968. Effects of controlled flow reductions on aquatic insects in a stream riffle. M. S. thesis, Mont. State Univ., Bozeman. 29 pp.

A study was conducted on Blacktail Creek in southwestern Montana from May 1966 to September 1967 to determine the effects of controlled flow reductions on the ecology of aquatic insects. Two riffles were selected for study: one served as a control; the other, the test riffle, was subjected to flow reductions of 75 and 90 percent during the summers of 1966 and 1967, respectively. Four samples of aquatic insects were collected with a Surber sampler along a transect in each riffle on each sampling date. Samples were collected bimonthly during the periods of dewatering and monthly during the period of natural flow. Physical and chemical data were collected on each sampling date. Average depth, average water velocity, and water volume were the physical parameters most affected by flow reductions. During the period of 75 percent dewatering, aquatic insect populations in the control riffle increased, while those in the test riffle remained stable. Insect densities in the test riffle, relative to those in the control riffle, were higher during the period of 75 percent dewatering than during the full-flow period. A decline in the numbers of aquatic insects/m^2 in the test riffle was associated with the resumption of natural flow conditions. Total numbers of insects in the test riffle did not reach their initial high value until 2 months after the initial high was reached in the test riffle. Trichoptera were affected most by flow reductions. (Author abstract.)

F McCrimmon, H. and W. Kwain. 1966. Use of overhead cover by rainbow trout exposed to a series of light intensities. J. Fish. Res. Board Can. 23(7):983-990.

Fingerling and yearling trout (Salmo gairdneri Richardson) responded differently when exposed to a series of artificial daylight illuminations. Fingerling trout showed no apparent response to the overhead cover, being randomly distributed at all light intensities. Yearling trout, except in total darkness, exhibited a positive response to the overhead cover, but their pattern of behavior differed with the light intensity and the positioning of the cover. (Author abstract.)

I McDowell, W. H. and S. G. Fisher. 1976. Autumnal processing of dissolved organic matter in a small woodland stream ecosystem. Ecology 57(3):561-569.

A mass balance approach was used to construct a dissolved organic matter (DOM) budget for Roaring Brook, a small New England stream, in autumn. Total litter input to the stream ecosystem during the 77-day study period was 345 g/m^2, 21 percent of which occurred as lateral transport. Nearly 17 percent of litter input was released to the water as DOM within 3 days of entry. This leachate input represents 42 percent of total DOM input to the 1,260-m study section. The remainder entered by way of inflowing surface and subsurface water. Autumn uptake of DOM was equivalent to 77 percent of leachate input and 33 percent of total DOM input. Approximately 88 percent of DOM removed from the water column is retained within the system and at least 67 percent is energetically degraded by consumer respiration in autumn. Based upon total annual energy budgets for similar streams, we estimate that DOM utilization in autumn accounts for from 7 to 11 percent of annual ecosystem respiration in Roaring Brook. (Author abstract.)

F McFadden, J. T., E. L. Cooper, and J. K. Andersen. 1965. Some effects of environment on egg production in brown trout (Salmo trutta). Limnol. Oceanogr. 10(1):88-95.

Brown trout collected from fertile and infertile streams in Pennsylvania were compared to determine differences in fecundity and in the age at first sexual maturity. Trout from infertile streams were older at first sexual maturity and produced fewer eggs because of smaller average size than trout from fertile streams. Fish of the same size produced a smaller total weight of eggs in infertile waters than in fertile water. Sexual maturation depended on both size and age. It was concluded that in waters of low basic productivity few eggs are produced per adult trout in the stock and that this depressed rate of reproduction is important in keeping brown trout populations in equilibrium with the low basic productivity of the environment. (Author abstract.)

I McIntire, C. D. 1966. Some effects of current velocity on periphyton communities in laboratory streams. Hydrobiologia 27(3-4):559-570.

Slower current permitted development of green filamentous algae (Stigeoclonium, Oedogonium, and Tribonema). These assemblages, when well established, appeared bright green and resembled pond-type aggregations. However, in the faster current the assemblage formed a dense, beltlike growth and was dark-green or brownish, consisting of mostly diatoms.

Accumulation of biomass on gravel-rubble substrate was much more rapid in fast current than slow but did stabilize after a period of time, subsequently being similar at both velocities. The highest productivity was maintained in fast current as was biomass export. The percentage of organic matter present was higher in green algae-dominated streams.

I McIntire, D. C. and H. K. Phinney. 1965. Laboratory studies of periphyton production and community metabolism in lotic environments. Ecol. Monogr. 35(3):237-258.

The export of periphyton from the stream was enhanced greatly during turbid conditions. Periphyton growing in lighted areas had much more chlorophyll a than those growing in the shade. Thus, community succession was a much slower process in shaded conditions. Green algae supplemented the diatom flora during the warmer months.

F,W Mihursky, J. A. and V. S. Kennedy. 1967. Water temperature criteria to protect aquatic life. Pages 20-32 in A Symposium on Water Quality Criteria to Protect Aquatic Life. Am. Fish. So., Spec. Publ. 4.

The ecological significance of temperature in the aquatic habitat is discussed in relation to the thermal loading of ecosystems by electric power plants. It is pointed out that nuclear plants will produce greater amounts of waste heat per kilowatt of electricity than the conventional fossil fuel plants.

Effects of temperature on behavior, metabolism, and mortality of aquatic organisms are described to indicate the difficult problems involved in determining acceptable standards for a healthy fish population. A multivariate analysis of interactions between temperature and other environmental factors is suggested.

Standards for temperature regulation are described for three ecosystems: (1) coldwater salmonid streams, (2) warmwater centrarchid environments, and (3) estuaries. (Author abstract.)

I Minshall, G. W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48(1):139-149.

The most important benthic animal food source was allochthonous leaf materials, which occurred as suspended material in the water, as a component of materials attached to the streambed, and as whole leaves and fragments. Diatoms were the only other important source of plant materials and constituted the greatest proportion of the attached organic fraction.

Mean standing crop measurements of potential foods for five sampling stations ranged from 0.6 to 1.0 kcal/m^3 for suspended particulate organic matter; 12 to 19 kcal/m^2 for attached particulate organic matter; and 4.7 to 13 kcal/m^2 for allochthonous leaf materials. Analysis of gut contents and determination of the principal pathways of energy flow in the stream indicate that imported organic matter in the form of allochthonous leaf materials provides the main source of energy for the primary consumers and, indirectly, for the entire benthic community of Morgan's Creek. Of the 37 taxa of animals studied, 24 were herbivores, 5 omnivores, and 8 carnivores. In general, detritus made up from 50 to 100 percent of all the materials ingested by both the herbivores and omnivores. The total number of benthic animals was comprised by 14 percent herbivores, 83 percent omnivores, and 3 percent carnivores. Gammarus minus was the single most important member of the fauna. It contributed 81 percent of the total number of invertebrates, and well over 90 percent of its diet consisted of allochthonous leaf detritus. (Taken from author abstract.)

I Minshall, G. W. 1968. Community dynamics of the benthic fauna in a woodland springbrook. Hydrobiologia 32:305-339.

The main source of food material for the herbivores was allochthonous; diatoms were the only other source of food. Many species were reduced or absent in pool habitats. Numerous, relatively small populations are indicative of a climax community. Variations in community structure result from the interaction of three environmental components: temperature, substrate, and flow. In a spring environment the number of insect species is limited and related to the constant environmental conditions present there.

Species with short life cycles are able to adjust faster to changing conditions than those with long life cycles. Competition among various species of insects with similar ecological requirements is prevented by the staggering of life cycles. Species greatly decreased in areas where no overstory existed because of the lack of leaf detritus (not changing temperatures) which was shown to be the most important source of plant material eaten by herbivores.

I Minshall, G. W. 1978. Autotrophy in stream ecosystems. Bioscience 28(12):767-771.

There are many streams which rely on an autotrophic energy supply, such as headwater streams in semiarid regions with sparse overstory. However, streams in forested areas with dense canopies get most of their energy from allochthonous materials. Autotrophy plays a major role in formation of energy sources in large rivers and small streams where the canopy is not a factor.

Two main patterns of production may occur: with vascular plants and macrophytic algae present there will be low productivity because as the plants die energy is utilized as detritus, and with a low standing crop the accumulation of detritus does not exist because of the high rate of export and utilization by grazers and filter feeders causing a high turnover. Although streams may differ with regard to heterotrophy or autotrophy, they are all based on detritus-related energy.

I Minshall, G. W. and J. N. Minshall. 1977. Microdistribution of benthic invertebrates in a Rock Mountain (U.S.A.) stream. Hydrobiologia 55(3):231-239.

Current velocity, substrate, and food are primary factors affecting macroinvertebrate distribution. Stones, when placed in a pool area, markedly increase the abundance of invertebrates. Environmental requirements of a species may vary with different life stages.

I Minshall, G. W. and P. V. Winger. 1968. The effect of reduction in stream flow on invertebrate drift. Ecology 49(3):580-582.

Artificial reduction of stream discharge resulted in an increase in benthic invertebrates in the drift. Virtually all bottom-dwelling forms were affected. Entry into the drift seemed an active process initiated by changes in current velocity and depth, and resulting in reversal of the normal avoidance response to light. All benthic insects sampled qualitatively were found in the drift samples. Reductions in water velocity during daylight would cause invertebrates to be unnaturally available during these hours for predation. (Taken from author abstract.)

