DOI: 10.1007/s002670010053

ENVIRONMENTAL AUDITING

Patterns of Aquatic Species Imperilment in the Southern Appalachians: An Evaluation of Regional Databases

PATRICIA A. FLEBBE*
Southern Research Station
U.S. Forest Service
Department of Fisheries and Wildlife Sciences
Virginia Tech, Mail Code 0321
Blacksburg, Virginia 24061, USA

JAMES A. HERRIG
Cherokee National Forest
U.S. Forest Service
P.O. Box 2010
Cleveland, Tennessee 37320, USA

ABSTRACT / For regional analyses of species imperilment patterns, data on species distributions are available from the U.S. Fish and Wildlife Service and from the state heritage programs. We compared these two different databases as sources of best available information for regional analyses of patterns of aquatic species imperilment for 132 counties in the southern Appalachians and examined patterns produced from the databases. The heritage program database contained information about a greater number of imperiled species because species need not be federally listed as threatened or endangered to be included in this database. In the southern Appalachians, about half of imperiled molluscs and about one-fourth of imperiled fish were listed as threatened or endangered; much smaller proportions of other taxonomic groups were federally listed. Most threatened and endangered species appeared on both lists, but for about 40% of the species inconsistencies exist, notably a lack of recent records in the heritage program dataset. Numbers of species in each county were significantly different between the two datasets for Georgia, Tennessee, and Virginia, where the largest number of threatened and endangered species reside. Nevertheless, some counties always appeared as centers of imperilment, and the general spatial patterns of imperilment were similar.

The southern Appalachian Mountains have been identified by several authors as "hot spots" of species endangerment (Flather and others 1994, 1998, Dobson and others 1997, Master and others 1998). In the southern Appalachians south of the Roanoke and New Rivers, there are about 350 fish species, 64 of which are imperiled (Walsh and others 1995). Diversity of mussels in the southeast is not only the highest in the world, but the percentage of species now imperiled exceeds 50% for all six southern Appalachian states (Williams and Neves 1995). Both fish and molluscs exhibit high degrees of endemism in the southeast, a major factor in species endangerment (Williams and others 1989, Neves 1991, Warren and Burr 1994, Flather and others 1994, Dobson and others 1997).

Threatened and endangered (T&E) species are of greatest concern when considering patterns of imperilment. These species are officially listed as endangered, threatened, or proposed endangered or threatened by the U.S. Department of the Interior, Fish and Wildlife Service (FWS) under the Endangered Species Act of 1973 (FWS 1994a, 1994b, 1994c, 1994d, 1994e).

Additional species may be of special concern because of limited distributions, but the legal listing process has not been completed. We will refer to special concern species as those formerly (in early 1995) designated as C2 candidates by the FWS or globally ranked by the network of state natural heritage programs, experts, and The Nature Conservancy as Gl, G2, G3, or a variant. Species ranked Gl are extremely rare and critically imperiled species, with five or fewer occurrences or very few remaining individuals or especially vulnerable to extinction; G2 species are very rare and imperiled, with 6 to 20 occurrences or few remaining individuals or vulnerable to extinction; and G3 species are either very rare and local throughout their range or found locally (sometimes abundantly) in a restricted range or vulnerable to extinction, with usually fewer than 100 occurrences documented. In this paper, imperiled species are defined broadly as the T&E species plus these special concern species.

KEY WORDS: Aquatic species, Fish, Molluscs, Species imperilment, Hot spots, Southern Appalachians. Regional analysis

*Author to whom all correspondence should be addressed.

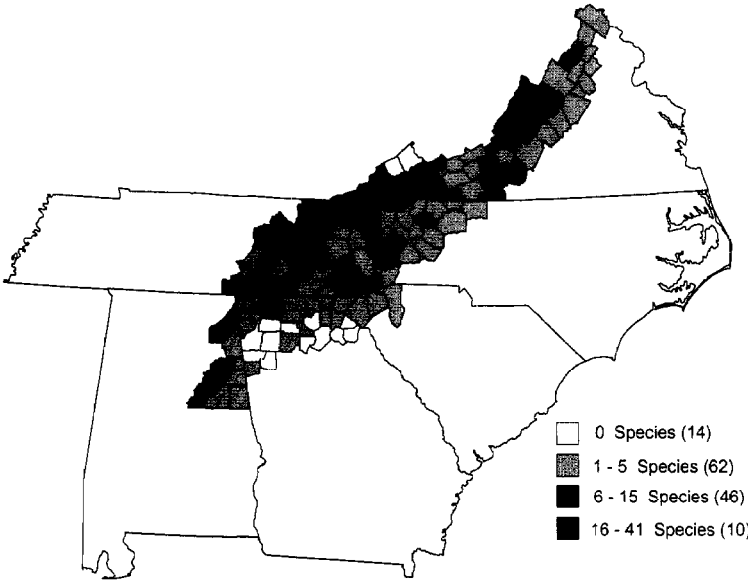

Figure 1. Geographic distribution of all imperiled aquatic species (EOR dataset) in 132 counties in the southern Appalachians. Counties are assigned to the four categories based on number of imperiled species that occur in each county. Numbers in parentheses denote the number of counties in the given category.

Progress toward species recovery depends on knowledge about species distribution patterns as well as a clear understanding of habitat and life history requirements of species. Questions often arise about the patterns of imperilment at regional and national scales (Flather and others 1994, 1998, Dobson and others 1997), particularly the degree to which distributions of imperiled species overlap in "hot spots." Multiple species management of imperiled species assumes that several imperiled species co-occur in a given area.

The Southern Appalachian Assessment (SAA), carried out by federal and state agencies under the auspices of the Southern Appalachian Man and the Biosphere program, was designed to be a regional assessment of all resources, natural and human, in a delineated area of 132 counties (and encompassed Virginia cities) in mountain sections of Virginia, Tennessee, North Carolina, South Carolina, Georgia, and Alabama (Figure l), plus three West Virginia counties not considered here. Two sources of data were available for conducting regional analyses of imperiled species distributions in the SAA (Flebbe and others 1996). The state heritage programs, usually a state agency function, in cooperation with The Nature Conservancy, keep records of all historic and current occurrences of species by site. The Tennessee Valley Authority Regional Natural Heritage Program regularly contributes historic and current data to all six states, except South Carolina (P. Shute, personal communication). Offices of the FWS keep current lists of known and possible occurrences by county of all federally listed and proposed T&E species. The two databases are not entirely independent because data are sometimes shared between the FWS and heritage programs. The issue for regional analyses of imperilment patterns is to determine which of these sources of information provides the best available information.

Imperiled aquatic species distributions in the SAA area were reported in cursory fashion in the SAA aquatic report (Flebbe and others 1996, pp. 35–44). In this paper, we provide greater detail concerning the databases, analyses, and findings presented in the SAA aquatic report for imperiled aquatic species. We compare the two databases as sources of best available information in the southern Appalachians by addressing four questions:

1. How many imperiled aquatic species in the southern Appalachians are protected as federally listed T&E species?
2. What T&E species are included in each database and how closely do the lists match?
3. How do the datasets compare in terms of the number of T&E species identified as present in each county in the area?
4. How are concentrations of imperiled species spatially distributed across the area, given the information in each dataset?

Methods

We obtained databases for analysis during early 1995. Therefore, we also used the FWS (1994a, 1994b, 1994c,

1994d, 1994e) listings and The Nature Conservancy rankings of that time to determine federal status and global ranking, respectively. Several changes to federal status and rankings have occurred since that time, but we chose to maintain temporal consistency among all data for this paper.

