JOURNAL OF THE TENNESSEE ACADEMY OF SCIENCE 70(3-4):65-76 JULY-OCTOBER 1995

INTRODUCED SPECIES OF FISHES IN THE SOUTHERN APPALACHIANS: CONSEQUENCES FOR CONSERVATION

CAROL E. JOHNSTON, JOHN S. RAMSEY, STEPHEN T. SOBASKI, AND C. KELLY SWING

Center for Biodiversity, Illinois Natural History Survey, Champaign, IL 61820
Office of Information Transfer, United States Fish and Wildlife Service, Fort Collins, CO 80524
Center for Aquatic Ecology, Illinois Natural History Survey, Champaign, IL 61820
Museum of Natural Science, Louisiana State University, Baton Rouge, LA 70893
Present address of CEJ: USDA Forest Service, Forest Hydrology Laboratory, Oxford, MS 38655
Present of address of CKS: Universidad San Francisco de Quito, Quito, Ecuador

ABSTRACT—Sites from four major river drainages (Chattahoochee, Savannah, Tennessee, and Santee) in the Southern Appalachians were sampled for fishes in 1962 and 1990. Numerous unusual or new drainage records were discovered during both sampling periods. Due to the faunal distinctiveness of these drainages, the probable origins of these species can be traced. Although the distributions of some species may support hypotheses of headwater stream capture between drainages, the possibility of human introduction cannot be dismissed, and the presence of some species is almost certainly the result of introduction. The potential consequences of these introductions on the maintenance of fish diversity in the drainages of the Southern Appalachians is discussed.

Faunal surveys conducted by universities or state or federal agencies at benchmark localities and regular intervals provide a continuous record for tracking changes in faunal composition and population dynamics of individual species. Such changes might be indicative of habitat degradation, species introduction, or other antropogenic perturbation. Early warning of changes at localities present managers and conservationists with an opportunity to address problems before biodiversity is lost and damage is irreparable. However, despite the value of such information, historical and current surveys are unavailable for most drainages.

The invasion of exotic organisms is viewed as one of the most serious threats to conservation in coming years (Coblentz, 1990; Soule, 1990). Although changes in the range of plant and animal species is a natural process, it is being accelerated by humans (Lodge, 1993) with unknown effects. Stocking of fishes (including game species), accidental introductions, and habitat alteration via drainage linkage contribute to the breakdown of faunal distinctiveness. The impact of introduced species on native faunas is difficult to predict; yet, it is often negative, leading to the decline of one or more native species (Lemley, 1985; Allendorf and Leary, 1988). An extreme example of species introduction is the New River in Virginia, where 43% of the fish species present have been introduced within the past 30 years (Hocutt et al., 1996). The numbers of introduced species in other drainages of the Southeast are not well documented.

A survey of fishes of many river drainages of the Southern Appalachians was conducted by Ramsey (1962, 1965). Numerous drainage records of species known only from nearby rivers were found during this survey. This work provided the impetus for reassessing the status of these unusual populations and to document any new records of species (probable introductions). Our objective was to resample many of the sites surveyed in 1962 and document any changes in the fish fauna of these drainages.

MATERIALS AND METHODS

Thirty-three of the 137 sites surveyed by Ramsey (1962) were re-surveyed in 1990 (Fig. 1, Appendix I). Sites of potential headwater stream capture, unusual records of species, or potential conservation importance were selected for re-sampling in 1990. Collections were made at a minimum of two sites per river drainage. The construction of major impoundments (Lake Jocassee) or other hydroelectric facilities (Bad Creek) made surveys of most of the original sites on the Toxaway, Whitewater, and Thompson rivers (Keowee River drainage) impossible.

Procedures used in the original survey were followed as closely as possible. Seines (3.05 m in length) were used for all collections, with a sampling duration of 60-75 min. All accessible habitats were sampled. In 1962, collections were made from June through August; in 1990, collections were made primarily during October. The collections from 1962 were deposited primarily at the Tulane University Museum of Natural History and the University of Richmond, Virginia. Collections from 1990 were deposited at the Illinois Natural History Survey.

RESULTS

Species collected in 1962 and 1990 are presented in Tables 1-8. Numbers of species and individuals and percent species composition are summarized for each drainage by site and survey. The total number of species common between years and the percentage shared between years (number of species shared/total number of species) also are summarized for each site.

Savannah River Drainage—Three major tributaries of the Savannah River have headwaters in the montane Highlands region. These are, from east to west, the Keowee, Chattooga, and Tallulah rivers. A total of 13 sites on these three rivers was sampled (Tables 1-3; Appendix I). Much of the Keowee River has been impounded, and many of the sites