I Müller, K. 1954. Investigations on the organic drift in north Swedish streams. Rep. Inst. Freshwater Res. Drottningholm 35:133-148.

A colonization cycle which includes the emergence of insects and the subsequent movement upstream while slowly depositing eggs is described. The accumulation of eggs and the competition for available space and food upon hatching can induce drift. Changes in water levels and velocity may reduce available habitat. Regulation and balance of the population results from the drift phenomenon.

F Munther, G. L. 1970. Movement and distribution of smallmouth bass in the Middle Snake River. Trans. Am. Fish. Soc. 99(1):44-53.

The movement and distribution of smallmouth bass, Micropterus dolomieui, were studied in the Snake River, a large western river, prior to impoundment.

Ninety-nine (76 percent) of the recovered fish free at least 7 days were found in the same pool or defined location in which they were tagged, while 22 of the 31 fish recovered outside the pool in which they were marked had moved less than 1,200 metres (1,312 yards). A few moved several kilometers upstream or downstream from the release point. The distances moved at various seasons were not significantly different, nor was the seasonal direction of movement.

A preference for broken rock substrate was indicated in the river by high fish densities over this type of substrate. Few smallmouth bass were found over a solid rock substrate, and none was observed over sand. In late fall, as water temperatures dropped below 15.5°C (60°F), smallmouth bass could not be located by electrofishing in water less than 2.3 metres (8 feet) deep but were found in still rocky pools at least 3.6 metres (13 feet) deep by detonating primacord on the pool bottoms.

The distribution of smallmouth bass within a pool changed during the 24-hour day. Smallmouth bass observed in early morning were all near the edge of the current. When the location of the edge of the current changed due to fluctuating water level, the bass shifted to the new position of current edge. Nocturnal positions of smallmouth bass were on or beneath a broken rock substrate in still water. When beneath the substrate bass faced toward an exit. No movement by smallmouth bass was observed in the river at night.

In the laboratory, smallmouth bass fed during the day and went on or beneath the substrate during darkness. This change in position took place at dusk. Fish came out from beneath the substrate at low light intensities in the morning. Activity decreased with temperature. Most of the fish remained beneath the substrate while temperatures were less than 6.7°C (44°F) and came from beneath the substrate when the water temperature reached 8.7°C (46°F). (Taken from author abstract.)

I Nebeker, A. V. 1971. Effect of water temperature on nymphal feeding rate, emergence, and adult longevity of the stonefly Pteronarcys dorsata. J. Kans. Entomol. Soc. 44(1):21-26.

The highest feeding rate occurred at 20°C. No feeding occurred at 1°C or 35°C. The adults that emerged at 10°C lived twice as long as those that emerged at 20°C. None emerged at 5°C or 25°C. The best egg production occurred at 15°C. The average adult life span was 17.5 days from nymphs reared at 20°C, 31 days from nymphs held at 15°C, and 36 days from larvae reared at 10°C. (Taken from author abstract.)

F Needham, P. R. and A. C. Jones. 1959. Flow, temperature, solar radiation, and ice in relation to activities of fishes in Sagehen Creek, California. Ecology 40(3):465-474.

Ecological studies carried out on trout in Sagehen Creek indicate that the long periods of temperature acclimation in the fall and spring prepare fish for winter and summer temperatures.

Bottom macrofauna is abundant as food for trout in winter and trout were observed to feed on numerous occasions when the water temperature was between 0 and 0.6°C. It is concluded that 0°C is within the zone of tolerance of trout and that trout are able to resist water temperatures below 0°C for short periods of time. Floods may act as a decimating factor to fish populations by destroying eggs and reducing bottom macrofauna.

Anchor ice was shown to be an important ecological factor since it raises the water level in pools and reduces the flow over riffles. Anchor ice formed only in those areas of the stream which had no upwelling of relatively warm groundwater through the substratum. Anchor ice, when it is breaking up, melting, or otherwise dispersing, dislodges considerable amounts of the bottom macrofauna, thus making more food available to trout at such times.

Trout exhibited territorial behavior, showed a strong preference to occupy sheltered locations, and in shallow water were more numerous during the night than during the day.

The high winter mortalities of trout populations which have been observed are probably not the result of lack of food or long periods of low temperatures. More likely causes are sudden catastrophies such as severe floods or suffocation under collapsed snowbanks or dewatering of stream sections by ice dams.

F Needham, R. G. 1966. A study of reduced stream flows resulting from irrigation. Mont. Fish Game Dep., Fed. Aid Proj. F-9-R-14. 6 pp. (Mimeogr.)

Streamflow measurements were made on Hyalite Creek and its irrigation diversions to evaluate various stream-gaging procedures.

Discharge measurements obtained with a velocity head-rod were generally of poor quality. The current meter is recommended for future work of this nature. The dewatering season in 1965 was shorter than normal because of above-normal runoff. Flow reductions in excess of 85 percent occurred in approximately 45 percent of the stream length. The fish population was sampled at six stations, but could not be correlated with dewatering levels due to extreme variations in habitat conditions. (Author abstract.)

F Nielson, R. S., N. Reimers, and H. D. Kennedy. 1957. A 6-year study of the survival and vitality of hatchery-reared rainbow trout of catchable size in Convict Creek, California. Calif. Fish Game 43(1):5-42.

The survival rate of hatchery rainbow trout both alone and in combination with wild brown trout was tested. The average survival rate over the 4-year test period was slightly higher for the rainbow trout (52.5 percent) than for the brown trout (50.7 percent). Brown trout exhibited slightly higher winter survival, while rainbow trout had a higher summer survival. No evidence of interspecific competition was indicated.

F Nikolski, G. V. 1933. Of the influence of the rate of flow on the fish fauna of the rivers of Central Asia. J. Anim. Ecol. 2:266-281.

The fish community in the Chu River reflects the physical conditions present in the river. In areas of high flow, torpedo-shaped fish predominate, while in pool areas high-bodied fish predominate. The wide variety of physical conditions in a geologically new river result in a diverse fish community.

W Odum, H. T. 1956. Primary production in flowing waters. Limnol. Oceanogr. 1:102-117.

Respiration, photosynthetic production, and diffusion interact to produce the daily curve of oxygen change in a segment of flowing water. Conversely, the observed curves of oxygen in streams can be used to calculate the component rates of production, respiration, and diffusion. New production values obtained with these analyses of oxygen curves from various sources, as well as a few previously existing estimates of primary production, indicate a generally higher rate of production in flowing waters than in other types of aquatic environments.

The ratio of total primary production to total community respiration is used to classify communities quantitatively according to their predominantly heterotrophic or autotrophic characteristics. Longitudinal succession within a stream tends to modify the ratio toward unity from higher values for autotrophic and from lower values for heterotrophic communities. (Taken from author abstract.)

F Opheim, B. R. 1952. Fishing pressure and the relation of the angler catch to the actual stream fish population, Prickley Pear Creek. Mont. Fish Game Dept., Fed. Aid Proj. F-5-R-1, pp. 40-43. (Mimeogr.)

A comparison of angler's catch to trout population composition revealed that rainbow trout, while less numerous in the stream than brown trout, comprised a larger share of the creel.

F Oregon State Game Commission. 1963. The fish and wildlife resources of the Middle Willamette Basin, Oregon, and their water use requirements. A report to the State Water Resources Board, Oreg. State Game Comm., Basin Invest. Sec., 24 pp.

The fish and the game resources of the Middle Willamette Basin are outlined and a description of the streamflow study is given. Flows primarily for anadromous fish production are recommended, and these flows should be sufficient for maintenance of resident game fish. The recommended flows are below the average annual discharges for most streams, but the rearing flows will frequently exceed those existing naturally, particularly in the smaller and lower elevation streams.

To determine the volumes needed for spawning and passage, studies were conducted whenever possible at the time of actual fish movement and spawning. Measurements of water depth and velocity, over the available spawning gravel, were obtained as were streamflow volumes.

Straight-line transects were established on eleven basin streams to measure percentages of streambed gravel available for salmon and steelhead spawning under varying flow volumes. Detailed water depth and velocity data were recorded during three to five study periods on each stream.

F Paloumpis, A. A. 1958. Responses of some minnows to flood and drought conditions in an intermittent stream. Iowa State Coll. J. Sci. 32:547-561.

Squaw Creek, located in central Iowa, is an intermittent stream which experiences flood and drought conditions almost every year. The Squaw Creek bed is predominantly shifting sand which results in an unstable and unproductive habitat. During drought periods, the creek is reduced to a series of isolated pools.

Fish were collected from Squaw Creek by seines, wire traps, electric shocker, and rotenone during 2 drought years, 1953 and 1955, and 1 year of floods, 1954. Most of the species have been successful in maintaining themselves regardless of the drastic changes which occur in the habitat. The fish population changes seem to be rather small compared to observed habitat changes.

Carp, bluntnose minnows, and fathead minnows seem to be maintained largely by floodplain ponds. These ponds probably also provided the few black bullheads and sunfishes taken from the creek. Creek chubs, stonerollers, common shiners, and the suckers are probably maintained largely by migrations from Skunk River. There was some evidence that the red shiner was capable of withstanding crowding in isolated pools even better than the bigmouth shiner. The emerald shiner practically disappeared as the stream became a series of isolated pools.

