AN ASSESSMENT AND STRATEGY FOR CONSERVATION OF AQUATIC RESOURCES ON THE DANIEL BOONE NATIONAL FOREST, INTERIM REPORT, APRIL 2001

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Table of Contents Page

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Purpose and Need for an Assessment and Strategy

Kentucky's Daniel Boone National Forest (DBNF) supports a highly diverse assemblage of aquatic species including 141 native fishes, 16 introduced fishes, 67 mussels, and 15 crayfish. These aquatic resources and their habitats have great regional and National scientific and conservation value. They are a major attraction for visitors from all over the country. Just one use, fishing and related activities, each year accounts for more than 250,000 recreational-visitor-days on the Forest.

Demand for the many products, amenities, and recreational opportunities provided by the DBNF is high and is expected to increase over the next few years. To meet this demand while protecting or maintaining all resource values, managers of the DBNF must have the most up-to-date, accurate information available. The aquatic fauna - fish, mussels, and other invertebrates - is especially vulnerable to changes in land use and the general decline of many aquatic species throughout the southern U.S. has heightened public awareness and concern for aquatic ecosystem health.

A cursory review conducted by DBNF personnel in 1996 suggested that managers would benefit from a comprehensive inventory of existing information and analysis of the status of aquatic resources. In early 1997, the management team of the DBNF commissioned a review of the aquatic fauna and associated habitats found within the Forest's proclamation boundaries. This review had four primary purposes: 1) to assess the current status of aquatic species and their habitats on the Forest; 2) to develop a strategy for maintaining and restoring aquatic and riparian habitats; 3) to recommend standards and guidelines for activities that may affect aquatic and riparian resources; and 4) to develop direction for the short- and long-term monitoring of these resources.

I. ASSESSMENT OF AQUATIC RESOURCES ON THE DANIEL BOONE NATIONAL FOREST

The Physical Setting

The Daniel Boone National Forest contains parts of several physiographic regions or ecological subsections (fig. 1) and portions of three major river systems: the Licking, Kentucky, and Cumberland rivers.

Ecological Subsections

The DBNF lies within or is bordered by several sections and subsections within the Eastern Broadleaf Forest (Oceanic and Continental) provinces and the Central Appalachian Broadleaf-Coniferous Forest Province (Keys and others 1995). The western part of the DBNF lies primarily within the Northern Escarpment, Southwestern Escarpment, and Low Hills Belt subsections of the Northern Cumberland Plateau Section and is bordered to the west by the Highland Rim and Bluegrass sections (Eastern Broadleaf Forest Continental Province). The eastern part of the DBNF lies primarily within the Rugged Eastern Hills subsection (Northern Cumberland Plateau Section) (fig. 1). The southern and southeastern boundaries of the forest also encompasses the Jellico Mountains subsection of the Cumberland Mountains Section (Central Appalachian Broadleaf-Coniferous Forest Province).

Northern Cumberland Plateau Section (221H)

Rugged Eastern Hills (221Ha) This subsection is located in southeastern Kentucky and includes land on the Redbird Ranger District. The Rugged Eastern Hills are characterized by moderate-relief hills and ridges that range in elevation from 365 to 760 m (1,200 to 2,500 feet). Ridges are capped by a mixture of clay shales, siltstone, sandstone, and coal. Valley floors are soft clay shales and siltstones. The geology consists of Pennsylvanian-aged Lower- and Middle-Breathitt formations. The geomorphic processes primarily responsible for shaping this landscape are erosion and mass wasting. The small cliffs found in some valleys are primarily the result of stream incision. Landslides are frequent throughout this subsection but are most common in its southernmost portion. Ridges are characterized by soils that range in depth from 50 to 100 cm (20 to 40 inches) or more. Most subsoils have moderate clay content, and the soils are moderately well to well drained. Soils on the slopes are typically over 100 cm (40 inches) deep, with a few rock outcrops occurring on the lower slopes of the more entrenched valleys. Most have moderate to high clay content in the subsoil and are moderately well drained.

The Rugged Eastern Hills subsection has a moderate number of small- to medium-sized intermittent and perennial streams. Typically, the relatively steep valleys of smaller streams are V-shaped, narrow, and boulder-dominated. Valleys of the larger streams also tend to be narrow but less steep, broader, and have more alluvial deposits. Drainage patterns are dendritic, and dissection is moderately high, with about 11 km of perennial, intermittent, and ephemeral streams per square kilometer (18 mi/square mile). The Middle Fork of the Kentucky River is the largest stream traversing this subsection.

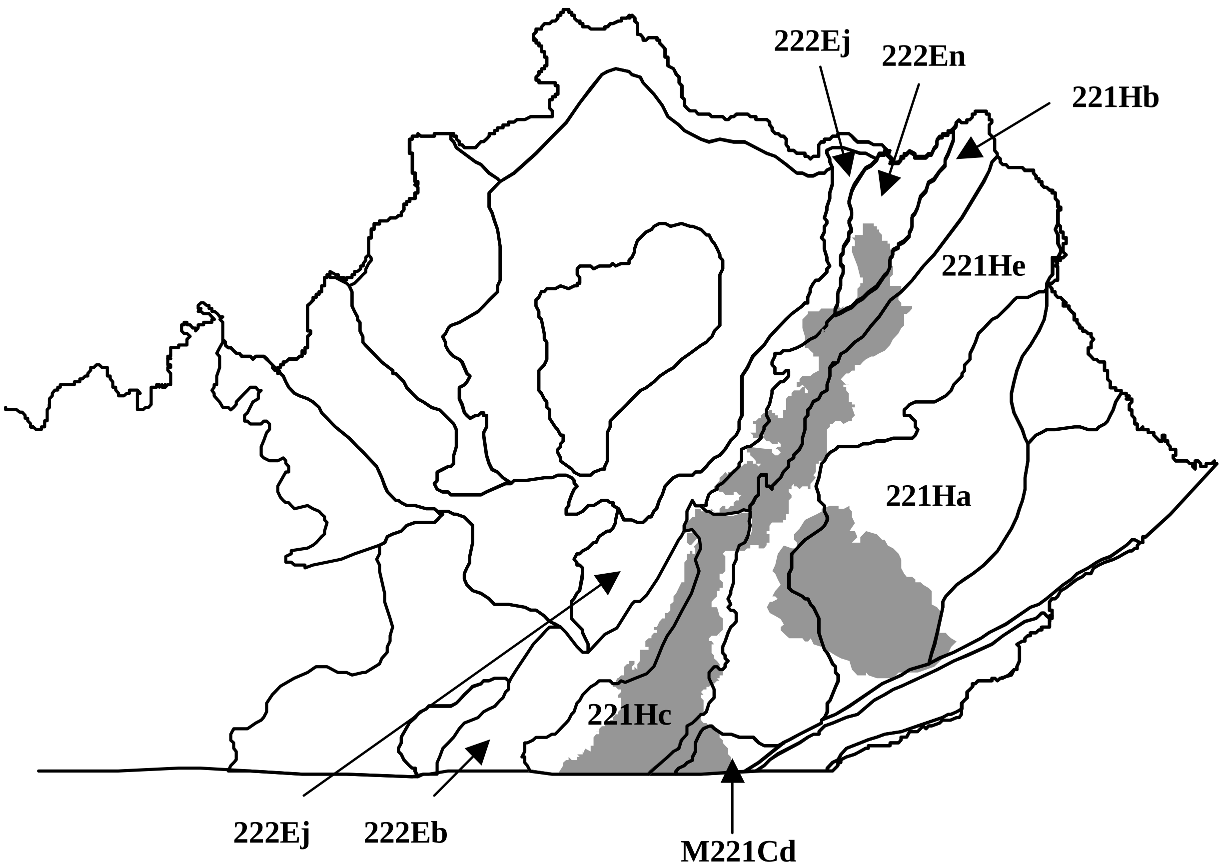

Figure 1. Ecological subsections of east-central Kentucky. Shaded area denotes the Daniel Boone National Forest.

Northern Escarpment (221 Hb) This subsection is located in east-central Kentucky and includes land on the Morehead, Stanton, and London Ranger Districts. The Northern Escarpment is transitional between the Highland Rim and the Cumberland Plateau and is characterized by narrow to broad winding ridges with side slopes averaging 50 percent, but may exceed 65 percent in the most entrenched valleys. Rock outcrops and cliffs are common in all but the shallowest valleys. Single and moniliform knobs, with wide valleys and well-developed flood plains are prevalent to the north and west. Ridges are capped by resistant conglomerate and sandstone; although mixtures of soft clay shales, siltstone, sandstone and coal also are present. Cliffs are sandstone/conglomerate and limestone. The floors of the largest valleys consist of cherty limestone, sandstone, shale, and siltstone. The geology includes Pennsylvanian-Age Lower Breathitt and Lee formations on the ridges and sideslopes, and Mississippian-Age Borden and Newman formations lower in the larger valleys. The geomorphic processes primarily responsible for shaping this landscape are erosion and block slides. Soils on the ridges are typically 50 to 75 cm (20 to 30 inches) deep and moderately well to well drained with moderate clay content in the subsoil. Rock fragments are common. Sideslope soils are usually over 100 cm (40 inches) deep and moderately well drained with moderate to high clay content in the subsoil. Some outcrops and talus slopes are present.

Side valleys are narrow with short, steep slopes and waterfalls are frequent. Fourth- and fifth-order streams have moderately broad, flat valleys with well-developed alluvial bottoms. Stream gradients are moderate and the discharge regime is somewhat modified by karst hydrology. Drainage patterns are dendritic, and dissection is moderately high with about 11 km of perennial, intermittent, and ephemeral streams per square kilometer (18 mi/square mile). Parts of both the Kentucky and Licking watersheds are within this subsection.

Southwestern Escarpment (221Hc) This subsection is located in east-central Kentucky and Tennessee. Included within it are large portions of the London, Somerset, and Stearns Ranger Districts, as well as the southwest portion of the Berea Ranger District. The Southwestern Escarpment is transitional between the Highland Rim and the Cumberland Plateau and contains characteristics of both. To the west, this subsection is intricately dissected into narrow ridges bordered by deep valleys with precipitous walls and cliffs. Many ridges have been truncated to cliff-bound knobs. To the east, in an area known as the London-Corbin Plain, the southwestern escarpment becomes much flatter with broad ridges and short, gentle slopes. Cliffs are present but much less frequent than to the west. Broad ridges usually are capped in a mixture of soft clay shales, siltstone, and coal with underlying, resistant sandstone that forms cliffs when exposed. Narrow ridges often are capped in sandstone. The valley floors are clay shales and siltstones, or, in some cases, limestone. The ridges are Pennsylvanian-Age Lower Breathitt formation, and the valleys are of the Lower Breathitt and Lee formations. Soils on ridges are up to 100 cm (40 inches) deep, with moderate clay content in the subsoil and are moderately well- to well-drained. Rock outcrops and fragments are common above and below cliff faces; outcrops occur less often on the gentler sideslopes. Soils on the slopes are typically deeper than 100 cm (40 inches), have moderate to high clay content in the subsoil, and are moderately well drained.

Stream channels in this subsection often flow through solid and broken, cliff-lined box canyons and have narrow alluvial bottoms. The valleys are broader to the west and slightly narrower to the east. Stream gradients in the main channels are usually 1 to 2 percent. Tributaries have relatively steep channel gradients (2 to 10 percent) and are armored with rocks that sometimes form cascade-like habitat, often with 12 to 25 m (40-80 foot) waterfalls. The drainage pattern is dendritic, and drainage densities are moderate. Typical stream hydrographs for the area show a seasonal increase in flow from November through January in response to increased precipitation and decreased evapotranspiration. The steep slopes of the area cause rapid surface runoff that, coupled with the semi-impervious nature of the soils and geology, limits the infiltration of precipitation to aquifers. As a result, most streams that drain less than 259 square kilometers (100 square miles) dry up occasionally (Leist and others 1982). The largest streams in this subsection are the Rockcastle and Upper Cumberland Rivers.

Low Hills Belt (221He) This subsection is located in central eastern Kentucky and includes land on the Morehead, Stanton, and Berea Ranger Districts. The Low Hills Belt is characterized by low-relief rolling ridges with short, gentle slopes that are occasionally broken by rock outcrops in the largest valleys. The relief becomes greater and the valleys more V-shaped in the southern portion of this subsection. Elevations range from 275 to 520 m (900 to 1,700 feet). Ridges are broad and rolling with some narrow, winding ridges. Sideslopes average 30 to 40 percent but may exceed 50 percent in the most entrenched valleys. Rolling ridges are capped with a mixture of soft clay shales, siltstone, and coal and a few ridges have small caps of resistant conglomerate. The geology includes Pennsylvanian-Age, Lower Breathitt and Lee formations. The geomorphic processes primarily responsible for shaping this landscape are erosion and fluvial deposition. Ridges are characterized by soils which range from 50 to 100 cm (20 to 40 inches) deep. Most have moderate clay content in the subsoil and are moderately well to well-drained. Soils on the slopes are typically over 100 cm (40 inches) deep, with occasional rock outcrops and fragments occurring on lower slopes of the more entrenched valleys. Most have moderate to high clay content in the subsoil and are moderately well drained.

The Low Hills Belt subsection has a moderate number of small- to medium-sized, moderately high gradient intermittent and perennial streams. Most have moderately wide, flat valleys with some floodplain development. Fourth- and fifth-order streams have broad alluvial bottoms. Drainage patterns are dendritic and dissection is moderate with about 10 to 11 km of perennial, intermittent, and ephemeral streams per square kilometer (16 to 18 mi/square mile). The Licking, Kentucky, and Cumberland Rivers all transect this subsection.

Interior Low Plateau, Highland Rim Section (222E)

Eastern Karst Plain (222Eb) This subsection is located along the western boundary of the Somerset and Stearns Ranger Districts. The Eastern Karst Plain consists of a relatively low, rolling plain that is interrupted by moderate-elevation domes and a few knobs. The surface plain also is punctuated with small to large sinkholes that indicate underlying cave systems. Elevations typically range between 244 to 275 m (800 to 900 feet) on the plain and 305 to 335 m (1,000 to 1,100 feet) on the knobs. The highest elevations are on the eastern side of the subsection, where the knobs are capped in soft clay shales, siltstone coal, and sandstones. Many lower knobs are capped with moderately resistant limestone. The valley floors are soft, easily eroded limestones and dolomites. The dominant geology of the valleys and sideslopes is Mississippian-Age formations and of the ridges Pennsylvanian-Age material. The geomorphic processes primarily responsible for shaping this landscape are erosion, karst solution, and stream incision. Slopes of the knobs and domes are characterized by soils that range from 0 to 100 cm (0 to 40 inches) deep with relatively thin surface horizons. Most subsoils have moderate to high clay content and are moderately well to well-drained. Soils on the plain are characteristically deep, usually over 100 cm (40 inches) to bedrock. They have high clay content in the subsoil and occasionally in the surface horizon.

This subsection has a low number of small- to medium-sized intermittent and perennial streams. Most have wide valleys and low gradients. Dissection is greatest in the east, and drainage patterns are dendritic. Stream systems often are influenced by well-developed karst topography and hydrology. The Cumberland River crosses the Eastern Karst Plain and has been dammed to form Lake Cumberland.

Eastern Knobs Transition (222Ej) The Eastern Knobs Transition is located in east-central Kentucky along the western boundary of the DBNF. Forest Service land is limited in this subsection. Within this subsection, the Eastern Karst Plain is characterized by broad, plain-like valleys, from which rise scattered, low-relief ridges and knobs. Elevations typically range between 210 to 335 m (700 to 1,100 feet), but a few peaks are as high as 460 m (1,500 feet). The ridges characteristically are steep sided with slopes of 50 percent or greater. Knobs and ridges are capped in shale and sandstones, and the valley floors are soft, acid shales, limestones, and dolomites. The geology is dominated by Silurian/Ordovician-Age formations in the valleys and Mississippian/Devonian-Age material on the ridges. The primary geomorphic process responsible for shaping this landscape is erosion. Average soil depths on the slopes of knobs and domes are 20 inches, with relatively thin surface horizons. Most have moderate to high clay content in the subsoil and are moderately well to well-drained. Soils on the lower slopes and bottoms are characteristically deep, usually over 100 cm (40 inches) to bedrock. They have high clay content in the subsoil and occasionally in the surface horizon.

This subsection has broad valleys with well-developed flood plains, often with multiple terraces. There are few small- to medium -sized intermittent and perennial streams. Most flow through wide valleys and have low gradients. Dissection is greatest in the east, and drainage patterns are dendritic. The Licking and Kentucky Rivers cross this subsection at right angles.

Kinniconick and Licking Knobs (222En) This subsection is located in northeast Kentucky and includes land on the Morehead Ranger District. The area features broad, plain-like valleys from which rise scattered, moderate-relief ridges and knobs. Elevations range from over 200 to nearly 370 m (700 to 1,200 feet). The ridges are characteristically steep sided, with slopes of 50 percent or more. Knobs and ridges are capped in cherty limestone, sandstone, shale and siltstone and valley floors are covered by shales, limestones, and sandstone. Silurian-Age and Mississippian/Devonian-Age formations dominate in the valleys and Mississippian-Devonian-Age material is prevalent on the ridges. The primary geomorphic processes responsible for shaping this landscape are erosion and, to a lesser extent, mass wasting. Soils on the slopes of knobs and ridges average 50 cm (20 inches) in depth and are moderately well to well-drained. Surface horizons are relatively thin, with moderate to high clay content in the subsoil. Soils on the lower slopes and bottoms typically exceed 100 cm (40 inches) in depth and have high clay content in the subsoil. Some soils have fragipans.

