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Recovery of a Warmwater Fish Assemblage after the Initiation of a Minimum-Flow Release Downstream from a Hydroelectric Dam

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Abstract.—Artificial fluctuations in streamflow caused by hydroelectric power dams can degrade fish habitat and reduce the abundance and diversity of riverine fish faunas. Increased minimum water releases and reduced fluctuations in discharge may mitigate these effects. In this study, we compared shoreline fish abundance and diversity before and after an enhanced flow regime was implemented on the Tallapoosa River (Alabama) downstream of a hydroelectric dam. Before the minimum-flow regime, only eight species of fish were collected 3 km downstream from the dam, and all were classified as macrohabitat generalists. After the minimum flow was initiated, species richness 3 km below the dam more than doubled, and over half of the species collected were classified as fluvial specialists. Fish community response to the enhanced flow was not as great at a site 37 km downstream from the dam, where species richness was similar between the two periods. However, more species classified as fluvial specialists were collected after the minimum flow regime than before enhanced flows at this site. Additionally, relative abundance of species classified as fluvial specialists increased from less than 40% of fish collected before enhanced flows to over 80% after minimum flows began. Our results suggest that the enhanced flow regime provided conditions supporting a relatively abundant and diverse fish assemblage more reflective of a riverine system.

The United States has sustained a major loss in the diversity of fish and other taxa in rivers and streams (Benke 1990; Hughes and Noss 1992; Allan and Flecker 1993) resulting primarily from habitat degradation. One pervasive form of habitat degradation in rivers is modification of natural flow (Fraser 1972; Ward and Stanford 1983) by discontinuous and erratic water releases from hydroelectric dams. There is clear empirical evidence showing that highly regulated flows alter stream communities (Petts 1984; Cushman 1985; Irvine 1985). Many hydroelectric dams are currently undergoing relicensing by the Federal Energy Regulatory Commission and this process permits fishery agencies to request enhanced flow regimes to restore fish resources. However, direct evidence is scarce that increased minimum flows and reduced flow fluctuations downstream from hydroelectric dams result in more abundant and diverse river fish communities.

Bain et al. (1988) identified artificial flow fluctuations from hydroelectric dams as a disturbance that degrades fish communities, and Bain and Boltz (1989) hypothesized that rivers downstream of hydroelectric dams would exhibit a longitudinal (i.e., upstream–downstream) gradient of change in fish community characteristics. The hypothesized fish community gradient was regarded as a recovery gradient because disturbance effects would diminish with downstream attenuation of flow fluctuations. Near hydroelectric dams with erratic water releases, shoreline fish assemblages would be expected to be sparse and dominated by species that maintain populations in a wide variety of aquatic systems (macrohabitat generalists) because the shoreline is continually relocated by fluctuating water levels. With increasing distance downstream, the extent of artificial flow fluctuation would decline because of the dynamics of pool storage (channel pondage, Dunne and Leopold 1978) and inflow from tributaries and groundwater, and the shoreline fish assemblage would be expected to become more abundant and diverse with the addition of species largely restricted to rivers and streams (fluvial specialists).

Kinsolving and Bain (1993) tested this hypothesis and found that the shoreline fish assemblage near Thurlow Hydroelectric Dam on the Tallapoosa River in Alabama was depauperate and dominated by macrohabitat generalists. With declines in the magnitude of flow fluctuations downstream of the dam, fish assemblages became more abundant and diverse as fluvial specialists were added. Scheidegger and Bain (1995) documented a similar pattern of regulated flow effects on the larval fish assemblage in the Tallapoosa River, with the clearest effects evident in shallow, shoreline waters. After these studies were completed, a continuous minimum water release of 34 m^3/s from Thurlow Dam began in February 1991 as part of the relicensing agreement for this hydroelectric project.

