EVALUATION OF INSTREAM FLOW REQUIREMENTS OF FISHES IN THE OZARK AND OUACHITA NATIONAL FORESTS, ARKANSAS

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INTRODUCTION

The Clean Water Act of 1972 (PL 92-500) had a goal of assuring the Nation's waters were "fishable and swimmable". Investigators soon learned that even minimal effects of land usage in a drainage basin could dramatically change water quality and flow in streams. The western United States has long experienced water shortages due to low annual precipitation, increasing populations, and intensive agricultural and livestock grazing practices. As a result, numerous instream methodologies have been developed to assist in prioritizing water usage (Hutchins 1977; Orth 1980; Orth and Maughan 1980, 1981, 1982; Stalnaker and Arnette 1976; Sweetman 1980; Tennant 1975). Bayha (1976) after summarizing the nationwide water problems in the 1970's advised the eastern states to "get ahead" of the instream flow problem through plan formulation and investigation. Ten years later we are still attempting to formulate plans. Is it too late?

Instream flow requirements have been defined by the Bureau of Land Management (1979) as "the quantity of water needed to maintain the existing and planned inplace uses of water in or along a stream channel or other water body and to maintain the natural character of the aquatic system and its dependent systems". Aquatic and riparian ecosystems and stream physical features were the dependent systems postulated by the BLM (1979). Stream physical features included channel, stream bed, flood plain, and flow pattern. Potential stream uses included human consumption, groundwater recharge, livestock watering, agricultural irrigation, recreation, and preservation of fish and wildlife.

Judy and co-workers (Judy et al. 1984) reported that in a normal year 69% of the nation's water courses had water available the entire year for fish requirements (breeding, spawning, foraging, and maintenance); 14% were not usable by fish during a portion of the year because of low or no flow; and 17% were used primarily in spring and summer. They mentioned that water quality problems affected fish in 68% of the nation's waters. Forty-one percent of perennial waters were adversely affected. Major water quality problems included below optimum flows (32%), occasional low flows (23%), and excessive flow fluctuation (17%). One half of the waters were adversely affected by natural low flow conditions. Agricultural diversions adversely affected 14% of all waters. Stalnaker (1981) encouraged fishery and water quality agencies to protect instream resources by aggressively pursuing the establishment of stream flow standards as a parallel effort to water quality standards under the Clean Water Act of 1972. He reasoned that stream habitat is very dynamic, changing with the season and the annual water yield. Therefore, alternation of the stream flow not only alters habitat conditions, but may also change the order of relative abundance of fish species. This dynamic nature of the fishery ruled out use of historic low flows as a realistic minimum flow. Historic low flows as a minimum flow ignores the long-term recovery of a fishery that must occur after a severe drought. The establishment of historic low flows as allowable minimum levels would reduce the fishery to perpetual worst case conditions. Various instream flow methodologies have been developed to quantify stream flow standards. These plans made it possible to satisfy all water uses during some years, while in other years, certain water uses went unsatisfied. Past management schemes relying on impoundment and manipulation of streams have been only marginally effective in resolving this problem (Sweetman 1980). In Arkansas, only a few streams are completely unaffected by water development. These effects have been slight in some areas, while in others, streams have shown little similarity to natural flows (Hines 1975).

INSTREAM FLOW METHODOLOGIES

The necessity to obtain practical and defensible instream flow requirements has resulted in the development of over 40 methods. Many of these techniques were simply modifications of a few basic methodologies to compensate for climate, fish species, and river type. Most fisheries biologists agree that the potential of a stream to support a specific assemblage of fish species depends on the amount of water flowing in the stream; however, the technique used to determine the minimum stream flow varies from region to region and state to state.