The Kinniconick and Licking Knobs subsection has broad valleys with well-developed flood plains, often with multiple terraces. There are a few low-gradient, small- to medium -sized intermittent and perennial streams. Dissection is greatest in the east, and drainage patterns are dendritic. The Licking River crosses this subsection at a right angle.

Northern Cumberland Mountains Section (M221C)

Southern Cumberland Mountains (M221Cd) This subsection is located in southern east-central Kentucky and northern east-central Tennessee. The Southern Cumberland Mountains are characterized by moderately wide and winding ridges with relatively high relief and side slopes that average 50 to 60 percent. Elevations range from 305 to 700 m (1,000 to 2,300 feet). Ridges are capped in a mixture of soft clay shales, siltstone, coal, and resistant sandstone. The sandstone, which frequently is bounded by rock outcrops or small cliffs, often forms ridges that are 90 to 120 m (300 to 400 feet) wide. The floors of the broader, lower valleys are composed of soft clay shales and siltstones. Pennsylvanian-Age, Lower Breathitt formations dominate and erosion and mass wasting are the primary geomorphic processes responsible for shaping this landscape in which landslides are frequent. Soils on the ridges are typically 25 to 75 cm (10 to 30 inches) deep, and many are rocky. Most have moderate to high clay content in the subsoil and are moderately well drained. Soils on slopes are deeper (typically over 100 cm (40 inches)) with numerous rock outcrops and fragments.

The Southern Cumberland Mountains have a high number of small- to medium-sized intermittent and perennial streams. Higher elevation valleys are narrow and V-shaped. The largest valleys are moderately broad and have well-developed alluvial bottoms. Drainage patterns are dendritic and dissection is moderately high, with about 11 km of perennial, intermittent, and ephemeral streams per square kilometer (18 mi/square mile). Clear Fork and Jellico Creek flow through this subsection and the Cumberland River lies to the north.

Hydrographic Features

Kentucky has over 143,000 km (89,000 mi) of perennial rivers and streams (Kentucky Division of Water 1998) of which about 11,900 km (7,400 mi) lie within the proclamation boundaries of the DBNF. Because so many perennial watercourses run through the DBNF, as well as about 55,700 km (34,600 mi) of ephemeral and intermittent streams, DBNF land managers have a significant task in providing streamcourse protection and ensuring water quality.

The DBNF manages between 6 and 10 percent of the watersheds within the Ohio River Basin, including portions of the Kentucky and Upper Cumberland Rivers (fig. 2). Collectively, these watersheds cover 4.2 million ha (10.3 million acres) or 40 percent of the State and provide the surface and groundwater resources for more than a million people. The major features of the segments of these three river systems that flow through the DBNF are described in the following section, including major tributaries, reservoirs, and specially designated rivers.

Cumberland River System

The headwaters of the Cumberland River are in the Cumberland Mountains of southeastern Kentucky, an area with the highest elevations in the State. From the confluence of Poor and Clover forks in Harlan County, the Cumberland River flows 496 km (308 mi) generally west and south through a gap in Pine Mountain and across the Cumberland Plateau and Highland Rim before entering Tennessee near the southeastern corner of Monroe County. The river then flows in a broad southward arc in north-central Tennessee, turning north-westward through Nashville and reentering Kentucky in south-central Trigg County. Two segments are within the DBNF proclamation boundaries; the middle segment, which includes drainages from Cumberland Falls downstream to the Kentucky-Tennessee border, and the upper segment, which includes the basin above Cumberland Falls (Burr and Warren 1986).

Middle Cumberland River Drainage -- Most of the middle Cumberland River drainage lies in the Highland Rim of Kentucky and Tennessee and the Central Basin of Tennessee (Quarterman and Powell 1978), although portions of the basin drain the Cumberland Plateau. The Kentucky portion of this segment encompasses 12,991 sq km (5,016 sq mi), of which roughly 10 percent is National Forest. In an upstream direction, major tributaries of the Kentucky portion of the middle basin include the Big South Fork, Rockcastle, and Laurel Rivers. The mainstream is dammed in southwest Russell County to form Lake Cumberland, a 20,336-ha (50,230-ac) reservoir, which impounds the lower reaches of tributaries upstream to the confluence of Laurel River. Laurel River is impounded above its confluence with the Cumberland River, forming a 2,452-ha (6,056-ac) reservoir, which floods a considerable portion of its tributaries. The area is heavily forested and scenic and contains some of the most pristine waters remaining in the state. Four stream and river segments in the basin have been designated Kentucky Wild Rivers including a 25.6-km (15.9-mi) segment of the lower Rockcastle River, a 16.7-km (10.2-mi.) segment of Little South Fork, a 29-km (18 mi) segment of Rock Creek, and a 16.4-km (10.1-mi) segment of Big South Fork. The Big South Fork also is designated a National River and Recreation area. Both Rock Creek and Rockcastle River are being considered as national wild and scenic rivers (United States Forest Service 1992, 1994).

Streams and rivers of the middle Cumberland River are upland in nature, with alternating riffles and pools, incised meanders, narrow floodplains, and rocky substrates. Streams and rivers bordering or heading on the sandstone-capped Southwestern Escarpment and Cumberland Plateau (i.e. Rockcastle, Laurel, and Big South Fork rivers) have high gradients with low waterfalls, boulder-strewn swift shoals, and deep holes. Creeks and streams draining the Cumberland Plateau immediately below Cumberland Falls also are high gradient, and several have falls near their mouths. These falls and hanging valleys were created by the upstream progression of Cumberland Falls (Burr and Warren 1986).

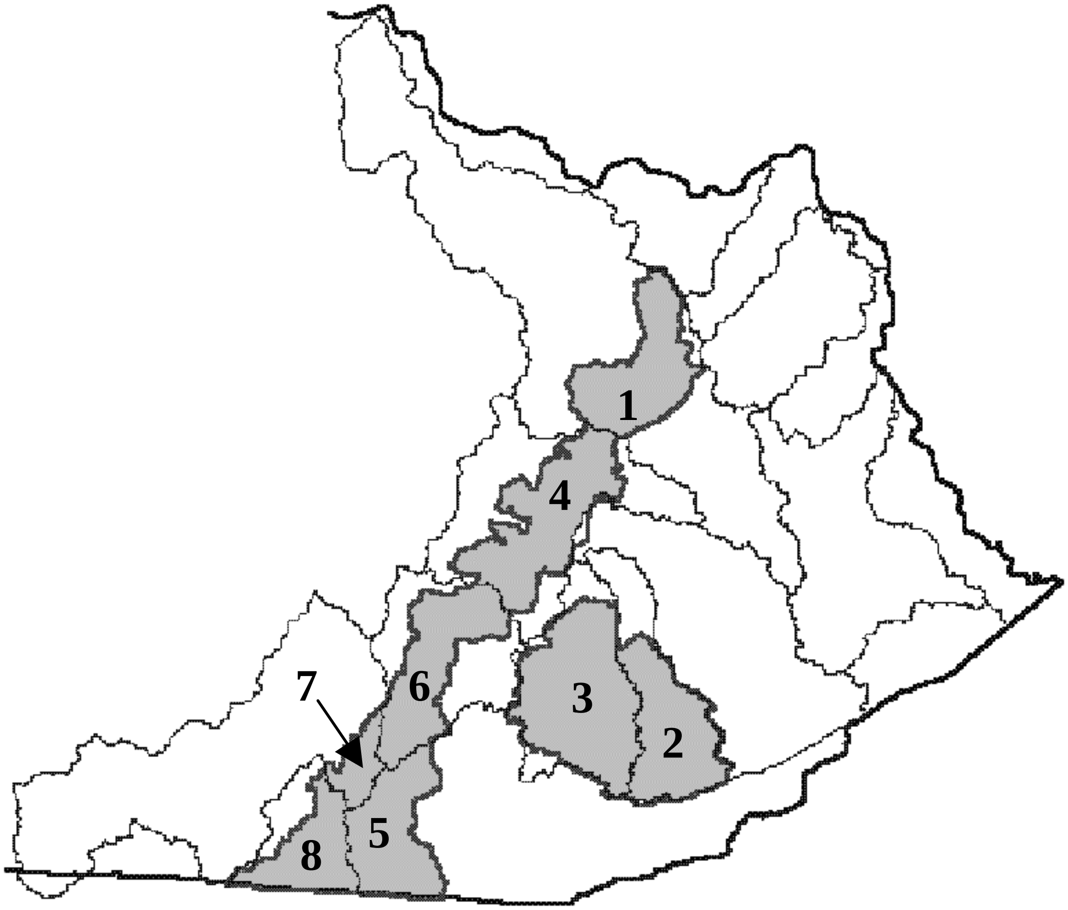

Figure 2. Proclamation boundaries and hydrologic units of the Daniel Boone National Forest. Portions of hydrologic units (HU) within the proclamation boundaries of the forest are referenced by number on the map: 1 = Licking River (HU 05100101); 2 = Middle Fork Kentucky River (HU05100202); 3 = South Fork Kentucky River (HU 05100203); 4 = Kentucky River - Red River (HU 05100204); 5 = Upper Cumberland River (HU 05130101); 6 = Rockcastle River (HU 05130102); 7 = Cumberland River - Buck Creek (HU 05130103); 8 = Big South Fork Cumberland River (HU 05130104).

Upper Cumberland River Drainage -- The Upper Cumberland River Drainage includes about 5,120 square km (1,977 square mi) above Cumberland Falls. The mainstream of the river begins at the confluence of Clover Fork and Poor Fork near Harlan in the southeastern most part of Kentucky. From its headwaters, the Cumberland River drains the Cumberland Mountains to the southeast and the Pine Mountain Overthrust to the northwest. The Cumberland is joined from the north by Straight Creek before entering the Cumberland Plateau near Pineville. Other major tributaries entering from the north include Stinking, Richland, and Watts Creeks. Many southern tributaries, including Clear Fork, Jellico, and Marsh creeks, have their headwaters in northern Tennessee. Near the mouth of Marsh Creek, the mainstream abruptly turns north before plunging over 17-m (55-ft) Cumberland Falls. Cumberland Falls probably originated near Burnside, Kentucky about 72 km (45 mi) downstream of its present position, and the upstream progression of the falls has left a 121 m (400 ft) gorge through the surrounding Cumberland Plateau. A 25.9 km (16.1 mi) section of the Cumberland River (including Cumberland Falls) in McCreary and Whitley Counties is a Kentucky Wild River and has been proposed for National Wild and Scenic designation. Marsh Creek in McCreary County also has been proposed for Federal designation (United States Forest Service 1992, 1994).

The creeks, streams, and rivers of this basin are examples of the most scenic and pristine upland waters in Kentucky. Tributaries draining the Cumberland Mountains and Pine Mountain Overthrust have extremely high gradients and few pools but numerous riffles, waterfalls, and large standstone substrates. Tributaries draining the Cumberland Plateau, which encompasses most streams in the DBNF, are similar although they originate at lower elevations than tributaries draining the Cumberland Mountains and the Pine Mountain Overthrust. Extensive reaches of the Cumberland River mainstream and its large tributaries flow over bedrock and contain long boulder- and cobble-strewn shoals and deep, rocky pools. The substrates of the region are sandstone, shale, siltstone, and coal (Burr and Warren 1986).

Kentucky River System

The headwaters of the Kentucky River system originate in the rugged mountain area along the Pine Mountain Overthrust on the Cumberland Plateau. The DBNF manages approximately 6 percent of the 18,042 sq km (6,966 sq mi) watershed. From the confluence of the North, Middle, and South Forks near Beattyville, the river flows north-westward 411 km (256 mi) through the Bluegrass section before joining the Ohio River near Carrollton. Major tributaries from the mouth upstream include Eagle Creek, Elkhorn Creek, Dix River, Red River, and the North, Middle, and South Forks. A 14.6-km (9.1-mi) section of the Red River has been designated a Kentucky Wild River and is proposed for designation as a National Wild and Scenic River (United States Forest Service 1992, 1994). War Fork Creek in Jackson County is also proposed for Federal designation. Buckhorn Lake (498 ha; 1,230 ac) on the Middle Fork in Leslie and Perry Counties is the only major flood control and recreational reservoir within the Kentucky River system that is within the Daniel Boone’s proclamation boundary. The streams and rivers of the basin have been characterized as upland; however, many smaller streams in the Bluegrass section are intermittent, and have hanging valleys up to their confluence with the mainstream. The mainstream itself is impounded by locks and dams that extend from near the mouth upstream to Beattyville. The pooling of much of the mainstream and the lower reaches of many tributaries resulted in the loss of most riffle and shallow water habitat.

Licking River System

The Licking River system begins on the Cumberland Plateau in Magoffin County and flows north-westward through the Blue Grass for about 496 km (310 mi) before joining the Ohio River near Covington. The basin encompasses approximately 9,601 sq km (3,707 sq mi), of which 6 percent is managed by the DBNF. The river is joined by two major tributaries, the North and South Forks, near Milford and Falmouth, respectively. The basin is bounded on the north and northeast by the Ohio River, Kinniconick Creek, Tygarts Creek, and Little Sandy River drainages; on the east by the Big Sandy drainage; and on the south and southwest by the Kentucky River drainage. The Licking River is dammed near Morehead to form Cave Run Lake (3,347 ha; 8,267 ac), which impounds 61 km (38 mi) of the mainstream, as well as the lower reaches of several tributaries. The creeks, streams, and rivers of the basin are generally upland, having moderate- to high-gradients, well-developed riffles and shoals, rocky substrates, and poor to moderate floodplain development (Burr and Warren 1986).

Description of the Aquatic Fauna

The aquatic fauna of the Daniel Boone National Forest is nested within a large natural area, including disparate subregions of the southeastern Ohio River basin and portions of a number of ecological sections and subsections (see Physical Setting, Ecological Subsections). Lands within the proclamation boundary of the DBNF are drained by three major river systems: the Licking, Kentucky, and Cumberland. The Licking and Kentucky Rivers are in the Teays Subregion (Mississippi Region, Arctic-Atlantic Subzone), and the Cumberland River is in the Tennessee-Cumberland Subregion (Mississippi Region, Arctic-Atlantic Subzone) (Maxwell and others 1995). From a terrestrial perspective, the rivers traverse several ecological subsections of the Northern Cumberland Plateau Section (Avers and others 1994). The DBNF's western proclamation boundary closely parallels three subsections of the Interior Low Plateaus, Highland Rim Section and each of the major rivers traversing the forest breach this major ecotone. These factors—different river systems, each with a unique ecological setting and history—are largely responsible for the highly diverse, distinctive populations of aquatic organisms found in the DBNF.

The objective of this section of the Assessment is to characterize the diversity of aquatic fauna on the DBNF. The Description of Aquatic Fauna focuses on two groups, fishes and mussels, because they are the best-known components of the aquatic fauna (Burr and Warren 1986, Schuster 1988, Cicerello and others 1991). In general, inventory data for other aquatic organisms are inadequate or have been inadequately synthesized to permit similar assessments (Kentucky State Nature Preserves Commission 1997). Individual fish and mussel species distributions, total species richness, and the extirpation or introduction of species are accounted for in each of the forest's major hydrologic units. In addition, the primary historical zoogeographic factors that contributed to produce and maintain unique assemblages of fishes or mussels, e.g., endemic species, shared species are identified.

Methods of Faunal Assessment

To account for the fauna, species were assigned (fishes and mussels) to one or more of eight U.S. Geological Survey (USGS) hydrologic units occurring within the DBNF proclamation boundaries (fig. 2). The following are working definitions of the boundaries used to determine species occurrence in a hydrologic unit.

One hydrologic unit was used for the Licking River (L) (HU 05100101), which includes that portion of the river extending from a point just upstream of the mouth of Craney Creek downstream to (and including) Salt Lick Creek. For the Kentucky River, three hydrologic units were used: the Middle Fork Kentucky River (MFK) (HU 05100202), South Fork Kentucky River (SFK) (HU 051002303), and Kentucky River-Red River (K-R) (HU 05100204). That portion of the Middle Fork unit that is within the proclamation boundaries includes the headwaters and extends downstream , about to the Breathitt-Leslie County line. The South Fork unit extends downstream from the headwaters to a point south of Booneville, Kentucky. The Kentucky River-Red River unit includes the mainstream and tributaries of the Kentucky River, from about Beattyville to east of Irvine, Kentucky. It also includes that segment of the Red River extending downstream from the mouth of Stillwater Creek on the North Fork Red River to the mouth of Cane Creek.