The fish population in Squaw Creek is able to survive drought and flood periods largely in certain areas or stream havens. During flood periods, small tributary streams probably serve as havens. During drought, isolated pools in the channel, floodplain ponds, and the Skunk River are the important havens. (Taken from author summary.)

I Patrick, R. 1962. A study of the number and kinds of species found in rivers in Eastern United States. Proc. Acad. Nat. Sci. Phila. 113(10):215-258.

The number of taxa competing for available niches is greater than the number present, so available niches are filled with different taxa with low densities. In organisms with short life cycles, a short time span can reveal considerable changes in population size. Collectable populations will vary from month to month.

I Patrick, R. 1970. Benthic stream communities. Am. Sci. 58(Sep-Oct):546-549.

Floods reduce the size of a population, but a sufficient number of individuals are usually left to maintain the population. They escape the rapid current in protected areas where flow is reduced.

A small body size, short generation time, and high reproductive rate aid in the survival of stream benthos. A large number of taxa may perform the same function in the community but at different times of the year. Young communities have widely fluctuating population sizes, high metabolic rates, short life cycles, and high reproductive rates. Generally, stream communities exhibit these characteristics, thus they are considered relatively immature systems.

I Pearson, W. D. and D. R. Franklin. 1968. Some factors affecting drift rates of Baetis and Simuliidae in a large river. Ecology 49(1):75-81.

Light, population density of all other organisms, and temperature had significant influences on drift rates of both organisms. Turbidity and water-level fluctuations were related to changes in drift rates indirectly through influence upon light penetration and population density, respectively. Dissolved oxygen concentration, date, and depth of water at the sample site did not clearly affect drift rates of either organism. In areas where population densities were high, the light factors tested accounted for 65-81 percent of the variability observed in drift rates. Maximum drift rates were 170 x 10^6, Baetis sp. nymphs (63.2 kg) and 10.9 x 10^6, Simuliidae larvae (5.4 kg) per day. (Taken from author abstract.)

I,W Pennak, R. W. 1977. Trophic variables in Rocky Mountain trout streams. Arch. Hydrobiol. 80(3):253-285.

Bound carbon dioxide and hydrogen-ion concentration of 20 small turbulent mountain streams were correlated with geography, altitude, and streamflow. Low suspended inorganic loads were correlated with low suspended organic loads, but high suspended inorganic loads were associated with a wide range of suspended organic loads. TDS below 50 mg/ℓ was associated with 2 to 20 mg/ℓ total suspended load, but TDS above 500 mg/ℓ was associated with 3 to 500 mg/ℓ total suspended load. Bottom fauna macrospecies densities often varied ten-fold or more at single stations from month to month. Average standing crops were mostly "poor" with a wet weight biomass range of 0.7 to 18.6 g/m^2. Annual production (wet weight) was 1.75 to 46.50 g/m^2/year. Lithophyton organic matter and algal populations were usually lowest in spring but otherwise varied widely with time and place. Most samples consisted of 70 to 99 percent organic detritus. Diatoms and blue-greens were the dominant algae. There was no quantitative relationship between lithophyton organic matter and bottom macrofauna biomass. The fauna is characterized as "opportunistic" and adapted to both "feast" and "famine" conditions.

Food availability in streams has been traditionally classified as being poor with 0-1076 organisms/m^2, average with 1076-2152 organisms/m^2, and rich with greater than 2152 organisms/m^2.

Benthic macroinvertebrates collected in Surber samples are generally the most common and abundant species. Some other species may occur in other available habitats but are rare and contribute little to the total biomass. (Includes author abstract.)

I Percival, E. and H. Whitehead. 1929. A quantitative study of the fauna of some types of stream-bed. J. Ecol. 17:282-314.

Different aquatic species prefer different types of substrate in various degrees of preference. Baetis, Rhithrogena, Ecdyurus, Agapetus, and Chironomidae prefer a loose stone habitat. Ancylus, Chironomidae, and many Trichoptera prefer a cemented stone habitat in swift current 2.3-2.6 m/sec. Chironomidae dominate Cladophora-covered substrate.

Baetis are spasmodic swimmers in still water, but they can sink to the bottom and become swept away at currents of 1.3 m/sec. Most are found in areas where stones are sticking out of the water so they can creep down the sides for oviposition. Thithrogena are poor swimmers, but well fitted for life among loose, smooth rounded stones. Plecopterans are poor swimmers and can be found on stones with moss or burrowed into the sand. Trichopterans are found within cases on stones with little or no vegetation. Gammarus are strong swimmers and found in areas where thick moss exists.

Carnivores form no more than 10 percent of the total fauna in a given substrate type. Ephemeropterans are "voracious herbivores."

I Peterson, A. R. 1977. Biological and physical conditions in Minnesota's rivers and streams as related to physical stress. Minn. Dep. Nat. Res., Div. Fish Wildl., Spec. Publ. 122. 63 pp.

Environmental stress is caused by the alteration of the environment to such an extent that the habitat is either reduced or eliminated. Chronic stress is caused by periodic water level fluctuations.

Riffles are more productive than pools so fish seek out pools because they act as catch basins for animals swept down from riffles. Large macrophytes are not common in streams except in areas where the current is greatly reduced. Aquatic plants do not occur where water velocities are more than 0.67 m/sec. Flash floods, unstable substrate, excessive turbidity, and water level fluctuations are responsible for the reduction of benthos and fish. High water velocities or severe summer storms cause streambed erosion and loss of the bottom fauna. Benthos standing crop appears to be twice as high where limestone is present than in granite areas due to alkalinity increases.

I Philipson, G. N. 1954-1955. The effect of water flow and oxygen concentration on six species of caddis fly (Trichoptera) larvae. Proc. Zoo. Soc. Lon. 124:547-564.

Certain species, like Rhyacophila dorsalis, Hydropsyche instablis, and Wormaldia subnigra, are more characteristic of swifter flowing waters while Anabolia nervosa and Polycentropus flavomaculatus are more prevalent in slower waters. Some animals have become dependent on current for their food and have morphological adaptations which enable them to live in these environments. Net-spinning larvae are dependent upon water flow for food.

F Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem classification. Surface Environment and Mining Program. U.S. Forest Service. 199 pp.

Investigations were conducted from July 1970 through September 1972 of (1) the physical structure of aquatic environments in granitic, mountainous lands in Idaho, (2) the relationship between physical stream structure and fish populations, (3) the influence of geomorphic process of aquatic ecosystems, (4) the relation of order within landforms in relation to uniformity in aquatic environments, and (5) the potential for classifying aquatic environment from land classification systems. A 397-square-mile (1,028-km^2) area in the upper south fork of the Salmon River watershed was stratified into four geologic process groups and 12 geomorphic types. Within that area, 38 streams were studied by analyzing 2,482 transects for physical aquatic and streambank environments, while 291 areas were investigated as to fish populations.

The streams had distinguishing structural features that had resulted from the influences of geomorphic processes. Some areas of each stream studied had been dominated by one type of external variable such as glaciation. Multivariate control from geomorphic processes, however, exercised the most influence on general stream conditions. Spatial differences in dissolved and suspended substances in the streams appeared to depend on the degree of decomposition of bedrock and possibly on the elevation of the channel. Time, as related to streamflow movement through the drainage, had little influence.

In turn, certain aquatic structural characteristics controlled the density of fish populations and the composition of fish species. Stream depth, width, and the elevation of the stream channel were the most important such characteristics, with salmonids apparently adapted to almost all streams in these high elevation granitic lands. Variations in water chemistry did not seem correlated with the density of fish populations.

The fish population total density decreased or increased in a uniform manner as certain variables in the aquatic structure changed. Some individual fish species, however, responded in an opposite manner and certain species showed no correlation. The variables that described the structure of the study streams often proved to be directly related. If one changing variable was identified, most other structural variables responded in a predictable manner. (Author abstract.)

I Poole, W. C. and K. W. Stewart. 1976. The vertical distribution of macrobenthos within the substratum of the Brazos River, Texas. Hydrobiologia 50(2):151-160.

Fifteen of 25 species recovered occurred below 10 cm. Mean percentages of total organisms recovered were 66.4 percent, 20 percent, 6.1 percent, and 7.5 percent per 10-cm level, respectively, from the surface down. Dominant insects were Neochoroterpes mexicanas naiads, chironomids, Simulium, Cheumatopsyche, and Stenelmis larvae. Seasonal population peaks of these five groups in the top 10 cm correspond with observed emergence peaks. The smaller size classes were generally predominant in the 0-10 cm level. Larvae of Stenelmis were the most evenly distributed among the various 10-cm levels in all size classes. A movement of Cheumatopsyche and Neochototerpes to lower levels was observed following a large flood, suggesting an escape response to increased silt load and scouring.

Dissolved oxygen ranged from saturation at the surface down to 0.4-0.7 ppm at 30-40 cm, indicating that it was possibly limiting at lower levels. Maximum temperature differences between 10-cm levels was only 3°C. Flow was negligible below 10 cm.

The vertical stratification sampler recovered significantly greater populations in the surface 20 cm, but not in the total 40 cm, than a modified Hess square foot sampler. (Taken from author abstract).

I Post, H. A. and A. A. DeLaCruz. 1977. Litterfall, litter decomposition, and flux of particulate organic material in a coastal plain stream. Hydrobiologia 55(3):201-207.