Three of the best known procedures to quantify instream flows have been discharge methods, single transect methods, and multiple transect methods (Metzger and Hanerkamp 1983). The "Montana" method as developed by Tennant (1975) has been the best known of the discharge methods and requires no actual field work if precise water flow records are available. With this method, fisheries biologists have done analysis with the aid of hydrological data provided by the US Geological Survey. Tennant (1975) evaluated his method on 11 streams in 3 states involving physical, chemical, and biological analyses of 38 different flows at 58 cross-sections on 196 stream miles in warm and coldwater streams. His results indicated that the condition of the aquatic habitat is remarkably similar on most streams carrying the same portion of the average flow. Similar analysis of hundreds of additional flow regimens near US Geological Survey stream gauges in 21 different states during the past 17 years has substantiated this correlation. This method has been proven to be quick and relatively easy to use. It assures consistency from stream to stream and never has produced zero flow recommendations. Tennant (1975) also found that in 86 of 305 instances (28%) in the Missouri River Basin, instream flow criteria modeled from 7 day Q10's resulted in zero flow. In 236 of 305 cases (77%) the 7 day Q10 was less than 10% of the average flow. This flow was considered by Tennant to be in the severe degradation. If applied all-time, historic minimum flows might be disasterous and cause eventual depletion of the fishery. Researchers have found Tennant's method to closely approximate instream flow requirements computed form exhaustive field work. Newcombe (1981) obtained cross-section areas of a stream, water depths, and water velocities over a range of discharges. He then weighted them in accordance with frequency distribution of water depth and water velocities preferred by life-history stages of native sport fish in the Pacific Northwest. Comparison of his results indicated substantial agreement with Tennant's qualitative method.

After careful analysis of the "Montana" method, Filipek et al. (1985) stated that it did not appear applicable to Arkansas' instream flow needs because its framework followed hydrologic processes more common to western states. Western hydrologic processes being the relative importance of winter snowmelt that provided the majority of water during a single water year. Winter is not a high flow period in western climates as in Arkansas.

ARKANSAS WATER HISTORY

Arkansas has rarely had water quantity problems. Legislation has granted allocation powers to the Arkansas Soil and Water Conservation Commission during drought years. Reported plans for piping surplus Arkansas water to other states (e.g. Texas), interbasin transfer of water within the state, declining aquifers, and increasing human populations have placed high demand on the state's surface waters. The rapidly increasing human population has placed increased angler demands on the total stream resource. Increased angler demand plus heightened stream diversion demands have prompted numerous state and federal agencies to define instream flow requirements and formulate flow recommendations for fish and wildlife.

In 1980, an extensive drought occurred in Arkansas. Excessive demands for stream water, particularly in the Mississippi Delta ecoregion, resulted in numerous streams being pumped literally dry with little concern for fishery resources (Filipek et al. 1985). In response to these recent occurrences the Arkansas method of instream flow determination and fisheries was developed.

THE ARKANSAS METHOD

The "Arkansas" method of instream flow determination, according to Filipek et al. (1985), is based on the fact that average flow of a stream is a composite of the size of the drainage basin, geomorphology of the stream channel, climate, vegetation type and abundance, and related land uses. This flow reflects the average, natural hydrograph of the stream, and the aquatic fauna and flora which evolved to "fit" the specific characteristics of that stream. The method divides the water year into three physical/biological units or seasons. These units are categorized by the physical processes that occur in the stream and critical life cycle stages of the fish and other aquatic organisms inhabiting the stream. The first unit is during high flow, November through March, is the time of the year when increased flows flush silted substrates and septic wastes and bring in organic nutrients from surrounding watersheds establishing basic fertility in the stream. Sixty percent of the mean monthly flow (MMF) is necessary for this process (Filipek et al. 1985). Tennant (1975) remarked that 100-200% of annual average flow was good for moving sediment and bedload, and provided for white water types of recreational activities. Recharge of aquifers and groundwater is also an important process during this time.