Based on past studies of Tallapoosa River fishes and the general model of regulated flow effects developed in Bain and Boltz (1989), we predicted that minimum flows below Thurlow Dam on the Tallapoosa River should increase abundance and diversity of fish. In the present study, we compared shoreline fish collections before and after minimum water releases from Thurlow Dam. Specifically, we tested the prediction that enhanced flows would increase diversity and abundance of shoreline fishes near the dam and shift assemblage dominance from macrohabitat generalists to fluvial specialists because of changes in water depth and velocity. We focused on the shallow shoreline fish assemblage because (1) these habitats are important refugia and nursery waters for many river fishes (Schlosser 1985, 1987; Copp 1989); (2) shoreline habitats can contain the majority of fish species in a river (Bain et al. 1988; Lobb and Orth 1991); (3) shoreline habitats are most sensitive to fluctuating streamflow effects (Bain et al. 1988), and (4) obtaining quantitative samples of fish in deep, main-channel river habitats is often difficult (Mahon 1980; Mann and Penczak 1984).

Methods

The Tallapoosa River in east-central Alabama (Figure 1) has been extensively developed for hydroelectric power production. This river has an average annual discharge of 135 m^3/s and is considered a medium-sized river (order 7) in the context of the river continuum concept of Vannote et al. (1980). Fish were sampled in two 2-km sections of the Tallapoosa River downstream of Thurlow Dam, the lowermost hydroelectric dam above the confluence of the Coosa and Tallapoosa Rivers. The most upstream site was about 3 km downstream of Thurlow Dam (Figure 1). From 1988 through 1990, 27 fish samples were collected in shallow, shoreline waters before enhanced minimum flow releases began. Another 27 samples were collected in the same area during 1992, a year after the enhanced minimum flow regime was implemented. A second 2-km-long study site was 37 km downstream from Thurlow Dam (Figure 1). At this site, 30 samples were collected from 1988 through 1990, and 30 samples were collected in 1992.

Each 2-km study site was divided into ten 200-m potential sampling segments. During each day of sampling, we selected a 200-m segment with a random number table. To select the sampling location within the 200-m segment, we traveled a randomly selected number of seconds (range 0–60) from the upstream end of the 200-m segment. If the randomly selected location had shoreline depths greater than 1 m, the site was rejected, and the first location encountered shallower than 1 m was used. Except for three samples collected in December 1990 at the upper site, samples were taken from March through September at about 16-d intervals (range 5–32 d) during both preminimum and postminimum flow periods.

Fish were collected with pre-positioned area electrofishers (Bain et al. 1985; Bain and Finn 1991), and sampling protocols followed those of Kinsolving and Bain (1993). Our sampling design allowed us to characterize conditions during low-flow periods both before and after the instituted minimum flow. We sampled only during periods of nongeneration during preminimum flow conditions, whereas after the minimum flow regime was instituted, we sampled during periods when only the minimum flow was being discharged. Collections were not made at any other time because higher discharges precluded sampling. All fish were preserved in the field and later identified in the lab. The electrofishers used in 1988 measured 1.5 × 12 m but were smaller (1.5 × 6 m) starting in 1989. To determine if reduced size of electrofishers changed capture efficiency of fish, we compared density of fish collected with the large electrofisher in 1988 to density of fish collected with