Import of allochthonous material in terms of litterfall in a third-order stream in the Mississippi coastal plain was 386 grams dry wt/m^2/yr. Litter materials consisting of deciduous leaves, pine needles, and woody twigs collected during different seasons showed some differences in ash-free dry weight, caloric, carbon, hydrogen, nitrogen, and phosphorus contents. In situ decomposition to particulate form of deciduous and pine litter enclosed in nylon litter bags showed 15 percent and 65 percent, respectively, of the litter remaining after 334 days. Downstream net transport of suspended particulate organic material in the river averaged 688,290 kg dry wt/yr with a range of 456,061 to 920,518 kg dry wt/yr. There was a tendency for the particulate organic matter load of the water to increase during ebbtide and to decrease during floodtide. (Author abstract.)*

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* Allochthonous material is often more important than autochthonous production in streams. The accumulation of undecomposed litter is prevented by occasional flooding and decomposition is slower in slower moving water.

I Rabeni, C. F. and G. W. Minshall. 1977. Factors affecting micro-distribution of stream benthic insects. Oikos 29:33-43.

Thirty-one percent more organisms occurred in trays placed in a riffle than in those placed in a pool. In both riffle and pool the amount of colonization for most taxa was least on the smallest substratum sizes studied (0.5 to 0.7-cm diameter), was greater on the 1.0 to 2.0-cm size, reached a maximum on the 2.5 to 3.5-cm size, and was markedly reduced on the largest substratum size (4.5 to 7.0 cm). The reduction of current velocity alone accounted for reductions in the numbers of four or five species, while the addition of a light coating of silt (<1-mm deep) significantly reduced the numbers of only three species. The 1.0 to 2.0-cm substratum trays consistently contained more small-sized (<395 mm) detritus particles than did the trays filled with the largest size substratum. When the amount of these particles was similar in both sizes of substrata, the preference previously shown by the insects for the small substratum did not hold. Thus, insects may colonize small (1.0 to 3.5 cm) substrata primarily because these serve as a better food-collecting device than do larger (or smaller) substrata, and manipulation of the substratum may alter the productivity of a stream through an influence on its detritus storage capability. The substratum-detritus interaction was the overriding influence on insect macrodistribution under the conditions of this study and current velocity and a light deposition of silt play only secondary roles. (Taken from author abstract.)

F Radway, A. K. 1969. Distinctive aspects of the ecology of stream fishes: a review. J. Fish. Res. Board Can. 26(6):1429-1438.

The essential feature of a stream is the continuous flow of water, and the various schemes of classification of streams and the associated fish fauna are largely based on factors which determine the average velocity. These schemes have been better developed in Europe than elsewhere, probably due to the relative uniformity of the climate. The characteristic features of fish inhabiting the more rapid streams can be related to the constraints imposed by this environment, and particularly by the need for the population to maintain its position against the continuous tendency of the stream to transport it downstream. Physiological factors associated with the normally high oxygen level and the need for continuous activity include a high routine metabolic rate, a high oxygen threshold for full activity, and possibly, a high lower lethal limit for dissolved oxygen. Adult fish maintain their position either by continuous swimming in midwater, and these usually have a streamlined shape which is circular or laterally compressed in cross section, or by avoiding the current and living closely attached to or in the substrate and these are usually dorso-ventrally depressed. The eggs are usually protected from the current by burying them in the substrate, sometimes in a well-developed nest. The general absence of vegetation in rapid streams results in the fish generally feeding principally on the available animal food, usually small invertebrates taken either in the drift or off the bottom. The solitary territorial behavior which characterizes most stream-living fish probably leads to more even distribution and more efficient utilization of the food supply. (Author abstract.)

F Reed, R. 1968. Mark and recapture studies of eight species of darters in three streams in northwestern Pennsylvania. Copeia 1968(1):172-175.

Darter populations on three Pennsylvania stream riffles were studied to determine darter density and stability. Density of darters was estimated at 11.8 darter/m^2 with about 40 percent of the population remaining on the riffle throughout the summer.

F Reimers, N. 1957. Some aspects of the relation between stream foods and trout survival. Calif. Fish Game. 43(1):43-69.

This paper is a study of winter feeding response and starvation of rainbow and brown trout in Convict Creek, California.

Digestion of food at low temperatures was found to be at a constant slow rate. Healthy trout are, however, adapted to and capable of long periods of fasting, particularly in cold water. Starvation was found to be only a secondary factor in winter survival. Shifting ice and other external conditions are responsible for most of the overwintering loss.

F Reimers, N. 1963. Body condition, water temperature, and overwinter survival of hatchery-reared trout in Convict Creek, California. Trans. Am. Fish. Soc. 92(1):39-46.

Catchable-sized, hatchery-reared rainbow trout (Salmo gairdneri) undergoing survival tests in controlled sections of a mountain stream repeatedly declined in coefficient of condition for several months after being stocked. Examples of the extent of this decline, together with records of stream temperatures and associated mortality, are used to demonstrate the relationship among poor body condition, rising temperature, and breakdown of trout vitality during the critical late-winter period. Possible advantages of fall stocking and of breeding some hatchery trout for superior adaptability are discussed. (Author abstract.)

F Reiser, D. W. and T. A. Wesche. 1977. Determination of physical and hydraulic preferences of brown and brook trout in the selection of spawning locations. Water Resour. Series 64. Water Resour. Res. Inst., Univ. Wyoming. 100 pp.

During the fall of 1975, 121 brown and 54 brook trout redds were located and intensively studied in seven stream sections of southeastern Wyoming. Depth, mean velocity, and point velocity were measured at the upper edge, pit, and tailspill of each redd. A representative substrate sample was collected from the tailspill and later analyzed using a series of nine sieves. Permeability of the substrate was measured at the redd site using a Mark VI standpipe. The distance to the nearest usable cover was also measured for each redd.

Spawning criteria were then developed for brown and brook trout using the middle 80 percent of the upper-edge mean velocity measurements, the upper-edge depth which 90 percent of the measurements were greater than or equal to, and the substrate size interval comprising 70 percent of the total weight. For brook trout these criteria were determined to be: velocity, 0.12-1.11 fps (3.6-33.8 cm/sec); depth, ≥0.2 foot (6.1 cm); substrate size, 0.132-1.99 inches (0.34-5.05 cm). For brown trout: velocity, 0.45-1.50 fps (13.7-45.7 cm/sec); depth, ≥ 0.3 foot (9.1 cm); substrate size, 0.25-2.99 inches (0.64-7.60 cm). The criteria can be used to aid in determining suitable spawning flows for Wyoming's smaller streams.

An egg-planting experiment was conducted to attempt to determine the combination of parameters affording the highest percentage survival of brown trout eggs. (Author abstract.)

I Resh, V. H. 1977. Habitat and substrate influences on population and production dynamics of a stream caddisfly, Ceraclea ancylus (Leptoceridae). Freshwater Biol. 7:261-277.

Riffle areas were more productive than pools or submerged vegetation. Higher production was noted in areas with larger sized substrate particles and increased numbers of particles which possibly could be due to the increase of food or attachment sites.

I,W Rosenberg, D. M. and A. P. Wiens. 1978. Effects of sediment addition on macrobenthic invertebrates in a northern Canadian river. Water Res. 12(10):753-763.

As a result of sediment addition, numbers of macrobenthos drifting from the sediment addition channel (S) increased significantly over those drifting in the control (C) in August (= summer) and September (= fall). Total drift from S was >3 times higher in August and >2 times higher in September than from C. Significantly higher numbers of macrobenthos drifted in fall than summer. Numbers of macrobenthos drifting during sediment addition were significantly related to time in September but not in August, indicating a seasonal difference in temporal response to sediment addition. Two explanations are proposed for the response of the September community, as indicated by shape of a polynomial regression curve, to sediment addition. No significant difference existed in standing crops of macrobenthos in the substrate in C and S after sediment addition.

Sediment addition caused (1) higher numbers of Oligochaeta and Simuliidae to drift in August and September, (2) higher numbers of Plecoptera and Ephemeroptera to drift in September but not in August, and (3) higher numbers of Hydracarina and Chironomidae to drift in August but not September.

We suggest that future work try to relate amounts of settled rather than suspended sediments to quantitative responses of stream macrobenthos. We recommend that highway and pipeline construction undertaken in watersheds of Mackenzie Valley streams during the open-water period, resulting in sediment addition to these streams, should be done during summer rather than spring or fall, providing river discharge is adequate to transport the added sediment. (Author abstract.)

F Ruhr, C. E. 1957. Effect of stream impoundment in Tennessee on the fish populations of tributary streams. Trans. Am. Fish. Soc. 86:144-157.

Data from a statewide survey of warmwater streams in Tennessee were used to determine the extent to which gizzard shad (*Dorosoma cepedianum*), carp (*Cyprinus carpio*), smallmouth buffalo (*Ictiobus bubalus*), and drum (*Aplodinotus grunniens*) inhabit smallmouth bass-rock bass streams. Reproduction of those species in tributary streams was minor or absent. By comparing samples from streams that were accessible from an impoundment and streams that were in an unimpounded watershed, it was shown that large populations of gizzard shad, carp, smallmouth buffalo, and drum in streams originate in impoundments. Mill dams on tributary streams were found to be effective barriers to the upstream movement of fish from the impoundment. Once reservoir fish populations were well established, there appeared to be no consistent variation in the populations of lake fish in tributary streams from one reservoir to another. In streams without migration barriers there was no decrease in the concentration of lake fish with an increase in the distance from an impoundment. Population pressure among fish of the various species in the impoundment is advanced as the reason for movement of gizzard shad, carp, smallmouth buffalo, and drum into streams. It is suggested that mill dams be preserved as barriers to movement of lake fish and that preimpoundment surveys include consideration of the effect not only on the inundated stream but on the streams above the full-pool level of the proposed reservoir. (Author abstract.)