During the next unit, April through June, 70% of the MMF is necessary for fisheries instream flow needs because it is the primary spawning time for the majority of native Arkansas fish. It has been erroneously assumed by some investigators that late summer or low flow periods are the only critical times for stream fish populations and therefore are the only time when instream fisheries requirements need protection. Native fishes must experience a satisfactory spawn in the spring of each year, otherwise detrimental effects might be experienced by the population over several years. Decreases in stream flows contribute to increased mortality by stranding eggs and fry out of water or by reducing a sufficient flow of oxygenated water to developing fish eggs or fry. Reduced flows may also result in increased deposition of silt in spawning areas (Peters 1982). In low gradient streams with expansive floodplains, high water stages may trigger a large portion of the stream fish population to move into backwater or overbank areas to feed or spawn (Cyprinidae, Catostomidae, and Centrarchidae). The extent of their feeding, growth, and reproduction may be related to time, coverage, and duration of flooding (Wood and Whelan 1962). Certain species of fish, such as walleye, white bass, redhorse, and paddlefish require spring flows for upstream spawning migrations.

The final unit of this method spans July through October when stream flows usually reach absolute minimums in respect to the water year in Arkansas. There is an inverse relationship between mean flows and mean water temperatures. This season is the production time (rapid growth and development) of the biological year, when warmer water temperatures accelerate the numerous processes in the food chain from bacterial digestion of seston to production of periphyton, plankton, macrobenthic invertebrates, forage fish, and predatory fish. If water temperatures become too high, which might occur with removal of water from a stream reach, the dissolved oxygen saturation capacity of the water may be greatly reduced. Decreased oxygen levels limits growth, total production and survival of stream organisms. During the third time unit, stream flows have less capacity for variation compared with other periods. For this reason 50% of the MMF for certain spring-dominated streams may result in a value less than the 7 day Q10. In these situations the median flow for the monthly period would provide adequate protection for stream fish populations. The minimum flow requirement during the third period is 50% of the MMF to the median monthly flow, which ever is greater (Filipek et al., 1985).

These flows allow for adequate coverage of the stream substrate or wetted perimeter. Without this magnitude of protection, shoal or riffle areas and sloughs could be exposed rendering them nonproductive. Streambank cover for fish would diminish and riparian vegetation and associated wildlife would suffer. Reduced flows would reduce the oxidation capacity of the stream and therefore its ability to assimilate and dilute sewage and other waste products. Concentrations of pollutants and sediments in the water would increase and water quality would be degraded. Extreme low flows result in crowding of fish populations thereby increasing stress which might trigger higher levels of fish diseases and parasite infestations (Filipek et al. 1985).

Filipek et al. (1985) illustrated an example of the instream flow requirements of the Arkansas method using temperature and calendar month for the Ouachita River River near Felsenthal, Arkansas. The authors gave an idea of stream water temperature in relation to percent flows necessary for adequate protection of stream fisheries. Without such minimum flows reserved for the fisheries, repetitive abiotic factors such as excessive low flows may control and decimate fish populations (Orth and Maughn 1980; Layher 1983). Although specific stream flow requirements for terrestrial and semi-aquatic wildlife were not addressed by Filipek et al. (1985), they stated that when instream flow needs for fisheries are met many instream requirements for other wildlife forms are also satisfied.

STREAM FLOWS AND FISH POPULATIONS

Schlosser (1985) stated that temporal variation in stream flow strongly affected the assemblage structure of stream fishes, but varied among age groups of fishes in Jordan Creek, Illinois. He found that total diversity and species richness of adults was relatively stable between years even when varying flow regimes occurred. In contrast to adult populations, juvenile (age 0) density, species richness and species composition were all highly variable between years due to high flow regimes on juvenile recruitment. Abundance, species richness, and species composition of young age classes may have been strongly influenced by physical factors, while similar attributes of older age classes may have been more strongly regulated by biotic interactions.