Four hydrologic units were used for the Cumberland River: the Upper Cumberland River (UC)(HU 5130101), Rockcastle River (RR) (HU 05130102), Cumberland River-Buck Creek (C-B) (HU 05130103), and Big South Fork Cumberland River (BSF) (HU 05130104). That portion of the Upper Cumberland unit within the proclamation boundaries of the DBNF includes the drainage from Clear Fork (above Cumberland Falls) extending downstream to the mouth of the Rockcastle River. It also includes the Laurel River drainage, upstream from the mouth to west of Corbin, Kentucky. The Rockcastle unit includes the entire river drainage, except South Fork Rockcastle River and the extreme headwaters of western tributaries, i.e., Skegg and Roundstone Creeks. The Cumberland River-Buck Creek unit includes that portion of the drainage downstream from the mouth of Rockcastle River (on the north), to and including most of Buck Creek, and downstream to the mouth of Big South Fork. The unit also includes an area from the mouth of Buck Creek, upstream to about Ula, Kentucky. The Big South Fork unit includes all of the drainage north of the Kentucky-Tennessee State line, extending west from (and including) Little South Fork, to the eastern drainage divide.

Fishes within each hydrologic unit were classified as native (N), considered extirpated (EX), may be extirpated (EX?), introduced (I), or possibly introduced (I?). The distributional status of fishes within a particular hydrologic unit was determined primarily from maps (Burr and Warren 1986) and associated collecting records available at Southern Illinois University at Carbondale. The maps in Burr and Warren (1986) were updated to reflect information collected through 1996 (Burr and Warren [unpublished]). This information was augmented from fish distributional information presented in Page and Burr (1991), Etnier and Starnes (1993), Jenkins and Burkhead (1994), Burr and Warren (1997), and Warren and others (1997). Additional information was derived from Lee and others (1980) and Starnes and Etnier (1986). Distributions of undescribed species, or species described subsequent to publication of the works cited above, were obtained from Page and Burr (1991, *Noturus sp. cf. flavus*); Burr and Page (1993, *Percina stictogaster*); Warren and others (1994, *Notropis albizonatus*); Dimmick and others (1996, *Lythrurus fasciolaris*); P. Ceas, Eastern Kentucky University, personal communication *(Etheostoma sp. cf. spectabile*); and S. Layman, University of Alabama, personal communication *(Etheostoma sp. cf. stigmaeum*).

Mussels occurring within each hydrologic unit were classified as present (X), considered extirpated (EX), may be extirpated (EX?), or of questionable status (?). The distributional status of mussels within a particular hydrologic unit was determined from distributional information presented in Schuster (1988), Bakaletz (1991), Richardson (1989), Anderson and others (1991), Cicerello and others (1991), Cicerello (1992, 1993, 1994, 1995, 1996a, 1996b), Layzer and Anderson (1992), Houp (1993), Houslet (1996), and Cicerello and Laudermilk (1997), Kentucky State Nature Preserves Commission (1996a, 1997) and from papers cited in these sources. The information was augmented with associated collection records and unpublished distributional maps (R. Cicerello, Kentucky State Nature Preserves Commission, personal communication).

Fish Distribution and Diversity

The DBNF is located within the southeastern United States, an area that harbors the richest freshwater fish fauna on the North American continent (Warren and Burr 1994, Warren and others 1997). Kentucky has a greater diversity of fishes than any other inland area of comparable size in North America, except Tennessee and Alabama (Burr and Warren 1986, Warren and Burr 1994, Warren and others 1997) and the DBNF's running waters support a significant proportion of this diversity. At least 141 native fish taxa have been identified or are thought very likely to occur in the rivers and streams of the DBNF (Burr and Warren 1986, Burr and Warren 1997). Running waters on the Daniel Boone support about 60 percent of Kentucky's native fishes, 28 percent of all native southeastern U.S. fishes, and about 18 percent of the native freshwater fishes in the United States (Warren and Burr 1994, Warren and others 1997).

Native fish diversity is relatively evenly distributed among portions of the eight hydrologic units (nested in three major drainages), despite differences in hydrologic unit area (Table 1). Including taxa of known or probable occurrence, species richness averages 78 taxa (1SD=14.6) per hydrologic unit; ranging from 49 in the Upper Cumberland unit, to 95 in the Licking River unit. Daniel Boone National Forest rivers and streams show exceptional representation of fishes from the much larger Licking, Upper Kentucky, and Cumberland River drainages. Approximately 83 percent of native fish in the Licking River drainage occur or probably occur in the DBNF Licking River unit, 84 to 90 percent of Upper Kentucky River drainage fauna occurs or probably occurs in the Kentucky River units, and nearly 100 percent of the Cumberland River fauna of Kentucky occurs or probably occurs in the Cumberland River units (Burr and Warren 1986).

Native fish diversity is unevenly divided among families in the forest. Twenty fish families have native species within the forest. The most diverse families are the minnows (Cyprinidae) and darters (Percidae), with 40 and 37 native taxa, respectively. Other diverse families include the suckers (Catostomidae; 15 native taxa), catfishes (Ictaluridae; 13 native taxa), and sunfishes (Centrarchidae; 10 native taxa). Other families have fewer representatives, but the forest supports a significant number of all southeastern taxa in those families. For example, six of the eight species of lampreys (Petromyzontidae) that are native to the southeast occur in DBNF drainages.

Sixteen non-native fishes (introduced or thought to have been introduced) have been collected in one or more hydrologic units (Table 1). Several are associated with recreational fishing and were either deliberately introduced or were bait fishes released by anglers. The Kentucky Department of Fish and Wildlife Resources currently stocks two non-native species of trout in DBNF streams: rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*). Brook trout (*Salvelinus fontinalis*) are not stocked but remain in streams on the DBNF from past stocking (see Recreational Fishing section). Several other non-native fishes also have been stocked for fishery management purposes. The redbreast sunfish (*Lepomis auritus*) has become established in the Upper Cumberland River unit, where it is considered limiting to native centrarchids and establishment of self-sustaining trout fisheries (Stephens 1994).

A striped bass (*Morone saxatilis*) fishery is maintained by stocking in Lake Cumberland (Kinman 1988). Another recreational fish, the northern pike (*Esox lucius*), has been stocked in at least one private, fee-fishing lake within the proclamation boundaries (Burr and Warren 1986); its establishment in DBNF waters is possible but unknown. The threadfin shad (*Dorosoma petenense*) was established as a forage fish in several large reservoirs.

The golden shiner (*Notemigonus crysoleucas*) may be present in forest waters as a result of bait-fish release. Brook stickleback (*Culaea inconstans*) are often transported with bait fish, and records of this species may stem from that source. Neither brook stickleback nor goldfish (*Carassius auratus*) are known to have established permanent populations in forest streams.

Other fishes were introduced widely in the late 1800's (common carp, *Cyprinus carpio*) or during this century (mosquitofish, *Gambusia affinis*); and these are now permanent components of the DBNF fish fauna. The northern studfish (*Fundulus catenatus*) is a relatively recent non-native addition to fauna of the Licking River, where it has apparently been established and is increasing its range (Burr and Warren 1986, Meade 1992). Private landowners often stock grass carp (*Ctenopharyngodon idella*) in ponds from which they may escape, eventually finding their way into larger forest streams and rivers (Etnier and Starnes 1993).

Table 1. Distribution of fishes of the Daniel Boone National Forest in hydrologic units within the proclamation boundaries (unit boundaries are defined in the text).

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Petromyzontidae-Lampreys								
Ichthyomyzon bdellium Ohio lamprey	N	N	N	P	-	N	N	N
Ichthyomyzon fossor northern brook lamprey	-	N	N	N	-	-	-	-
Ichthyomyzon greeleyi mountain brook lamprey	-	-	-	-	-	N	-	N
Ichthyomyzon unicuspis silver lamprey	-	N	P	N	-	-	-	-
Lampetra aepyptera least brook lamprey	N	P	N	N	N	N	-	-
Lampetra appendix American brook lamprey	P	N	P	N	-	-	-	-
Acipenseridae-Sturgeons								
Acipenser fulvescens lake sturgeon	-	-	-	-	EX[a]	-	-	-
Scaphirhynchus platorynchus[b] shovelnose sturgeon	EX	-	-	-	-	-	-	-
Polyodontidae-Paddlefishes								
Polyodon spathula paddlefish	N	-	-	P	-	-	-	N
Lepisosteidae-Gars								
Lepisosteus osseus longnose gar	N	N	N	N	-	-	N	N
Amiidae-Bowfins								
Amia calva bowfin	I	-	-	-	-	-	-	-
Hiodontidae-Mooneyes								
Hiodon tergisus mooneye	N	-	-	N	-	-	-	P
Anguillidae-Freshwater eels								
Anguilla rostrata American eel	N	-	-	N	-	EX	-	-
Clupeidae-Herrings and Shads								
Alosa chrysochloris skipjack herring	N	-	-	-	-	-	-	P
Dorosoma cepedianum gizzard shad	N	N	N	N	I	N	N	N
Dorosoma petenense threadfin shad	I	I	-	-	I	-	I	-
Cyprinidae-Minnows and Carps								
Campostoma anomalum central stoneroller	N	N	N	N	N	N	-	-
Campostoma oligolepis largescale stoneroller	-	-	-	-	-	N	N	N
Carrasius auratus goldfish	I	I	-	-	-	-	-	-
Clinostomus elongatus redside dace	N	-	-	N	-	-	-	-

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Clinostomus funduloides[c] rosyside dace	-	-	-	-	-	-	-	I?
Cyprinella galactura whitetail shiner	-	-	-	-	N	N	N	N
Cyprinella spiloptera spotfin shiner	N	N	N	N	N	N	N	N
Cyprinella whipplei steelcolor shiner	N	N	N	N	N	N	N	-
Cyprinus carpio common carp	I	I	I	I	I	I	I	I
Ericymba buccata silverjaw minnow	N	N	N	N	N	N	N	-
Erimystax dissimilis streamline chub	P[d]	N	N	P	-	N	N	N
Erimystax insignis blotched chub	-	-	-	-	-	-	-	N
Hemitremia flammea flame chub	-	-	-	-	EX[a]	-	-	-
Hybopsis amblops bigeye chub	N	N	N	N	-	N	N	N
Luxilus chrysocephalus striped shiner	N	N	N	N	N	N	N	N
Lythrurus fasciolaris rosefin shiner	-	N	N	N	N	N	N	N
Lythrurus umbratilis redfin shiner	N	-	-	-	-	-	-	-
Macrhybopsis aestivalis speckled chub	N	N	N	-	-	-	-	-
Macrhybopsis storeriana silver chub	N	P	N	N	-	-	-	-
Nocomis effusus redtail chub	-	-	-	-	-	-	-	N
Nocomis micropogon river chub	N	N	N	N	N	N	-	N
Notemigonus crysoleucas golden shiner	I?	-	-	-	-	-	-	-
Notropis albizonatus palezone shiner	-	-	-	-	-	-	-	N
Notropis ariommus popeye shiner	-	N	N	N	-	N	N	N
Notropis atherinoides emerald shiner	N	N	N	N	-	-	N	N
Notropis boops bigeye shiner	N	-	N	N	-	-	P	P
Notropis buchanani ghost shiner	P	-	-	N	-	-	N	P
Notropis leuciodus Tennessee shiner	-	-	-	-	-	-	-	EX?
Notropis ludibundus sand shiner	N	N	N	N	-	-	-	N
Notropis photogenis silver shiner	N	N	N	N	-	N	N	N
Notropis r. rubellus northern rosyface shiner	N	N	N	N	N	-	-	-
Notropis r. micropteryx southern rosyface shiner	-	-	-	-	-	N	N	N
Notropis telescopus telescope shiner	-	-	-	-	-	-	N	N
Notropis volucellus mimic shiner	N	N	N	N	N	N	-	N
Notropis sp. cf. spectrunculus sawfin shiner	-	-	-	-	-	-	-	N

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Phenacobius mirabilis suckermouth minnow	N	-	-	-	-	-	-	-
Phenacobius uranops stargazing minnow	-	-	-	-	-	EX?	-	-
Phoxinus cumberlandensis blackside dace	-	-	-	-	N	N	N	-
Phoxinus erythrogaster southern redbelly dace	N	N	N	N	N	N	N	N
Pimephales notatus bluntnose minnow	N	N	N	N	N	N	N	N
Pimephales promelas fathead minnow	N	N	N	P	N	N	P	N
Pimephales vigilax bullhead minnow	N	N	N	N	-	-	-	-
Rhinichthys atratulus blacknose dace	N	N	N	N	N	N	P	N
Semotilus atromaculatus creek chub	N	N	N	N	N	N	N	N
Catostomidae-Suckers								
Carpiodes carpio river carpsucker	N	N	P	P	-	-	-	-
Carpiodes cyprinus quillback	N	N	N	N	-	-	N	P
Carpiodes velifer highfin carpsucker	P	N	-	P	-	-	N	-
Catostomus commersoni white sucker	N	N	N	N	N	N	N	N
Cycleptus elongatus blue sucker	-	-	-	-	-	-	P[e]	P[e]
Hypentelium nigricans northern hog sucker	N	N	N	N	N	N	N	N
Ictiobus bubalus smallmouth buffalo	N	-	-	N	-	-	N	P
Ictiobus cyprinellus bigmouth buffalo	N	-	-	P	-	-	-	-
Minytrema melanops spotted sucker	N	N	N	N	-	-	-	-
Moxostoma anisurum silver redhorse	N	-	N	N	-	N	-	N
Moxostoma breviceps shorthead redhorse	N	N	N	N	-	N	N	N
Moxostoma carinatum river redhorse	N	N	-	N	-	N	N	N
Moxostoma duquesnei black redhorse	N	N	N	N	N	N	N	N
Moxostoma erythrurum golden redhorse	N	N	N	N	N	N	N	N
Moxostoma lacerum harelip sucker	-	-	-	-	-	EX	-	EX
Ictaluridae-Bullhead catfishes								
Ameiurus melas black bullhead	N	-	N	N	N	P	-	N
Ameiurus natalis yellow bullhead	N	N	N	N	N	N	-	N
Ameiurus nebulosus brown bullhead	N	-	-	N	-	-	-	-
Ictalurus furcatus blue catfish	N	-	-	-	-	-	N	-
Ictalurus punctatus channel catfish	N	N	N	N	N	N	N	N
Noturus eleutherus mountain madtom	N	N	N	-	-	-	-	-

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Noturus exilis slender madtom	-	-	-	-	-	-	-	P
Noturus flavus stonecat	N	N	N	N	-	-	-	-
Noturus sp. cf. flavus Cumberland stonecat	-	-	-	-	-	N	N	N
Noturus miurus brindled madtom	N	N	N	N	P	-	-	-
Noturus nocturnus freckled madtom	-	EX?	-	-	-	-	-	-
Noturus stigmosus northern madtom	N	N	N	-	-	-	-	-
Pylodictis olivaris flathead catfish	N	N	N	N	N	N	N	N
Esocidae-Pikes								
Esox americanus grass pickerel	N	-	-	-	-	-	-	-
Esox lucius northern pike	I	-	-	-	-	-	-	-
Esox masquinongy muskellunge	N	N	N	N	-	-	-	-
Salmonidae-Trouts, salmons and whitefishes								
Oncorhynchus mykiss rainbow trout	I	I	I	I	I	I	I	I
Salmo trutta brown trout	I	-	I	I	I	-	-	I
Salvelinus fontinalis brook trout	-	-	-	I	-	-	-	-
Percopsidae-Trout-perches								
Percopsis omiscomaycus trout-perch	EX?[f]	-	-	-	-	-	-	-
Amblyopsidae-Cavefishes								
Typhlichthys subterraneus southern cavefish	-	-	-	-	-	-	N	-
Atherinidae-Silversides								
Labidesthes sicculus brook silverside	N	N	N	N	N	N	N	N
Fundulidae-Topminnows								
Fundulus catenatus northern studfish	I	-	-	-	-	N	N	N
Fundulus notatus blackstripe topminnow	N	-	-	-	-	-	-	-
Poeciliidae-Livebearers								
Gambusia affinis mosquitofish	I?	-	-	I?	I	-	-	-
Gasterosteidae-Sticklebacks								
Culaea inconstans brook stickleback	I	-	-	-	-	-	-	-
Cottidae-Sculpins								
Cottus bairdi mottled sculpin	N	N	-	N	-	-	-	-
Cottus carolinae banded sculpin	-	-	-	N	-	N	N	N