I Ryck, F. 1976. The effect of scouring floods on the benthos of Big Buffalo Creek, Missouri. Proc. Annu. Conf. Southeast. Assoc.

Game Fish. Comm. 29:36-45.

Flash floods that scoured stream substrates had little effect on water quality assessments although they did cause the temporary dislocation and dispersal of riffle benthic macroinvertebrates. The density and structure of this community were essentially identical to pre-flood conditions 1 month after floods. Diversity index values for samples collected 8 days after a flood were near normal. Apparently, riffle invertebrates were not dispersed over great distances and were therefore able to rapidly repopulate scoured areas. At the end of the study, after seven severe floods, the density, diversity, and species composition of the macroinvertebrate fauna were nearly identical to values observed at the start of the study. The mechanism for the recovery of a riffle after scouring is most likely a combination of downstream drift, upstream movement of larvae, and upstream oviposition flights of adults. (Taken from author abstract.)

F Saunders, J. W. and M. W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Am. Fish. Soc. 91(2):185-188.

Thirteen dams, twelve deflectors, and several covers were constructed in a 450-yard section of Hayes Brook, Prince Edward Island, to create suitable hiding places for brook trout, Salvelinus fontinalis (Mitchill). In the following year the standing crop of fingerlings (age 0) was above average. The numbers of age I and older trout were approximately doubled. The alterations had no noticeable effect on the growth of trout. (Author abstract.)

F,W Saunders, J. W. and M. W. Smith. 1965. Changes in a stream population of trout associated with increased silt. J. Fish. Res. Board Can. 22(2):395-404.

Low standing crops of brook trout, Salvelinus fontinalis, were closely associated with silting in Ellerslie Brook, Prince Edward Island, and appeared to result from the destruction of hiding places. Spawning was also curtailed by silting. Following scouring, trout stocks soon increased. The remarkable adaptability of trout to silting, in a habitat with favorable flow and water temperature, was illustrated. (Author abstract.)

F Seegrist, D. W. and R. Gard. 1972. Effects of floods on trout in Sagehen Creek, California. Trans. Am. Fish. Soc. 101(3):478-482.

Effects of winter and spring floods on rainbow (Salmo gairdneri) and brook (Salvelinus fontinalis) trout were evaluated over a 10-year period in Sagehen Creek, California. Winter floods decimated developing eggs of fall-spawning brook trout. Because of reduced competition by young brook trout, survival of spring-spawned rainbow fry increased in years following winter floods. Conversely, spring floods destroyed rainbow eggs, thereby enhancing survival of young brook trout. Floods changed the species composition markedly and these changes endured for several years. Adult trout were adversely affected by the worst flood studied, but were unaffected by other floods of lesser magnitude. Effects of floods were not nearly as pronounced or predictable on adult trout as they were on young trout. (Author abstract.)

F Serebrov, L. I. 1973. Effects of a current on the intensity of feeding in certain fish. Hydrobiol. J. (Engl. Transl. Gidrobiol. Zh.). 9(2):68-70.

Feeding guppies (lentic species) and minnows (lotic species) were observed in flowing- and still-water environments. Guppies fed more intensely in flowing water than in still water. Minnows fed at about the same rate in flowing and still waters.

F Sheldon, A. L. 1968. Species diversity and longitudinal succession in stream fishes. Ecology 49(2):193-198.

A quantitative survey was made of the distribution and abundance of fishes in Owego Creek, New York. Four of the five headwaters species occurred throughout the area and two of these species dominated the fauna in all areas. Thirty-one species were found in the area. Succession took the form of additions to the headwaters assemblage and replacement was of minor importance. Regression analyses show that the number of species in any area was correlated most strongly with stream depth although an effect of position was also significant. Species diversity (information theoretic) was independent of position and depended on depth alone. Behavioral observations support the importance of the depth factor. (Author abstract.)

I,W Sherberger, F. F., E. F. Benfield, K. L. Dickson, and J. Cairns, Jr. 1977. Effects of thermal shocks on drifting aquatic insects; a laboratory simulation. J. Fish Res. Board Can. 34(4):529-536.

Consistent statistically significant differences in mortality between treatment and control groups were not evident until shock temperatures neared the respective upper lethal limits for the insects. While consistent treatment related differences in molting frequency in Isonychia were not obtained, changes in the patterns of molting were observed. Behavioral tests with Isonychia indicated no discernible effects of treatment on rheotaxis, phototaxis, and substrate orientation. No discernible effects of treatment on susceptibility to predation of Isonychia by Cottus carolinae were observed.

There was no significant change in oxygen consumption or reproduction observed until shock temperatures came within 1-2°C of the upper lethal limit.

F Shuck, H. A. 1945. Survival, population density, growth, and movement of the wild brown trout in Cyrstal Creek. Trans. Am. Fish. Soc. 73:209-230.

The survival rate of wild brown trout in Crystal Creek, New York, over a one-year period was 24.1 percent, while hatchery brown trout had a survival rate of only 0.25 to 6.3 percent. Brown trout were found to be relatively nonmobile with 42 of 46 tagged fish recaptured at the point of release. The majority of tagged trout were observed migrating upstream to spawn in October and November, followed by a return to the area of tagging.

F,W Smith, L. L., Jr., and D. M. Oseid. 1974. Effects of hydrogen sulfide on development and survival of eight freshwater fish species. Pages 417-430 in J. H. S. Blaxter, ed. The Early Life History of Fish. Springer-Verlag, New York.

The egg and fry of eight species of North American freshwater fish were subjected to concentrations of hydrogen sulfide (H_2S) varying from 0.006-0.086 mg/ℓ. In general, survival was reduced, fry length at hatching shortened, and fry deformity increased with increasing H_2S concentration. Treatment of fish of some species prior to spawning reduced fecundity and egg survival. Low dissolved oxygen concentration increased resistance of fry but decreased resistance of eggs. The no-effect levels of H_2S were substantially lower than acutely toxic levels as described by median lethal concentrations. Levels of H_2S commonly found in natural systems may inhibit or prevent reproduction in some fish species. It was concluded that many habitats with unexplained absence of satisfactory fish reproduction should be examined for possible natural contamination with H_2S in potential spawning and nursery areas. (Author summary.)

F Smith, P. W. 1963. A study of seasonal distribution of fishes in the Kaskaskia River Ditch, a highly modified stream in eastern Illinois. Copeia 1963(2):251-259.

Three sites on the Kaskaskia River headwaters in east-central Illinois, from which standardized seine hauls were made each month of the year, indicate that availability of fish and number of species represented vary with season and water level. Number of fish present is highest in winter, lowest in spring and early summer; number of species present is highest in late summer and fall, lowest in spring. Greatest seasonal fluctuation occurs in Pimephales notatus. Spring runs of catostomids and other migratory species do not now occur in the highly modified headwaters of this stream. (Author abstract.)

I Sprules, W. M. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Stud. Biol. 56:1-81.

Events which induced significant alterations of the stream resulted in changes in insect composition. These alterations included freshets, flow cessation, and sedimentation of riffle areas.

Diversity decreased in going from rubble to gravel to muck and sand areas. Different species emerged in the same sequence each year, but the date of first emergence and the length of the period varied depending on water temperatures. Individual species emerged at the same time each day but different species emerged at different times of the day. The maximum emergence occurred during the dark hours of the day. The numbers of insects present depend on the utilizable surface area available.

A scoured section of a stream can have a 50 percent reduction in insects. Plecopterans, ephemeropterans, and trichopterans have a very low tolerance for alteration of their environment by desiccation or other conditions associated with intermittent flow. Chironomids seem to be able to withstand desiccation to a greater degree.

A decrease in the number of microhabitats which accompanies a change in bottom can account for a decrease in benthos diversity. Current is the important limiting factor in the distribution of insects, everything else being equal.

F Stalnaker, C. B. 1975. Effects of reduced stream flow upon trout populations. Coop. Fish. Unit, Utah St. Univ., Final Report PRYNE-074-3, 123 pp.

A simulation model is developed to determine minimum streamflows for trout. The intent of this study is to examine the system requirements of stream trout and to develop an approach for determining minimum flow requirements at all times of the year. This predictive ability is necessary before rational decisions can be made for wise water use. It is intended to be a general stream model which may be applied to streams anywhere.

The model as developed to date has the <u>potential</u> of being an experimental as well as a management tool. Its theoretical value lies in its use in studying the dynamics of the total ecosystem through time. The model tracks through time all exchanges of the ecosystem with the surrounding biosphere, the biomass of all components of the system, and the production of trophic levels, either in daily increments or total production for an entire simulation period.

As a management tool the model may be used for predictive purposes by changing the driving variables to correspond with planned or projected perturbations. The simulation approach described has certain limitations which have been identified and need special mention.

The general stream simulation model can be used as a management tool only after it has been validated by comparison of predicted model output with measured field data collected over a relatively long period of time. Field validation would ideally include data measurements from an existing stream environment over all seasons of the year followed by controlled flow manipulation and system response measurements on altered and control sections of the stream.