Although watersheds (i.e., hydrologic units) are intuitively the logical spatial unit for considering aquatic species, we used counties for several practical reasons. Hydrologic units in the study area vary greatly in size, much more so than do counties, so that species-area relations confound the patterns observed for the region. Many hydrologic units extend well beyond the southern Appalachians into other physiographic provinces. The databases do not organize data by watershed, and the information to do so is unavailable to most users. Finally, national analyses of patterns of endangerment (Flather and others 1994, 1998, Dobson and others 1997) have focused on county units for these reasons and to allow comparisons of patterns among species groups.

We obtained Element Occurrence Record (EOR) data from the six state heritage programs through the SAA effort and assigned all sample locations to counties (Flebbe and others 1996). The EOR data represent observations of individual species at particular locations, with dates of first and last observation at that location. Data were requested to be current as of December 1994, but some states included 1995 EORs when the data were received in May 1995. For some EORs the date of last observation was not recent, although about 60% were dated in the last 20 years. In this paper, all references to dates and age relate to the last observation date of the EOR.

With the aid of standard references, we selected fish; mussels; and aquatic and semiaquatic species of amphibians (salamanders) and reptiles (turtles) (Conant 1975, Martof and others 1980), insects (Merritt and Cummins 1984), snails (Hubricht 1985, Burch 1989), and other invertebrates (Pennak 1989). There were no truly aquatic plants (e.g., *Utricularia)* in the EOR database that met the imperiled criteria, and riparian species were not considered for this paper.

We corrected inconsistencies among state EOR datasets using primarily the FWS (1994a, 1994b, 1994c, 1994d, 1994e) lists and secondarily the standard references listed above and Robins and others (1991) to resolve scientific names. Where different global rankings were given by different states, we consulted The Nature Conservancy office in Boston to reconcile differences. We assigned FWS (1994a, 1994b, 1994c, 1994d, 1994e) rankings to all species in the EOR dataset. Finally, we selected the imperiled species that met the above criteria. The resulting dataset had 2659 observations of 189 species and subspecies and included information on county of each sighting location, dates of first and last observation, federal status, and global ranking.

We prepared a second set of data from FWS records of known and possible occurrences of federally listed and proposed T&E species in counties of the SAA area. Digital text files were obtained from the Atlanta (current as of April 1995) and White Marsh, Virginia (current as of August 1996), offices of the FWS and converted manually to a database file for analysis. In this dataset, species are designated as "known" or "possible" in counties—"known" occurrences are recently documented, and "possible" generally refers to historic occurrences. The Virginia dataset differs from that of the other states: It includes both known and possible occurrences, but the distinction is not recorded in the database. For Virginia, all occurrences are treated as "known." No special concern species, including candidate species, were included in this FWS dataset (only Virginia had provided data about former C2 species). Decisions about aquatic and semiaquatic species of snails, salamanders, and other invertebrates and species names were made as described above for the EOR dataset.

We addressed our first two questions by qualitative analysis of tabular data (i.e., comparing counts of species in the two datasets). To compare numbers of species among the lists for the 132 counties, we counted numbers of species observed in the datasets for each county (see Appendix). From these data, we made four paired comparisons (nonparametric Wilcoxon signed-rank test), using only T&E species counts in the EOR dataset: (1) all EOR T&E data versus FWS known and possible data; (2) all EOR T&E data versus FWS known data; (3) EOR T&E data for 1975-95 versus FWS known data; and (4) EOR T&E data for 1985-95 versus FWS known data. We used SAS (1990) for all statistical tests and a Bonferoni-adjusted alpha level of 0.0125 (=0.05/4) for the four paired comparisons (unadjusted *P* values are presented).

Finally, to determine regional patterns of distribution, we plotted the county data on maps (Figures l-8). Each map represents a subset of one of the two datasets as noted in the captions. For each figure, four categories representing numbers of species in each county were selected to identify (1) the 8-10 counties on each map with the greatest number of species, and (2) the

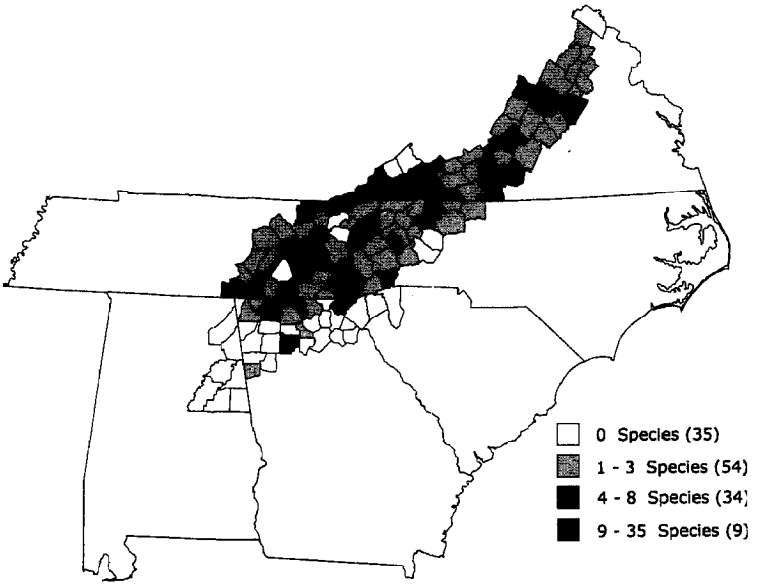

Figure 2. Geographic distribution of imperiled aquatic species observed since 1975 (EOR dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

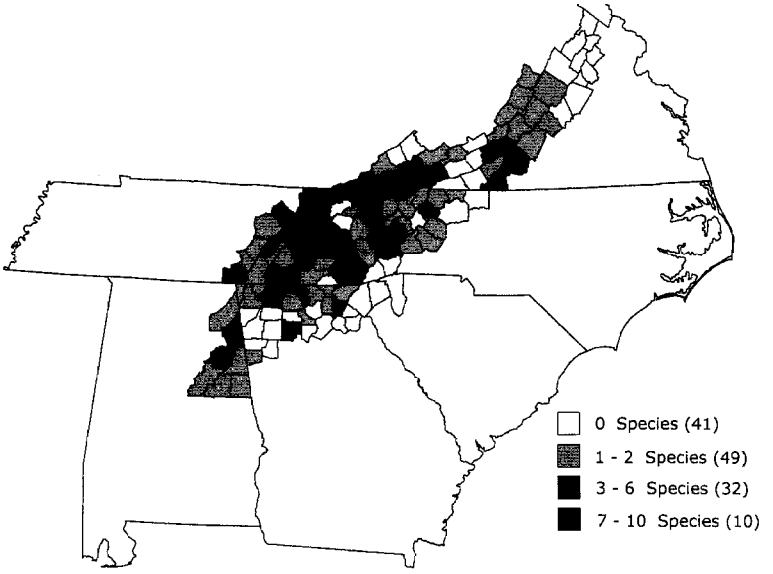

Figure 3. Geographic distribution of imperiled fish species (EOR dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

counties with no species. Breakpoints between the two intermediate classes were selected arbitrarily.

Results

Comparison of EOR and FWS Datasets

The EOR dataset had information on 189 aquatic imperiled species and 48 T&E species (Table 1). Limiting EORs to the last 20 years (1975-95) reduced the number of T&E species to 39, and to the last 10 years (1985-95) to 29 species. Of the 53 species in the FWS dataset, 46 were known to occur in at least one county and seven others were possible (but not known) in one or more counties in the study area.