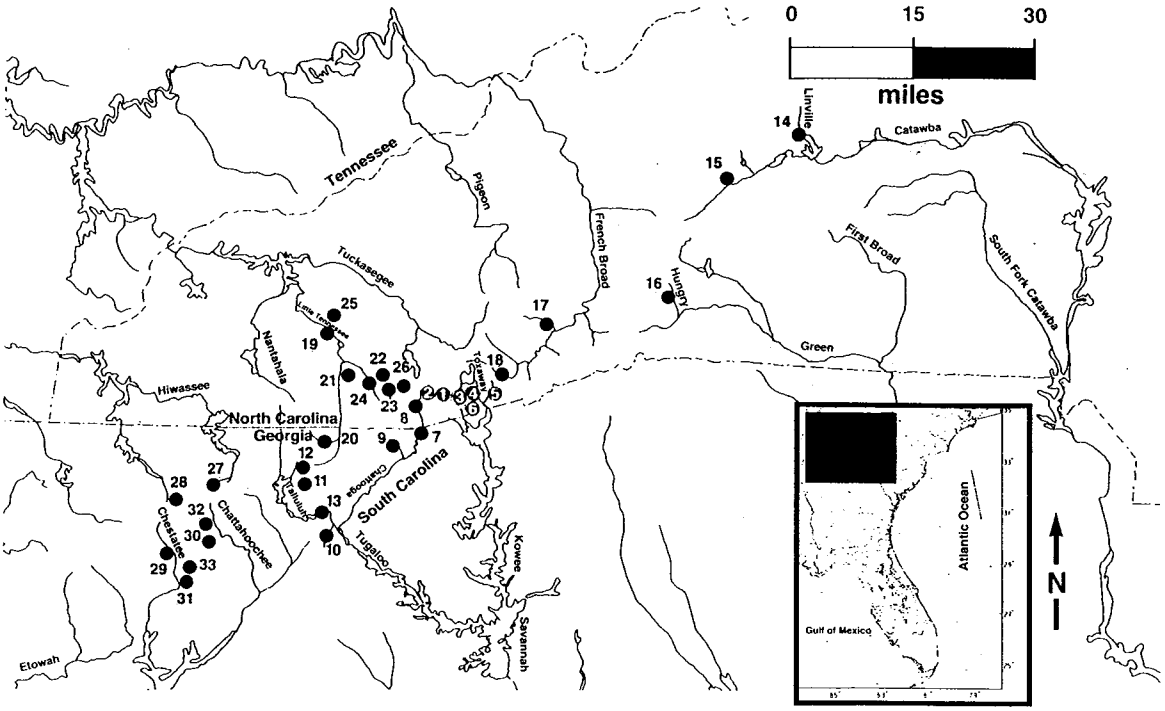

FIG. 1. Sites in four drainages of the Southern Appalachians sampled for fishes (30 miles = 48.28 km). Locations of sites are described in Appendix I.

surveyed by Ramsey (1962) were inaccessible. Sites 5 and 6 (Table 1) are from the Toxaway River system, and sites 1-4 are from the Horsepasture River, a major tributary.

Of particular interest is the occurrence of *Notropis rubricroceus*, a Tennessee River species in Toxaway Creek (site 5, Table 1). *Rhinichthys cataractae* and *Luxilus coccogenis*, also shared with the Tennessee River drainage, were present at this site as well.

The Horsepasture River (sites1-4, Table 1) is designated as a North Carolina Natural and Scenic River, which protects it from impoundment but does not restrict land-use except on lands owned by the state. The Horsepasture River currently is bordered along most of its course by housing developments and golf courses, many of which have been built in the system. The fish fauna of this river was not very diverse when collected in 1962, and total species diversity has not changed significantly. Some faunal changes are evident in the species composition, however. Site 3 is dominated by centrarchids, which is unusual for a flowing montane stream. Only three species are shared between the two sampling periods (*Lepomis auritus*, *Luxilus coccogenis*, and *Nocomis leptocephalus*). Four species present in 1962 were not found in 1990. This faunal shift may be due to habitat degradation and the influence of impoundments. Evidence of this was seen in the visible degradation of the site: the water was turbid and oil was obvious on stream debris and on our bodies after sampling. Riparian vegetation had been completely eliminated to the water's edge.

Very few individuals of any species were collected at site 1. Although a riparian zone existed at this site, the water was turbid, perhaps related to nearby construction work. A strong, chlorine odor was evident on approaching the stream, and we suspect that this site has been polluted.

The 1990 samples from sites 2 and 4 share most species with the 1962 samples from the Horsepasture River. *Luxilus coccogenis*, *Notropis spectrunculus*, and *Rhinichthys cataractae* are shared with the Horsepasture River and the Tennessee River.

The Chattooga River (Table 2) was designated a National Wild and Scenic River in 1974. The river is protected by at least a 0.4-km corridor for 80.5 km. Much of the area surrounding the river is wilderness, and access is limited. Collections made in 1990 contained more species and greater numbers of individuals than those made in 1962 at all three sites, which can be interpreted as a sign of habitat improvement, even though the collections were made at slightly different times of the year. *Cyprinella pyrrhomelas*, previously unknown from this drainage, was collected at site 1 and is most likely the result of introductions by fishermen through bait buckets. *Cyprinella galactura*, *Luxilus coccogenis*, *Notropis leuciodus*, *Notropis spectrunculus*, and *Rhinichthys cataractae* are species found here that are shared with the Tennessee River (Table 2). Samples from all sites suggest that the Chattooga River has maintained a healthy fish fauna.

All Tallulah River locations except site 12 produced at least half of the species collected in 1962 (Table 3). The great difference in species composition at site 12 is due primarily to the absence of all centrarchid species in 1990. *Notropis hypselpsis* also was not collected in 1990. The

TABLE 1. List of species and number of specimens (percent relative abundance in parentheses) collected from the Keowee River (Savannah River drainage). Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is four, three, four, and seven for sites 2-5, respectively.

	Site 1[1]	Site 2		Site 3		Site 4		Site 5		Site 6[1]
Species and parameters	1990	1962	1990	1962	1990	1962	1990	1962	1990	1990
Oncorhynchus mykiss	0	0	0	0	0	0	0	P	4 (2.4)	0
Salmo trutta	0	0	0	1 (1.5)	0	0	0	0	0	0
Salvelinus fontinalis	0	0	0	1 (1.5)	0	1 (1.6)	0	0	0	5 (100.0)
Campostoma anomalum	5 (22.7)	29	179 (31.3)	0	4 (9.3)	0	0	4	9 (5.4)	0
Luxilus coccogenis	0	170	187 (32.7)	40 (62.0)	5 (11.6)	30 (47.6)	63 (44.0)	0	20 (12.0)	0
Nocomis leptocephalus	1 (4.5)	7	200 (35.0)	3 (4.6)	7 (16.3)	10 (15.9)	20 (14.0)	27	15 (9.0)	0
Notemigonus crysoleucas	6 (27.3)	0	0	0	0	0	0	0	0	0
Notropis lutipinnis	0	1	0	0	0	0	0	0	0	0
Notropis rubricroceus	0	0	0	0	0	0	0	31	84 (50.3)	0
Notropis spectrunculus	0	0	0	17 (26.1)	0	19 (30.2)	49 (34.3)	0	0	0
Rhinichthys atratulus	0	1	0	1 (1.5)	0	1 (1.6)	0	25	18 (10.8)	0
Rhinichthys cataractae	0	0	0	0	0	0	0	3	12 (7.2)	0
Semotilus atromaculatus	0	0	0	0	0	0	0	0	1 (0.6)	0
Catostomus commersoni	0	0	0	0	0	0	0	0	1 (0.6)	0
Moxostoma rupiscartes	0	0	0	0	0	0	0	5	3 (1.8)	0
Lepomis auritus	9 (40.9)	3	6 (1.0)	3 (4.6)	24 (55.8)	2 (3.2)	4 (2.8)	0	0	0
Lepomis macrochirus	0	P	0	0	0	0	0	0	0	0
Ambloplites rupestris	0	0	0	0	0	0	5 (3.5)	0	0	0
Micropterus dolomieu	0	0	0	0	3 (7.0)	0	2 (1.4)	0	0	0
Micropterus salmoides	1 (4.5)	P	0	0	0	0	0	0	0	0
C. anomalum x *N. leptocephalus*	0	1	0	0	0					
Total	22	211+	572	65	43	63	143	95+	167	5
Species richness	5	9	4	7	5	6	6	7	10	1
Percentage of species shared		44	100	43	40	67	67	100	70	