F Stalnaker, C. B. and J. L. Arnette. 1976. Methodologies for the determination of stream resource flow requirements: An assessment. U. S. Fish Wildl. Serv., OBS, Western Water Allocation. Fort Collins, Colo. 199 pp.

This report is a collection of papers given at a workshop at Utah State University in 1975 to determine the state of the art of instream flow methodologies. Methods currently used in the areas of fisheries, wildlife, water quality, recreation, and aesthetics are presented.

It was originally intended that this workshop provide a complete compilation of methodologies, emphasizing the approaches of agencies, institutions, and individuals actually involved in or practicing streamflow management in its various forms. Some of the sections are relatively complete or they provide the basis for additional development. However, certain sections do not describe all appropriate or available methodologies, but emphasize fundamental concepts or particular approaches. Section 1 presents nomenclature for instream assessments. Section 2 provides a general overview of hydrologic and hydraulic concepts as they relate to instream flow assessment. The authors of Section 3 present mathematical modeling and nomograph analysis as the primary methods for determining the relationships between water quality and instream flow. Sections 6 and 7 consider the interactions between recreation, aesthetics, and instream flow from a sociological and social psychological view, emphasizing attitude scaling techniques. The latter two sections do not evaluate, in any depth, flow assessment methodologies used by landscape architects, outdoor recreationists, and resource management agencies. These various orientations may, in the future, prove to be the most appropriate, particularly the modeling approach. However, readers of these sections, especially those from other disciplines, must be aware that the state of the art as it presently exists is not completely represented. (From author preface.)

F,W Starret, W. C. 1951. Some factors affecting the abundance of minnows of the Des Moines River, Iowa. Ecology 32(1):13-27.

Fish collections were made in the Des Moines River, Boone County, Iowa, from 1946 to 1948. Emphasis in the investigation was placed on the changing abundance of the various species of minnows. The spotfin shiner and southwestern sand shiner were consistently the most abundant minnows in the river.

Floods and silt appear to be important factors affecting the Des Moines River fish population. The abundant species of minnows in the Des Moines spawn in late July and August, a period usually with low-water levels and reduced silt loads.

Population size and space are considered to be important factors in limiting spawning success of minnows. Spawning failures of minnows occurred when water levels remained low throughout the year and when the population size was high. Isolation of abundant minnows in temporary backwaters following a flood reduces that population and it appears that this might be beneficial to the population. (Author summary.)

F Stefanich, F. A. 1952. The population and movement of fish in Prickley Pear Creek, Montana. Trans. Am. Fish. Soc. 81:260-274.

A 2-year study was made on the populations and movements of fish in Prickley Pear Creek, Montana. The most numerous species present were freshwater sculpins, brown trout, rainbow trout, and longnose suckers.

The number of brown trout was higher in 1949 than in 1950. Their number in relation to all trout was approximately 60 percent in 1949 and 54 percent in 1950. However, their weight in relation to that of all trout was approximately 74 percent in 1949 and 73 percent in 1950. Rainbow trout made up most of the remainder of the salmonid population. The number of trout in relation to all fish was approximately 79 percent in both years and their weight approximately 58 percent in 1949 and 47 percent in 1950. Weights of the trout remained relatively constant for the sampling periods each year but showed a significant difference between years. Suckers were numerous in the first sampling periods of each year but decreased sharply in the late summer months. The total weights of all fish vary from 58.87 to 241.10 lb/acre (66.0-270.2 kg/ha) at the different sampling periods. Large numbers of fish were recaptured in the areas where they were tagged. Eleven trout were recovered six times in the same area. Some of the fish moved and of these the general movement was downstream. (Author abstract.)

F Stewart, P. A. 1970. Physical factors influencing trout density in a small stream. Ph.D. thesis. Colo. State Univ., Fort Collins, 78 pp.

The mean depth of a stream and the amount of rock cover were determined to be the most important factors in influencing rainbow trout density. The density of brook trout was determined by these two factors together with the amount of undercut banks and the turbulence of the water. The usage of artifical cover by fish was determined to be due to the height, overall size, and the percentage of light penetration in the structure.

I Sublette, J. E. 1956. Seasonal changes in bottom fauna of an Ozark headwater stream (Clear Creek, Washington County, Arkansas). Southwest. Nat. 1(4):148-156.

The bottom fauna was dominated by insects. Of the 53 groups, 44 were insects. Differences in relative composition between upstream and downstream stations were observed. The rather low fall standing crop gradually increased until late winter at which time the maximum occurred. This large standing crop was then abruptly reduced by the erosional effects of floodwaters. Following flooding, the relative composition of the standing crop was altered, apparently as a direct result of certain members being able to better withstand the erosional conditions. Tendipedidae survived the turbid conditions which resulted in a change of species composition. (Taken from author abstract.)

F,I Surber, E. W. 1937. Rainbow trout and bottom fauna production in one mile of stream. Trans. Am. Fish. Soc. 66:193-202.

Plantings of rainbow trout fingerlings in approximately a mile (1.6 km) section of a spring fed creek averaging 11.4 feet (3.5 metres) in width and comprising about 1.65 acres (0.67 ha) were followed up to determine their survival and the annual production of fish in pounds per acre (kg/ha). The results of four years' observation showed little variation in the production for the years 1933-36, when 29.7, 27.7, 34.8, and 30.2 pounds per acre (33.3, 31.0, 39.0, and 33.8 kg/ha) of trout, respectively, were removed. When the number of fish planted during the fall of 1935 was doubled, the production remained the same, although the flood of middle March 1936 may have had some effect on the number of fish that survived.

The condition factors of all trout were determined, and this factor, which had not yet varied significantly, still remained at a satisfactory level (42.6) during 1936 after the stocking intensity had been doubled. In all seasons, the majority of these planted fish have made excellent growth, most of them attaining a length of 9 inches or more by late May.

Food studies made during 1934 demonstrated the great dependence of the rainbow trout on terrestrial insects during the summer period, but these studies also showed greater dependence on the aquatic forms in the creek than during the previous season of 1933.

Bottom samples were taken monthly for a two-year period. When the results for the two years in grams per square foot were compared, they were found surprisingly alike. During the first year beginning in August 1933, the average wet weight of bottom animals was 5.047 grams, dry weight 0.982 grams. The averages for the succeeding year were 6.695 grams wet and 1.321 grams dry weight, respectively. (Author summary.)

F Swank, G. W. and R. W. Phillips. 1976. Instream flow methodology for the Forest Service in the Pacific Northwest Region. Pages 334-343 in J. F. Orsborn and C. H. Allman, eds. Instream Flow Needs. Vol. 2. American Fisheries Society, Washington, D.C.

An instream flow analysis procedure developed in the Pacific Northwest Region was used on two streams to evaluate the optimum flow needed for fish using various streamflow velocity and depth criteria for spawning, rearing, and food production purposes. This same procedure was interpolated for other streams on a broad basis. (Author abstract.)

I Tarter, D. C. and L. A. Krumholz. 1971. Life history and ecology of Paragnetina media (Walker) (Insecta: Plecoptera) in Doe Run, Meade County, Kentucky. Am. Midl. Nat. 86(1):169-180.

Nymphs of P. media were almost entirely carnivorous in their feeding habits; adults do not feed. Immature stages of aquatic insects (mainly Baetis vagans, Hydropsyche sp., Cheumatopsyche sp., and chironomids) comprised the most abundant food items in the diet of stonefly nymphs. The percentage of empty stomachs reached its highest levels in December and July. Length-frequency distributions indicate that nymphs require 2 years to complete the life cycle. Mature nymphs were found in the stream in April and May. Emergence began early in May and reached its peak in mid-July. The chi-square test was applied to 477 nymphs and no significant departure from the 1:1 sex ratio at the 0.05 level was observed. Total egg counts ranged from 394 to 1,296 per female; the average number of eggs was 802. (Taken from author abstract.)

F Tarzwell, C. M. 1938. Factors influencing fish food and fish production in southwestern streams. Trans. Am. Fish. Soc. 67:246-255.

For the past two years surveys have been in progress on the mountain streams of the Southwest. These investigations included chemical analyses, quantitative counts of bottom food organisms, a study of the physical character of the streams, and studies of the fish such as species present, relative abundance, age, and growth rate. An intensive creel census has been undertaken in several streams. An intensive study is being made on two experimental streams, one of which has been improved to the practical limit (Horton Creek) and the other (Tonto Creek) left in its original condition.

The surveys have shown that vegetative cover on the watershed and especially in the canyon bottoms is of great importance in maintaining productivity. Vegetative cover is essential for retaining moisture and preventing severe floods which have been found to be the outstanding limiting factor in southwestern streams. Floods not only roll and grind the bottom materials and widen the streambed destroying pools and cover, but they also sweep away rich organic materials essential for an abundant bottom fauna and deposit light-colored inorganic silt which is almost barren of life. It has been found that streams not subject to severe floods for some years are much richer than those streams having frequent floods.

The above was clearly demonstrated on the experimental streams. An intensive creel census and food study has shown that the improved stream, Horton Creek, is now the better stream. It was found from food studies made at different times throughout the year that Horton Creek had an estimated yield of over 300 pounds (136 kg) more food than Tonto Creek. Also, the creel census revealed that Horton Creek yielded a greater number of fish. In addition, the catch per hour was greater on Horton Creek and the average total number of fish for each fisherman was greater. Scale studies reveal that prior to improvement the growth rate of the fish was more rapid in Tonto Creek, but since improvement it is more rapid in Horton Creek. (Taken from author abstract.)