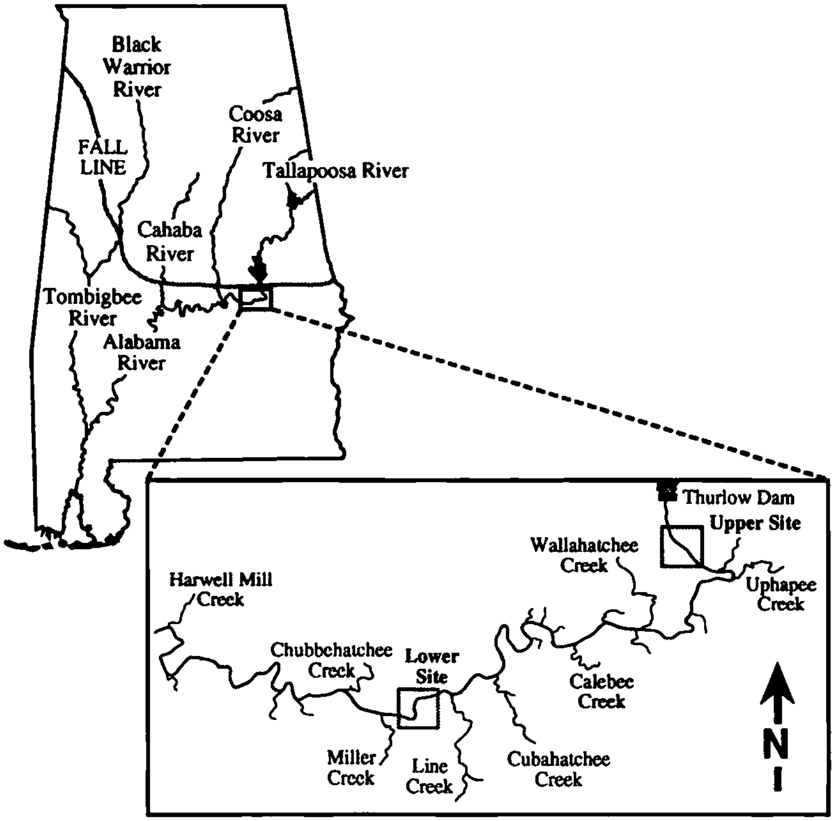

FIGURE 1.—Sampling locations on the Tallapoosa River, Alabama.

the small electrofisher in 1989 and 1990 using data from the lower site. Capture efficiency was similar (t = 1.49, df = 26, P = 0.15) between the two sizes. Therefore, data from the preminimum flow period were pooled, and density (N/100 m^2) was computed for each species to account for the change in size of the electrofishers.

All species were categorized as fluvial specialists or macrohabitat generalists with information on habitat use and distribution compiled from Scott and Crossman (1973), Pflieger (1975), Lee et al. (1980), Becker (1983), Burr and Warren (1986), Robison and Buchanan (1988), and Etnier and Starnes (1993). Species classified as fluvial specialists were usually reported from streams and rivers and often described as requiring flowing-water habitats throughout life. Some information may have indicated that a species is occasionally found in lakes or reservoirs, but most information indicated a strong association with riverine environments. Macrohabitat generalists included those species that were commonly found in lakes, reservoirs, and streams and could complete their life cycle in many of these environments. In most cases, the category for a species was obvious. However, even rheophilic species such as darters (Percidae) have sometimes been recorded in reservoirs; consequently, the distinction between groups is not always clear.

After fish were collected, water depth was measured to the nearest centimeter, and mean water column velocity (cm/s) was recorded at 0.6 maximum depth with a Marsh–McBirney flowmeter. Mean values for water depth and current velocity were then used to test for differences in these microhabitat characteristics in shallow shoreline waters under low-flow conditions (between 0 and 34 m^3/s) with a t-test.

We used Morisita's index of community similarity (Morisita 1959; Brower and Zar 1984) to evaluate temporal changes in fish assemblage composition between pre- and postminimum flow years. Morisita's index derives values from zero (no faunal similarity) to about 1.00 (identical fauna) and is usually insensitive to rare or missing species (Hurlbert 1978); therefore, the index gives greater weight to changes in abundant species. Ross et al. (1985) considered values less than 0.3 and greater than 0.7 to be indicative of distinct and indistinct faunal groups, respectively, and we used these values to differentiate between distinct and indistinct assemblages in our study. We also used Spearman's rank correlation to examine changes in assemblage composition. A high correlation between ranked species densities between pre- and postminimum flow periods would indicate that the minimum flow regime had little effect on assemblage composition.

Finally, we identified individual species whose numbers increased or decreased after the enhanced minimum flow regime was initiated. A sign test was used to test if species classified as fluvial specialists responded differently as a group to the enhanced flow regime than did species classified as habitat generalists. A significant ($P < 0.10$) result from the sign test indicated that abundance of species in that particular group changed at each site. We chose an alpha level of 0.10 for this test because the sign test has the disadvantage of eliminating information on the magnitude of differences between the two periods being compared (i.e., large unidirectional changes in abundance for a few species can be masked if small changes in abundance occur for the same number of species in the opposite direction).

Results

Before 1991, river discharge below Thurlow Dam fluctuated frequently, often daily, and ranged from 0 to about 225 m^3/s (Figure 2). The enhanced flow regime that began in 1991 did not eliminate daily fluctuations in flow. However, the enhanced flow regime did reduce the severity of fluctuations by increasing the minimum flow present at all times. Daily peaks still occurred at about 225 m^3/s, but minimum daily discharges rarely dropped below 34 m^3/s (Figure 2). Consequently, flowing water microhabitats were always present downstream of Thurlow Dam under the enhanced flow regime. Although minimum flows decreased the severity of daily flow fluctuations, mean daily discharges were similar before and after the enhanced flow regime was instituted and averaged 134.4 m^3/s from 1988 through 1990 and 134.7 m^3/s from 1991 through 1992. Additionally, mean daily discharges from Thurlow Dam during 1988–1992 were similar and averaged 72, 164, 168, 122, and 148 m^3/s, respectively. Thus, the primary difference in flow regime between pre- and postminimum flow periods was the maintenance of a minimum flow.