With varying flows, different life stages of fish and macrobenthos, due to their distinct preferences for various combinations of flows, may find a given stream reach either suitable or unsuitable at a given discharge and time. Thus, altering stream flow may alter habitat conditions and change the relative abundance of particular species (Stalnaker 1979). Stalnaker (1981) in a review paper on low stream flows and warmwater streams wrote "I therefore submit that flow management is potentially the most important limiting factor to fish populations in warmwater streams". As part of his evaluation of fish requirements for flows Stalnaker's strategy program involved:

1. identification of designated instream uses including fishery management objectives of specific reaches (target fish species and carrying capacity, defined use and management objectives).
2. establishment of species criteria for temperature, velocity, depth, substrate, and cover. Bovee (1978) described behavior of fish species under natural conditions.
3. study of stream specific instream flows of the fishery habitat conditions present. Proposed methods of establishment of stream flow standards relating physical habitat to changes in streams flow have been described by Bovee and Milhous (1978) and Stalnaker (1979).
4. development of flow regime recommendations for a wide range of conditions, based on analysis of instream habitat and historical flow records following Milhous and Bovee (1978).
5. development of a monitoring program and rules for enforcing legally established average and drought flow standards.

Stalnaker (1981) stated that the techniques involved obtaining data consistent for a fish species throughout its life history, and measurement of depth, velocity, temperature, substrate, cover, and other characteristics at specific stream reach locations. The data are then used to define a distribution over a continuum of each physical characteristic (essentially HSI curves (FWS)). Due to variability no specific, standardized approach was considered in data procurement by Stalnaker (1981). He stated further, that the number of observations for a given species depended on the range of conditions inhabited over its life cycle (Arkansas methods' units). If the range was narrow and all life stages frequented essentially the same habitats, 200-300 individual observations taken in timely sequence over 3-5 years usually sufficed to determine the frequency of distribution. If the range was wide and there was a distinct gradation from one habitat type to another as the species matured, 300-1,000 observations may be required for each life stage. Differing geographic areas, availability of habitat, competition, food, and spatial limitation dictated that criteria for each species be developed on a state or regional basis. Stalnaker (1981) used the example that smallmouth bass in the Ozarks may select slightly different physical conditions than smallmouth bass in Idaho. He estimated individual species analysis costs range from $50,000 for one species, to approximately $15,000 per species when multiple species were studied. Rare or endangered species costs were estimated at $75,000 per species.

The number of site observations and costs related in Stalnaker's (1981) paper seem unrealistic for an agency to undertake. Since his limiting factor paper, seasonal flow requirements of specific fish species have been defined by Habitat Suitability Index (HSI) models (US Fish and Wildlife Service) and various published and unpublished species life histories (exp. Layer and Maughan (1980)). Numerous models are now available which consider habitat, flow, sedimentation, and fish species requirements (exp. the US Forest Service has GAWS (General Aquatic and Wildlife Systems) and COWFISH). Additional Forest Service studies addressing Wildlife and Fish Habitat Relationships (WFHR) include Fisheries Habitat Relationships (FHR) methodology, Guide for Predicting Salmonid Response to Sediment Yields in Idaho Batholith Watersheds, and Methods for Evaluating Stream, Riparian, and Biotic Conditions. The current Forest Service models and methodologies are of western origin and require modification before being applicable to the eastern United States.

ARKANSAS APPLICATIONS

In Arkansas, the Department of Pollution Control and Ecology (ADPC&E) and Arkansas Game and Fish Commission (AGFC) have sampled streams for many years. In 1984 and 1985 a unified effort between the two agencies completed a project that "provided a sound scientific basis for development, review, and adoption of water quality standards in the state of Arkansas". The comprehensive assessment of Arkansas least disturbed streams involved 65 streams. Physical, chemical, and biological characteristics of least-disturbed streams in watershed of various sizes within physiographic regions were determined. Initially, the state was divided into "ecoregions". The approach, based on Omernike et al. (1981), utilized topographic characteristics, soils, vegetation and land use to characterize ecoregions on: 1. predominant general unifying characteristic of an ecoregion; 2. calculation and mapping the combination of characteristics; 3. selection of typical and atypical areas in coregions; 4. identification of broad homogeneous areas appearing to regionalize aquatic ecosystems within ecoregions. Six categories were delineated (Bennett et al. 1985). Watersheds were selected and sampled (20-500 sq. mi.). Two sample periods, late summer (August-September) and early spring (March-April) were selected. Least-disturbed streams within the state were used based on staff experience (ADPC&E 1984 (305 (b) report)). Two systems within each ecoregion were extensively sampled and evaluated.