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Moronidae-Temperate basses								
Morone chrysops white bass	N	N	-	-	N[a]	N	N	N
Morone saxatalis striped bass	-	I	-	-	-	-	I	I
Centrarchidae-Sunfishes								
Ambloplites rupestris rock bass	N	N	N	N	N	N	N	N
Chaenobryttus gulosus warmouth	N	-	N	N	I	-	I	-
Lepomis auritus redbreast sunfish	I	-	-	-	I	-	-	-
Lepomis cyanellus green sunfish	N	N	N	N	N	N	N	N
Lepomis gibbosus pumpkinseed	I	-	-	-	-	-	-	-
Lepomis macrochirus bluegill	N	N	N	N	N	N	N	N
Lepomis megalotis longear sunfish	N	N	N	N	N	N	N	N
Lepomis microlophus redear sunfish	I	I	-	-	-	I	I	-
Micropterus dolomieu smallmouth bass	N	N	N	N	N[a]	N	N	N
Micropterus punctulatus spotted bass	N	N	N	N	N	N	N	N
Micropterus salmoides largemouth bass	N	N	N	N	N[a]	N	N	N
Pomoxis annularis white crappie	N	N	P	N	N	N	N	N
Pomoxis nigromaculatus black crappie	N	N	N	N	N	N	N	N
Percidae-Perches and Darters								
Ammocrypta pellucida eastern sand darter	N	N	N	N	-	-	-	-
Crystallaria asprella crystal darter	-	-	-	-	-	-	-	EX?
Etheostoma baileyi emerald darter	-	N	N	N	N	N	-	N
Etheostoma b. blennioides greenside darter ssp.	N	N	N	N	-	-	-	-
Etheostoma b. newmanni greenside darter ssp.	-	-	-	-	N	N	N	N
Etheostoma caeruleum rainbow darter	N	N	N	N	N	N	N	N
Etheostoma camurum bluebreast darter	P[g]	N	N	-	-	N	N	N
Etheostoma cinereum ashy darter	-	-	-	-	-	N	N	N
Etheostoma flabellare fantail darter	N	N	N	N	-	N	P	N
Etheostoma kennicotti stripetail darter	-	-	-	-	N	-	-	N
Etheostoma maculatum spotted darter	-	EX?	-	-	-	-	-	-
Etheostoma nigrum nigrum johnny darter	N	N	N	N	-	EX	-	-
Etheostoma nigrum susanae Cumberland johnny darter	-	-	-	-	N	-	-	-
Etheostoma obeyense barcheek darter	-	-	-	-	-	-	-	N

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Etheostoma percnurum duskytail darter	-	-	-	-	-	-	-	N
Etheostoma s. sagitta Cumberland arrow darter	-	-	-	-	N	N	N	N
Etheostoma s. spilotum Kentucky arrow darter	-	N	N	N	-	-	-	-
Etheostoma sanguifluum bloodfin darter	-	-	-	-	-	N	N	N
Etheostoma simoterum Tennessee snubnose darter	-	-	-	-	-	-	-	EX
Etheostoma s. spectabile orangethroat darter	N	-	-	N	-	-	-	-
Etheostoma sp. cf. spectabile cf. orangethroat darter	-	-	-	-	N	N	N	N
Etheostoma tippecanoe Tippecanoe darter	N	P	N	-	-	-	-	N
Etheostoma variatum variegate darter	N	N	N	N	-	-	-	-
Etheostoma virgatum striped darter	-	-	-	-	-	N	N	-
Etheostoma zonale banded darter	N	N	N	N	-	N	N	N
Etheostoma sp. cf. stigmaeum longhunt darter	-	-	-	-	-	N	N	N
Percina burtoni blotchside logperch	-	-	-	-	-	-	-	EX
Percina caprodes logperch	N	N	N	N	N	N	N	N
Percina copelandi channel darter	N	N	N	N	-	-	-	N
Percina evides gilt darter	N	N	N	-	-	-	-	N
Percina macrocephala longhead darter	-	-	EX	-	-	-	-	EX
Percina maculata blackside darter	N	N	N	N	N	N	N	N
Percina oxyrhynchus sharpnose darter	N	N	N	P	-	-	-	
Percina sciera dusky darter	-	N	N	N	-	-	-	N
Percina shumardi river darter	N	P	P	-	-	-	-	-
Percina squamata olive darter	-	-	-	-	-	N	-	N
Percina stictogaster frecklebelly darter	-	-	N	N	-	-	-	-
Stizostedion canadense sauger	N	P	P	-	-	N	N	N
Stizostedion vitreum walleye	N	-	-	-	N[a]	N	N	N
Sciaenidae-Drums								
Aplodinotus grunniens freshwater drum	N	N	P	N	-	N	N	N
Total Extant Native Species (N)	88	75	74	78	46	67	64	77
Total Extirpated (Ex and Ex?)	2	2	1	0	2	4	0	6
Total Probable (P)	5	4	6	8	1	1	5	8
Total Introduced (I and I?)	14	6	3	5	8	3	6	5

N = native, I = introduced, I? = suspected introduction, EX = considered extirpated, EX? = may be extirpated, P = probable occurrence (occurs upstream or downstream of Daniel Boone National Forest proclamation boundaries).
[a] These species are not part of the historical fish fauna known from above Cumberland Falls.
[b] The shovelnose sturgeon is known only historically (ca. 1930's) from downstream of the forest (Burr and Warren 1986).
[c] The native or introduced status of the redside dace is equivocal. Its status within the Big South Fork results from one questionable record from Little South Fork drainage and from the headwaters of Rock Creek (Burr and others 1990).
[d] The streamline chub is known in the Licking River from one record in Magoffin County upstream of the Daniel Boone National Forest proclamation boundary.
[e] The blue sucker was last identified in the mainstem Cumberland River near the mouth of Big South Fork Cumberland River in 1961 (Burr and Warren 1986) and may be extirpated.
[f] The trout-perch has not been collected in the Licking River since the late 1930's and may be extirpated from the Daniel Boone National Forest.
[g] The bluebreast darter is known to occur downstream of the mouth of Slate Lick Creek in the Licking River in a few dispersed, but highly localized populations. Its occurrence within the Daniel Boone National Forest proclamation boundary in the Licking River is highly probable (Burr and Warren 1986, Kornman 1989).

Fish assemblages among drainages

Each forest drainage has unique fish assemblages that were derived over geological time in response to differing physiographies and drainage histories. Much of the diversity of fishes present today existed prior to Pleistocene glaciation as part of a more widespread North American highlands fish fauna (Wiley and Mayden 1985, Burr and Page 1986, Mayden 1988). The highlands fauna is remnant as a result of fracturing by midcontinental glaciers during the Pleistocene. The highlands were split into eastern and western components comprising the present-day Eastern Interior Highlands, including the Interior Low Plateaus and Applachian Plateaus provinces in the east, and the Central Interior Highlands, including the Ozark Plateau, Arkansas River Valley, and Ouachita Mountains in the west. Fishes in the DBNF are part of a large, unique assemblage of upland fishes, e.g., streamline chub *(Erimystax dissimilis*), rosefin shiner *(Lythrurus fasciolaris*), river chub (*Nocomis micropogon*), popeye shiner (*Notropis ariommus*), longhead darter (*Percina macrocephala*), which occupy rivers of the Eastern Interior Highlands (Mayden 1988, Warren and others 1991).

Three other factors producing unique, diverse fish assemblages may be overlaid on this initial historical template: (1) isolation of drainages and derivation of endemic fishes; (2) glaciation and development of glacial relicts; and (3) faunal interactions between and among drainages. Assemblages of native fishes in the forest may therefore be classified into three non-mutually exclusive groups: (1) fishes or lineages of fishes endemic to the highlands; (2) fishes, often endemics, associated with the isolation of a particular drainage or sets of drainages, or those relictual to the area because of the retreat of Pleistocene glaciers, e.g., Licking and Kentucky Rivers, Cumberland River above Cumberland Falls; and (3) fish faunal interactions between or among drainages, e.g., Kentucky and Cumberland Rivers.

Licking and Kentucky Rivers - The Licking and Kentucky Rivers contain Eastern Interior Highland fishes, which are fishes derived in large part from the isolation of these rivers in the headwaters of the pre-Pleistocene Teays River system (see reviews in Burr and Warren 1986, Burr and Page 1986), and fishes representing Pleistocene relicts. In fish faunal similarity analyses (Warren and others 1991) and vicariance biogeographic analyses (Mayden 1988), fishes of the Kentucky and Licking Rivers are more closely allied to drainages of the pre-Pleistocene Teays River than to present-day sister tributaries to the lower Ohio, e.g., the Green and Cumberland

Rivers. The Teays River, whose headwaters were in northeastern Kentucky, West Virginia, western Virginia, and northwestern North Carolina, flowed generally north and west across present-day central Ohio, Indiana, and north-central Illinois where it joined the ancestral Mississippi River (Burr and Page 1986, Burr and Warren 1986). At that time, the Licking and Kentucky Rivers were effectively isolated from tributaries of the ancestral Ohio River, such as the Cumberland-Tennessee systems. Exemplars in the forest portion of the Kentucky and Licking Rivers demonstrating their former Teays River connection include the variegate darter (*Etheostoma variatum*) and sharpnose darter (*Percina oxyrhynchus*).

Endemic and Exclusively Shared Fishes—Unlike the Licking River, which has no endemic or exclusively shared fishes, the Kentucky River has one endemic fish, the Kentucky arrow darter (*Etheostoma sagitta spilotum*)(Table 2.). The Kentucky River also exclusively shares the frecklebelly darter (*Percina stictogaster*) with the Green River. About half the Kentucky arrow darter's entire range and one third of the frecklebelly darter's range lie within the proclamation boundaries of the DBNF. The Kentucky River also exclusively shares several fishes with the Cumberland River (see Cumberland River discussion), and all of these have their primary ranges within the proclamation boundaries of the DBNF

Relict fishes—Several fishes in the Kentucky and Licking Rivers have distributions that are primarily northern. Pleistocene glaciation resulted in intermittent ponding of the lower reaches of the Licking and Kentucky Rivers, northward truncation of the Teays River, and eventual diversion of the Licking and Kentucky into the present-day Ohio River (Burr and Warren 1986, Warren and others 1991). Many northern fishes used the area south of the glacial maxima as a refugium during glaciation and, as glaciers receded, subsequently dispersed northward, leaving behind relict populations of fishes. Prominent examples in the Kentucky and Licking River units include the northern brook lamprey (*Ichthyomyzon fossor*), mottled sculpin (*Cottus bairdi*), redside dace (*Clinostomus elongatus*), and trout-perch (*Percopsis omiscomaycus*)(Table 2.).

Cumberland River - A major portion of fauna in the Cumberland River units are derived from the Eastern Interior Highlands fish fauna. This assemblage also is greatly enriched by fishes shared with the Tennessee River system. By virtue of their geographic juxtaposition, shared physiographic attributes, relative isolation, and complex drainage histories (Starnes and Etnier 1986, Mayden 1988, Warren and others 1991), the Tennessee and Cumberland Rivers have one of the most distinctive and richest ichthyofaunas in North America. The Cumberland River drainage is further enriched with its own endemic fishes and by historical interactions with adjacent drainages, as evidenced by exclusively shared taxa, i.e., Upper Kentucky River and Green River. Finally, the presence of Cumberland Falls (a major waterfall on the Cumberland River) isolated the drainage upstream and had a major influence on fish assemblages in all the Cumberland River hydrologic units (Burr and Warren 1986, Starnes and Etnier 1986).

Table 2. Fishes of known or probable occurrence in the DBNF that are endemic to a single drainage, exclusively shared species between drainages, or are relictual from Pleistocene glaciation.

Species	Drainage
Endemic	
Kentucky arrow darter (*Etheostoma sagitta spilotum*)	Kentucky
Blackside dace (*Phoxinus cumberlandensis*)	Cumberland
Cumberland johnny darter (*Etheostoma nigrum susanae*)	Cumberland
Barcheek darter (*Etheostoma obeyense*)	Cumberland
Cumberland arrow darter (*Etheostoma sagitta sagitta*)	Cumberland
Bloodfin darter (*Etheostoma sanguifluum*)	Cumberland
Striped darter (*Etheostoma virgatum*)	Cumberland
Longhunt darter (*Etheostoma sp. cf. stigmaeum*)	Cumberland
Cumberland darter (*Etheostoma sp. cf. spectabile)*	Cumberland
Exclusively Shared	
Frecklebelly darter (*Percina stictogaster*)	Kentucky-Green
Emerald darter (*Etheostoma baileyi*)	Kentucky-Cumberland
Arrow darter (*Etheostoma sagitta*)	Kentucky-Cumberland
Blotched chub (*Erimystax insignis)*	Cumberland-Tennessee
Palezone shiner (*Notropis albizonatus*)	Cumberland-Tennessee
Sawfin shiner (*Notropis sp. cf. spectrunculus*)	Cumberland-Tennessee
Rosyface shiner ssp. (*Notropis rubellus micropteryx*)	Cumberland-Tennessee
Cumberland stonecat (*Noturus sp. cf. flavus*)	Cumberland-Tennessee
Ashy darter (*Etheostoma cinereum*)	Cumberland-Tennessee
Duskytail darter (*Etheostoma percnurum*)	Cumberland-Tennessee
Tennessee snubnose darter (*Etheostoma simoterum*)	Cumberland-Tennessee
Blotchside logperch (*Percina burtoni*)	Cumberland-Tennessee
Olive darter (*Percina squamata*)	Cumberland-Tennessee
Redtail chub (*Nocomis effusus*)	Cumberland-Tennessee-Green
Stargazing minnow (*Phenacobius uranops*)	Cumberland-Tennessee-Green
Relictual	
Northern brook lamprey (*Ichthyomyzon fossor*)	Licking, Kentucky
Mottled sculpin (*Cottus bairdi*)	Licking, Kentucky
Redside dace (*Clinostomus elongatus*)	Licking
Trout-perch (*Percopsis omiscomaycus*)	Licking

Endemic and exclusively shared fishes—The Tennessee and Cumberland systems support at least 14 exclusively shared species, i.e., species found only in these two drainages (Starnes and Etnier 1986). Ten of these occur within Cumberland River hydrologic units. Among them, the palezone shiner (*Notropis albizonatus*), ashy darter (*Etheostoma cinereum*), and olive darter (*Percina squamata*) all have significant proportions of their extant ranges within the DBNF. Other exclusively shared Tennessee-Cumberland River taxa include the blotched chub (*Erimystax insignis*), sawfin shiner (*Notropis sp. cf. spectrunculus*), rosyface shiner subspecies (*Notropis r. micropteryx*), Cumberland stonecat (*Noturus sp. cf. flavus*), duskytail darter (*Etheostoma percnurum*), snubnose darter (*Etheostoma simoterum*), and blotchside logperch (*Percina burtoni*).

Endemicity of fishes is high in the Cumberland River drainage; and for several of the endemics, much of their entire range is within DBNF waters. Of at least 12 fishes that are endemic to the Cumberland River (Starnes and Etnier 1986, Burr and Mayden 1992, Warren and others 1997), eight occur in the Cumberland River hydrologic units: blackside dace (*Phoxinus cumberlandensis*); Cumberland johnny darter (*Etheostoma nigrum susanae*); barcheek darter (*Etheostoma obeyense*); Cumberland arrow darter (*Etheostoma s. sagitta*); bloodfin darter (*Etheostoma sanguifluum*); striped darter (*Etheostoma virgatum*); longhunt darter (*Etheostoma sp. cf. stigmaeum*); and Cumberland darter (*Etheostoma sp. cf. spectabile).* Of these, the Cumberland johnny darter has over 90 percent of its known range within DBNF waters, the blackside dace and Cumberland arrow darter have about 50 percent, and the barcheek darter and bloodfin darter about 33 percent (Burr and Warren 1986, Etnier and Starnes 1993).

On the basis of shared species, there is considerable evidence of faunal exchanges between the Cumberland and the Kentucky rivers, especially in the region above Cumberland Falls (Burr and Warren 1986, Starnes and Etnier 1986). Several such exchanges have led to differentiation of taxa, as evidenced in the Cumberland River by the Cumberland arrow darter (*Etheostoma sagitta sagitta*) and Cumberland johnny darter; and, in the Kentucky River by their respective sister taxa, the Kentucky arrow darter (*E. s. spilotum*) and johnny darter (*E. n. nigrum*). The emerald darter (*Etheostoma baileyi*) is another exclusively shared species of these two drainages and has nearly two thirds of its entire range within the DBNF proclamation boundaries.

Effects of Cumberland Falls - Cumberland Falls has had enormous influence on fish fauna of the Cumberland River. Its primary effects have resulted from its presence as a barrier to fish dispersal, its upstream geological recession, and its location near the interface of two distinct physiographic regions, the Highland Rim and the Cumberland Plateau. Cumberland Falls, which is located in McCreary-Whitley Counties, is 17 m (55 ft) high and resulted from the river's downcutting through rock strata, e.g., sandstone, shale, and limestone, with differential resistance to erosion (Burr and Warren 1986). From its supposed site of origin near Burnside, Kentucky, the Falls have receded upstream about 72 km (45 mi), leaving a deep, often sinuous gorge.

The most apparent effect of the Falls is reflected in the distinct but impoverished ichthyofauna of about 49 native species in the Upper Cumberland River upstream from Rockcastle River. The Falls also are responsible for the exclusion of other aquatic organisms such as mussels (Cicerello and Laudermilk 1997). One endemic fish, the Cumberland johnny darter (*Etheostoma nigrum susanae*), has its entire range above the Falls. Other fishes indicative of the Upper Cumberland's interaction with the adjacent Kentucky River, including the central stoneroller (*Campostoma anomalum*) and rosyface shiner subspecies (*Notropis r. rubellus*), also have their entire range above the Falls. The primary distributions of the endemic Cumberland arrow darter (*Etheostoma s. sagitta*) and blackside dace (*Phoxinus cumberlandensis*), as well as the stripetail darter (*Etheostoma kennicotti*), are above the Falls but each also occurs in drainages that lie between its supposed site of origin and its present location. The latter distributional pattern has been attributed to the capture of lateral headwater streams both above and below the Falls. Alternatively, the present-day distribution downstream from the Falls may antedate the Falls' regression (Burr and Warren 1986, Starnes and Etnier 1986).