The degree to which species were federally protected varied among taxonomic groups (Table 1). Nearly 53% of imperiled mollusc and 26% of imperiled fish species were listed by FWS. If former C2 candidate species were also protected, these percentages would increase to 90% and 53%, respectively. The largest numbers of FWS listed or candidate species were fish and molluscs, reflecting higher survey effort, higher risk of endangerment, and prominence of these taxa in aquatic systems.

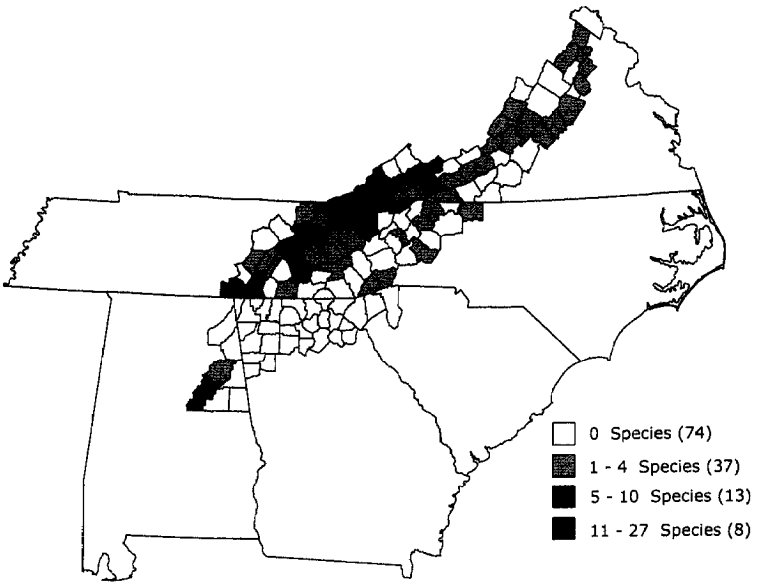

Figure 4. Geographic distribution of imperiled mollusc species (EOR dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

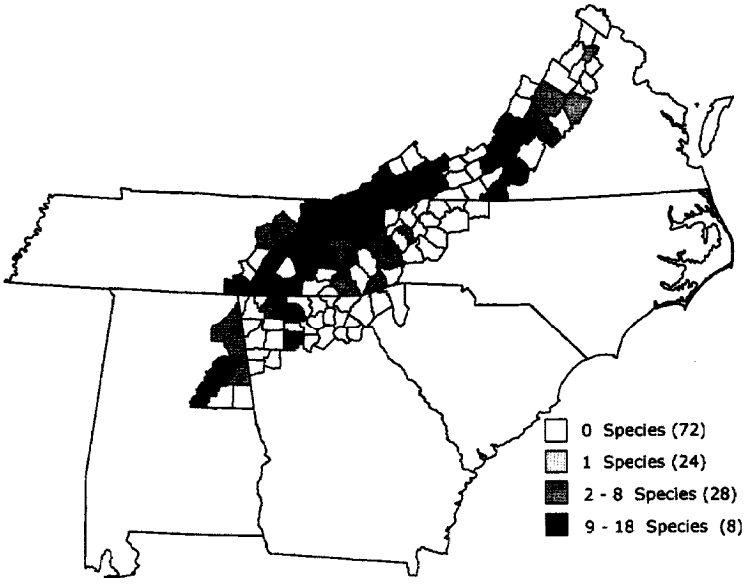

Figure 5. Geographic distribution of T&E species observed (EOR dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

Only five salamander species and one turtle were included in the EOR dataset, and because none had been listed by the FWS, none were in the FWS dataset (Table 1). Likewise, although 26 insect species with aquatic life stages met the imperiled designation, none had federal status. Most of the 39 "other invertebrates" were species of cave isopods and amphipods, but the EOR dataset also included five crayfish (three of them former C2 candidates). Only two isopod species, in both the EOR and FWS datasets, were federally listed as T&E (Table 2).

A total of 57 T&E species were included in one or both datasets (Table 2). We also identified occurrence of these 57 species in three subsets of the original datasets: EORs with last observations in the last 20 years (1975-95), EORs with last observations in the last 10 years (1985-95), and known occurrences in the FWS dataset (Table 2). Eight different cases (Table 3) summarize the patterns in Table 2, and the two databases may be considered to be in general agreement for cases 1, 5, 6, and 8.

For slightly more than half of the mollusc and more than one-third of the fish species, the species appears in all five columns of Table 2—the two databases are in

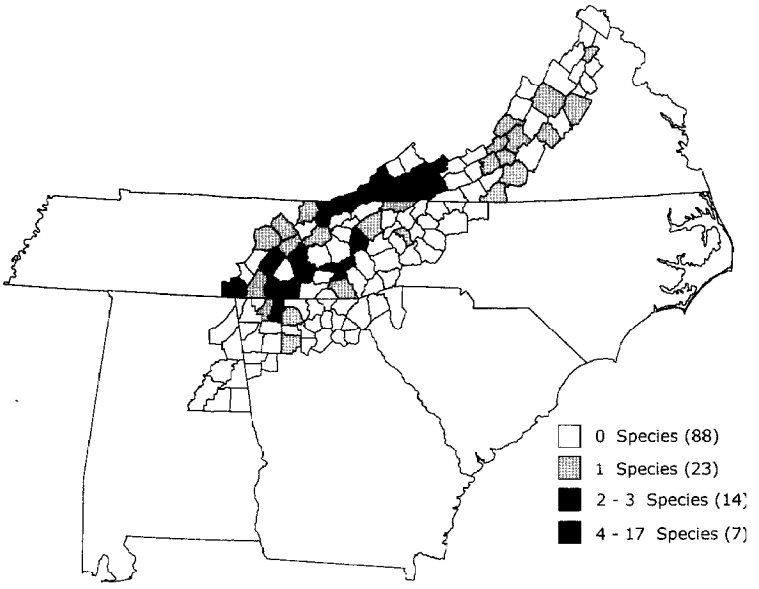

Figure 6. Geographic distribution of T&E species observed since 1975 (EOR dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

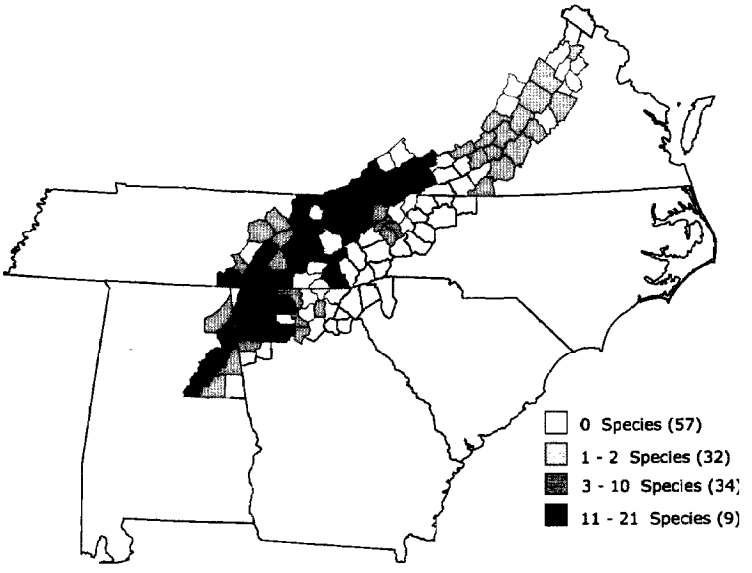

Figure 7. Geographic distribution of T&E aquatic species known to occur or possible (FWS dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

agreement in that species are known to occur (FWS) and have been observed in the past 10 years (EOR) (case 1, Table 3). The next three cases, species known to occur (FWS) but not observed in the three versions of EOR data, represent observations considered by FWS that have not been incorporated in the EOR databases. Of particular concern are 7 out of 39 mollusc species that are known to occur, but do not appear in the EOR database (case 4). Species considered possible by FWS and with either EORs prior to 1975 (case 5) or no EORs (case 6) may also be considered species for which the databases are in general agreement. Two species have been observed since 1985, but are not considered possible by FWS (case 7); this case represents species for which FWS data have probably not been updated. One, the Cherokee darter, was observed in 1994 at one site in Georgia. The other, the royal snail, was observed in 1988 or 1991 at three different Tennessee sites. Finally, the turgid-blossom has not been observed since 1975 (EOR) and is not considered possible (FWS) in any of the counties (case 8); this species is possibly extinct (Williams and others 1993) and is designated as such in the EOR dataset.