[1]No data from 1962 available for this site.

TABLE 2. List of species and number of specimens (percent relative abundance in parentheses) collected from the Chattooga River (Savannah River drainage). Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is five, seven, and six for sites 7-9, respectively.

	Site 7		Site 8		Site 9	
Species and parameters	1962	1990	1962	1990	1962	1990
Oncorhynchus mykiss	0	0	P	0	0	0
Salmo trutta	0	0	P	1 (0.1)	P	0
Campostoma anomalum	0	14 (1.8)	0	13 (1.8)	0	0
Clinostomus funduloides	0	1 (0.1)	0	0	0	0
Cyprinella galactura	21 (9.5)	4 (0.5)	0	0	3	11 (2.5)
Cyprinella pyrrhomelas	0	5 (0.6)	0	0	0	0
Luxilus coccogenis	95 (43.0)	39 (5.0)	0	0	15	33 (7.6)
Hybopsis rubrifrons	24 (10.9)	0	0	0	8	58 (13.4)
Nocomis leptocephalus	9 (4.1)	4 (0.5)	2	18 (2.4)	3	1 (0.2)
Notropis leuciodus	3 (1.4)	0	0	0	1	0
Notropis lutipinnis	0	13 (1.7)	0	285 (38.6)	1	6 (1.4)
Notropis spectrunculus	53 (24.0)	667 (86.0)	117	362 (49.0)	0	313 (72.1)
Rhinichthys atratulus	0	9 (1.2)	2	1 (0.1)	0	0
Rhinichthys cataractae	0	5 (0.6)	2	11 (1.5)	0	0
Hypentelium nigricans	4 (1.8)	0	0	0	0	5 (1.2)
Moxostoma rupiscartes	0	14 (1.8)	22	35 (4.7)	2	0
Lepomis auritus	0	0	0	1 (0.1)	0	3 (0.7)
Micropterus coosae	0	0	0	0	0	1 (0.2)
Etheostoma inscriptum	12 (5.4)	1 (0.1)	3	12 (1.6)	24	3 (0.7)
Total	221	776	148+	739	57+	434
Species richness	8	12	8	10	9	10
Percentage of species shared	62	42	88	70	67	60

reasons for these absences is not readily apparent. *Luxilus zonistius* is shared with the Chattahoochee River.

Santee River Drainage—Three sites in the Santee River drainage were sampled. The Linville River is a designated North Carolina Natural and Scenic River (site 14, Table 4). Several species shared with the Tennessee River are present in the Santee River drainage, including *Notropis rubricroceus*, *Notropis spectrunculus*, *Notropis telescopus*, *Luxilus coccogenis*, and *Cyprinella galactura*. *Notropis procne* was collected in 1990 but not in 1962, perhaps indicating the spread of this species or introduction by fishermen. *Micropterus coosae*, an unusual species record for the Santee drainage, was collected at site 1 in 1962 but not in 1990. Sites 15 and 16 (Table 4) appear mostly unchanged between the two sampling periods.

Tennessee River Drainage—Collections were made at two sites in the French Broad River in 1962 and 1990 (Table 5). Fewer species were collected at both sites in 1990. Three species of darters were collected in 1962 but were absent in the 1990 collection. *Notropis photogenis*, a species that may be intolerant of poor water quality, was present in the 1962 sample at site 18 but was not collected in 1990. Although these species could have been missed by chance, these results might indicate a decline in habitat quality and suggest that these sites merit monitoring.

The eight sites sampled in 1962 and 1990 in the Little Tennessee River shared over half of the species between the two samples (Table 6). The river drainage has high species diversity, and there has been little change in the faunal composition. *Notropis photogenis*, present at two sites in 1962, was completely absent in the 1990 collections, indicating that this species may be declining throughout its range. *Notropis lutipinnis* has been introduced in this drainage and appears to be expanding its range and abundance. Of special importance is the record of *Cyprinella monacha*, a federally threatened species, taken at site 25, Cowee Creek (Table 6). The species richness at this site has more than doubled since 1962, while species richness has decreased at site 26.

The collections from 1962 and 1990 at site 27 in the Hiwassee River (Table 7) have essentially the same species composition, while site 28 has gained eight species (mostly centrarchids and an introduced species, *Luxilus zonistius*) and lost five. We are not aware of any reason for this faunal change at site 28.

Chattahoochee River System—All of the sites in the Chattahoochee River system still have essentially the same species composition as they did in 1962 (Table 8). *Notropis xaenocephalus* and *Hypentelium etowanum* are shared with the Etowah River drainage. *Notropis lutipinnis* appears to be expanding its range. *Hybopsis rubrifrons*, found in South Atlantic drainages, is present in Dukes Creek, a tributary of the Chattahooche River system.