Distributional patterns of fishes downstream also implicate the Falls as an effective barrier to upstream migration, suggesting that the Falls' upstream displacement over time may have played a role in producing present-day distributional patterns. Several species that are present below the falls but not above, e.g., telescope shiner *(Notropis telescopus*), blotched chub (*Erimystax insignis*), redline darter *(Etheostoma rufilineatum*), reach their upstream limits near the Falls' point of origin. Others apparently have penetrated upstream of the point of origin and into the Rockcastle River, but no further, e.g., largescale stoneroller *(Campostoma oligolepis*), northern studfish (*Fundulus catenatus*), bluebreast darter *(Etheostoma camurum*), banded darter *(E. zonale*), bloodfin darter (*E. sanguifluum*). For many fishes, the gorge that was created when the Falls receeded, especially in the area above the mouth of Rockcastle River, probably was an effective barrier to upstream migration. Numerous low waterfalls and large, boulder-strewn rapids are common features of the gorge; and streams tributary to the gorge often have high waterfalls near their mouths. Likewise, the lower Rockcastle and Laurel Rivers lie in deep gorges with extreme gradients, low waterfalls, and hanging tributaries; and these features may have served as physical filters for immigrating fishes. Aside from the direct physical influence of the Falls, many species adapted to limestone-based Highland Rim streams may be incapable of adapting to the sandstone-based streams of the Cumberland Plateau (Starnes and Etnier 1986). Both direct and indirect influences of the Falls may explain the absence of species in the Rockcastle and Laurel River systems that are otherwise characteristic of the Cumberland system, e.g., telescope shiner.

Recreational fisheries

Recreational fishing is a major use of waters of the DBNF. Many streams provide opportunities for fishers to pursue bass (primarily spotted and largemouth basses), panfish (e.g., bluegill), rock bass, and walleye. Here, only two recreational fisheries are addressed (muskellunge and trout) because information on the status and use of other fisheries is not adequately synthesized for summary.

Muskellunge—Native populations of muskellunge *(Esox masquinongy*) occur or have occurred in both the Licking and Kentucky River drainages. For populations remaining in Kentucky, some of the most important habitat occurs within DBNF proclamation boundaries, especially within the Kentucky River drainage (Axon and Kornman 1986). The Kentucky Department of Fish and Wildlife Resources has intensively studied several streams that support muskellunge, surveying the fish and macroinvertebrate fauna (Brewer 1980; Kornman 1985, 1989; Prather 1985; Axon and Kornman 1986). Principal factors limiting muskellunge habitat in these drainages are loss of spawning area due to impoundment, e.g., Licking River unit-Cave Run Reservoir, Middle Fork Kentucky River unit-Buckhorn Reservoir; sedimentation and acidic runoff from coal mines; high turbidity; lack of large woody debris, e.g., South Fork Kentucky River unit; and illegal harvest (Axon and Kornman 1986). These areas currently provide a muskellunge fishery that is maintained by supplemental stocking (L. E. Kornman, personal communication).

Oil drilling and associated brine disposal, as well as possible oil-shale development are potential problems in the Kentucky-Red River unit. Several authorized U.S. Army Corps of Engineers dams were identified as the greatest potential threat to muskellunge fish habitat, e.g., Falmouth Dam-Licking River, Booneville Dam-South Fork-Kentucky River (Axon and Kornman 1986). The most important management need identified for muskellunge populations in Kentucky streams was maintaining and enhancing habitat integrity, including maintenance of deep pools, protection of riparian zones, and recruitment of coarse (large) woody debris (CWD). Supplemental stocking was undertaken in streams that historically supported native muskellunge fisheries with the recovery goal of producing self-sustaining populations (Axon and Kornman 1986). Management now consists of annual to biannual stocking of muskellunge into streams because natural reproduction is considered too low to sustain populations (L. E. Kornman, personal communication).

Several streams within the Kentucky River drainage of the forest support viable muskellunge populations, but most are being augmented with supplemental stocking by the Kentucky Department of Fish and Wildlife Resources (Jones and Stephens 1984, Kornman 1985, Prather 1985). Sexton Creek, Goose Creek, and Collins Fork of the South Fork Kentucky River unit were considered high-quality muskellunge streams. Muskellunge habitat has been eliminated from Little Goose Creek by loss of pools from sediment accumulation. Aside from these four streams, supplemental stocking of muskellunge also occurs in South Fork Kentucky River mainstem and the Redbird River. In the Middle Fork Kentucky River unit, native muskellunge populations declined markedly after construction of Buckhorn Reservoir, a decline that was attributed to blocked spawning migrations into headwater tributaries. The Middle Fork Kentucky River unit is being considered for efforts designed to restore the lost fishery (Prather 1985, Axon and Kornman 1986). In the Kentucky River-Red River unit, the Red River, Station Camp Creek, and Sturgeon Creek support muskellunge. Red River and Station Camp Creek are considered good muskellunge streams but surveys in Sturgeon Creek show that populations have declined over time (Brewer 1980, Kornman 1985).

The Licking River unit, downstream of Cave Run Dam, also supports an important muskellunge fishery, which is augmented by supplemental stocking. This reach is the primary source of broodstock for the Kentucky Department of Fish and Wildlife Resources' supplemental stocking program. It was intensively surveyed by Kornman (1989), who concluded that it is one of the highest-quality large river habitats in Kentucky for muskellunge, other native fishes, mussels, and aquatic macroinvertebrates. This muskellunge population is augmented by stocking.

Trout—No trout are native to Kentucky (Burr and Warren 1986); however, in the 1980's, the Kentucky Department of Fish and Wildlife Resources began emphasizing the establishment of self-sustaining trout fisheries (Axon and Carroll 1989, Stephens 1994, Kentucky Department of Fish and Wildlife Resources 1996). Today, 16 streams in the DBNF offer a total of 123 km (72.9 mi) of trout fishing waters, ranging in quality from exceptional to marginal (Kentucky Department of Fish and Wildlife Resources 1996). The DBNF contains 28 percent (88 km; 54.5 mi) of the waters in Kentucky rated as exceptional or high-quality trout streams (Kentucky Department of Fish and Wildlife Resources 1996). Rainbow trout are stocked in several forest streams each year, primarily on a put-take basis; brown trout are stocked on a put-grow-take basis (Stephens 1994, Kentucky Department of Fish and Wildlife Resources 1996). Rainbow trout reproduction is marginal to nonexistent in DBNF waters and, to date, efforts to establish self-sustaining brown trout populations have been unsuccessful. Marginal reproductive success of brown trout in streams of the Upper Cumberland River unit has been attributed to (1) lack or scarcity of suitable spawning habitat; (2) presence of rainbow trout; and (3) competition from introduced redbreast sunfish (Stephens 1994). Brook trout fisheries that are at least partially self-sustaining ("wild" brook trout) are present in Kentucky River-Red River unit (Red River drainage). These fish were stocked by a private individual about 10 to 15 years ago (L. E. Kornman, personal communication). Anglers are told the locations of brook trout streams only by individual requests.

Extirpated and imperiled fishes

Extirpation—Twelve species are considered to be, or likely to have been, extirpated from all drainages in the DBNF. One of these, the harelip sucker (*Moxostoma lacerum*), which was known from the Rockcastle River and Big South Fork drainages, is extinct throughout its range (Burr and Warren 1986, Jenkins and Burkhead 1994). The largest number of extirpations are in the Cumberland River drainage, but all major drainages show extirpation to some extent (Table 1). Other species considered to be, or likely to be, extirpated from all forest waters are the lake sturgeon (*Acipenser fulvescens*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), flame chub (*Hemitremia flammea*), Tennessee shiner (*Notropis leuciodus*), stargazing minnow (*Phenacobius uranops*), freckled madtom (*Noturus nocturnus*), trout-perch (*Percopsis omiscomaycus*), crystal darter (*Crystallaria asprella*), Tennessee snubnose darter (*Etheostoma simoterum*), blotchside logperch (*Percina burtoni*), and longhead darter (*Percina macrocephala*). Historically, most of these were restricted to one or two hydrologic units. Extirpations of some large stream and river fishes, e.g., lake sturgeon, are attributable in part to construction of large impoundments like the Cumberland and Cave Run reservoirs. Such structures eliminated mainstem riverine habitat, ponded the lower reaches of major tributaries, e.g., Rockcastle River, Big South Fork, and blocked migration of many fishes. Some fishes of small- or medium-sized streams apparently disappeared from forest drainages in the late 1800's or early 1900's, e.g., flame chub, harelip sucker, trout-perch, Tennessee snubnose darter, longhead darter, blotchside logperch. Others seem to have disappeared more recently, e.g., stargazing minnow, freckled madtom (Burr and Warren 1986). It is possible that some of these species may be rediscovered in the DBNF, especially those designated as "may be extirpated" (EX?)(Table 3). Their apparent absence may result from a combination of factors, including low numbers of individuals or populations, highly localized or seasonal-related distributions, and difficulty in capture.

Imperilment—Approximately 30 percent of fishes in the DBNF, representing 8 of 20 fish families found there, have received conservation status designations from the U.S. Fish and Wildife Service (1995 and Amendments), American Fisheries Society (Williams and others 1989), Kentucky State Nature Preserves Commission (1996b), and/or the DBNF (Table 3). About two thirds of the fishes recognized as imperiled are in two families; the Percidae (all of these are darters of the genera *Ammocrypta*, *Percina*, and *Etheostoma*; 12 imperiled taxa) and minnows (Cyprinidae – 8 imperiled taxa). Darters show higher imperilment in proportion to their representation in the fauna than do minnows, a pattern congruent with these two fish families in the southeastern United States (Warren and Burr 1994, Warren and others 1997).

The U.S. Fish and Wildlife Service recognizes three fishes within the DBNF proclamation boundaries as endangered or threatened. The palezone shiner (*Notropis albizonatus*) and duskytail darter (*Etheostoma percnurum*) both have been listed as endangered (Biggins 1993), and both are found on the DBNF in the Big South Fork Cumberland River. The extant range of the palezone shiner is restricted to two streams; the Paint Rock River (Tennessee River drainage) in Alabama, and the Little South Fork (Big South Fork Cumberland River) in Kentucky (Warren and others 1994). Only one population of the duskytail darter (*Etheostoma percnurum*) has been found in the mainstem of the Big South Fork Cumberland River (Burr and Eisenhower 1996), and only four others have been found in the Upper Tennessee River of eastern Tennessee and southwestern Virginia (Etnier and Starnes 1993, Jenkins and Burkhead 1994).

About half of the entire range of the Threatened blackside dace (*Phoxinus cumberlandensis*) (U.S. Fish and Wildlife Service 1988), lies within small, cool headwater streams of the Cumberland River drainage in the DBNF. Recent assessments of distribution (Cicerello and Laudermilk [unpublished]) and population sizes (Leftwich and others 1995, 1997) of blackside dace have provided significant inventory information, identified important refugia, highlighted the susceptibility of populations to disturbance, and identified significant metapopulations (Strange and Burr 1995).

For other fishes of concern, i.e., those recognized by the American Fisheries Society and the Kentucky State Nature Preserves Commission, the DBNF often supports the largest remaining populations within the species range, the only known population within Kentucky, or species that occur nowhere else in a particular drainage. For example, the ashy darter (*Etheostoma cinereum*) has been extirpated from at least 4 of the 10 stream systems in which it once existed (Shepard and Burr 1984), although the healthiest remaining populations occur in the Rockcastle River and Big South Fork mainstems (Etnier and Starnes 1993; Burr and Eisenhower 1996; G. Schuster and P.

Table 3. Conservation status of fishes in the Daniel Boone National Forest.

Species	U.S. Fish and Wildlife Service	American Fisheries Soc.	Kentucky State Nature Preserves Commission	Daniel Boone National Forest
Petromyzontidae—Lampreys				
Ichthyomyzon bdellium Ohio lamprey	-	-	-	CS
Ichthyomyzon fossor northern brook lamprey	-	-	T	CS
Ichthyomyzon greeleyi mountain brook lamprey	-	-	T	S
Lampetra appendix American brook lamprey	-	-	T	CS
Acipenseridae—Sturgeons				
Acipenser fulvescens lake sturgeon	-	T	E	S
Polyodontidae—Paddlefishes				
Polyodon spathula paddlefish	-	SC	-	CS
Cyprinidae—Minnows and Carps				
Clinostomus elongatus redside dace	-	-	-	CS
Clinostomus funduloides rosyside dace	-	-	SC	-
Erimystax insignis blotched chub	-	-	E	CS
Hemitremia flammea flame chub	-	SC	X	-
Notropis albizonatus palezone shiner	E	T	E	E
Notropis sp. cf. spectrunculus sawfin shiner	-	-	E	S
Phenacobius uranops stargazing minnow	-	-	SC	-
Phoxinus cumberlandensis blackside dace	T	E	T	T
Amblyopsidae—Cavefishes				
Typhlichthys subterraneus southern cavefish	-	-	SC	S
Percopsidae—Trout-perches				
Percopsis omiscomaycus trout-perch	-	-	SC	-

Species	U.S. Fish and Wildlife Service	American Fisheries Soc.	Kentucky State Nature Preserves Commission	Daniel Boone National Forest
Ictaluridae—Bullhead catfishes				
Noturus exilis slender madtom	-	-	E	-
Noturus stigmosus northern madtom	-	-	SC	CS
Percidae—Perches and Darters				
Ammocrypta pellucida eastern sand darter	-	T	SC	S
Crystallaria asprella crystal darter	-	SC	X	-
Etheostoma cinereum ashy darter	-	SC	T	S
Etheostoma maculatum spotted darter	-	SC	T	S
Etheostoma nigrum susanae Cumberland johnny darter	-	T	T	S
Etheostoma percnurum duskytail darter	E	T	-	E
Etheostoma s. spilotum Kentucky arrow darter	-	-	SC	CS
Etheostoma tippecanoe Tippecanoe darter	-	-	SC	S
Percina burtoni blotchside logperch	-	SC	X	S
Percina evides gilt darter	-	-	SC	CS
Percina macrocephala longhead darter	-	T	T	S
Percina squamata olive darter	-	-	E	S

Status sources are: U.S. Fish and Wildlife Service, American Fisheries Society (Williams and others 1989), Kentucky State Nature Preserves Commission (1996b), and Daniel Boone National Forest. E = endangered, T = threatened, PE = proposed endangered (federally), PT = proposed threatened (federally), SC = of special concern , CS=conservation species, S=sensitive species, and X = presumed extirpated from Kentucky or extinct.

Ceas, Eastern Kentucky University [personal communication]; R. Cicerello, Kentucky State Nature Preserves Commission [personal communication]).

In Kentucky, the only extant population of blotched chub (*Erimystax insignis*) and one of two populations of the sawfin shiner (*Notropis sp. cf. spectrunculus*) are found in the Big South Fork drainage. In the entire Kentucky River drainage, the only known populations of northern madtom (*Noturus stigmosus*) occupy the Middle and South Forks of the Kentucky River.

In addition, several lampreys receive conservation recognition. Two nonparasitic lampreys—the northern brook lamprey (*Ichthyomyzon fossor*) and the mountain brook lamprey (*Ichthyomyzon greeleyi*)—are found on the DBNF in the Kentucky River and Cumberland River units of the forest, respectively. For these species, concerted efforts to collect aggregated spawning adults in the spring may reveal larger numbers and wider distribution on the DBNF than are presently known (Etnier and Starnes 1993).

Mussel distribution and abundance

The Daniel Boone National Forest lies within a region, the southeastern United States, that harbors the richest freshwater mussel fauna on Earth (Williams and others 1993). Kentucky has a higher diversity of freshwater mussels than any other state except Tennessee and Alabama (Cicerello and others 1991). The running waters of the DBNF support a significant proportion of this globally unique mussel fauna. At least 67 native mussel species are known presently or historically from rivers and streams in the DBNF (Table 4). This fauna represents greater than half of the total native mussel fauna of Kentucky (Cicerello and others 1991) and 22% of the fauna of North America (Williams and others 1993).

Historically, mussel diversity was unevenly distributed among the eight DBNF drainage units. Units in the Cumberland River drainage had greater diversity—an average of 40 species per unit—than units in the Kentucky and Licking River drainages, with an average of 25 species per unit. However, because habitat destruction has resulted in the loss of many species in the Cumberland drainages, mussel diversity is relatively evenly distributed among hydrologic units. Today, Cumberland River units have an average of 25 species, and the Kentucky and Licking River units have an average of 24 (Table 4). About 67 percent of the entire Cumberland River drainage fauna is found in the Cumberland River units in the DBNF. The Kentucky and Licking River units also harbor a large proportion of the total fauna of their respective drainage basins, at 55 and 57 percent, respectively.