Numbers of imperiled and T&E species in each county for both datasets and subsets are given in the Appendix. Within the EOR dataset, total T&E species

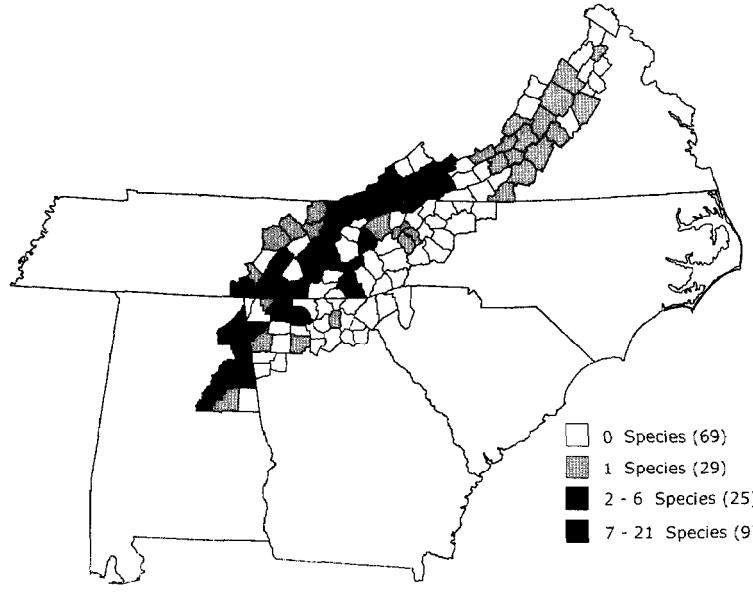

Figure 8. Geographic distribution of T&E aquatic species known to occur (FWS dataset) in 132 counties in the southern Appalachians. Details as for Figure 1.

Table 1. Number of aquatic species in the datasets for the southern Appalachians, by taxonomic groups and federal and global rank categories. Numbers in global ranking rows Gl, G2, and G3 include only taxa that are not also federally listed, proposed, or former candidate taxa. Four proposed endangered molluscs are included in totals for T & E species. Entries for the FWS dataset are known (single numbers) or known/possible (dual numbers)

	Fish	Mollusc	Herpetile	Insect	Other invertebrate	All species
EOR dataset						
Endangered	7	26	0	0	1	34
Threatened	9	0	0	0	1	10
Proposed	0	4	0	0	0	4
C2	17	21	5*	7	12	62
Gl	0	1	0	8	11	20
G2	9	2	0	0	8	19
G3	20	3	1	11	5	40
Total T&E	16	30	0	0	2	48
Total Imperiled	62	57	6	26	38	189
FWS dataset						
Endangered	6/1	23/6	0	0	1	30/7
Threatened	8	3	0	0	1	12
Proposed	0	4	0	0	0	4
Total T&E	14/1	30/6	0	0	2	46/7

*Includes one Cl population that could not be separated from a C2 population in the database.

counts were not significantly different ($P > 0.025$) from those for the last 20 years or 10 years for all states except Tennessee ($P = 0.0001$ for both comparisons) and Virginia ($P = 0.008$ for total counts versus the last 10 years). Within the FWS dataset, known and possible species counts were significantly different from known species counts only for Georgia and Tennessee ($P < 0.0001$).

Differences for the paired comparisons between datasets of T&E species counts (Table 4) were calculated from the numbers in the Appendix. The mean differences for all four comparisons were significantly different among the six states (ANOVA, $P < 0.00125$)—the datasets differed from each other differently for each state.

In the seven Alabama counties, no species were observed after 1974, and all species in the FWS dataset were known to occur (Appendix). None of the four paired comparisons (Table 4) was significant ($P > 0.0125$). For all seven counties, although more T&E species were known in the FWS dataset than were observed in the EOR dataset, the difference was not significant ($P = 0.031$).

For Georgia counties, there were more FWS known and possible species than T&E species in the EOR dataset (Table 4). Although there were also more FWS known species than T&E species in the EOR dataset, the difference was not significant ($P = 0.08$). The numbers of imperiled species observed since 1975 and 1985 were lower than all EOR observations (Appendix), but similar declines did not occur for T&E species (Appendix) because few counties had any T&E species observations in the EOR dataset.

None of the four comparisons was significant for North Carolina. Most counties had no T&E species and those that did had three or fewer species (Appendix). Nearly all FWS species numbers were known and similar

Table 2. Threatened and endangered (T & E) aquatic species in the southern Appalachians. Scientific names are those given on FWS lists. An X in the last 5 columns denotes that the species appears in the designated dataset. Column headings denote all years (A), last observed in 1975-95 (20), and last observed in 1985-95 (10) in the EOR dataset and known and possible (K & P) and known (K) occurrences in the FWS dataset