Summary of New or Unusual Species Records—Three probable introductions were discovered in the 1990 collections: *Luxilus zonistius*

TABLE 3. List of species and number of specimens (percent relative abundance in parentheses) collected from the Tallulah River (Savannah River drainage). Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is four, four, and six for sites 10-13, respectively.

	Site 10		Site 11		Site 12		Site 13	
Species and parameters	1962	1990	1962	1990	1962	1990	1962	1990
Oncorhynchus mykiss	0	1 (0.2)	P	0	P	0	0	0
Salvelinus fontinalis	1 (0.80)	0	0	0	0	0	0	0
Campostoma anomalum	0	1 (0.2)	0	1 (1.3)	1	0	0	19 (9.3)
Campostoma oligolepis	0	0	0	0	0	13 (15.3)	0	0
Clinostomus funduloides	0	0	0	1 (1.3)	0	0	1 (0.5)	0
C. funduloides x *N. lutipinnis*	0	0	0	0	1	0	0	0
Cyprinella nivea	0	0	0	0	0	0	55 (27.6)	35 (17.1)
Luxilus coccogenis	0	0	3	52 (67.5)	0	0	0	0
Luxilus zonistius	45 (37.8)	89(15.1)	0	0	0	0	31 (15.6)	72 (35.1)
Nocomis leptocephalus	9 (7.6)	46 (7.8)	0	5 (6.5)	2	7 (8.2)	24 (12.1)	10 (4.9)
Notropis hypselepis	0	0	0	0	7	0	0	0
Notropis lutipinnis	63 (52.9)	439 (74.4)	2	0	14	42 (49.4)	83 (41.7)	43 (21.0)
N. lutipinnis x *L. zonistius*	0	1 (0.3)	0	0	0	0	0	0
Semotilus atromaculatus	1 (0.8)	13 (2.2)	0	0	5	0	0	0
Hypentelium nigricans	0	0	1	4 (5.2)	6	2 (2.4)	2 (1.0)	13 (6.3)
Moxostoma rupiscartes	0	0	0	0	0	1 (1.2)	0	1 (0.5)
Lepomis auritus	0	0	2	0	10	0	3 (1.5)	8 (3.9)
L. auritus x *L. macrochirus*	0	0	0	0	1	0	0	0
Lepomis cyanellus	0	0	0	0	0	0	0	1 (0.5)
Lepomis macrochirus	0	0	P	5 (6.5)	2	0	0	0
Micropterus dolomieu	0	0	0	0	0	0	0	2 (1.0)
Micropterus punctulatus	0	0	0	2 (2.6)	0	0	0	0
Micropterus salmoides	0	0	0	0	1	0	0	1 (0.5)
Perca flavescens	0	0	4	0	7	0	0	0
Cottus bairdi	0	0	2	7 (9.1)	25	20 (23.5)	0	0
Total	119	590	14+	77	81+	85	199	205
Species richness	5	7	8	8	14	6	7	11
Percentage of species shared	80	57	50	50	29	67	86	54

in the Hiwassee River system; *Notropis leuciodus* in the Chattahoochee River system; *Cyprinella pyrrhomelas* in the Chattooga River. *Notropis lutipinnis* was introduced in the Little Tennessee system (Ramsey, 1965) and appears to be expanding its range. *Cyprinella monacha*, a federally threatened species, was collected in Cowee Creek, Little Tennessee system, and this may indicate a range expansion for this species.

Unusual or unreported records collected in 1962 include: *Hypentelium etowanum*, an Alabama River endemic in the Chestatee River (Chattahoochee River system); *Hybopsis rubrifrons*, a South Atlantic drainage native, found in the Chattahoochee system; *Notropis telescopus*, a Tennessee River species found in the Catawba River system (Santee River drainage); *Notropis hypsilepsis*, a Chattahoochee River species found in the Tallulah River; *Notropis leuciodus*, a Tennessee River species found in the Keowee and Chattooga rivers (Savannah River drainage); *Notropis rubricroceus*, a Tennessee River species found in the Santee and Toxaway (Savannah) River drainages; *Notropsis spectrunculus*, a Tennessee River form found in the Santee River drainage; *Notropis xaenocephalus*, an Alabama River species found in the Chestatee River (Chattahoochee River drainage); *Luxilus zonistius*, a Chattahoochee River species found in the Tallulah River (Savannah River drainage); *Rhinichthys cataractae*, a northern species reaching its southern range limit in the Savannah River drainage; *Micropterus coosae*, previously unknown from the Santee River drainage; and *Etheostoma zonale*, a widespread species previously unknown from the Santee River drainage.

Several minnow hybrids were collected in 1962 and 1990 (e.g., *Notropis lutipinnis* x *Luxilus zonistius*; *Clinostomus funduloides* x *N. lutipinnis*; *Luxilus coccogenis* x *C. funduloides*). Although hybrids are often thought to be the result of habitat degradation, these hybrids are the results of multispecies nesting associations, where the nests of *Nocomis*, *Semotilus*, or *Campostoma* are used simultaneously by numerous species, and are not necessarily the result of habitat degradation.

TABLE 4. List of species and number of specimens (percent relative abundance in parentheses) collected from the Santee River drainage. Locatins of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is seven, five, and nine for sites 14-16, respectively.