I Thorup, J. 1966. Substrate type and its value as a basis for the delimitation of bottom fauna communities in running waters. Pages 59-74 in K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman, eds. Organism-Substrate Relationships in Streams. Pymatuning Laboratory of Ecology, Spec. Publ. 2, Univ. Pittsburgh.

Faunal types are associated with certain substrates and in some areas may be called communities. Variations in the fauna of a certain substrate occur both quantitatively and qualitatively from one place to another. Substrate types can be used to define faunal types when distinguishing communities. The substrate type is a manifestation of other ecological factors because it depends on stream velocity, vegetation, light conditions, chemical components of the water, and the geological history of the locality.

F Turner, S. E. 1972a. Brown trout literature review. Mo. Dep. Conser., Fed. Aid Proj. No. F-1-R-2. 20 pp. (Mimeogr.)

Fifty-one papers were reviewed and annotated. Brown trout can withstand water temperatures in excess of 80°F (26.7°C) depending on age, size, acclimation period, and duration of the exposure. Mortality was highest during the first year of life and ranged from 14 to 86 percent thereafter. Growth rates ranged from

approximately 2.0 to 8.4 inches (5.1-21.3 cm) per year with the best growth occurring during the spring and summer in water temperatures from 45 to 66°F (7.2 to 18.9°C). Brown trout were difficult to rear; when stocked they were difficult to catch, did not disperse from release sites, and became piscivorous. Harvest of stocked brown trout ranged from 0.7 to 79 percent. Effects of predation were considered important when the fishery was maintained or augmented with stocked brown trout and predator control justified on the basis of economics. (Author abstract.)

F Turner, S. E. 1972b. Rainbow trout literature review. Mo. Dep. Conser., Fed. Aid Proj. No. F-1-R-21. 9 pp. (Mimeogr.)

Thirty-three papers pertaining to the reproduction of steelhead trout and rainbow trout are presented and annotated. Spawning activities appeared to be initiated by changes in water temperatures, day-length, and increased streamflow. Water temperatures during spawning ranged from 33.8 to 66.2°F (1.0 to 19.0°C). Predation by trout, sculpins, birds, and bullfrogs was found to reduce survival of fry after they emerged from the gravel. Gravel movement during freshets and floods, siltation, and low oxygen levels of under-gravel water flows were found to adversely affect egg and fry survival in the redds. (Author abstract.)

F U. S. Department of Health, Education, and Welfare. 1958. Oxygen relationships in streams. Robert A. Taft Sanitary Engineering Center. Tech. Rep. W58-2, Cincinnati, Ohio. 194 pp.

Oxygen resources in streams and other aquatic environments are summarized in a collection of papers presented at the First National Seminar on Dissolved Oxygen Relationships.

I Vaught, G. L. and K. W. Stewart. 1974. The life history and ecology of the stonefly *Neoperla clymene* (Newman) (Plecoptera: Perlidae) Ann. Entomol. Soc. Am. 67(2):167-178.

Semimonthly samples of *Neoperla clymene* (Newman) populations were made from November 1970 to October 1971 in the Brazos River, Texas. Emergence occurred from May through July. Mean fecundity of females based on dissection was 646 eggs. Females deposited up to 3 egg masses in the laboratory. Field-collected females deposited an average of 173 eggs per mass. Eggs required incubation at 24 ± 2°C and 15-hour photophase. Nymphal growth exhibited 3 phases, males and females underwent 18-20 and 20-23 instars, respectively. The greatest growth occurred during the spring. Standing crops ranged from 21.5 individuals/m^2 in July to 225/m^2 in May.

Stomachs of 443 nymphs, during spring growth, contained primarily Trichoptera eggs, *Cheumatopsyche* larvae, *Neochoroterpes* nymphs,

N. clymene eggs, chironomid larvae, Simulium larvae and nematodes; nymphs predominately fed at night.

Utilization of Ivlev's Electivity Index showed preference in feeding for chironomid larvae and pupae, Elophilia larvae, Chimmarra, and Cheumatopsyche. Significant overlap in feeding occurred between N. clymene and the associated insectivore Corydalus cornutus during March and April. (Author abstract.)

I Wallace, J. B., J. R. Webster, and W. R. Woodall. 1977. The role of filter feeders in flowing waters. Arch. Hydrobiol. 79(4):506-532.

Net-spinning trichopteran larvae are used as examples of filter-feeding stream insects to show that various species feed upon a range or particle sizes. Evolution of individual species has resulted in cropping various particle sizes of drifting stream seston. Mechanisms of how this is achieved are discussed. The evolutionary diversity of filter feeders has important consequences for stream ecosystems that transcend the individual species involved. (Author abstract.)

I Waters, T. F. 1961. Standing crop and drift of stream bottom organisms. Ecology 42(3):532-537.

The distribution of rates of drift of invertebrate animals among five Minnesota trout streams compared favorably with a ranking of expected productivities.

The distribution of standing crops of the bottom fauna among the five streams was not at all similar to the ranking of expected productivities nor to the distribution of drift rates, until the standing crop samples were qualitatively limited to groups of organisms having similar longevities. When the standing crop samples were limited only to those organisms having two or more generations per year, the distribution was similar to the ranking of expected productivities and remarkably close to the distribution of drift rates.

It is postulated that the mean rate of drift of invertebrate animals and qualitatively limited standing crop may be useful as indices to the production rate of a stream bottom fauna. (Taken from author summary.)

I Waters, T. F. 1962. Diurnal periodicity in the drift of stream invertebrates. Ecology 43(2):316-320.

Diurnally recurring changes in the drift rate (defined as the quantity or organisms drifting downstream per unit time per unit stream width) of several species of invertebrate organisms were observed in a small Minnesota stream. These changes usually were

a precipitous increase in drift rate about 1 hour after sunset, a decrease through the night, and a sharp return to daytime low values at about sunrise. In some cases, a second peak in drift rate occurred during the night, possibly being related to the occlusion of moonlight. Active, free-swimming species, the crustacean Gammarus limnaeus Smith and the mayfly Baetis vagans McDunnough, exhibited these changes most strongly. Glossosoma intermedium (Klapalek), a stone-encased caddisfly, exhibited similar changes in drift rate but was present in the drift without its case. Data on the dipertan Dixa, though inconclusive also suggested a slight increase in drift rate at night. An adult bug, Hesperocorixa, exhibited high drift rates in early night, apparently the result of an evening flight originating elsewhere. Simulium was common in the drift but exhibited no diurnal periodicity. A snail and another stone-encased caddisfly, Limneophilus, though abundant in the stream, appeared only rarely in the drift. For all species, drift rates were much higher in summer than in winter. (Author summary.)

I Waters, T. F. 1964. Recolonization of denuded stream bottom areas by drift. Trans. Am. Fish Soc. 93(3):311-315.

The downstream drift of some stream invertebrates is a sufficient mechanism to return disturbed populations to normal levels in a short time. Organisms such as Baetis or Gammarus that exhibit high drift rates, especially during the summer months, were returned to normal conditions within one or two days. The failure of some formerly abundant organisms to recolonize quickly allowed other competing species to repopulate at higher than original levels.

I Waters, T. F. 1969. Invertebrate drift: ecology and significance to stream fishes. Pages 121-134 in T. G. Northcote, ed. Symposium on Salmon and Trout Streams. H. R. MacMillan Lectures in Fisheries. Univ. B. C., Vancouver.

Many invertebrate species exhibit high rates of downstream drift. Diel drift patterns consist of one or more peaks that occur at various times depending on the species. Most species are night active indicating inducements by light intensity. A few species are day active indicating water temperature inducement. The magnitude of the drift is dependent on the water temperature, current velocity, stage of life cycle, population density, and growth rate. (Taken from author abstract.)

I Waters, T. F. 1972. The drift of stream insects. Annu. Rev. Entomol. 17:253-272.

A review of the literature on stream insect drift. Three distinct types of drift are noted: (1) catastrophic--caused by

disturbance of the streambed, (2) behavioral, and (3) constant. It is stated that diel drift is primarily the result of nocturnal foraging behavior.

F Waters, T. F. 1976. A methodology for evaluating the effects of different stream flows on salmonid habitat. Pages 254-266 in J. F. Orsborn and C. H. Allman, eds. Instream Flow Needs, Vol. 2. American Fisheries Society, Washington, D.C.

Stream resource managers need to be able to determine the relationships between flows and various fish habitat parameters in order to evaluate the effects of a present or proposed project which can alter flow regimes. A technique was developed which uses field measurements and a digital computer to quantitatively express the relationships between streamflow and available food producing, spawning, resting microhabitat, and cover areas for trout. The changing of a few weighting factors can adapt the program to various species of salmonids. A discussion of the benefits from application of the methodology to release flow evaluation is given. (Author abstract.)

F Wesche, T. A. 1973. Parametric determination of minimum streamflow for trout. Water Resour. Series 37. Water Resour. Res. Inst., Univ. Wyoming, Laramie. 102 pp.

Three physical stream characteristics were used to determine suitable minimum stream channel flows for the preservation of trout populations. Based on the average daily flow (ADF), they were: (1) hydrologic parameters, (2) surface area and its composition, based on water depth and velocity, and (3) available trout cover.