Scientific name	Common name	Federal status	EOR			FWS	
			A	20	10	K&P	K
Fish							
Cottus pygmaeus	Pygmy sculpin	T	**X**			X	X
Cyprinella caerulea	Blue shiner	T	**X**	X	X	X	X
Cypinella monacha	Spotfin chub	T	**X**	X	X	X	X
Erimystax cahni	Slender chub	T	**X**	X	X	X	X
Etheostoma scotti	Cherokee darter	T	**X**	X	X		
Etheostoma sp 3	Duskytail darter	E	**X**	X		X	X
Notropis sp 3	Palezone shiner	E	**X**			X	
Noturus baileyi	Smoky madtom	E	**X**	X		X	X
Noturus flavipinnis	Yellowfin madtom	T	**X**	X		X	X
Noturus stanauli	Pygmy madtom	E	**X**	X		X	X
Percina antesella	Amber darter	E	**X**	X	X	X	X
Percina aurolineata	Goldline darter	T	**X**	X		X	X
Percina jenkinsi	Conasauga logperch	E	**X**	X		X	X
Percina rex	Roanoke logperch	E	**X**	X	X	X	X
Percina tanasi	Snail darter	T	**X**	X		X	X
Phoxinus cumberlandensis	Blackside dace	T	**X**	X	X	X	X
Molluscs							
Alasmidonta raveneliana	Appalachian elktoe	E	**X**	X	X	X	X
Athearnia anthonyi	Anthony's river snail	E	**X**	X	X	X	X
Conradilla caelata	Birdwing pearlymussel	E	**X**	X	X	X	X
Cyprogenia stegaria	Fanshell	E	**X**	X	X	X	X
Dromus dromas	Dromedary pearlymussel	E	**X**	X	X	X	X
Epioblasma brevidens	Cumberlandian combshell	PE	**X**	X	X	X	X
Epioblasma capsaeformis	Oyster mussel	PE	**X**	X	X	X	X
Epioblasma florentina florentina	Yellow-blossom pearlymussel	E	**X**			X	
Epioblasma metastriata	Upland combshell	E				X	X
Epioblasma othcaloogensis	Southern acornshell	E				X	X
Epioblasma torulosa gubernaculum	Green-blossom pearlymussel	E	**X**	X	X	X	X
Epioblasma torulosa torulosa	Tubercled blossom	E	**X**			X	X
Epioblasma turgidula	Turgid-blossom	E	**X**				
Epioblasma walkeri	Tan riffleshell	E	**X**	X	X	X	X
Fusconaia cor	Shiny pigtoe	E	**X**	X	X	X	X
Fusconaia cuneolus	Fine-rayed pigtoe	E	**X**	X	X	X	X
Hemistena lata	Cracking pearlymussel	E	**X**	X	X	X	X
Lampsilis abrupta	Pink mucket	E	**X**	X	X	X	X
Lampsilis altilis	Fine-lined pocketbook	T				X	X
Lampsilis virescens	Alabama lampmussel	E	**X**			X	
Medionidus acutissimus	Alabama moccasinshell	T				X	X
Medionidus parvulus	Coosa moccasinshell	E				X	X
Pegias fabula	Little-wing pearlymussel	E	**X**	X	X	X	X
Plethobasus cicatricosus	White wartyback	E	**X**			X	
Plethobasus cooperianus	Orange-foot pimpleback	E	**X**	X		X	X
Pleurobema collina	James spinymussel	E	**X**	X	X	X	X
Pleurobema decisum	Southern clubshell	E				X	
Pleurobema georgianum	Southern pigtoe	E				X	X
Pleurobema perovatum	Ovate clubshell	E				X	
Pleurobema plenum	Rough pigtoe	E	**X**	X		X	X
Ptychobranchus greeni	Triangular kidneyshell	E				X	X
Pyrgulopsis ogmoraphe	Royal snail	E	**X**	X	X		
Quadrula cylindrica strigillata	Rough rabbitsfoot	PE	**X**	X	X	X	X
Quadrula intermedia	Cumberland monkeyface	E	**X**	X	X	X	X
Quadrula sparsa	Appalachian monkeyface	E	**X**	X	X	X	X
Toxolasma cylindrellus	Pale lilliput	E	**X**			X	

Table 2. (Continued)

Scientific name	Common name	Federal status	EOR			FWS	
			A	20	10	K&P	K
Tulotoma magnifica	Tulotoma livebearing snail	E	X			X	X
Villosa perpurpurea	Purple bean	PE	X	X	X	X	X
Villosa trabalis	Cumberland bean pearlymussel	E	X	X	X	X	X
Other invertebrates							
Antrolana lira	Madison cave isopod	T	X	X	X	X	X
Lirceus usdagalun	Lee County cave isopod	E	X	X		X	X

Table 3. Summary of differences between T & E species in EOR and FWS datasets. Table entries are number of species of each group in Table 2 that comply with the stated case. In the case descriptions, "observed" refers to the EOR dataset and "known" and "possible" refer to the FWS dataset

Case	Fish	Molluscs	Other
1. Known and observed since 1985	6	20	1
2. Known and observed 1975-85	7	2	1
3. Known and observed prior to 1975	1	2	
4. Known but not observed in EOR		7	
5. Possible and observed prior to 1975	1	4	
6. Possible but not observed in EOR		2	
7. Observed since 1985 but not possible	1	1	
8. Observed prior to 1975 and not possible		1	
Total	16	39	2

Table 4. Paired comparisons between datasets of numbers of T & E species in counties by state. Only significant (Wilcoxon signed-rank test; $P < 0.0125$) mean differences are given in the table (P values). If the first-named dataset has more species than the second-named dataset, the mean difference will be positive. Bonferoni-adjusted α values were 0.017 for Virginia and 0.0125 for the other states

	Georgia	Tennessee	Virginia
EOR T&E versus FWS known and possible	–2.50 (0.001)		N/A
EOR T&E versus FWS known		2.27 (0.001)	–0.46 (0.004)
1975-95 EOR T & E versus FWS known			–0.74 (0.001)
1985-95 EOR T & E versus FWS known		–1.97 (0.001)	–1.08 (0.001)

to T&E species observations in the EOR dataset, regardless of time frame. For special concern species, however, many observations were historical (Appendix).

In the three South Carolina counties, no species were observed after 1974, and there were no T&E species in either dataset (Appendix). Comparisons between datasets could not be made.

Tennessee counties had large numbers of EOR species observations, both for imperiled and T&E species, but observations of T&E species in the last 10 or 20 years were lower (Appendix). Known species counts in the FWS dataset were lower than T&E species observed in the EOR dataset (Table 4) and not significantly different from EOR T&E species counted in the last 20 years ($P > 0.125$), but EOR T&E species in the last 10 years were lower than FWS known species counts (Table 4).

Some Virginia counties also had large numbers of imperiled and T&E species (Appendix). All three comparisons of Table 4 were significant ($P < 0.017$), and FWS counts of known species were greater than the EOR T&E species counts for all time periods.

To summarize, the two datasets were most consistent for North and South Carolina, where few counties have T&E species. Although not significant, fewer T&E species were reported in the EOR dataset relative to species known to the FWS for Alabama. In Georgia, there were significant numbers of known and possible species occurrences that were not reported in the EOR dataset. In Virginia, significantly fewer T&E species were reported in the EOR dataset relative to species known to the FWS. For Tennessee counties, the total EOR T&E counts and FWS known and possible occurrence counts were similar, whereas the FWS known occurrences were most like the EOR counts of the past 20 years. Here, species may have been extirpated from

many counties—for many counties, fewer species in the EOR dataset had been observed recently, and species were believed possible but not known by the FWS.

Spatial Patterns—Imperiled Species

Ten counties had 16 to 41 imperiled species in the EOR dataset: six counties in the Powell and Clinch River drainages and Knox, Anderson, Roane, and Monroe Counties, Tennessee (Figure 1). The EOR observation dates and sampling effort may influence the overall pattern in Figure 1. Anderson, Knox, and Roane Counties, Tennessee, were not among the counties that had the largest numbers of imperiled species observations (Figure 2) dated in the last 20 years (1975-95); many species have been extirpated from these counties. In the six counties in the Powell and Clinch river drainages with at least 16 imperiled species (Figure 1), at least two-thirds of the imperiled species have been observed in the past 20 years (Appendix). Two counties that make up the Holston River drainage in Virginia and Polk County, Tennessee, were among the nine counties with more than nine species EORs since 1975 (Figure 2).

Ten counties with 7 to 10 fish species in the EOR dataset (Figure 3) were scattered in four areas: the Clinch River, Virginia, and upper Holston River, Virginia and Tennessee; Patrick County, Virginia; Claiborne County, Tennessee, in the Powell River drainage; and Polk, Monroe, and Blount Counties, Tennessee.

Eight counties with 11 to 27 mollusc species in the EOR dataset were in two areas: six counties in the Powell and Clinch River drainages of Virginia and Tennessee; and Knox and Anderson Counties, the urban area of Knoxville and Oak Ridge, Tennessee (Figure 4). Most of the mollusc EORs in Anderson and Knox Counties predated the construction of many Tennessee River reservoirs, and none were more recent than 1973.