In direct relation to the fisheries, the study delineated representative fish families or groups, key fish species, and characteristic fish species per ecoregion. Coupled with the extensive flow, physical, chemical, and invertebrate data, this document is invaluable in assessment of flow requirements for fish species. Filipek et al. (1985) used results of the study in a portion of instream flow requirements of the lower Ouachita basin, Arkansas.

Many Arkansas streams have their headwaters on Forest Service lands where summer and early fall subsurface flows are not evident. Yet, many of these streams contain populations of native smallmouth bass (Micropterus dolomieui) and other coolwater species. The Arkansas Method for instream flows has been compared with other techniques on large river systems (Filipek et al. 1985). The method may need refinement on 1st to 4th or 5th order watersheds during low flow when there is little or no above surface flow. Bovee (1978) has developed habitat suitability curves for several salmonids and numerous other species requirements have been determined (Layher and Maughan 1980; Orth and Maughan 1982). There is little current information from which curves for Arkansas fishes can be derived. Orth and Maughan (1982) determined habitat suitability curves for three species of fish found in the Ozark or Ouachita mountains. Further investigation of habitat and flow requirements of Arkansas fishes are needed if the Arkansas method is to be adequately evaluated. The objectives of this study were to: 1. test the Arkansas Method of instream flow determination in Forest streams; 2. determine low flow requirements for fish populations in Forest streams; 3. determine habitat requirements for eleven species of fish representative of Ozark and Ouachita mountain streams.

STUDY SITES

The Ozark Highlands region includes both the Salem and Springfield Plateaus. This area is located in the northwestern and north central portions of Arkansas. Surface rocks are composed of limestones, dolomites, and chert. This region is uplifted with little folding. Rock strata are horizontal and continuous, intricately cut by numerous streams and rivers. Soils are shallow on hill sides and deep in valley floors. Streams are composed of pools and riffles, with bedrock, chert, rubble, or gravel substrate dominating. Gradients are moderate to high with numerous springs and sinkholes. Streams have very low turbidity and high recreational value. Forests are upland hardwood and in some area uplifted prairies. Part of the Ozark National Forest is in this region (Bennett et al. 1985).

The Boston Mountains region lies north of the Arkansas River Valley extending roughly east-west from Batesville, Arkansas to the Arkansas-Oklahoma state line. This area is the most uplifted and eroded mountain region in the state. Rock strata are generally horizontal, are slightly folded, and consist of sandstones and shales. Soils are thin except in valley floors. Streams in the region consist of pools and riffles and have a substrate composition of sand, gravel, rubble, boulder, and bedrock. During low flow, water flows through or under the rubble riffle areas. The streams have a slight turbidity, a greenish-blue tinge, and a high recreational and aesthetic value. Land use patterns consist of upland forest, small farms, and pastureland. The majority of the area is within the Ozark National Forest (Bennett et al. 1985).

The Ouachita mountain region is located in the west-central portion of Arkansas west of Little Rock extending into Oklahoma. The region is bordered on the north by the Arkansas River Valley and the south by the Gulf Coastal Plains. The mountains are composed of severely folded and faulted sandstones, shales, and novaculites. Topography is characterized by rolling hills and very steep rugged terrain. Streams usually follow east-west valleys, occasionally cutting across ridges, producing impressive rapids and waterfalls. These streams can rise 20 to 30 feet in a few hours during high runoff-rainfall periods, and have a high recreational value. Forest are a mixture of pine, oak, and hickory. (Bennett et al. 1985).