At the upstream site, the mean water depth of 1988–1990 samples was 0.16 m during periods of nongeneration. During periods of minimum flow releases (34 m^3/s), mean water depth in sampled microhabitats increased ($P < 0.01$) to 0.40 m. Mean current velocity in sampled areas was also higher ($P < 0.01$) when discharge was 34 m^3/s compared with preminimum flow periods (0.16 m/s and 0.04 m/s respectively).

Unlike the case for the upstream site, enhanced flows did not change ($P \geq 0.19$) water depth or

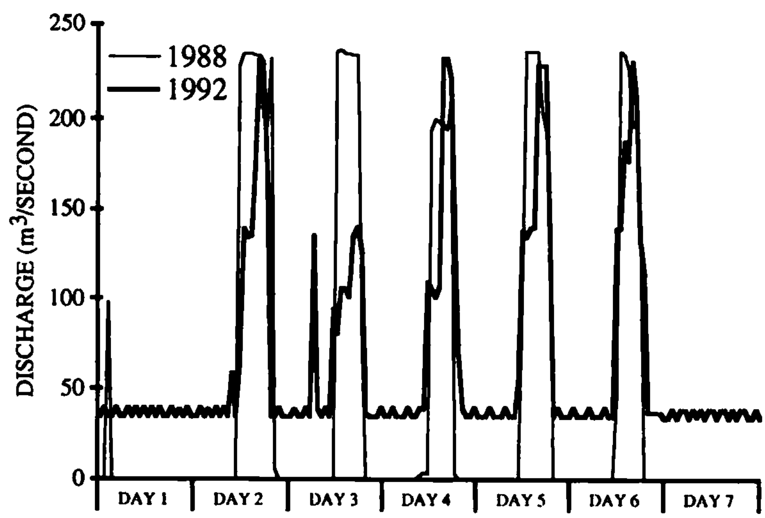

FIGURE 2.—Hourly discharge from Thurlow Dam for a representative 7-d period in early July without minimum flows (1988) and under the enhanced flow regime (1992).

TABLE 1.—Density of species in shoreline samples (±95% confidence intervals) at the site 3 km below Thurlow Dam before and after the enhanced minimum flow regime was implemented. The "response" column indicates the overall increase (+) or decrease (−) in catch between the two time periods (1988–1990 and 1992). Species were classified as fluvial specialists (FS) or macrohabitat generalists (HG).

Common name	Scientific name	Density (number/100 m²) Preminimum flow	Density (number/100 m²) Postminimum flow	Response	Macrohabitat classification
Speckled chub	*Macrhybopsis aestivalis*	0 ± 0	2.9 ± 21.9	+	FS
Silver chub	*Macrhybopsis storeriana*	0 ± 0	0.5 ± 4.9	+	FS
Clear chub	*Notropis winchelli*	0 ± 0	0.5 ± 4.9	+	FS
Emerald shiner	*Notropis atherinoides*	2.4 ± 24.8	5.4 ± 38.0	+	HG
Pretty shiner	*Lythrurus bellus*	0 ± 0	0.5 ± 4.9	+	FS
Alabama shiner	*Cyprinella callistia*	0 ± 0	0.5 ± 4.9	+	FS
Fluvial shiner	*Notropis edwardraneyi*	0 ± 0	21.4 ± 152.9	+	FS
Weed shiner	*Notropis texanus*	1.4 ± 8.9	3.4 ± 34.7	+	HG
Skygazer shiner	*Notropis uranoscopus*	0 ± 0	6.3 ± 41.9	+	FS
Blacktail shiner	*Cyprinella venusta*	0.2 ± 2.1	0 ± 0	−	HG
Bullhead minnow	*Pimephales vigilax*	0 ± 0	2.9 ± 29.8	+	HG
Alabama hog sucker	*Hypentelium etowanum*	0 ± 0	0.5 ± 4.9	+	FS
Redbreast sunfish	*Lepomis auritus*	1.4 ± 7.3	1.5 ± 8.3	+	HG
Bluegill	*Lepomis macrochirus*	0 ± 0	8.3 ± 79.4	+	HG
Longear sunfish	*Lepomis megalotis*	0.5 ± 4.9	0 ± 0	−	HG
Redear sunfish	*Lepomis microlophus*	0.2 ± 2.1	0 ± 0	−	HG
Spotted bass	*Micropterus punctulatus*	1.7 ± 11.5	0.5 ± 4.9	−	HG
Largemouth bass	*Micropterus salmoides*	0.8 ± 6.6	0.5 ± 4.9	−	HG
Speckled darter	*Etheostoma stigmaeum*	0 ± 0	2.9 ± 20.6	+	FS
Blackbanded darter	*Percina nigrofasciata*	0 ± 0	1.5 ± 10.9	+	FS
Bronze darter	*Percina palmaris*	0 ± 0	4.9 ± 37.3	+	FS
Banded sculpin	*Cottus carolinae*	0 ± 0	14.1 ± 54.4	+	FS