Spatial Patterns—T&E Species

Distributions of federally listed T&E species in the EOR dataset (Figure 5) were similar to those for imperiled species (Figure 1). The counties with 9 to 18 T&E species (Figure 5) included five of the six counties in the Clinch and Powell River drainages, two of the three Knoxville-area counties, and Monroe County, Tennessee, identified in Figure 1. Likewise, six of the seven counties with 4 to 17 observations of T&E species in the past 20 years (Figure 6) were in the same Clinch and Powell River counties identified in Figures 1, 2, and 4. Marion County, Tennessee, is the seventh county in this group, with only four species (Appendix).

Although 75 counties had at least one known or possible occurrence in the FWS dataset (Figure 7), only 63 counties had known occurrences of these species (Figure 8). Five (Figure 7) or six (Figure 8) of the counties with high species counts were the same counties in the Powell and Clinch River drainages that were identified in the EOR dataset (Figures 1–2, 4–6). Grainger and Knox Counties, Tennessee, both in drainages of the Tennessee River, had mostly possible occurrences of T&E species (cf. Figures 7 and 8). Knox County had the second highest (tie) count of known or possible species (Appendix). Murray and Whitfield Counties, Georgia, are primarily in the Conasauga River drainage, another area known for its diversity (Etnier and Starnes 1993).

Discussion

Neither dataset provided a complete picture of imperilment patterns. The EOR dataset provided information about more species because special concern species that are not federally listed were included. The heritage programs are concerned with a broader array of imperiled species than just the federally listed species. In the southern Appalachians, about half of imperiled molluscs and about one-fourth of imperiled fish were listed by the FWS; much smaller proportions of other taxonomic groups were federally listed. The FWS dataset is more restrictive in that only the listed or proposed T&E species are included. Most T&E species appeared on both lists, but for about 40% of species, inconsistencies exist (Table 3), notably, lack of recent records in the EOR dataset. Several heritage programs are known to have a backlog of data that awaits entry into the database.

The information in the two datasets is a combination of the distributions of imperiled species, the processes by which information is included in the datasets, and intended purposes of the data. Most heritage programs are operated by state agencies and are largely dependent on sharing of data from various agencies and experts, sometimes collected for particular reasons at particular sites (e.g., bridge sites). With these data, observed patterns are a function of both where people search and distribution patterns of species. Criteria for inclusion of data in both datasets also include quality assurances required for the legal arena in which data may be used.

The FWS dataset is a compilation of the information on “known” and “possible” locations of species that is

acquired as part of the listing process. "Possible" is not well defined by the FWS, and its use varies from office to office; indeed, the Virginia office includes historic information, but does not distinguish "known" from "possible" in the dataset (C. Shultz, personal communication). Historic information may contribute to a species being identified as "possible" in a county. Many sources of information are consulted in the process, and observations that do not appear in the EOR dataset may contribute to this dataset. Of course, only federally listed and proposed species are included in the FWS dataset. Former C2 candidate species were not included, and at the time we compiled these datasets, the northern population bog turtle was the only Cl candidate species in the datasets (FWS 1994c; now threatened). The FWS does not keep track of species designated as globally rare by The Nature Conservancy, unless they are also federally listed.

There is some ambiguity in the identification of a particular county as having few or many species in these two datasets. A county may have many species in the datasets for several contradictory and interrelated reasons: the county is a refuge for many species, the county once had many endemic species that are now imperiled, the county is relatively large (the species–area relation), or people spend more time looking for species there than in other counties. Likewise, several explanations may apply to counties with no or few identified species.

One of the more serious shortcomings of both datasets is the lack of information on some special concern species, especially former C2 candidate species. All states in the southern Appalachians have a backlog, some severe, of species recognized by fisheries professionals as threatened or endangered but which are not federally listed (Warren and Burr 1994). These species are not included in the FWS dataset because they have not been federally listed. Yet these species are of concern to many experts. Several former C2 candidate species are also not included on the EOR list, even though published information exists. For example, the finescale saddled darter (a.k.a. candy darter, *Etheostoma osburni)* does not appear on the EOR list, although it has historically been located in several Virginia counties (Jenkins and Burkhead 1994) and still exists in at least one Virginia county (K. Leftwich, personal communication).

The EOR dataset includes both current and historical information, and dates are associated with EORs. The dataset is not large enough to produce an analysis of trends, but users can assess currency of information. The Tennessee Heritage Program appears to have the most data on historical distributions, followed by Virginia. If users exclude all EOR data where observations are more than 10 or 20 years old, many known T&E species would be excluded from consideration (Table 2) and county species counts would be lower than are known to the FWS (Appendix, Table 4).

The EOR data set may suffer from underreporting, especially for recent years, either because data do not meet criteria for inclusion or because data entry is backlogged. For example, the Conasauga River counties in Georgia that were identified in the FWS dataset and elsewhere (Freeman and others 1996) were not identified in the EOR dataset. This may be a case of underreporting in the Georgia Heritage Program EOR dataset because this is an area of intense sampling effort (Freeman and others 1996).

Data in the EOR dataset are based on sampling effort that is not uniform through time and space. For example, many counties had EORs dated 1993–95. But Hancock County, in a remote part of Tennessee, had 26 imperiled species, 24 of which were last observed between 1975 and 1979 and none since 1985. Although this county, containing unimpounded sections of both the Clinch and Powell Rivers, appears to be a refuge for imperiled species, either no sampling has occurred here in the past 15 years or data have not been reported or entered into the EOR dataset. Without additional information about how sampling effort was expended over time and across the region, the EOR dataset should be viewed with some caution.

Patterns of imperilment, based on number of species in each county, were significantly different between the two datasets for Georgia, Tennessee, and Virginia, where the largest number of threatened and endangered species reside. Nevertheless, some counties always appear as centers of imperilment and the general patterns of imperilment are similar.

The Clinch and Powell River drainages are clearly areas with many imperiled aquatic species (Figures l–2, 4–8), particularly molluscs (Figure 4), and this result is common to all datasets examined. The neighboring Holston River drainage is also an important refuge for fish (Figure 3). The Powell River drainage is an area in which coal mining and associated effects of acid mine drainage and increased sedimentation have contributed to endangerment of molluscs (Neves and others 1997). The counties with high species counts are upstream from the major reservoirs of the Tennessee River and may thus constitute a refuge for many mussel species.

Several counties in the area where the Clinch,

Powell, Holston, and other tributaries converge on the mainstem Tennessee River were also identified as historical (prior to 1975) or possible locations of imperiled species (cf. Figures 1 and 5, 7 and 8). These are urbanized areas around Knoxville; but perhaps more critical to aquatic species, especially molluscs (Figure 4), these sections of the rivers have been impounded into reservoirs. Conversion of rivers to reservoirs results in loss of unique habitat—the large river with associated shoals—for many species, especially mussels. Impoundment of rivers and degradation of water quality have been implicated in the loss of mussel species in the Tennessee River (Neves and others 1997). This area probably no longer functions as a refuge for imperiled species (Figures 2, 6, 8).

This paper was not intended to be a detailed discussion of aquatic species imperilment in the southern Appalachians. Several recent papers present more detailed discussions of imperilment patterns for Southeastern aquatic species (Williams and others 1989, Neves 1991, Williams and others 1993, Warren and Burr 1994, Walsh and others 1995, Taylor and others 1996, Burkhead and others 1997, Neves and others 1997, Warren and others 1997).