	Site 14		Site 15		Site 16	
Species and parameters	1962	1990	1962	1990	1962	1990
Oncorhynchus mykiss	0	0	0	0	P	1 (0.9)
Dorosoma cepedianum	P	0	0	0	0	0
Campostoma anomalum	11	2 (1.3)	2 (1.1)	7 (2.9)	102	41 (37.6)
Cyprinella galactura	3	7 (4.6)	0	0	0	0
Cyprinella nivea	6	17 (11.1)	1 (0.6)	44 (18.5)	0	0
Cyprinella pyrrhomelas	8	22 (14.4)	37 (20.2)	100 (42.0)	0	0
Luxilus coccogenis	16	18 (11.8)	60 (32.8)	39 (16.4)	0	0
Hybognathus nuchalis	7	0	0	0	0	0
Nocomis leptocephalus	0	2 (1.3)	0	27 (11.3)	11	2 (1.8)
Notemigonus crysoleucas	0	0	0	0	0	1 (0.9)
Notropis procne	0	4 (2.6)	0	0	0	0
Notropis rubricroceus	0	0	0	0	294	25 (22.9)
Notropis scepticus	25	3 (2.0)	83 (45.3)	18 (7.6)	0	0
Notropis spectrunculus	0	30 (19.6)	0	0	0	0
Notropis telescopus	23	16 (10.5)	0	0	0	0
Rhinichthys atratulus	0	0	0	0	83	26 (23.8)
Semotilus atromaculatus	0	1 (0.6)	0	0	4	3 (2.8)
Catostomus commersoni	0	0	0	0	4	2 (1.8)
Hypentelium nigricans	P	0	0	0	0	0
Moxostoma robustum	0	0	0	0	0	1 (0.9)
Moxostoma rupiscartes	0	0	0	0	23	2 (1.8)
Ameiurus brunneus	0	1 (0.6)	0	0	0	0
Lepomis auritus	0	17 (11.1)	0	1 (0.4)	0	0
Micropterus coosae	1	0	0	0	0	0
Micropterus dolomieu	0	1 (0.6)	0	0	0	0
Etheostoma flabellare	0	3 (2.0)	0	1 (0.4)	0	0
Etheostoma olmstedi	0	9 (5.9)	0	0	0	0
Percina crassa	0	0	0	1 (0.4)	0	0
Cottus bairdi	0	0	0	0	3	5 (4.6)
Total	117+	153	183	238	524+	109
Species richness	11	16	5	9	9	11
Percentage of species shared	64	44	100	56	100	82

DISCUSSION

The results of this study indicate that three species have been introduced into Southern Appalachian drainages in just 30 years. In addition to the unpredictable effects of introduced species, the conservation of fishes in the Southern Appalachians faces threats from habitat destruction (e.g., impoundments) and degradation (Neves and Angermeier, 1990). The information provided by repeated surveys can alert conservationists to potential problems caused by these threats before biodiversity is lost.

Introduction of species into the drainages of the southern Appalachians is becoming a common occurrence. Introductions through bait buckets by fishermen across drainages of close proximity are the probable cause of these range expansions, which are detectable due to the distinctiveness of the faunas of the various drainages. Stocking of game and forage fishes also are contributing to the breakdown of regional distinctiveness (Sheldon, 1988). Competition with introduced species can cause displacement of native species. While the contact of previously separated species offers unique opportunities for ecological studies, such contacts are of concern to conservationists, because it is not known how vulnerable gene pools of endemic species are to genetic intrusions from closely related exotic species. Many of the endemic minnows in the Appalachians are particularly vulnerable to hybridization due to the spawning strategy of nest association, in which numerous species spawn simultaneously over the nest of another species. Such situations often produce hybrids, but this is normally prevented in

TABLE 5. List of species and number of specimens (percent relative abundance in parentheses) collected from the French Broad River (Tennessee River drainage). Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is six for site 17 and 11 for site 18.

Species and parameters	Site 17		Site 18	
	1962	1990	1962	1990
Oncorhynchus mykiss	P	0	0	0
Salmo trutta	1	0	0	0
Salvelinus fontinalis	0	0	P	0
Campostoma anomalum	3	7 (31.8)	22	0
Luxilus coccogenis	1	5 (22.7)	135	115 (50.5)
Nocomis micropogon	0	1 (4.5)	1	6 (2.6)
Notropis leuciodus	0	2 (9.1)	2	11 (4.8)
Notropis photogenis	0	0	23	0
Notropis rubricroceus	20	2 (9.1)	77	20 (8.7)
Notropis spectruculus	0	0	136	40 (17.4)
Notropis telescopus	0	0	1	0
Phenacodius crassilabrum	0	0	0	1 (0.4)
Rhinichthys atratulus	8	1 (4.5)	8	0
Rhinichthys cataractae	3	1 (4.5)	9	1 (0.4)
Semotilis atromaculatus	0	0	6	0
Catostomus commersoni	0	0	2	0
Hypentelium nigricans	0	0	2	1 (0.4)
Moxostoma duquesnei	0	0	0	1 (0.4)
Lepomis auritus	0	0	1	0
Etheostoma flabellare	2	0	5	21 (9.1)
Etheostoma rufilineatum	1	0	2	4 (1.7)
Etheostoma swannanoa	15	0	12	1 (0.4)
Cottus bairdi	7	3 (13.6)	17	8 (3.5)
Total	61+	22	461+	230
Species richness	11	8	19	13
Percentage of species shared	54	75	58	85

closely-related species by their geographic isolation in distinct drainages.

Impoundments fragment the riverine habitat and large impoundments can create situations where corridors for dispersal are functionally absent. Extinction of species following habitat fragmentation (impoundment) is predicted by species-area relationships (Sheldon, 1988) and has been documented for one Tennessee River species, *Hybognathus nuchalis* (Etnier et al., 1979). Numerous impoundments also saturate drainages with species such as sunfish that may displace other species. Lemley (1985) found that introduced green sunfish (*Lepomis cyanellus*), a typical impoundment species, suppressed populations of native fishes in North Carolina Piedmont headwaters.

Another serious threat to native fishes in habitat degradation. Water quality can be affected by siltation and pollution resulting from runoff of developed areas. Cutting of native vegetation also can change flow regimes and discharge rates in streams. In the past 2 decades, development in the Highlands, North Carolina, area has proceeded at a rapid pace. Without regular surveys, the potential impact of this development on the fish fauna of local drainages will be unknown.

The results of this and other studies emphasize the importance of monitoring biodiversity for conservation efforts. Comparative surveys can act as early-warning signals, alerting conservationists to potential problems by detecting faunal changes, species introductions, and population changes. Streams with recently introduced species should be carefully monitored for adverse faunal effects. Such monitoring also will increase our understanding of stream communities.

LITERATURE CITED

ALLENDORF, F. W., AND R. F. LEARY. 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conserv. Biol., 2:170-184.