current velocity at the downstream site. Mean water depth of sampled areas was 0.26 m during nongeneration periods and 0.22 m when discharge was 34 m^3/s. Mean current velocity within sampled areas was 0.11 m/s before the minimum flow regime and 0.13 m/s after.

The shoreline fish assemblage was depauperate at the upstream site during the preminimum flow years. Eight species were represented by 30 individuals collected from 1988 to 1990 (Table 1). Species richness more than doubled (19 species), and the number of individuals collected was five times as great (162 individuals) under the enhanced flow regime. Samples without fish dominated (70%) collections before the enhanced flow regime, whereas after it began, samples without fish decreased to 30%.

Differences in the recorded fish assemblage during the pre- and postminimum flow periods at the upstream site involved changes in both species composition and fish abundance. All eight species collected before the minimum flow regime began were macrohabitat generalists (Table 1). Dominant species included emerald shiners, weed shiners, redbreast sunfish, and spotted bass. A year after the enhanced flow regime began, the shoreline community was composed of both macrohabitat generalists and fluvial specialists, with the latter accounting for over 70% of the fish collected. The dominant species in 1992 included such fluvial species as speckled chubs, fluvial shiners, skygazer shiners, speckled darters, bronze darters and banded sculpins (Table 1).

Preminimum and postminimum flow fish assemblages were very dissimilar. Morisita's index of similarity was 0.192 between the preminimum and postminimum flow periods at the upstream site. Similarly, Spearman's rank correlation was low (−0.267) and nonsignificant ($P > 0.05$). The sign test indicated that the density of fluvial specialists increased ($P < 0.001$), whereas the density of macrohabitat generalists did not change ($P = 1.00$).

The fish assemblage at the downstream site was much more diverse than at the upstream site. From 1988 to 1990, 26 species and 1,573 individuals were collected in 30 samples. After the enhanced flow regime began, we collected 26 species and 1,005 individuals in 30 samples. Samples without fish were uncommon both before and after the enhanced flow regime (13% for each period).

Before the enhanced flow regime, macrohabitat generalists accounted for a majority (60%) of the fish collected at the downstream site, but species richness was almost equally divided between mac-

TABLE 2.—Density of species in shoreline samples (±95% confidence intervals) at the site 37 km below Thurlow Dam before and after the enhanced minimum flow regime was implemented. The "response" column indicates the overall increase (+) or decrease (−) in catch between the two time periods (1988–1990 and 1992). Species were classified as fluvial specialists (FS) or macrohabitat generalists (HG).