These two databases form a reasonable starting point for identifying regional imperilment patterns, yet neither is complete. Our evaluation was made at the county level, and differences in the species attributed to individual counties were found. At smaller spatial scales, such as those used for conservation planning, these differences would be more pronounced. Those seeking to focus conservation efforts should examine all available evidence, including these datasets, state game department records, and published distribution accounts, where they exist (e.g., Etnier and Starnes 1993, Jenkins and Burkhead 1994, Mettee and others 1996). Unfortunately, even a relatively heroic effort to incorporate all available evidence will still be limited by inadequate sampling, especially of mollusc and other invertebrate populations.

Acknowledgments

We thank G. Gaines, D. Norris, S. Croy, and members of the SAA terrestrial team for acquiring the EOR data from each of the heritage programs and for their assistance with these data. We also thank the staffs of the various state heritage program and FWS offices who contributed data, either directly or indirectly. J. Friddell and P. Shute reviewed the draft SAA report and made suggestions that led to improvements in this manuscript. We thank B. Albanese, K. Krueger, P. Meier, R. Morgan, and P. Shute for reviewing this manuscript.

Appendix: Counts of Imperiled Species

Number of species in each southern Appalachian county for the two datasets. For the EOR dataset, numbers of imperiled and T & E species that have been observed in the past 10 and 20 years are given, as well as the total number of species. FWS numbers are presented separately for species known or possible in each county

	EOR						FWS	
	Imperiled			T&E				
	Total	75-95	85-95	Total	75-95	85-95	Known	Pos
Alabama								
Calhoun	9	0	0	3	0	0	5	0
Cherokee	3	0	0	1	0	0	4	0
Clay	1	0	0	0	0	0	1	0
Cleburne	2	0	0	1	0	0	2	0
Dekalb	6	0	0	1	0	0	2	0
Randolph	1	0	0	0	0	0	0	0
Talladega	8	0	0	2	0	0	3	0
Georgia								
Banks	0	0	0	0	0	0	0	0
Bartow	0	0	0	0	0	0	0	6
Catoosa	2	1	0	0	0	0	1	2
Chattooga	1	0	0	0	0	0	2	7
Cherokee	4	4	2	2	2	2	1	3
Dade	4	0	0	0	0	0	0	0
Dawson	1	1	0	0	0	0	0	1
Fannin	4	4	0	0	0	0	0	1
Floyd	0	0	0	0	0	0	1	8
Forsyth	0	0	0	0	0	0	0	1
Franklin	0	0	0	0	0	0	0	0
Gilmer	2	1	0	2	1	0	2	2
Gordon	0	0	0	0	0	0	0	10
Habersham	3	0	0	0	0	0	0	0
Hall	0	0	0	0	0	0	0	0
Haralson	1	1	0	0	0	0	0	0
Lumpkin	0	0	0	0	0	0	0	0
Murray	6	6	0	2	2	0	10	2
Paulding	0	0	0	0	0	0	0	0
Pickens	0	0	0	0	0	0	0	0
Polk	0	0	0	0	0	0	0	1
Rabun	-	4	2	0	0	0	0	0
Stephens	;	0	0	0	0	0	0	0
Towns	1	0	0	0	0	0	0	0
Union	2	1	0	0	0	0	0	0
Walker	2	1	1	0	0	0	0	3
White	1	0	0	0	0	0	1	0
Whitfield	6	5	0	1	1	0	10	2
North Carolina								
Alleghany	4	1	1	0	0	0	0	0
Ashe	5	4	4	0	0	0	0	0
Avery	2	1	1	0	0	0	0	0
Buncombe	7	1	1	1	0	0	0	0
Burke	2	0	0	0	0	0	0	0
Caldwell	1	0	0	0	0	0	0	0
Cherokee	4	1	1	0	0	0	0	0
Clay	2	1	1	0	0	0	0	0
Graham	4	3	1	0	0	0	0	0
Haywood	3	3	3	0	0	0	0	0
Henderson	4	4	3	0	0	0	0	0
Jackson	7	6	4	0	0	0	0	0

Appendix: (Continued)

	EOR						FWS	
	Imperiled			T&E				
	Total	75-95	85-95	Total	75-95	85-95	Known	Pos
McDowell	2	1	0	0	0	0	0	0
Macon	8	7	5	1	1	1	2	1
Madison	7	3	1	1	0	0	0	0
Mitchell	3	2	2	1	1	1	1	0
Surry	2	1	1	0	0	0	0	0
Swain	7	6	4	3	3	3	3	0
Transylvania	6	3	2	1	0	0	0	0
Watauga	6	5	5	0	0	0	0	0
Wilkes	1	1	1	0	0	0	0	0
Yancey	7	5	4	0	0	0	1	0
South Carolina								
Greenville	2	0	0	0	0	0	0	0
Oconee	2	0	0	0	0	0	0	0
Pickens	4	0	0	0	0	0	0	0
Tennessee								
Anderson	17	2	1	12	0	0	1	2
Bledsoe	2	1	1	0	0	0	0	0
Blount	11	6	0	4	0	0	5	2
Bradley	6	3	1	3	2	1	6	1
Campbell	8	4	3	3	1	1	1	4
Carter	3	2	1	0	0	0	0	0
Claiborne	26	23	4	16	14	2	9	5
Cocke	5	4	0	2	2	0	2	2
Cumberland	6	3	1	1	1	0	1	0
Grainger	9	0	0	7	0	0	2	12
Greene	10	6	0	3	1	0	1	5
Hamblen	6	2	0	3	0	0	0	6
Hamilton	11	4	1	6	1	0	2	6
Hancock	26	24	0	18	16	0	13	2
Hawkins	9	2	0	6	0	0	2	6
Jefferson	3	0	0	2	0	0	0	9
Johnson	3	3	2	0	0	0	0	0
Knox	21	4	2	13	1	0	2	13
Loudon	10	7	0	4	3	0	2	1
McMinn	3	0	0	0	0	0	0	1
Marion	13	7	5	6	4	2	3	5
Meigs	6	5	2	3	3	1	5	2
Monroe	16	6	0	9	3	0	3	2
Morgan	6	3	0	1	1	0	1	1
Polk	14	10	1	5	3	0	6	1
Rhea	7	3	2	4	2	1	4	6
Roane	16	7	5	8	1	0	0	2
Sequatchie	1	1	0	0	0	0	1	0
Sevier	5	3	0	1	0	0	0	0
Sullivan	12	3	0	5	1	0	2	6
Unicoi	2	2	0	0	0	0	1	1
Union	6	3	3	5	2	2	0	0
Washington	2	1	0	0	0	0	0	1
Virginia								
Albemarle	4	4	3	1	1	1	1	— *
Alleghany	6	3	2	1	1	1	1	—
Amherst	3	3	3	1	1	1	1	—
Augusta	7	5	5	1	1	1	1	—
Bath	9	2	0	0	0	0	0	—
Bedford	3	3	1	0	0	0	1	—
Bland	2	2	1	0	0	0	0	—

Appendix: (Continued)