COBLENTZ, B. E. 1990. Exotic organisms: a dilemma for conservation biology. Conserv. Biol., 4:261-265.

ETNIER, D. A., W. C. STARNES, AND B. H. BAUER. 1979. Whatever happened to the silvery minnow (*Hybognathus nuchalis*) in the Tennessee River? Proc. Southeastern Fishes Council, 2:1-3.

TABLE 6. List of species and number of specimens (percent relative abundance in parentheses) collected from the Little Tennessee River (Tennessee River drainage). Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods nine, eight, nine, seven, one, seven, three, and four for sites 19-26, respectively.

	Site 19		Site 20		Site 21	
Species and parameters	1962	1990	1962	1990	1962	1990
Oncorhynchus mykiss	0	0	0	0	0	0
Salmo trutta	0	0	0	0	0	0
Campostoma anomalum	0	2 (1.2)	1 (0.9)	10 (5.7)	0	2 (1.6)
Clinostomus funduloides	0	0	10 (9.1)	4 (2.3)	1 (0.6)	0
Cyprinella galactura	8 (6.2)	6 (3.6)	0	3 (1.7)	5 (2.8)	4 (3.3)
Cyprinella monacha	0	0	0	0	0	0
Luxilus coccogenis	61 (47.3)	73 (43.2)	30 (27.3)	67 (38.5)	71 (40.3)	71 (58.2)
L. coccogenis x *C. funduloides*	0	0	0	1 (0.6)	0	0
Nocomis leptocephalus	0	0	0	0	0	0
Nocomis micropogon	19 (14.7)	26 (15.4)	2 (1.8)	20 (11.5)	8 (4.5)	7 (5.7)
Notemigonous crysoleucas	3 (2.3)	0	0	0	0	0
Notropis leuciodus	11 (8.5)	13 (7.7)	16 (14.5)	22 (12.6)	19 (10.8)	3 (2.5)
Notropis lutipinnis	0	0	0	13 (7.5)	0	1 (0.8)
Notropis photogenis	0	0	3 (2.7)	0	0	0
Notropis rubellus	3 (2.3)	19 (11.2)	0	0	0	0
Notropis rubricroceus	0	0	0	0	0	0
Notropis spectrunculus	0	0	9 (8.2)	0	28 (15.9)	3 (2.5)
Notropis telescopus	0	0	0	0	0	0
Phenacobius crassilabrum	3 (2.3)	3 (1.8)	0	0	0	0
Rhinichthys atratulus	0	0	0	0	0	0
Rhinichthys cataractae	0	0	6 (5.4)	0	0	0
Semotilis atromaculatus	0	0	0	0	3 (1.7)	0
Catostomus commersoni	0	0	0	0	0	0
Hypentelium nigricans	1 (0.8)	0	2 (1.8)	1 (0.6)	12 (6.8)	1 (0.8)
Minytrema melanops	0	0	0	0	0	0
Moxostoma duquesnei	3 (2.3)	1 (0.6)	0	0	0	0
Moxostoma erythrurum	0	0	0	0	3 (1.7)	0
Moxostoma	0	0	0	0	0	0
Ictalurus punctatus	1 (0.8)	0	0	0	0	0
Ambloplites rupestris	0	4 (2.4)	1 (0.9)	2 (1.2)	0	1 (0.8)
Lepomis auritus	0	0	0	0	0	0
Lepomis cyanellus	0	0	0	1 (0.6)	0	0
Lepomis macrochirus	0	0	1 (0.9)	0	1 (0.6)	2 (1.6)
Micropterus dolomieu	0	3 (1.8)	0	0	0	0
Micropterus salmoides	0	0	0	0	0	0
Etheostoma blennioides	0	0	1 (0.9)	0	0	0
Etheostoma chlorobranchium	0	0	1 (0.9)	0	1 (0.6)	0
Etheostoma vulneratum	0	2 (1.2)	0	0	0	0
Etheostoma zonale	1 (0.8)	14 (8.3)	0	0	0	0
Percina aurantiaca	0	2 (1.2)	0	0	0	0
Percina evides	8 (6.2)	1 (0.6)	0	0	6 (3.4)	2 (1.6)
Cottus bairdi	7 (5.4)	0	27 (24.5)	30 (17.2)	18 (10.2)	25 (20.5)
Total	129	169	110	174	176	122
Species richness	13	14	14	12	13	12
Percentage of species shared	69	64	57	67	69	75

TABLE 6. Continued.

Site 22		Site 23		Site 24		Site 25		Site 26	
1962	1990	1962	1990	1962	1990	1962	1990	1962	1990
0	0	0	4(26.7)	0	0	0	0	0	0
0	0	0	0	0	0	0	0	P	0
0	1 (0.8)	0	0	0	6 (7.5)	0	5 (3.6)	8	0
0	0	0	0	2 (2.2)	8(10.0)	0	0	0	0
6 (4.0)	0	0	0	0	7 (8.8)	2 (3.6)	0	12	0
0	0	0	0	0	0	0	1 (0.7)	0	0
60(39.5)	95(75.4)	1 (8.3)	0	37(39.8)	34(42.5)	44(80.0)	78(56.9)	5	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	6	35(37.2)
5 (3.3)	4 (3.2)	1 (8.3)	0	0	5 (6.2)	2 (3.6)	6 (4.4)	0	0
0	0	0	0	0	0	0	0	0	1 (1.1)
35(23.0)	10 (7.9)	0	0	28(30.1)	4 (5.0)	6(10.9)	27(19.7)	1	0
0	0	0	0	0	0	0	0	1	0
2 (1.3)	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	22	0
10 (6.6)	1 (0.8)	0	0	5 (5.4)	0	1 (1.8)	0	2	0
0	0	0	0	0	0	0	9 (6.6)	0	0
0	0	0	0	0	1 (1.2)	0	3 (2.2)	0	0
0	0	0	2(13.3)	0	3 (3.8)	0	0	14	48(51.1)
0	0	10(83.3)	1 (6.7)	1 (1.1)	5 (6.2)	0	0	0	0
0	0	0	0	1 (1.1)	0	0	0	0	0
0	0	0	0	0	0	0	0	9	5 (5.3)
7 (4.6)	1 (0.8)	0	0	2 (2.2)	1 (1.2)	0	0	2	2 (2.1)
0	0	0	0	0	0	0	1 (0.7)	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1 (0.7)	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	6 (4.8)	0	0	0	0	0	0	0	0
0	1 (0.8)	0	0	0	0	0	1 (0.7)	0	0
0	0	0	0	0	0	0	1 (0.7)	0	0
0	0	0	0	0	0	0	0	0	3 (3.2)
0	2 (1.6)	0	0	0	0	0	1 (0.7)	0	0
0	0	0	0	0	0	0	0	2	0
1 (0.7)	0	0	0	3 (3.2)	0	0	0	0	0
6 (4.0)	2 (1.6)	0	0	0	0	0	0	0	0
0	2 (1.6)	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
2 (1.3)	0	0	0	8 (8.6)	1 (1.2)	0	2 (1.5)	0	0
18(11.8)	1 (0.8)	0	8(53.3)	6 (6.4)	5 (6.2)	0	2 (1.5)	0	0
153	126	12	15	93	80	55	137	84+	94
12	12	3	4	10	12	5	13	13	6
58	58	33	25	70	58	60	23	31	67