MATERIALS AND METHODS

Each sample site was initially channel typed following Rosgen (1985). Stream reaches were delineated by channel morphology and substrate size following Brussock et al. (1986). Stream order for sample reaches was determined using the counter crennulation method.

Fish samples were collected from January 1986 to January 1989 resulting in 62 observations. Sites were isolated with block nets (6.4 mm mesh) at the upstream and downstream ends prior to estimates to prevent movement of fishes into or out of the study area. Fishes were captured with either a bank generator coupled with a variable voltage pulsator (Coffelt VVP-2C-2000) and hand held electrodes or a boat mounted generator, variable voltage pulsator (Coffelt VVP-2E) and boat mounted electrodes. Both shocking units used variable voltage, pulsed direct current or alternating current. The boat mounted unit was used in large deep pools. Fishes were captured on three or more complete passes through the site and held outside the site in live wells or buckets. Fishes from each unit of effort were either identified to species, counted, weighed (gm), and measured (mm) individually in the field or preserved in 10% formalin and returned to the laboratory for similar analysis. Representative specimens were cataloged into the freshwater fishes collection, Arkansas Tech University, Russellville, Arkansas.

Population estimates were made following the removal methods of Van Deventer and Platts (1985) and Carle and Strubb (1978). Biomass was estimated for each species at each site my multiplying the population estimate by the mean individual weight. The surface area of each study site was measured and standing stocks reported in kg/ha. Species frequencies for each site were estimated in depth, velocity, and substrate tables following Orth and Maughan (1982). The adjusted frequencies were summed over all seasons and sites and divided by the sample surface area (number/m^2). These densities were then displayed at various depths, velocities, and substrate types. Suitability curves were then constructed for the eleven representative species.

Entire riffle or pool reaches were sampled regardless of length. Eleven habitat parameters were measured every 10 m through each site (riffle/pool) following the methods of Ebert et al. (1987), a modification of the line transect system of Platts, Megahan and Minshall (1983), FHR (Fisheries Habitat Relationships) methodology of Parsons (1984), General Aquatic and Wildlife System (GAWS) of McBride et al. (1985), sampling designs for estimating the total number of fish in small streams (Hankin 1986), and methods for evaluating the riparian habitat with applications to management (Platts et al. 1987).

Population densities were estimated for eleven target fish species in relation to depth (cm), velocity (cm/sec), and substrate type (Table 1). For the majority of stream reaches samples, population estimates corresponded with Arkansas Method flow units, Actual number and biomass (gm/m^2) or weight (gm) of fish were plotted against velocity, depth, and substrate. Suitability curves were drawn for each fish species.

Nine water quality and flow measurements were collected during each sample collection (HACH DREL-5 kits) and compared with Forest Service and Geological Survey permanent reference sampling stations. Streamflow measurements were collected at each site using the Embody float method, or Pygmy/Swoffer current meters.

SELECTION OF TARGET FISH

Selection of fish species was based on fish occurrence across both Forests, representation of the fish community, available life history information, and stream habitat preference. The eleven species of fish were selected to represent dominant family groups (Table 1). Microhabitat preferences among the fish species were not evaluated. The target species had somewhat restricted macrohabitat preferences and were selected to encompass the range of habitats typified in Ozark and Ouachita streams (Keith 1987). Feeding guilds and habitats were delineated according to Pflieger (1975). Fish representing differing habitat-use categories were thought to exhibit varied habitat responses to discharge and were consequently studied for slack (pool) and fast (riffle) water habitats following procedures similar to Leonard et al. (1986) and Ebert et al. (1987). Based on the previously mentioned criteria, species most restricted to riffles and pools during their life stages were used as target species.