	EOR						FWS	
	Imperiled			T&E				
	Total	75-95	85-95	Total	75-95	85-95	Known	Pos
Botetourt	8	7	4	1	1	1	l	-
Buchanan	0	0	0	0	0	0	0	-
Carroll	3	3	1	0	0	0	0	-
Craig	8	7	4	1	1	1	l	-
Dickenson	0	0	0	0	0	0	0	-
Floyd	6	6	4	0	0	0	0	-
Franklin	7	7	5	1	1	1	l	-
Frederick	1	1	1	0	0	0	0	-
Giles	3	1	0	0	0	0	l	-
Grayson	6	6	2	0	0	0	0	-
Greene	1	0	0	0	0	0	0	-
Highland	6	5	2	0	0	0	0	-
Lee	27	22	15	12	10	8	14	-
Madison	2	1	1	0	0	0	0	-
Montgomery	11	5	4	1	1	1	1	-
Nelson	3	2	1	0	0	0	0	-
Page	3	1	1	0	0	0	0	-
Patrick	8	8	7	1	1	1	l	-
Pulaski	3	2	1	0	0	0	0	-
Rappahannock	3	2	2	0	0	0	0	-
Roanoke	5	3	2	1	1	1	l	-
Rockbridge	7	2	1	1	0	0	l	-
Rockingham	3	2	2	0	0	0	1	-
Russell	26	17	13	12	7	7	13	-
Scott	41	35	19	18	17	10	21	-
Shenandoah	6	3	3	0	0	0	0	-
Smyth	15	9	6	4	3	3	6	-
Tazewell	18	12	10	7	6	5	7	-
Warren	5	2	2	1	1	1	l	-
Washington	12	10	5	3	3	2	9	-
Wise	7	5	0	2	2	0	3	-
Wythe	4	3	2	0	0	0	0	-

*Distinction between known and possible was not made in the Virginia FWS dataset; all records are treated as known.

Literature Cited

Burch, J. B. 1989. North American freshwater snails. Malacological Publications, Hamburg, Michigan, 365 pp.

Burkhead, N. M., S. J. Walsh, B. J. Freeman, and J. D. Williams. 1997. Status and restoration of the Etowah River, an imperiled southern Appalachian ecosystem. Pages 375–444 *in* G. W. Benz and D. E. Collins (eds.), Aquatic fauna in peril: the Southeastern perspective. Special publication 1, Southeast Aquatic Research Institute, Decatur, GA.

Conant, R. 1975. A field guide to reptiles and amphibians of Eastern and Central North America, 2d ed. Houghton Mifflin, Boston, MA, 427 pp.

Dobson, A. P., J. P. Rodriguez, W. M. Roberts, and D. S. Wilcove. 1997. Geographic distribution of endangered species in the United States. *Science* 275:550-553.

Etnier, D. A., and W. C. Starnes. 1993. The fishes of Tennessee. University of Tennessee Press, Knoxville, TN, 681 pp.

Flather, C. H., L. A. Joyce, and C. A. Bloomgarden. 1994. Species endangerment patterns in the United States. General Technical Report RM-241, US Forest Service, Fort Collins, CO, 42 pp.

Flather, C. H., M. S. Knowles, and I. A. Kendall. 1998. Threatened and endangered species geography. *BioScience* 48:365–376.

Flebbe, P. A., J. Harrison, G. Kappesser, D. Melgaard, J. Riley, and L. W. Swift, Jr. 1996. Status of aquatic resources. Pages 15–63 *in* The Southern Appalachian Assessment aquatic technical report. US Forest Service, Southern Region, Atlanta, GA.

Freeman, B. J., G. W. Benz, and D. E. Collins. 1996. A stakeholder's guide to the Conasauga River and Tennessee. Conservation Bulletin no. 1, Southeast Aquatic Research Institute, Chattanooga, TN.

FWS (US Department of the Interior, Fish and Wildlife Service). 1994a. Endangered and threatened wildlife and plants; proposal to list the Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot as endangered species. *Federal Register* 59 (134) : 35900–35906.

FWS (US Department of the Interior, Fish and Wildlife Service). 1994b. Endangered and threatened wildlife and plants. (50 CFR 17.11 and 17.12) U.S. Government Printing Office, Washington, DC., 42 pp.

FWS (US Department of the Interior, Fish and Wildlife Service). 1994c. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species. *Federal Register* 59 (219):58982–59028.

FWS (US Department of the Interior, Fish and Wildlife Service). 1994d. Endangered and threatened wildlife and plants; Appalachian Elktoe determined to be an endangered species. *Federal Register* 59 (225) :60324–60334.

FWS (US Department of the Interior, Fish and Wildlife Service). 1994e. Endangered and threatened wildlife and plants; determination of threatened status for the Cherokee Darter and endangered status for the Etowah Darter. *Federal Register* 59 (243):65505–65512.

Hubricht, L. 1985. The distributions of the native land mollusks of the eastern United States. *Fieldiana: Zoology* 24:1–191.

Jenkins, R. E., and N. M. Burkhead. 1994. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, MD, 1079 pp.

Martof, B. S., W. M. Palmer, J. R. Bailey, and J. R. Harrison, III. 1980. Amphibians and reptiles of the Carolinas and Virginia. The University of North Carolina Press, Chapel Hill, NC, 264 pp.

Master, L. L., S. R. Flack, and B. A. Stein (eds.). 1998. Rivers of life: critical watersheds for protecting freshwater biodiversity. The Nature Conservancy, Arlington, VA, 71 pp.

Merritt, R. W., and K. W. Cummins (eds.). 1984. An introduction to the aquatic insects of North America, 2d ed. Kendall/Hunt, Dubuque, IA, 722 pp.

Mettee, M. F., P. E. O'Neil, and J. M. Pierson. 1996. Fishes of Alabama and the Mobile Basin. Oxmoor House, Birmingham, AL, 820 pp.

Neves, R. J. 1991. Mollusks. Pages 251–320 *in* K. Terwilliger (coord.), Virginia's endangered species: proceedings of a symposium. McDonald and Woodward, Blacksburg, VA

Neves, R. J., A. E. Bogan, J. D. Williams, S. A. Ahlstedt, and P. W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pages 43–85 *in* G. W. Benz and D. E. Collins (eds.), Aquatic fauna in peril: the Southeastern perspective. Special publication 1, Southeast Aquatic Research Institute, Decatur, GA.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States: protozoa to mollusca, 3d ed. Wiley, NewYork, 628 pp.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. Common and scientific names of fishes from the United States and Canada, 5th ed. American Fisheries Society, Bethesda, MD, 183 pp.

SAS Institute. 1990. SAS guides, version 6, edition 1. SAS Institute, Cary, NC.

Taylor, C. A., M. L. Warren, Jr., J. F. Fitzpatrick, Jr., H. H. Hobbs, III, R. F. Jezerinac, W. L. Pflieger, and H. W. Robison. 1996. Conservation status of crayfishes of the United States and Canada. *Fisheries* 21(4):25–38.

Walsh, S. J., N. M. Burkhead, and J. D. Williams. 1995. Southeastern freshwater fishes. Pages 144–147 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (eds.), Our living resources. U.S. Department of the Interior, National Biological Service, Washington, DC.

Warren, M. L., Jr., P. L. Angermeier, B. M. Burr, and W. R Haag. 1997. Decline of a diverse fish fauna: patterns of imperilment and protection in the southeastern United States. Pages 105–164 *in* G. W. Benz and D. E. Collins (eds.), Aquatic fauna in peril: the Southeastern perspective. Special publication 1, Southeast Aquatic Research Institute, Decatur, GA

Warren, M. L., Jr., and B. M. Burr. 1994. Status of freshwater fishes of the United States: overview of an imperiled fauna. Fisheries 19 (1):6–18.

Williams, J. D., and R. J. Neves. 1995. Freshwater mussels: a neglected and declining aquatic resource. Pages 177–179 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (eds.), Our living resources. U.S. Department of the Interior, National Biological Service, Washington, DC.

Williams, J. D., M. L. Warren, Jr., K S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18(9):5–*22.*

Williams, J. E., J. E. Johnson, D.A. Hendrickson, S. Contreras-Balteras, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. *Fisheries* 14(6):2–20.