Common name	Scientific name	Density (number/100 m²)		Response	Macrohabitat classification
		Preminimum flow	Postminimum flow		
Largescale stoneroller	*Campostoma oligolepis*	1.9 ± 16.3	1.8 ± 11.2	−	FS
Silverjaw minnow	*Notropis buccatus*	2.4 ± 16.7	64.5 ± 610.3	+	FS
Speckled chub	*Macrhybopsis aestivalis*	1.1 ± 9.6	91.2 ± 533.4	+	FS
Silver chub	*Macrhybopsis storeriana*	0 ± 0	12.3 ± 92.6	+	FS
Clear chub	*Notropis winchelli*	1.6 ± 12.1	10.5 ± 108.2	+	FS
Emerald shiner	*Notropis atherinoides*	5.3 ± 43.2	10.5 ± 98.9	+	HG
Rough shiner	*Notropis baileyi*	2.2 ± 16.7	0.9 ± 6.5	−	FS
Silverside shiner	*Notropis candidus*	0 ± 0	8.8 ± 89.4	+	FS
Fluvial shiner	*Notropis edwardraneyi*	32.6 ± 314.7	121.9 ± 575.4	+	FS
Orangefin shiner	*Notrpois ammophilus*	17.7 ± 137.4	5.3 ± 36.2	−	FS
Silverstripe shiner	*Notropis stilbius*	1.3 ± 14.1	0 ± 0	−	FS
Weed shiner	*Notropis texanus*	0.6 ± 4.4	0 ± 0	−	HG
Skygazer shiner	*Notropis uranoscopus*	91.2 ± 762.4	28.9 ± 98.7	−	FS
Blacktail shiner	*Cyprinella venusta*	129.7 ± 796.5	46.5 ± 181.8	−	HG
Mimic shiner	*Notropis volucellus*	66.2 ± 596.6	6.6 ± 25.1	−	FS
Bullhead minnow	*Pimephales vigilax*	229.9 ± 2,332.2	13.2 ± 48.8	−	HG
Quillback	*Carpiodes cyprinus*	1.6 ± 12.7	0.4 ± 4.7	−	FS
Smallmouth buffalo	*Ictiobus bubalus*	0 ± 0	0.4 ± 4.7	+	HG
Blackspotted topminnow	*Fundulus ovliaceus*	0.2 ± 2.0	0 ± 0	−	HG
Western mosquitofish	*Gambusia affinis*	32.5 ± 209.9	0.9 ± 9.4	−	HG
Redbreast sunfish	*Lepomis auritus*	0.2 ± 2.0	0 ± 0	−	HG
Green sunfish	*Lepomis cyanellus*	2.6 ± 28.3	0 ± 0	−	HG
Bluegill	*Lepomis macrochirus*	9.7 ± 52.5	0.9 ± 9.4	−	HG
Longear sunfish	*Lepomis megalotis*	13.3 ± 100.6	0.4 ± 4.7	−	HG
				+	HG
Spotted bass	*Micropterus punctulatus*	0.6 ± 3.3	1.3 ± 10.4	−	HG
Largemouth bass	*Micropterus salmoides*	1.9 ± 14.8	0 ± 0	+	FS
Naked sand darter	*Ammocrypta beani*	0 ± 0	1.3 ± 7.9	+	FS
Speckled darter	*Etheostoma stigmaeum*	0.7 ± 6.2	3.5 ± 17.8	+	FS
Blackbanded darter	*Percina nigrofasciata*	0.4 ± 4.7	0.9 ± 6.5	+	FS
Saddleback darter	*Percina vigil*	0 ± 0	2.2 ± 23.5	+	FS
Bronze darter	*Percina palmaris*	0 ± 0	3.9 ± 27.2	+	FS
Banded sculpin	*Cottus carolinae*	0.6 ± 5.9	1.8 ± 8.9	+	FS

rohabitat generalist (12) and fluvial specialist species (14) (Table 2). In 1992, 18 fluvial specialist species were collected, compared with 8 macrohabitat generalists (Table 2). The relative abundance of fluvial specialists increased to over 80% of the fish collected; the majority were cyprinid species including fluvial shiners, speckled chubs and silverjaw minnows.

Morisita's index of similarity was 0.320, indicating low similarity between the two assemblages. Spearman's rank correlation was 0.302 ($P < 0.05$) between the pre- and post-minimum flow assemblages at the lower site. Although the rank correlation was statistically significant, the low correlation coefficient indicated little biological similarity before and after the enhanced flow. The results from the sign tests for this site indicated that the abundance of fluvial specialists did not change ($P = 0.33$), but the abundance of macrohabitat generalists decreased ($P = 0.09$).