TABLE 7. List of species and number of specimens (percent relative abundance in parentheses) collected from the Hiwassee River (Tennessee River drainage). Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is five for site 7 and four for site 28.

	Site 27		Site 28	
Species and parameter	1962	1990	1962	1990
Oncorhynchus mykiss	P	0	P	0
Campostoma anomalum	2	33 (45.8)	2	23 (20.0)
Cyprinella galactura	0	0	0	35 (30.4)
Luxilus coccogenis	1	0	7	1 (0.9)
Luxilus zonistius	0	0	0	1 (0.9)
Notropis leuciodus	0	0	13	0
Notropis spectrunculus	5	10 (13.9)	4	1 (0.9)
Rhinichthys cataractae	12	2 (2.8)	0	7 (6.1)
Semotilus atromaculatus	40	19 (26.4)	0	21 (18.3)
Hypentelium nigricans	1	0	0	12 (10.4)
Moxostoma duquesnei	1	0	1	0
Lepomis auritus	0	1 (1.4)	0	0
Lepomis macrochirus	0	0	0	3 (2.6)
Micropterus punctulatus	0	3 (4.2)	0	0
Micropterus salmoides	0	0	0	1 (0.9)
Etheostoma rufilineatum	0	0	4	0
Etheostoma zonale	0	0	1	0
Perca flavescens	0	0	0	1 (0.9)
Cottus bairdi	14	4 (5.6)	2	9 (7.8)
Total	76+	72	34+	115
Species richness	9	7	9	12
Percentage of species shared	56	71	44	33

HOCUTT, C. H., R. E. JENKINS, AND J. R. STAUFFER. 1986. Zoogeography of the fishes of the Central Appalachians and Central Atlantic Coastal Plain. Pp. 161-211 *in* The zoogeography of North American freshwater fishes (C. H. Hocutt and E. O. Wiley, eds.). John Wiley & Sons, New York.

LEMLY, A. D. 1985. Suppression of native fish populations by green sunfish in first-order streams of Piedmont North Carolina. Trans. Amer. Fish. Soc., 114:705-712.

LODGE, D. M. 1993. Biological invasions: lessions for ecology. Trends in Ecol. Evol., 8:133-137.

NEVES, R. J., AND P. L. ANGERMEIER. 1990. Habitat alteration and its effects on native fishes in the upper Tennessee River system, east-central U.S.A. J. Fish Biol., 37:45-52.

RAMSEY, J. S. 1962. The distribution, relationships, and ecology of the fishes of the gorge streams of the southeastern escarpment of the Blue Ridge Mountains in the region of Highlands, North Carolina. Highlands Biological Station, Highlands, North Carolina, Interim Rept. 2.

——. 1965. Zoogeographic studies on the freshwater fish fauna of rivers draining the southern Appalachian region. Ph.D. dissert., Tulane Univ., New Orleans, Louisiana.

SHELDON, A. L. 1988. Conservation of stream fishes: patterns of diversity, rarity, and risk. Conserv. Biol., 2:149-156.

SOULE, M. E. 1990. The onslaught of alien species, and other challenges in the coming decades. Conserv. Biol., 4:233-239.

TABLE 8. List of species and number of specimens (percent relative abundance in parentheses) collected from the Chattahoochee River drainage. Locations of sites are described in Appendix I. P indicates a species present in collection but not quantified. The total abundance value of such samples reflects only those species with individuals counted. Total number of species shared between sampling periods is five, seven, six, six, and five for sites 29-33, respectively.