Mussel communities in the DBNF are composed of representatives of all major higher taxonomic groups of mussels. The family Margaritiferidae is represented by one species, the spectaclecase (*Cumberlandia monodonta*) but this species may be extirpated (Cicerello and Laudermilk 1997). All remaining species are members of the family Unionidae. Within the Unionidae, two subfamilies are currently recognized, the Anodontinae and Ambleminae (Lydeard and others 1996). The Anodontinae are represented in the DBNF by 11 species, including the genera

Alasmidonta, *Anodontoides*, *Lasmigona*, *Pegias*, *Pyganodon*, *Simpsonaias*, *Strophitus*, and *Utterbackia*. The Ambleminae is composed of at least three clades: the Lampsilini, the Pleurobemini, and a *Quadrula/Megalonaias* clade (Lydeard and others 1996). The Lampsilini is represented by at least 32 species, including the genera *Actinonaias*, *Epioblasma*, *Lampsilis*, *Leptodea*, *Medionidus*, *Potamilus*, *Ptychobranchus*, *Toxolasma*, and *Villosa*. The Pleurobemi is represented by at least six species, including the genera *Elliptio* and *Pleurobema*. The genera *Fusconaia* and *Plethobasus* also may be included, but their phylogenetic positions are unresolved (Lydeard and others 1996). The *Quadrula/Megalonaias* clade is represented by at least five species in these genera. Other genera within Ambleminae that are represented on the DBNF include *Amblema*, *Cyclonaias*, *Dromus*, *Hemistena*, *Truncilla*, and *Tritogonia*; their systematic relationship within the subfamily is unresolved.

Presently, only one introduced bivalve, the Asian clam (*Corbicula fluminea*), is known to exist on the DBNF. *Corbicula* was introduced into the Pacific Northwest in the 1930's and has since spread across most of North America (Counts 1986). This species is abundant in most large streams on the DBNF and in degraded streams it may be the only living bivalve. *Corbicula* is absent only from isolated headwater streams. Although some have speculated that *Corbicula* may have negative effects on native bivalves, such effects are not well documented. Since its introduction into the Great Lakes from Europe, the zebra mussel, *Dreissena polymorpha*, has spread across much of eastern North America in the last 10 years (Strayer 1991). There are no confirmed sightings of the zebra mussel in the DBNF; however, the range of this species is expanding, and it may be expected to appear in the waters of the DBNF at any time. The most dense, self-sustaining populations of zebra mussels are in large, algae-rich rivers or lakes, and it is uncertain how well the zebra mussel will be able to adapt to small upland streams and rivers (Strayer 1991). However, unlike *Corbicula*, the zebra mussel is known to have serious negative effects on native mussels (Haag and others 1993), and the establishment of this species in DBNF waters would pose a significant threat to native unionids.

Table 4. Distribution of freshwater mussels in hydrologic units within the Daniel Boone National Forest proclamation boundaries. Unit boundaries are defined in the text and in figure 2.

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Actinonaias ligamentina Mucket	N	N	N	N	N[a]	N	EX	EX
Actinonaias pectorosa Pheasantshell	-	-	-	-	N	N	N	N
Alasmidonta atropurpurea Cumberland elktoe	-	-	-	-	N	-	-	N
Alasmidonta marginata Elktoe	EX?	-	-	N	EX[a]	N	EX	N
Alasmidonta viridis Slippershell mussel	N	-	N	N	N	N	N	N
Amblema plicata Threeridge	N	N	N	N	-	N	-	-
Anodontoides denigratus Cumberland papershell	-	-	-	-	N	-	-	-
Cumberlandia monodonta Spectaclecase	-	-	-	-	EX[?]	-	EX	-
Cyclonaias tuberculata Purple wartyback	N	-	EX?	-	EX?[a]	N	N	N
Dromus dromas Dromedary pearlymussel	-	-	-	-	-	-	EX	EX
Ellipsaria lineolata Butterfly	?	-	-	-	EX[a]	-	EX	-
Elliptio crassidens Elephant-ear	-	-	-	-	N[a]	N	EX	N
Elliptio dilatata Spike	N	N	N	N	N	N	N	N
Epioblasma arcaeformis Sugarspoon	-	-	-	-	-	-	-	EX
Epioblasma biemarginata Angled riffleshell	-	-	-	-	-	-	-	EX
Epioblasma brevidens Cumberlandian combshell	-	-	-	-	-	EX	N	N
Epioblasma capsaeformis Oyster mussel	-	-	-	-	EX[a]	EX	N	N
Epioblasma florentina Tan riffleshell	-	-	-	-	-	-	EX	-
Epioblasma haysiana- Acornshell	-	-	-	-	-	-	EX	EX
Epioblasma lewisii Forkshell	-	-	-	-	-	-	EX	-

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Epioblasma obliquata Catspaw	-	-	-	-	-	-	EX	-
Epioblasma torulosa rangiana[b] Northern blossom	-	-	-	-	-	-	-	-
Epioblasma triquetra Snuffbox	N	N	N	N	-	-	N	EX
Fusconaia flava Wabash pigtoe	N	N	N	N	-	-	EX	-
Fusconaia subrotunda Long-solid	-	-	N	-	-	EX	EX	EX
Hemistena lata Cracking pearlymussel	-	-	-	-	-	-	EX	EX
Lampsilis cardium Plain pocketbook	N	N	N	N	N	N	N	N
Lampsilis fasciola Wavy-rayed lampmussel	-	N	N	N	N	N	N	N
Lampsilis ovata Pocketbook	-	-	-	-	EX	?	EX	EX
Lampsilis siliquoidea Fatmucket	N	N	N	N	-	-	-	-
Lampsilis teres Yellow sandshell	-	-	-	EX?	-	-	-	-
Lasmigona complanata White heelsplitter	N	-	-	-	-	-	-	-
Lasmigona costata Fluted-shell	N	N	N	N	N[a]	N	N	N
Leptodea fragilis Fragile papershell	N	N	?	N	-	N	N	N
Ligumia recta Black sandshell	-	-	-	EX?	N[a]	N	EX	N
Medionidus conradicus Cumberland moccasinshell	-	-	-	-	EX[a]	N	N	N
Megalonaias nervosa Washboard	N	N	N	N	-	-	-	-
Obliquaria reflexa Threehorn wartyback	N	-	-	-	EX[a]	EX	-	EX
Obovaria subrotunda Round hickorynut	N	N	N	N	-	EX	N	N
Pegias fabula Little-wing pearlymussel	-	-	-	-	-	N	-	N
Plethobasus cyphyus Sheepnose	N	-	-	-	-	-	-	-

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Pleurobema clava[b] clubshell	-	-	-	-	-	-	-	-
Pleurobema coccineum Round pigtoe	N	N	N	N	-	N	EX	N
Pleurobema oviforme Tennessee clubshell	-	-	-		-	-	N	NN
Pleurobema pyramidatum Pyramid pigtoe	-	-	-		- EX	-	-	EX
Potamilus alatus Pink heelsplitter	N	N	N	N	N[a]	N	N	N
Potamilus ohiensis Pink papershell	-	-	-		-	N[a]	N	N-
Ptychobranchus fasciolaris Kidneyshell	N	N	N	N	N[a]	N	N	N
Ptychobranchus subtentum Fluted kidneyshell	-	-	-		-	EX[a]	N	NN
Pyganodon grandis Giant floater	N	-	N	-	-	N	-	N
Quadrula cylindrica rabbitsfoot	-	-	EX	-	-	EX	EX	EX
Quadrula metanevra Monkeyface	N	-	-		-	-	-	EX-
Quadrula pustulosa Pimpleback	N	N	N	N	N[a]	N	EX	N
Quadrula quadrula Mapleleaf	N	-	-	N	-	-	-	-
Quadrula tuberosa Rough rockshell	-	-	-	-	-	-	EX	-
Simpsonaias ambigua Salamander mussel	P	N	N	N	-	-	-	-
Strophitus undulatus Creeper	N	-	N	N	-	N	-	N
Toxolasma lividus Purple lilliput	-	-	-	-	-	N	N	N
Toxolasma parvus Lilliput	-	-	-	-	-	-	-	EX
Tritogonia verrucosa Pistolgrip	N	N	N	N	N[a]	N	N	N
Truncilla donaciformis Fawnsfoot	-	-	-	-	EX[a]	-	-	EX
Truncilla truncata Deertoe	N	-	EX?	-	EX[a]	N	EX	EX

Species	Licking River	Middle Fork Kentucky River	South Fork Kentucky River	Kentucky River-Red River	Upper Cumberland River	Rockcastle River	Cumberland River-Buck Creek	Big South Fork River
Utterbackia imbecillis Paper pondshell	N	-	-	-	-	-	-	N
Villosa iris Rainbow	-	-	N	N	EX[a]	N	N	N
Villosa lienosa Little spectaclecase	N	N	N	EX?	EX	EX	EX	-
Villosa taeniata Painted creekshell	-	-	-	- -	EX[a]	N	N	N
Villosa trabalis Cumberland bean	-	-	-	-	EX[a]	N	N	N
Total Extant Species (N)	28	19	23	23	16	30	23	31
Total May be Extirpated (EX?)	1	-	2	3	1	-	-	-
Total Extirpated (EX)	-	-	1	-	14	7	23	15
Total Probable (P)	1	-	-	-	-	-	-	-

N = verified extant species, P = probable occurrence (occurs upstream or downstream of proclamation boundaries), EX = considered extirpated, EX? = may be extirpated, and ? = may occur, but records are questionable.
[a] Species is known to exist in the Upper Cumberland River unit only below Cumberland Falls. [b]Not recorded from Daniel Boone National Forest waters, but known to occur in parts of the Licking and Kentucky River drainages peripheral to the proclamation boundaries. Suitable habitat for establishment of populations and recovery of the species may exist within proclamation boundaries.

Mussel assemblages among drainages

The Cumberland River drainage contains representatives of two faunal elements—the Interior Basin fauna and the Cumberlandian fauna (Johnson 1978). The Interior Basin fauna is composed of species that are endemic to the Ohio River basin, as well as species more widely distributed in drainages east of the Rocky Mountains. Within DBNF proclamation boundaries, the original fauna of the Cumberland River system contained about 40 species derived from the Interior Basin fauna. Today, common members of Interior Basin fauna in the Cumberland River units include the mucket (*Actinonaias ligamentina*), threeridge, (*Amblema plicata*), spike (*Elliptio dilatata*), fluted-shell (*Lasmigona costata*), round pigtoe (*Pleurobema coccineum*), pink heelsplitter (*Potamilus alatus*), kidneyshell *(Ptychobranchus fasciolaris*), pimpleback (*Quadrula pustulosa*), creeper (*Strophitus undulatus*), and pistolgrip (*Tritogonia verrucosa*).

The Cumberlandian fauna is composed of species endemic to the Cumberland and/or Tennessee River systems. The original fauna on the Daniel Boone included about 18 Cumberlandian species. Today, the DBNF harbors at least 12 Cumberlandian species, including species endemic to the Cumberland River drainage only (Cumberland elktoe, *Alasmidonta atropurpurea* and Cumberland papershell, *Anodontoides denigratus*), and species found exclusively in the Cumberland and Tennessee River drainages: pheasantshell *(Actinonaias pectorosa*), Cumberland combshell *(Epioblasma brevidens*), oyster mussel *(E. capsaeformis)*, Cumberland moccasinshell (*Medionidus conradicus)*, little-wing pearly mussel (*Pegias fabula*), Tennessee clubshell (*Pleurobema oviforme*), fluted kidneyshell *(Ptychobranchus subtentum*), purple lilliput (*Toxolasma lividus)*, painted creekshell *(Villosa taeniata*), and Cumberland bean *(V. trabalis*). Cumberland Falls has acted as a barrier to upstream dispersal of mussel species in the drainage, and streams above Cumberland Falls lack many species found in the remainder of the drainage. However, one species, the Cumberland papershell (*Anodontoides denigratus*), is considered endemic to the Cumberland River drainage above the Falls.

The Licking and Kentucky River units have mussel assemblages derived exclusively from Interior Basin fauna. Common species include those listed for the Cumberland River units, with the addition of the Wabash pigtoe (*Fusconaia flava*). There are no endemic species in either drainage; and mussel faunas of both drainages are very similar. The Licking River unit contains at least 30 species, and the Kentucky River units combined contain at least 31. All but one of these species are found in both drainages and at least 25 species occur in both drainages within the proclamation boundaries of the DBNF.

Commercial importance

Historically, large streams in the DBNF supported limited commercial harvest of mussels, both for pearling and for use in the manufacture of shell buttons. The Cumberland River mainstem and the Middle Fork Kentucky River were the most heavily exploited (Wilson and Clark 1914, Danglade 1922). There is currently little or no harvest of shells in DBNF streams, and streams harboring federally listed species are off limits to commercial harvest. However, because of high prices paid for shells that are used in the cultured pearl industry, streams such as the South Fork and Middle Fork Kentucky River, Redbird River, and Rockcastle River may receive attention from commercial musselers. Other streams in Kentucky have been subjected to poaching and overharvest of mussels (Crowell and Kinman 1993). Forest Service personnel should be aware of the potential for such occurrences.

Extirpated and imperiled freshwater mussels

Streams within the DBNF proclamation boundaries have lost a large portion of their faunas over the last 50 years. Seventeen species are thought to have been extirpated from the DBNF (Table 4). However, individual drainage units have lost as many as 23 species (50 percent of their total fauna). Most extirpated species are big-river and/or Cumberlandian species. Of those extirpated, six are considered extinct throughout their range (*Epioblasma arcaeformis*, *E. biemarginata*, *E. florentina*, *E. haysiana*, *E. lewisii*, and *Quadrula tuberosa*). Most extirpations have resulted from elimination of big-river habitat by dams or water pollution from coal mining activities. *Quadrula sparsa* (Appalachian monkeyface, Federal endangered species) is listed as having occurred historically in the DBNF. This species probably never inhabited the Cumberland River drainage. The historical report of its occurrence likely was based on a misidentification of *Q. tuberosa* (R.R. Cicerello, personal communication).

The greatest known loss has been in the Cumberland River drainage, where an average of 37 percent of the fauna has been lost in each drainage unit (range = 19 to 50 percent). The direct cause of most of these extirpations was the construction of Wolf Creek dam in 1950, which eliminated all big-river habitat in this region (Cicerello and Laudermilk 1997). However, coal mining pollution has seriously affected the fauna in other streams and has greatly reduced the range of species not eliminated by impoundment. As early as 1949, fauna of the lower Big South Fork had been decimated by acid mine waste, and had declined from 38 species in 1911 (Wilson and Clark 1914) to 16 species (Neel and Allen 1964). Today, the lower, unimpounded sections of Big South Fork (Bear Creek confluence downstream) support few, if any, viable populations of mussels (Richardson 1989, Bakaletz 1991). Similarly, in 1911 the mainstem Rockcastle River was described as one in which "The mussels were excessively abundant. . .and, in favored localities. . . *Medionidus conradicus* covered the entire bottom.. . ." (Wilson and Clark 1914). This stream continued to support dense, diverse mussel communities into the early 1960's. However, by 1993, seven species were considered extirpated from the mainstem (including *Medionidus conradicus*) and densities of other species, such as *Villosa trabalis*, had declined to precipitously low levels (Cicerello 1993, 1994). During the same period, the mainstem Cumberland River below Cumberland Falls declined from 16 species in 1961 to 10 species in 1993 and numbers of almost all remaining species had declined by greater than 90 percent (Cicerello and Laudermilk 1997). More recently, the Little South Fork supported one of the most diverse and abundant mussel communities remaining in the entire Cumberland River drainage until large-scale strip-mining began in the drainage in the 1980's. From 1981 to 1987, the number of live species collected in the drainage declined from 19 to 12 and at some sites in the lower river, mussels were eliminated almost completely (Starnes and Bogan 1982, Anderson and others 1991). By 1998, only nine species were found alive and four of these were represented by one or two individuals in the entire drainage (Warren and Haag 1999).

Based on available information, the Licking and Kentucky River units appear to have experienced fewer species extirpations than the Cumberland. In the Licking River unit, only one species is thought to be extirpated; in the Kentucky River units a total of six species are thought to be extirpated from one or more hydrologic units (Table 4). However, no complete surveys were conducted in any of these drainages prior to widespread habitat destruction in the mid to late 20th Century and many streams in the region were not surveyed at all until recently (Cicerello 1996a and personal communication). The only early published survey results available for the upper Kentucky River were by Danglade (1922). Several species that are absent today were reported in the upper Kentucky River, including *Cyprogenia stegaria*, *Pleurobema clava*, *Quadrula cylindrica*, and *Epioblasma torulosa rangiana*. These species and perhaps others likely occurred in most larger streams in the upper Kentucky River and Licking River drainages. The low number of known extirpations in the Licking and Kentucky River units may be a reflection of a lack of historical collections within those drainages. Species extirpations in the upper Kentucky and Licking River units are probably due mostly to water pollution from coal mines, municipal sewage, and the construction of the Cave Run and Buckhorn reservoirs on the Licking and Middle Fork Kentucky Rivers, respectively.