RESULTS AND DISCUSSION

Slender madtom (Noturus exilis), orangethroat darter (Etheostoma spectabile), orangebelly darter (E. radiosum), banded sculpin (Cottus carolinae), and central stoneroller (Campostoma anomalum) were captured most frequently in shallow riffle or raceway habitat. These species preferred depths ranging from 0-30 cm, velocities from 0-20 cm/sec, and gravel-rubble substrate (Table 1). All of these species, with the exception of the banded sculpin were very common in all shallow riffle collections in the Boston Mountains, Ozark Highlands and/or Ouachita Mountains Ecoregions.

Our data confirmed findings by Orth and Maughan (1982), Pflieger (1975), Orth and Jones (1980), and Layher et al. (1978) concerning habitat and flow preferences of similar species. We found populations of these species to be somewhat lower during winter and spring (high flow units) sample periods when there was more wetted area present, faster velocities, and deeper waters. During the summer-fall low flow unit fish density was higher, but wetted area, velocity, and depth were much less. During this summer-fall unit the bottom substrate was densely covered by peryphyton in many reaches. Standing stock of stonerollers in these areas was consistently high. Moyle and Li (1979) have reported that central stonerollers reach maturity early, and may respond quickly to available environmental conditions. Stonerollers were the dominant herbivore in all sample reaches.

Lotrich (1973) and Small (1975) have commented that darter populations in small streams have high production to biomass ratios primarily because darters are small and mature rapidly. Winn (1958) and Sufert (1963) found that orangethroat darters were territorial and individuals were always separated by distances of 20 cm or more. This may indicate territorial conflicts during low flows. During the low flow unit in 1987 we observed orangethroat darters concentrated around upwelling subsurface flow areas below dry gravel-rubble riffles in the North Fork of Illinois Bayou, Boston Mountains Ecoregion.

Orth and Maughan (1982) correlated usable habitat and abundance of freckled madtom, central stoneroller, and orangebelly darter in Glover Creek, Oklahoma most significantly during summer low flows. Usable habitat was not correlated with the abundance of juvenile or adult smallmouth bass during any season. They concluded that usable habitat limited the three riffle dwelling species, but did not effect the lotic-lentic species. Riffle species apparently used similar microhabitat for feeding and resting, while the smallmouth bass did not rest in areas where it fed. The use of WUA/discharge relations for recommending instream flows was justified for riffle dwelling fishes for which relations between standing stock and WUA have been established.

The bigeye shiner (Notropis boops), northern hog sucker (Hypentilium nigricans), and greenside darter (E. blennioides) preferred an area somewhat between riffle and pool. These species were commonly taken in depths from 0 - 70 cm, velocities of 0 - 50 cm/sec, and gravel-rubble-boulder substrate and were not a pool species. During low flow bigeye shiners were taken in shallow slow riffles and periodically in shallow pools (Table 1).

Longear sunfish (Lepomis megalotis), green sunfish (L. Cyanellus), and smallmouth bass (Micropterus dolomieui) were captured in a wide variety of habitat depending on the fish's age (Table 1). Juveniles were taken in shallow slow-fast riffles, 0 - 30 cm in depth, 0 - 50 cm/sec velocity and gravel-rubble substrate. With increasing size the fish preferred slower and deeper water (0 30 cm/sec velocity, 0 - 120 cm depth, rubble-boulder to boulder-bedrock substrate). During the summer, juveniles were more frequently taken in riffle areas. Abundance of sunfish did not increase with WUA. Usable gravel-rubble substrate was dominant in many areas, while gravel or gravel-sand areas were lacking. Abundance of smallmouth bass was higher in summer-fall than winter-spring. This compares favorably with Glover Creek, Oklahoma studies by Orth and Maughan (1982).

We correlated total fish weight and number with WUA for various collecting sites and flow periods.

Both total weight (r^2=0.94) and number (r^2=0.61) were positively correlated with WUA. This may be primarily due to the large number of riffle dwelling species (darters, madtoms, juvenile sunfish, and stonerollers) inhabiting riffle areas. Depth-fish number (r^2=0.03, velocity-fish weight (r^2=0.07) and velocity-fish number (r^2=0.29) were not be strong positive correlations.