	Site 29		Site 30		Site 31		Site 32		Site 33	
Species and parameters	1962	1990	1962	1990	1962	1990	1962	1990	1962	1990
Ichthyomyzon gagei	0	0	0	1 (0.5)	0	0	0	0	0	0
Oncorhynchus mykiss	0	0	0	0	P	1 (0.5)	1 (1.0)	1 (0.2)	P	0
Campostoma pauciradii	4 (1.4)	3 (0.9)	40 (7.6)	2 (1.1)	0	2 (1.0)	6 (6.2)	4 (0.9)	0	17 (2.3)
Hybopsis rubrifrons	0	0	158 (30.0)	2 (1.1)	0	0	1 (1.0)	0	0	0
Luxilus zonistius	225 (79.8)	156 (46.8)	114 (21.6)	108 (58.7)	55	94 (46.5)	60 (61.9)	420 (93.5)	80	633 (86.6)
Nocomis leptocephalus	6 (2.1)	39 (11.7)	30 (5.7)	2 (1.1)	14	17 (8.4)	0	9 (2.0)	7	36 (4.9)
Notropis leuciodus	0	120 (36.0)	0	0	0	0	0	0	0	0
Notropis lutipinnis	0	0	0	61 (33.2)	3	68 (33.7)	0	0	0	23 (3.2)
N. lutipinnis x *L. zonistius*	0	0	0	0	1	0	0	0	0	1 (0.1)
Notropis xaenocephalus	10 (3.6)	5 (1.5)	0	0	0	0	0	0	0	0
Semotilus atromaculatus	0	0	12 (2.3)	0	1	0	3 (3.1)	0	1	9 (1.2)
Hypentelium etowanum	11 (3.9)	0	80 (15.2)	0	0	0	2 (2.1)	6 (1.3)	0	0
Moxostoma lachneri	6 (2.1)	0	2 (0.4)	0	11	2 (1.0)	2 (2.1)	0	1	0
Moxostoma duquesnei	0	0	70 (13.3)	0	0	0	0	0	0	0
Lepomis auritus	0	0	2 (0.4)	1 (0.5)	0	2 (1.0)	0	0	5	0
Lepomis cyanellus	0	0	0	0	0	3 (1.5)	0	0	0	0
Lepomis macrochirus	0	0	0	0	0	9 (4.4)	0	0	P	1 (0.1)
Micropterus coosae	0	4 (1.2)	1 (0.2)	0	1	0	0	0	0	0
Micropterus punctulatus	0	0	0	0	0	0	0	0	0	1 (0.1
Micropterus salmoides	0	0	0	0	0	1 (0.5)	0	0	0	0
Percina nigrofasciata	20 (7.1)	6 (1.8)	6 (1.1)	5 (2.7)	18	0	7 (7.2)	4 (0.9)	0	0
Cottus bairdi	0	0	11 (2.0)	2 (1.1)	6	3 (1.5)	16 (16.5)	5 (1.1)	12	10 (1.4)
Total	282	333	526	184	110+	202	98	449	106+	731
Species richness	7	7	12	9	10	11	9	7	8	9
Percentage of species shared	71	71	58	78	60	54	67	86	62	56

APPENDIX I. Sites surveyed for fishes during 1962 and 1990.

Drainage or system	Site	Location of site
Savannah River Drainage		
Keowee River	1	Horsepasture River; 0.8 mile SE Hwy. 64, Jackson Co., North Carolina
	2	Horsepasture River; 1.8 miles NE Cashiers, Hwy. 64, Jackson Co., North Carolina
	3	Horsepasture River; 1.1 miles SW Oakwood, Hwy. 64, Transylvania Co., North Carolina
	4	Horsepasture River; 2.0 miles SE Sapphire, Hwy. 281, Transylvania Co., North Carolina
	5	Toxaway Creek; 3.0 miles SW Rosman, County Road 1143, Transylvania Co., North Carolina
	6	Bearwallow Creek; 0.4 mile S Hwy. 64, Hwy. 28, Transylvania Co., North Carolina
Chattooga River	7	Chattooga River; at Georgia/South Carolina state line, Hwy. 28, Oconee Co., South Carolina
	8	Chattooga River; 1.1 miles N Georgia/South Carolina state line, Jackson Co., North Carolina
	9	West Fork; 0.5 mile W Pine Mountain, Clayton Road, Rabun Co., Georgia
Tallulah River	10	Panther Creek; 3.9 miles SW Tallulah Falls, Hwy. 411, Habersham Co., Georgia
	11	Persimmon Creek; 0.5 mile N Blalock, Rabun Co., Georgia
	12	Timpson Creek; 5.2 miles W Clayton, Hwy. 76, Rabun Co., Georgia
	13	Tallulah River; 3.5 miles N Tallulah Falls, just W Hwy. 411, Rabun Co., Georgia
Santee River Drainage	14	Linville River; 6.1 miles N Burke/McDowell Co. line, Hwy. 126, Burke Co., North Carolina
	15	Buck Creek; 1.0 mile E Pleasant Gardens, Hwy. 70, McDowell Co., North Carolina
	16	Hungry River; 2.6 miles ESE Dana, Henderson Co., North Carolina
Tennessee River Drainage		
French Broad River	17	Cathey's Creek; just N Hwy. 64, Transylvania Co., North Carolina
	18	West Fork; 1.5 miles W Rosman, Hwy. 64, Transylvania Co., North Carolina
Little Tennessee River	19	Little Tennessee River; 5.0 miles N Franklin, Hwy. 28, Macon Co., North Carolina
	20	Betty Creek; just S Dillard, Hwy. 441 and Hwy. 23, Rabun Co., Georgia
	21	Cartoogechaye Creek; 2.5 miles S Franklin, Hwy. 441, Macon Co., North Carolina
	22	Cullasaja River; 5.0 miles SE Franklin, Hwy. 64, Macon Co., North Carolina
	23	Walnut Creek; 11.0 miles NW Highlands, just E Hwy. 64, Macon Co., North Carolina
	24	Ellijay Creek; 6.0 miles SE Franklin, 0.5 mile E Hwy. 64, Macon Co., North Carolina
	25	Cowee Creek; 7.0 miles NW Franklin, Macon Co., North Carolina
	26	Cedar Creek; 4.4 miles N Cashiers, 0.5 mile E Hwy. 107, Jackson Co., North Carolina
Hiwassee River	27	Center Creek; 8.8 miles SSE Hiawassee, Hwy. 75, Towns Co., Georgia
	28	Town Creek; 6.4 miles S Blairsville, Hwy. 129, Union Co., Georgia
Chattahoochee River System	29	Chestatee River; 10.7 miles NW Cleveland, Hwy. 129, Lumpkin Co., Georgia
	30	Dukes Creek; 1.0 mile SW Nacoochee, Hwy. 75, White Co., Georgia
	31	Little Tesnatee Creek; 1.4 miles NW Cleveland, Hwy. 129, White Co., Georgia
	32	Spoilcane Creek; 6.6 miles S White/Towns Co. line, Hwy. 75, White Co., Georgia
	33	Town Creek; 7.1 miles NW Cleveland, Hwy. 129, White Co., Georgia