The remaining high-quality streams in the DBNF provide important refuge for at least 15 imperiled mussel species, including 5 federally endangered species: Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*E. capsaeformis*), Cumberland bean (*Villosa trabalis*), Cumberland elktoe (*Alasmidonta atropurpurea*), and little-wing pearlymussel (*Pegias fabula*). On the DBNF, all of these species occur only in the Cumberland River units. The Cumberland elktoe is endemic to the Cumberland River drainage and the largest known populations of this species on Earth are found in the DBNF in Marsh Creek (Upper Cumberland River unit) and Rock Creek (Big South Fork unit). Similarly, most known large populations of the Cumberland bean occur in the DBNF in Horse Lick Creek and Sinking Creek (Rockcastle River unit), Big South Fork, and Little South Fork (Big South Fork unit) The DBNF supports the only Kentucky populations of the Cumberlandian combshell and oyster mussel in the Big South Fork and Buck Creek. The little-wing pearlymussel, occurring in Horse Lick Creek (Rockcastle River unit), Big South Fork, and Little South Fork (Big South Fork unit), is known in Kentucky outside of the forest from only one specimen found at a single site in the Cumberland River drainage in western Kentucky (Cicerello and others 1991). Although *Pegias fabula* and *Villosa trabalis* were known from the Little South Fork as recently as 1987, these species may now be extirpated from that stream (Warren and Haag 1999).

In addition to the five species known to occur within the DBNF proclamation boundaries, two other federally endangered species, the northern riffleshell (*Epioblasma torulosa rangiana*) and clubshell (*Pleurobema clava*), are known from parts of the Licking and Kentucky drainages peripheral to the proclamation boundaries. It is likely that these species once occurred in the DBNF and continued survey efforts may reveal relict populations.

Nine mussel species are considered threatened or endangered by the American Fisheries Society (AFS)(Williams and others 1993) and/or the Kentucky State Nature Preserves Commission (KNP)(1996a) and one species is considered of special concern by the KNP (Table 5). Six of these occur in the Cumberland River units and four in the Kentucky and Licking River units. The fluted kidneyshell (*Ptychobranchus subtentum*) is found in Kentucky only within the proclamation boundaries in Rock Creek, Big South Fork, Little South Fork (Big South Fork unit), Horse Lick Creek (Rockcastle River unit), and Buck Creek. The DBNF supports the best and perhaps only viable populations of Tennessee clubshell (*Pleurobema oviforme*) and purple lilliput (*Toxolasma lividus*), in Kentucky in Buck Creek, Little South Fork (Big South Fork unit), and Horse Lick Creek (Rockcastle River unit). These species are known elsewhere in Kentucky only from small populations in the Cumberland River drainage in western Kentucky (Cicerello and others 1991). The remaining imperiled species are known from other populations outside the DBNF but streams in the Forest support the most important populations of these species in the State, or the only populations in a particular drainage basin. One of the largest Kentucky populations of elktoe (*Alasmidonta marginata*) occurs in the Red River, along with an important population of the salamander mussel (*Simpsonaias ambigua*). The only known populations of snuffbox (*Epioblasma triquetra*) in the entire Kentucky River drainage are currently found on the DBNF in the Red River and in the South and Middle Fork Kentucky River units. Similarly, the only known population of the long-solid (*Fusconaia subrotunda*) is found in the South Fork Kentucky River.

Table 5. Conservation status of mussels in the Daniel Boone National Forest[a]

Species	U.S. Fish and Wildlife Service	American Fisheries Soc.	Kentucky State Nature Preserves Commission	Daniel Boone National Forest
Alasmidonta atropurpurea Cumberland elktoe	E	E	E	E
Alasmidonta marginata Elktoe	-	SC	T	C
Anodontoides denigratus Cumberland papershell	-	-	E	PS
Cumberlandia monodonta Spectaclecase	-	T	E	S
Dromus dromas Dromedary pearlymussel	E	E	EX	E
Epioblasma arcaeformis Sugarspoon	-	EX	EX	-
Epioblasma biemarginata Angled riffleshell	-	EX	E	-
Epioblasma brevidens Cumberlandian combshell	E	E	E	E
Epioblasma capsaeformis Oyster mussel	E	E	E	E
Epioblasma flexuosa Leafshell	-	EX	EX	-
Epioblasma florentina florentina Yellow blossom	E	EX	EX	E
Epioblasma florentina walkeri Tan riffleshell	E	E	EX	E
Epioblasma haysiana Acornshell	-	EX	EX	-
Epioblasma lewisi Forkshell	-	EX	EX	-
Epioblasma obliquata obliquata Catspaw	E	E	E	E
Epioblasma torulosa rangiana Northern riffleshell	E	E	E	E
Epioblasma triquetra Snuffbox	-	T	SC	S

Species	U.S. Fish and Wildlife Service	American Fisheries Soc.	Kentucky State Nature Preserves Commission	Daniel Boone National Forest
Fusconaia subrotunda Long-solid	-	SC	T	C
Hemistena lata Cracking pearlymussel	E	E	EX	E
Lampsilis ovata Pocketbook	-	SC	E	C
Pegias fabula Little-wing pearlymussel	E	E	E	E
Plethobasus cyphyus Sheepnose	-	T	SC	S
Pleurobema clava Tennessee clubshell	E	E	E	E
Pleurobema oviforme Tennessee clubshell	-	SC	E	S
Pleurobema pyramidatum- Pyramid pigtoe	-	T	E	-
Ptychobranchus subtentum Fluted kidneyshell	-	SC	T	C
Quadrula cylindrica cylindrica Rabbitsfoot	-	T	T	-
Quadrula tuberosa Rough rockshell	-	EX	EX	-
Simpsonaias ambigua Salamander mussel	-	SC	T	S
Toxolasma lividus Purple lilliput	-	SC	E	S
Villosa lienosa Little spectaclecase	-	CS	SC	C
Villosa trabilis Cumberland bean	E	E	E	E

[a]Status sources are: U.S. Fish and Wildlife Service, American Fisheries Society (Williams and others 1993), Kentucky State Nature Preserves Commission (1996b), and the Daniel Boone National Forest. E = endangered, T = threatened, SC = of special concern, EX = presumed extirpated from Kentucky or extinct, CS = currently stable, C=conservation species, S=sensitive, PS=proposed sensitive.

Land Use and Current Resource Condition

The landscape of eastern Kentucky has changed dramatically since the late 1800's, when the dominant use was small-scale subsistence farming. Logging and land clearing for agriculture accelerated in the early 1900's, and by 1930 most of eastern Kentucky had been cleared. Faced with economic necessity, many people either abandoned or sold their land to the Federal Government in the 1920's and 1930's under the Weeks Act. From the 1920's to the 1970's, mining companies stripped and deep mined coal on adjacent private lands. Mining resulted in the loss of valuable topsoil, high rates of stream sedimentation, and degradation of aquatic habitats and faunal communities. Some of the mined lands also were acquired by the Federal Government.

The DBNF manages the largest contiguous block of land in eastern Kentucky. Within its proclamation boundary, the DBNF includes about one third of the 418 km (260 mi) of stream that either do not support or partially support beneficial uses (Kentucky Department of Fish and Wildlife Resources 1996; Table 6). Sedimentation and acid mine drainage from abandoned surface and underground coal mines, brine and oil residue from oil drilling, sedimentation and runoff of agricultural chemicals and animal wastes from farm lands, discharge from domestic wastewater systems, and sedimentation from roads and timber harvest constitute the primary water quality issues facing managers on the DBNF today (fig. 3; Table 7).

Mineral extraction has degraded aquatic systems primarily through sedimentation and acid mine drainage from coal mines and brine waste from oil drilling. Over 64 km (40 mi) of stream on the DBNF have been degraded by coal mining, and an additional 32 km (20 mi) by oil drilling. In recent years, both coal mining and oil drilling activities have decreased.

Soil erosion, the source of stream sedimentation, is the most serious land management conservation issue in Kentucky (USDA Natural Resources Conservation Service 1992). Mining, agriculture, and silviculture are the most significant contributors to sedimentation. Although agricultural activities on the DBNF are relatively minor, some farms adjacent to National Forest System lands have a profound effect on stream water quality, primarily due to sedimentation, but also to runoff of agricultural chemicals and animal wastes.

Sources of sedimentation from silvicultural activities include road construction and maintenance, and construction and use of log landings and skid trails (Fig. 3). A portion of this sedimentation can be attributed to landslides and debris flows generated by road construction, skidding, or maintenance and use of roads and trails but most sediment input results from eroding road surfaces, slopes, and ditches, particularly at stream channel crossings. Silvicultral activities on both private and public lands may contribute sediment to DBNF streams

Inadequate municipal sewer collection systems are a major concern for several DBNF streams. Surface waters periodically are affected by sewerage overflows, primarily during and immediately following rainfall events. In addition, poorly designed septic systems and straight pipes are affecting some DBNF streams.

An increase in the amount of off-highway-vehicle (OHV) use—on and off the DBNF—has increased stream sediment loads and adversely affected the aquatic biota. Many trails used by OHV's are old roads and railbeds designed for timber and mineral extraction early in the 20th century. Most of these roads were built to a very low standard and were located in river and stream bottoms. Many extended up narrow mountain hollows, where the stream channels were commonly used as road beds. Streams were crossed and recrossed many times with no provision for stream channel protection (Southern Appalachian Assessment 1996). Although most old byways were closed by natural revegetation after logging and mining were completed, in recent years many have been unofficially re-opened by OHV operators. The special problems generated by OHV's are addressed in a separate Environmental Impact Statement (Record of Decision and Final Environmental Impact Statement for Amending the Daniel Boone National Forest Off-Highway Vehicle Management Direction 2000).

Since implementation of the DBNF's 1985 Forest Land and Resource Management Plan (FLRMP), Agency managers have accomplished watershed improvement on 2,180 acres, improving hydrologic function, soil productivity, and water quality. While these projects demonstrate a commitment to watershed restoration, there is much to do. Recent Forest Service estimates indicate that 10 of 30 administrative watersheds are in need of restoration.

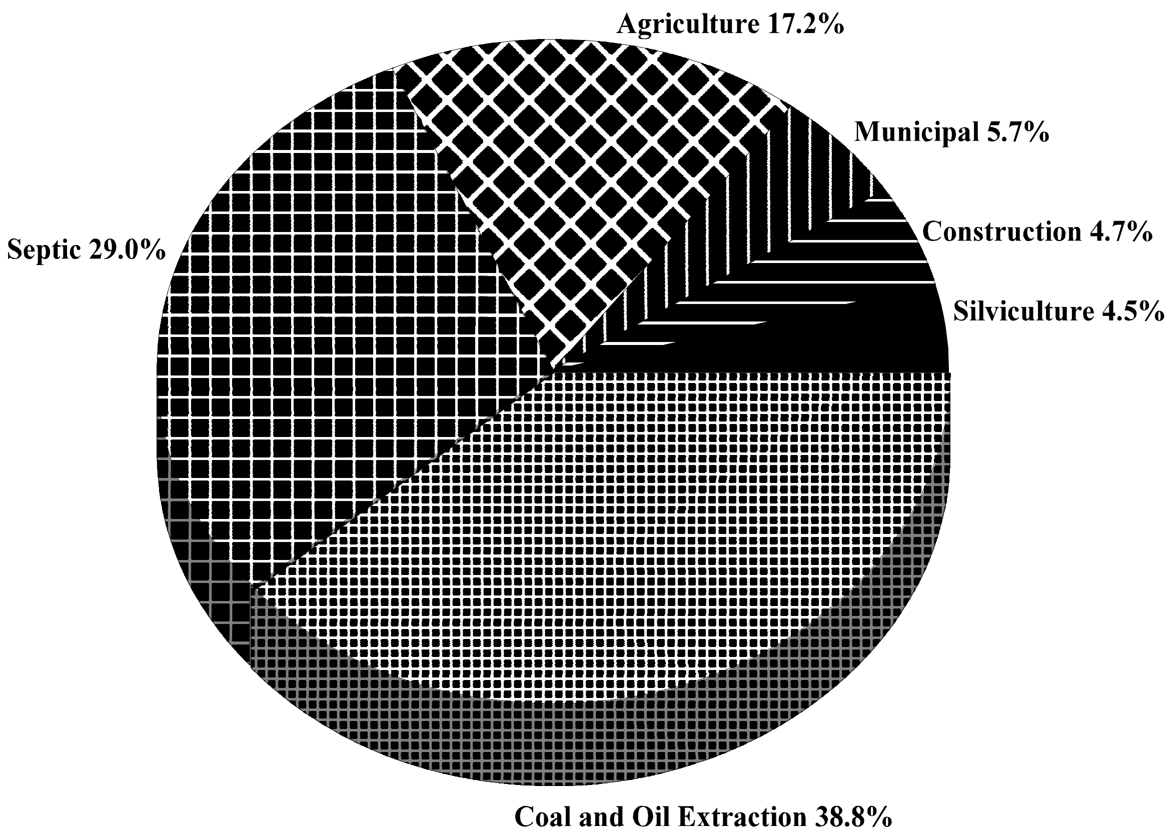

Figure 3. Impacts to stream water quality on the Daniel Boone National Forest. Data are based on the 1996 Kentucky 305(b) Report and do not include impacts from off-highway vehicles.

Table 6. Survey of the locations, uses, and causes and sources of impairment of streams on the Daniel Boone National Forest.

Stream name and county	Use not supported	Segment milepoints	Causes of the impairment	Sources of impairment
Cumberland River Basin				
Indian Creek Jackson Co.	AL-PS SW-PS	3.3 - 7.3 3.3 - 7.3	Suspended solids, pH, pathogens, nutrients	Resource extraction, silviculture
Bear Creek McCreary Co.	AL-NS SW-NS	0.0 - 3.2 0.0 - 3.2	pH	Subsurface mining; surface mining
Cane Branch McCreary Co.	AL-NS SW-NS	0.0 - 2.0 0.0 - 2.0	pH	acid mine drainage
Copperas Creek McCreary Co.	AL-NS SW-NS	0.0 - 3.8 0.0 - 3.8	pH	acid mine drainage
Devils Creek McCreary Co.	AL-NS SW-NS	0.0 - 2.4 0.0 - 2.4	pH	acid mine drainage
Jennys Branch McCreary Co.	AL-NS	0.0 - 5.5	suspended solids	construction
Lick Creek McCreary Co.	AL-NS SW-NS	0.0 - 5.7 0.0 - 5.7	suspended solids, pH, other habitat alteration, metals	resource extraction
Marsh Creek McCreary Co.	AL-NS	18.7 - 24.0	siltation, other habitat alteration	extraction, resource agriculture
Rock Creek McCreary Co.	AL-NS SW-NS	0.0 - 4.1 0.0 - 4.1	suspended solids, pH, other habitat alteration, metals	resource extraction
Ryans Creek McCreary Co.	AL-NS SW-NS	0.0 - 5.3 0.0 - 5.3	suspended solids, pH	acid mine drainage
White Oak Creek McCreary Co.	AL-NS SW-NS	0.0 - 4.2 0.0 - 4.2	suspended solids, pH, other habitat alteration, metals	resource extraction
Rockcastle River Pulaski Co.	SW-PS	8.5 - 41.3	pathogens	agriculture, septic tanks, municipal point sources
Wildcat Branch Pulaski Co.	AL-NS SW-NS	0.0 - 2.1 0.0 - 2.1	pH	acid mine drainage

Stream name and county	Use not supported	Segment milepoints	Causes of the impairment	Sources of impairment
Brush Creek Rockcastle Co.	SW-NS	1.1 - 7.5	pathogens	septic tanks; agriculture
Crooked Creek Rockcastle Co.	SW-PS	1.0 - 6.4	pathogens	septic tanks; agriculture
Horse Lick Creek Rockcastle Co.	SW-PS	0.0 - 21.2	pathogens	septic tanks
White Oak Creek Rockcastle Co.	AL-NS	0.0 - 4.0	suspended solids, other habitat alteration	silviculture
Bucks Branch Whitley Co.	AL-NS SW-NS	0.0 - 2.3 0.0 - 2.3	pH	acid mine drainage
Kentucky River Basin				
Middle Fork Kentucky River Lee Co .	AL-PS AL-NS SW-PS SW-PS	71.9 - 74.8 75.6 - 102.7 0.0 - 43.2 71.9 - 74.8	suspended solids, pathogens, enrichment/low DO	septic tanks, package organic plants, municipal point sources, resource extraction
South Fork Kentucky River Lee Co.	SW-PS	11.5 - 45.0	pathogens	package plants, municipal point sources
Red River Powell Co.	AL-PS SW-NS	59.9 -94.2 9.5 -41.1	pathogens, siltation, nutrients, un-ionized ammonia	streambank modification/ destabilization, removal of riparian vegetation, habitat modification, septic tanks, urban runoff storm sewers, agriculture, silviculture, municipal point sources
Sand Lick Fork Powell Co.	AL-NS	0.0 - 5.0	salinity/TDS chlorides	Petroleum activities
Big Sinking Creek Lee Co.	AL-NS	0.0 -10.0	salinity/TDS chlorides	petroleum activities
South Fork Red River Powell Co.	AL-NS	0.0 -10.1	salinity/TDS chlorides	petroleum activities
Crawfish Branch Clay Co.	SW-NS	0.0 - 0.2	pathogens	land disposal
Laurel Creek Clay Co.	AL-NS SW-NS	2.5 - 5.4 2.5 - 5.4	suspended solids, pathogens, nutrients, enrichment/low DO, un-ionized ammonia	municipal point sources; package plants

Stream name and county	Use not supported	Segment milepoints	Causes of the impairment	Sources of impairment
Little Goose Creek Clay Co.	AL-NS SW-NS	3.7 - 4.7 3.7 - 4.7	nutrients, pathogens	package plants
Red Bird River Clay Co.	AL-PS	81.7 - 82.3	suspended solids,	habitat alteration
Beech Fork Leslie Co.	AL-PS	0.0 - 6.0	suspended solids,	resource extraction other habitat alteration
Cutshin Creek Leslie Co.	AL-PS	0.0 - 28.8	suspended solids, oil and grease	petroleum activities, silviculture
Greasy Creek, Middle Fork Kentucky River Leslie Co.	AL-PS AL-PS	8.4 - 20.5 25.5 - 26.5	suspended solids, other habitat alteration	resource extraction
Licking River Basin				
Beaver Creek Menifee Co.	AL-NS	13.5 - 14.5	suspended solids	municipal point sources

AL=Aquatic Life, NS=Not Supporting, SW=Swimmable, PS=Partially supporting

Source: Kentucky Division of Water 1996. 1996 Kentucky Report to Congress on Water Quality. Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water, Frankfort.