Moyle and Vondracek (1985) have found that stream fish assemblage structure was persistent in small streams despite variable flow conditions. This suggested that biotic interactions played an important role in fish population regulation. In other streams, Grossman et al. (1985) and Schlosser (1985) suggested that stochastic factors such as variable flow, may be important, resulting in more variable fish assemblage structure.

Draft WUA-discharge curves for the eleven target species have been formulated. Filipek et al. (1987) analyzed WUA-discharge curves for various life stages of white crappie (Pomixis annularis), slough darter (E. gracile), smallmouth buffalo (Ictiobus bubalus), and channel catfish (Ictalurus punctatus) from an IFIM study on the L'Anguille River near Colt, Arkansas as part of the evaluation of the Arkansas Method.

Application of the Arkansas Method to small Forest streams located in various Arkansas Ecoregions is currently being evaluated. The nature of monthly flows during the low flow period July-October poses numerous problems. Analysis of mean monthly flow data from 1948 to 1970 in the North Fork of Illinois Bayou near Scottsville, Arkansas indicated July-October flows were biased by occasional flood events. On the average, over 23 years mean and median flows for this time period differ from 60-80%. This period is critical for Ozark and Ouachita stream fishes because stream reaches are dominated by intragravel flow. The Arkansas Method, based on mean monthly flow provides adequate protection of the fishery but does not account for total flow of streams. As part of the current instream flow study, the Arkansas Game & Fish Commission and Forest Service are evaluating subsurface flows during the low flow unit.

CURRENT STATUS

Stream reaches throughout all ecoregions in Arkansas have been selected as permanent sample sites. Field flow measurements, habitat analyses, water quality measurements, and quantitative fish samples are being collected using flow periods outlined in the Arkansas Method. This information will be correlated with habitat suitability curves determined for eleven species of fish common to Arkansas' ecoregions. WUA-discharge is being compared at all permanent sample sites. Once WUA-discharge curves are constructed we will be able to recommend instream flows for fish species.

Table 1. Substrate, velocity, depth, and habitat type requirements of eleven target fish species found on the Ozark and Ouachita National Forests, Arkansas.

Species	Substrate	Velocity	Depth	Habitat Type
Slender Madtom	gravel-rubble	0 - 60 cm/sec	0 - 30 cm	shallow fast riffle
Banded Sculpin	gravel-rubble	0 - 50 cm/sec	0 - 30 cm	shallow fast riffle
Orangethroat Darter	gravel-rubble	0 - 60 cm/sec	0 - 30 cm	shallow fast riffle
Orangebelly Darter	gravel-rubble	0 - 60 cm/sec	0 - 30 cm	shallow fast riffle
Greenside Darter	gravel-rubble	0 - 90 cm/sec	10 - 50 cm	shallow fast-slow deep riffle
Bigeye Shiner	gravel-rubble boulder-bedrock	0 - 60 cm/sec	10 - 50 cm	shallow fast-slow deep riffle
Longear Sunfish	gravel-rubble boulder-bedrock	10 - 50 cm/sec	10 - 120 cm	shallow fast-slow deep riffle-pool
Green Sunfish	gravel-rubble boulder-bedrock	10 - 60 cm/sec	10 - 120 cm	shallow fast-slow deep riffle-pool
Smallmouth Bass	gravel-rubble boulder-bedrock	10 - 60 cm/sec	10 - 210 cm	shallow fast-slow deep riffle-pool
Northern Hog Sucker	gravel-rubble boulder-bedrock	0 - 60 cm/sec	10 - 50 cm	shallow fast-slow deep riffle
Central Stoneroller	gravel-rubble boulder-bedrock	0 - 60 cm/sec	0 - 50 cm	shallow fast-slow riffle

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