Portions of Douglas Creek and Hog Park Creek, relatively small streams (average daily flows approximately 30 cu ft/sec (0.85 m^3/sec)) located in the North Platte River Drainage of southeastern Wyoming, were intensively investigated in the summer and fall of 1972 at 200, 100, 50, 25, and 12.5 percent ADF. Water depth, velocity, cross-sectional area, wetted perimeter, hydraulic radius, top width, total surface area having a velocity of at least 1.0 fps (0.3 m/sec), surface area of depth 0.5 feet (0.15 metre) or greater, and available brown trout cover were found to decrease at the greatest rate for the discharge reduction interval from 25 to 12.5 percent ADF. As a minimum flow, a discharge in the 25 percent ADF range will avoid the flow range for which the rate of habitat decrease is greatest. (Taken from author abstract.)

F Wesche, T. A. 1974. Relationship of discharge reductions to available trout habitat for recommending suitable stream flows. Water Resour. Series 53. Water Resour. Res. Inst., Univ. Wyoming, Laramie. 73 pp.

Changes in physical stream characteristics as streamflow was reduced were used to determine suitable flows to maintain trout habitat. Reductions in available trout habitat were studied in relation to cover preferences, food production, and spawning areas.

Trout cover has been defined as instream rubble--boulder areas and overhanging bank cover in association with a water depth of at least 0.15 metre. Using these cover preferences, a rating system was developed allowing comparisons of available trout cover in the same stream section at various discharge levels and for different stream reaches at approximately the same level of flow, based upon the average daily flows (ADF). Verification of the rating system as an indicator of the standing crop of trout present has been initiated in an effort to quantify the biological significance of instream dewatering in regard to trout populations.

The primary study area, Douglas Creek below Pelton Creek, had an average daily flow of 2.23 m^3/sec and was intensively investigated in 1973 at 100, 71, 51, 38, 27, and 11 percent ADF. Available trout habitat was found to decrease at the greatest rate for the discharge reduction interval from 27 to 11 percent ADF. These findings verify the results found by Wesche (1973) on two stream sections having smaller ADF. As a minimum flow to maintain trout habitat, a discharge in the 25 percent ADF range will avoid the flow range for which the rate of habitat decrease is greatest.

F White, R. J. 1975. Trout population responses to streamflow fluctuation and habitat management in Big Roche-a-Cri Creek, Wisconsin. Verh. Internat. Verein. Limnol. 19:2469-2477.

A 10-year study was conducted to determine the effectiveness of habitat management on trout abundance. It was concluded that (1) in a given stream reach, the more water, the more trout, (2) year-to-year change in streamflow regime may often govern trout abundance, (3) narrowing the stream and providing overhead cover can help to ameliorate unfavorable effects of a low flow, and (4) greatest benefits of such management accrue to the larger size classes of trout.

F White, R. J. and O. M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Wis. Dep. Nat. Resour., Tech. Bull. 39. 56 pp.

Many rivers and streams have been abused and therefore improvement of trout stream habitat is largely a task of restoration. This bulletin deals mainly with measures to improve the channel, the banks, and the plant life for welfare of trout.

Tailor habitat management to the individual stream. Preserve and restore the natural character of streams and their landscapes.

Not only protection but control of streambank vegetation is often advisable to maintain favorable trout habitat. Overshading is an especially acute hazard along small streams. Meadow creeks with low shrubs and grasses appear to have the best all-around combination of productivity and protection. Remove woody vegetation from banks of small streams where groundwater seepage is adequate to keep summer temperatures moderate. Remove dams and other obstacles to flow (but do not remove meanders). When building in-stream structures, do not impede the current unnecessarily. To aid spawning, protect and enhance naturally occurring streambed gravel rather than trying to bring in and deposit new gravel. Combat floods by reducing overland runoff back in the drainage basin above the stream, not solely by reinforcing streambanks.

F Whiteside, B. G. and R. M. McNatt. 1972. Fish species diversity in relation to stream order and physicochemical conditions in the Plum Creek drainage basin. Am. Midl. Nat. 88(1):90-101.

Water and fish samples were collected at 202 sampling stations throughout the Plum Creek drainage basin in south central Texas between January and April 1968. Fish species diversity ($\bar{D}$) was analyzed to determine its relationship to stream order and physicochemical conditions.

Fluctuations in physicochemical conditions decreased as stream order increased. Twenty-seven species of fishes were collected. Minimum, maximum, and mean numbers of species per stream increased as stream order increased through the first four stream orders and decreased in the fifth-order stream. Mean $\bar{D}$ values decreased from first-order to second-order streams, then increased through fourth-order streams, and decreased again in fifth-order streams. Cumulative $\bar{D}$ values increased through third-order streams and decreased in fourth- and fifth-order streams. In general, $\bar{D}$ values for adventitious streams correlated with trends in $\bar{D}$ values for the higher order stream into which the adventitious stream flowed. The decrease in number of species and in species diversity in the fifth-order stream may have been due to migration of fishes into lower order streams for spawning purposes and/or to escape abnormally high water in the fifth-order stream. Also, increased depth and obstacles, such as logs and barbed wire, may have reduced seining efficiency in the fifth-order stream. (Author abstract.)

F Wickham, M. G. 1967. Physical microhabitat of trout. M.S. thesis. Colo. State Univ., Fort Collins. 42 pp.

The physical microhabitat of stream-dwelling fishes is relatively unknown. Work done with albino brook trout suggests the operation of a previously unreported scheme of fish habitation, the focal point concept. This concept is expressed in focal point residency and in movements away from the focal point. Both focal point and movements have quantitative parameters. Each focal point is a relatively small area representing less than 3 percent of the area over which the fish ranged. During a 50-day study period, an average of 15 percent of each study section was utilized 95 percent of the time. Most focal points had a slow water area (0.33 ft/sec (0.1 m/sec) average) overlain by a swift water mass (0.86 ft/sec (0.26 m/sec) average). Study fish occupied the slow water area almost exclusively with the exception of occasional, short (time) trips into the swifter layer. All focal points show a high spatial correlation with cover. A high percentage of time (94 percent) was spent in shaded areas.

Movements are characterized by the occupation of small amounts of time (6 percent of all observational time) and relatively large areas of the stream (up to 25 percent of the available stream area). A large percentage of the movements (66 percent) go away from and directly back to a focal point.

Results from a number of one-way analysis of variance computations indicate important relationships between overlying physical factors and the microhabitat chosen by study fishes. (Author abstract.)

F Wickliff, E. L. 1941. Natural productivity of fish and crayfish in riffles. Trans. N. Am. Wildl. Conf. 5:149-153.

Fifty-two riffle areas in Blacklick Creek, Ohio, were depleted of fish and crayfish and recolonization was measured. Fish began recolonization within 48 hours, and within 1 month the riffles were fully colonized. Standing crop of fish (primarily darter) and crayfish varied seasonally from 885 kg/ha in May to 4.9 kg/ha in December.

I Wilhm, J., T. Dorris, J. R. Seyfer, and N. McClintock. 1977. Seasonal variation in plankton populations in the Arkansas River near the confluence of Red Rock Creek. Southwest. Nat. 22(4):411-420.

One hundred twenty-eight taxa of phytoplankton and 32 taxa of zooplankton were collected from three stations in the Arkansas River near its confluence with Red Rock Creek. Samples were taken on six dates between April 1975 and January 1976. Maximum numbers of taxa of both groups occurred in late spring. Minimum variety of phytoplankton existed in summer, while both variety and density of zooplankton were extremely low in fall and winter. Density of phytoplankton ranged from 34.2 to 533.1 cells/mℓ. Density values were low in winter and early spring and reached maximum levels in early fall. Zooplankton density ranged from 0.5 to 129.3 individuals/ℓ with maximum density occurring in summer. Diversity (d) of phytoplankton in the river was high, ranging from 2.3 to 3.8. Values on most dates exceeded 3.0. Diversity of zooplankton was generally low except in late spring. Chlorophyll a ranged from 0.04 to 0.30 mg/m^3. Highest values were measured in summer, while lowest values occurred in winter and late spring.

F Wipperman, A. H. 1967. Effects of dewatering on a trout population. Mont. Fish Game Dep., Fed. Aid Proj. F-9-R-15. 4 pp. (Mimeogr.)

Three sections of Blacktail Creek, a tributary to the Beaverhead River, were dewatered 75, 50, and 25 percent below normal low summer flows. The sections were dewatered for 3 months. Dewatering appeared to reduce the number of whitefish and redistribute brook trout in Section A where flows were reduced 75 percent. The standing crop of fish increased in all three test sections during the dewatering period. Movement of trout from one dewatered section to another was slight. There was very little tendency for fish to move from the dewatered study area. (Author abstract.)

I Zelinka, M. 1977. The production of Ephemeroptera in running waters. Hydrobiologia 56(2):121-125.

Live weight was calculated for the larvae of Ephemeroptera and other zoobenthos on many localities in the catchment areas of the Morava River. At monthly sampling the year-round production of the larvae was derived and the results tabulated for individual stretches in g m^{-2} year^{-1}. The communities were classified also saprobiologically and the effect of saprobity on the production of mayflies in the individual zones was presented in the second table. Mayflies are considered very important for fish production in running waters. (Author abstract.)