Discussion

Before the enhanced flow regime began in 1991, highly variable water releases created periods of low velocity and shallow shoreline habitats. These areas were sparsely occupied by a few macrohabitat generalist fishes, and empty microhabitats were very common. At the downstream site, fish were more abundant and assemblage composition was more diverse, with both macrohabitat generalists and fluvial specialists present. One year after the enhanced flow regime was implemented, shoreline microhabitats at the upstream site had constantly flowing water which was often deeper than before. The fish assemblage also shifted, with about twice as many species, five times the number of fish, a greater frequency of samples containing fish, and a major complement of fluvial specialist species. As expected, changes in the fish assemblage and habitat were less pronounced at the downstream site, but species composition did shift to one dominated by fluvial specialists. Overall, our results indicated that the enhanced flow regime provided conditions that support a diverse fish assemblage more reflective of a riverine system, particularly at the upstream site.

The frequency of flow fluctuations from Thurlow Dam did not change with enhanced minimum flows. Instead, the enhanced flow regime provided microhabitats with flowing water during non-peak generation periods and reduced the magnitude of flow fluctuations. Previous investigators studying fish communities along flow-regulated rivers (Bain et al. 1988; Kinsolving and Bain 1993; Scheidegger and Bain 1995) could not determine the relative impact of microhabitat instability caused by flow fluctuations and the impact caused by periodic loss of flowing water microhabitats. Although the present study was not designed to compare relative importance of microhabitat instability in relation to flow fluctuations with periodic loss of flowing water microhabitats, our results suggested that the continuous presence of flowing waters may be more important because the magnitude of flow fluctuations remained large after 1991. Thus, minimum flow regimes appear to be useful in enhancing fish assemblages below peaking hydroelectric facilities.

Weisberg and Burton (1993) examined the effects of a minimum flow regime on growth and condition of three fish species below a hydroelectric dam in Maryland. They found that growth and condition were both significantly higher after enhanced minimum flows began. Wolff et al. (1990) examined the effects of increased minimum flow on standing stock of brown trout *Salmo trutta* in Douglas Creek, Wyoming. Higher minimum flows were associated with 2 to 6-fold increases in standing stock of brown trout in the first 10 km below the dam. Paller et al. (1992) suggested that habitat quality for fish is largely determined by the flow rate of water in southeastern streams. The findings of these evaluations of minimum flow enhancements on certain species support our findings at the assemblage level, and they reinforce the importance of minimum flow regulations for enhancing fish resources.

Our results indicated that the greatest changes in assemblage composition and gains in fish abundance and diversity were attributable to restoring fluvial species that dominate collections in many streams and rivers. The less pronounced effect of enhanced flows on abundance and diversity of macrohabitat generalists was consistent with the hypothesis that flow regulation has little direct effect on species with broad habitat requirements. Studies on rainbow trout *Oncorhynchus mykiss* (Irvine 1987) and adult smallmouth bass *Micropterus dolomieu* (Bain et al. 1988) have indicated that highly regulated streamflows may not adversely affect species that thrive in lentic environments. The differential response of generalists and specialists corresponds with that of other studies, indicating that eurytopic species cope with habitat alterations better than stenotopic species (reviewed in Poff and Ward 1990).

In the present study, we posed and tested predictions in an unreplicated pre- and postexperiment without a control representing an unaltered river. There are relatively few unregulated and unimpounded rivers in the United States (Benke 1990), and future demands for river development will continue to cause declines in unaltered systems. It may already be impossible to develop truly controlled, replicated, large-scale river experiments. However, unreplicated experiments have provided extremely valuable data and understanding in fisheries (Carpenter 1989). Although we used statistics to detect change, our approach does not circumvent the lack of system replication. Nevertheless, this study does provide evidence for specific predictions developed independently from studies on the Tallapoosa River as well as from rivers in different regions in the United States.

The task of identifying the adequacy of any particular enhanced flow regime for restoring degraded fish communities remains undone. Schindler (1987) suggested monitoring sensitive ecosystem components as one approach. Fluvial specialist fishes as a group appear sensitive to flow-related disturbance, and measuring their relative abundance and diversity is practical for assessing mitigation measures intended to benefit fish. More study of enhanced flows is needed to further define the adequacy of different minimum flow levels and effects of reduced flow fluctuations. Nevertheless, our results provide empirical evidence that enhanced flows below hydroelectric dams can restore riverine fish resources and increase their diversity and abundance.

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