Table 7. Water quality issues and activities, and their possible effects on aquatic resources. Activities that occur on the DBNF are in italics.

Issue	Activity	Possible Effects
Water Quality Degradation		
1. sediment - increased suspended sediment, turbidity, change in bedload quantity and composition	*timber harvest or land clearing in riparian areas, road building, mining, OHV use, trails, recreation*	change in drinking water quality, effects on aquatic organisms, decline in recreational use and value
2. temperature	*timber harvest or land clearing in riparian areas*	change in summer maximum, winter minimum water temperature - change in aquatic community structure/loss of cool water dependent species
3. pH	*mining, acid rain*	changes in community structure, loss of acid-intolerant species
4. heavy metals/brine	*mining, oil drilling*	water supply contamination, loss of aquatic organisms, fish contamination
5. pesticides	*vegetation control, insect control*	loss of potable water supplies, change in aquatic community/loss of pesticide intolerant species
6. organic contaminants (coliforms and other microbes; nutrient enrichments)	feedlots adjacent to water courses, septic systems, *grazing in riparian corridors*	change in potable water quality, organic enrichment/loss of pollution intolerant species, increase in tolerant taxa
Water Quantity Changes		
1. change in timing, duration, and magnitude	*dams, diversions, roads, trails, parking areas, timber harvest, vegetation change*	loss of channel forming flows, increased impermeable surfaces leading to increased flow variation (higher peaks, lower base flows), channel erosion
Change in Habitat Quality and Quantity		
1. change in stream habitat (pool/riffle) characteristics, sediment composition, loss of CWD, bank integrity	*Forest/riparian timber harvest, road construction and maintenance, mining, OHV use in riparian areas and streams*	loss of pool habitat due to channel aggradation, increase in fine sediments, degraded spawning and rearing habitat, loss of instream cover
2. change in riparian habitat	*Forest/riparian timber harvest, road construction, mining, OHV use, recreation*	loss of canopy closure/temperature change, change in riparian and aquatic community structure, loss of woody debris production, change in riparian microclimate
Habitat Fragmentation		
1. Loss of connectivity among aquatic habitats	*dams/lakes, diversions, waterfalls, seasonal barriers, physical and chemical habitat alteration and barriers*	loss of meta population connectivity and communities, increased vulnerability to disturbance of small, isolated populations, loss of hosts for mussel reproduction
Population and Species Viability		
1. change in aquatic communities from introduction of non-native species, accidental non-native species introduction (bait fish, transient species)	*fish stocking, illegal and accidental species introductions*	increased predation and competition on native fauna, displacement, extirpation, loss of community diversity
2. genetic integrity	*fish stocking, fragmentation caused by physical and chemical habitat alteration and barriers*	hybridization, inbreeding/outbreeding depression, loss of rare allelles
3. community diversity	*fish stocking, physical and chemical habitat alteration and barriers*	loss of native species assemblages, changes in community structure
4. population structure	*fish stocking, physical and chemical habitat alteration and barriers*	loss of interaction among populations, change in age structure, change in breeding strategy

II A Conservation Strategy for the Protection and Restoration of Aquatic Resources on the Daniel Boone National Forest

Introduction

This section describes a conservation strategy for protecting aquatic resources on the Daniel Boone National Forest (DBNF). Measures outlined here are designed to address issues identified in the preceding Assessment. It is organized under the following general headings: Desired Conditions for Aquatic Resources, Watershed Analysis, A description of Key Watersheds and important waters for conservation and management on the DBNF, Recommendations for Operational Standards and Guidelines for the Protection of Aquatic Resources[1], Restoration and Recovery of Threatened or Endangered Species, Inventory of Fauna and habitat Conditions, Monitoring, and Information and Resource Needs.

Desired Conditions for Aquatic Resources

1. Goal—Maintain or exceed State water quality standards for beneficial downstream uses and aquatic biodiversity . Maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems and to ensure survival, growth, reproduction, and migration of aquatic and riparian-dependent species. Maintain the biological, physical, and chemical integrity of aquatic ecosystems.

Rationale—The National Forest Management Act (NFMA) of 1976 requires the Forest Service to maintain or enhance water quality. Further, the Clean Water Act of 1972 requires protection of beneficial uses and designates the State as the responsible agency to restore and maintain the chemical, physical, and biological integrity of the Nation's waters.

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[1]We, the members of the Assessment Team, wish to express our appreciation to the authors of *Silvicultural Best Management Practices for the Southern United States.* This state-of-the-art document was commissioned by the U.S. Environmental Protection Agency Region IV and the USDA Forest Service Southern Region in 1994 to bring together all sources of information - applied research, gray literature, agency handbooks, etc. - related to the mitigation of the effects of silviculture, timber harvest, and transportation systems on water quality. Most of the Best Management Practices (BMPs) and many of the recommended Standards and Guidelines were taken directly or modified from this document. The specifications are based on both "hard" science where available (and applicable) and the best technical judgement and experience of the authors. The BMPs not supported by specific research are based on sound scientific principles. Although the Standards and Guidelines and BMPs outlined in this document represent the best science and information available at the time it was prepared, we expect that many of the specific recommendations will be modified as new research and experience change our level of understanding and acceptance of risk. Any errors or misinterpretations are solely the responsibility of the authors of this Strategy

We emphasize that BMPs are not prescriptions and the use of BMPs does not automatically guarantee that water, riparian, and other aquatic resources will be protected. Managers who are responsible for project planning, implementation, and monitoring must bear in mind that BMPs are only tools to help them achieve the goal of resource protection.

2. Goal—Maintain and restore the physical integrity of aquatic systems, including streambanks, and substrate, including shorelines and other components of habitat.

Rationale—The biological potential of streams and other aquatic areas is limited by physical habitat quality. Restoration and maintenance of biological integrity is a primary objective of the Clean Water Act of 1972.

3. Goal—Manage aquatic habitats to maintain or restore native aquatic biodiversity. Streams and other aquatic habitats should foster the species composition, diversity, and functional organization comparable to that of natural habitats. Exceptions can be made for desired, non-native sport fish species.

Rationale—Under the NFMA, the Forest Service is required to conserve biological diversity by maintaining viable populations of native and desired, non-native vertebrate species. In addition, one of the mandates of the 1972 Clean Water Act is the maintenance of biological integrity. Frey (1975) defined biological integrity as "...the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region."

4. Goal—Restore and maintain the sediment regime under which the aquatic system evolved. Sediment regime elements include the timing, volume, rate, and character of sediment input, storage, and transport. Maintain sedimentation rates that are in equilibrium with the watershed and that stabilize or improve the biological condition of the stream. Riparian areas will contain a minimum amount of exposed mineral soil and effective mitigation will occur where surface disturbances or modifications concentrate runoff, accelerate soil erosion, or transport sediment to stream channels.

Rationale—Erosion is a natural process that contributes both organic and inorganic materials to streams. Sediment produced by erosion reaches a stream in varying amounts, depending on the area's geology, topography, vegetation, and land use. The amount of sediment in a stream affects characteristics of the stream and the habitat of many aquatic species. Increases in fine sediment, which result from road construction, OHV use, mining, forest harvest operations, or other disturbances may interfere with some species' ability to complete their life-history requirements.

5. Goal—Maintain and restore spatial and temporal connectivity within and among watersheds. Maintain chemically and physically unobstructed routes to areas that fulfill critical life-history requirements of aquatic and riparian-dependent species; prevent further fragmentation of aquatic habitats.

Rationale—Chemical and physical barriers may isolate fish and mussel populations into sub-optimal habitats. Fragmentation may reduce connectivity among or between populations and limit the ability of organisms to complete their life-history requirements. Chemical barriers on the

DBNF may include contaminants from mining, agriculture, and oil/gas wells. Physical barriers include any structure, e.g., dam, culvert, that prevents the passage of aquatic species.

6. Goal—Restore and maintain native species composition and the structural diversity of plant communities in riparian areas and wetlands to provide adequate thermal regulation, nutrient filtering, appropriate rates of surface and bank erosion, and sufficient amounts and distributions of CWD to sustain physical habitat complexity and stability. Management plans will feature riparian-dependent plant and animal species.

Rationale—Riparian areas may be associated with any perennial stream, lake, or other aquatic area, and they constitute some of the DBNF's most diverse and productive habitats. The type and structure of riparian plant communities has a large effect on stream channel morphology, input of organic material (including CWD), stream temperature, nutrient uptake and cycling, algal and macrophytic production, as well as the structure and function of biotic communities.

Watershed Analysis

Watershed analysis is a systematic procedure used to characterize important ecological processes operating within a watershed. It provides a vehicle for gathering and synthesizing information for forest planning and to support a variety of other inquiries and analyses that precede management activities. Watershed analysis may be used to help define riparian habitat management areas, management prescriptions, and potential restoration areas.

Watershed analysis procedures are designed to examine the physical and biological characteristics of a watershed that influence aquatic and riparian resources. Information used in an analysis may include, but is not limited to: maps of topography, stream networks, soils, vegetation, geology, habitat condition inventories, population status, and land use history. Analysis results are integrated to produce a description of the present conditions and ecological processes operating on the landscape. This information is used to help refine riparian area boundaries, identify where restoration activities may be appropriate, and help to define inventory and monitoring needs**.**

We recommend that watershed analysis procedures be developed and adopted to assess the status of aquatic resources in watersheds on the DBNF.

Key Watersheds

Key watersheds provide high-quality environments for the maintenance and/or restoration of aquatic species. Key watersheds typically share three significant values: exceptional water quality; unique assemblages of aquatic species; and unique habitats or groups of habitats. Streams and rivers within them foster source populations for the restoration of native aquatic organisms in adjacent or nearby watersheds. They may contain a variety of key refugia at all scales, from the small to the very large. They may serve to anchor the recovery of a species or groups of species and generally contain high-quality habitat or have high restoration potential. Criteria for establishing key watersheds may include:

(1) Watershed or basin fragment size The relationship among species and the amount of area occupied is well documented in the ecological literature. In general, large, well-connected areas support healthy, diverse aquatic communities. Many watersheds throughout the South have been fragmented by human activities such as dam construction, water supply diversions, road crossings, road culverts, and the imposition of other physical or chemical barriers. In many cases, aquatic species have become isolated by such activities, resulting in extinctions or local extirpations. Large, intact areas of watersheds provide a variety of habitat conditions at multiple scales, facilitating the continued existence of aquatic species.

(2) Clusters of organisms with high management interest Watersheds may contain a unique group or groups of aquatic organisms valuable to species diversity or, on the other hand, be of intrinsic value to humans. Examples include species of unionid mussels that represent a unique taxonomic association or, perhaps, an important sport fish.

(3) Unique habitats or groups of habitats The presence of unique habitats or groups of habitats may be used as a screening criterion to designate key watersheds when such habitats support or help to support a unique group of aquatic organisms. Unique habitats may include seeps and springs, unique geomorphic habitats, or wetlands that contribute to the conservation of desired species.

(4) Unique species or groups of species Watersheds may contain unique species or collections of species. Criteria for determining such watersheds include the identification of individual species or groups of species that exist within one watershed or localized area of a watershed, or fishes that exhibit seasonal movements into a watershed or a portion of a watershed to complete their life-history requirements.

(5) Exceptional water quality Such water reflects few anthropogenic influences and has little point or non-point source pollution. Exceptional water quality may also be determined by chemical or physical constituents that support or favor unique aquatic species or species assemblages.

(6) Land ownership Patterns of land ownership may influence the type, extent, and intensity of land management activities within a watershed. Watersheds having a high proportion of Federal ownership may provide more flexibility to manage aquatic habitats than lands in mixed ownership, where commodity production typically has a higher priority. A key watershed might be established because it contains a high proportion of lands that are publicly owned and managed.

(7) Aquatic diversity maintenance and recovery Each hydrological unit within the DBNF has watersheds that support increasingly significant and unique assemblages of recreational fishes, non-game fishes, and mussels, as well as other elements of the aquatic fauna, e.g., crayfishes and macroinvertebrates. These streams and rivers are important to the ultimate integrity of aquatic fauna on the DBNF, across Kentucky, and in the Forest Service Southern Region. The importance of such streams has been recognized by the Agency (e.g., U.S. Department of Agriculture, Forest Service 1992, 1993, 1994) and by other State and Federal agencies (e.g., Hannan and others 1982; Axon and Kornman 1986; Kentucky Division of Water 1990, 1991, 1996; Kentucky Division of Water and National Park Service 1992; Kentucky Department of Fish and Wildlife Resources 1996; Kentucky State Nature Preserves Commission 1996a).

Recent reviews of riverine health and aquatic biological diversity have urged whole-watershed management as the most appropriate approach to maintaining and recovering aquatic biota (Hughes and Noss 1992, Allan and Flecker 1993, Doppelt and others 1993, Moyle and Yoshiyama 1994, Dombeck and others 1997, Williams and others 1997, Warren and others (1997)). From this perspective, it seems that efforts to restore or maintain streams and rivers likely will be futile without modification of upslope land management activities (Williams and others 1997). In Kentucky as well as most of the southern States, land ownership is a complex mixture of private, municipal, and State jurisdictions. Several watersheds that are important for aquatic diversity are present within the DBNF proclamation boundaries; and some of these either have little of their catchment in Federal ownership, e.g., Buck Creek, Cumberland River-Buck Creek unit, Little South Fork, Big South Fork unit, or management of the watershed involves other Federal agencies, e.g., Big South Fork National River and Recreation Area. In many instances, whole-watershed management will require development of community coalitions with significant engagement and cooperation by Federal and State agencies. Watershed coalitions often serve to coordinate, conserve, and restore natural resources and resolve use conflicts (Dombeck and others 1997).

The following list of watersheds consists of streams and rivers important for the maintenance and restoration of aquatic diversity in the DBNF (Table 8). Although listed headwater streams that support single sensitive species are included, most of the listed watersheds contain several sensitive aquatic and terrestrial species or unique communities (Kentucky State Nature Preserves Commission 1996a, 1997). The most important streams or rivers are identified by hydrologic unit.

Table 8. Important watersheds for the maintenance and restoration of aquatic diversity on the DBNF

	Forest Service Ownership	Fragment Size	Clusters of Organisms/ Unique Species	Unique Habitat	Water Quality
Licking River Unit					
below Cave Run dam	None	Large	X	X	X
North Fork (1)	Moderate	Medium	?		X
Bucket Branch (1)	High	Small	?		X
North Fk. Triplett Ck.	Moderate	Large	X	X	X
Middle Fk. Kentucky River Unit					
Middle Fk. Ky. River (unimpounded portion)	Low	Large	X	X	?
Middle Fork Ky. River Unit					
Hell-for-Certain	Medium	Small	X	?	?
South Fork Ky. River Unit					
Collins Fork	Moderate	Large	X	X	?
Red Bird River	High	Large	X	X	?
South Fork Ky. River	Moderate	Large	X	X	?
Sexton Creek	Low	Large	X	X	?
Big Double	High	Small	X	?	?
Gilbert’s Big Creek	Medium	Small	X	?	?
Kentucky River-Red River Unit					
Indian Creek	Medium	Medium	X	?	?
Leatherwood Fork	High	Small	X	?	?
Station Camp Creek	Low	Large	?	?	X
South Fork Station Camp Creek	Moderate	Medium	?	?	X
War Fork Station Camp Creek	High	Medium	?	?	?
Sturgeon Creek	Medium	Large	X	X	X
Red River	High	Large	X	X	X
Upper Cumberland River Unit					
Bunches Creek	High	Small	X	X	X
Rock Creek	Moderate	Medium	X	X	X

	Forest Service Ownership	Fragment Size	Clusters of Organisms/ Unique Species	Unique Habitat	Water Quality
Dog Slaughter	High	Medium	X	X	X
Bark Camp Creek	Medium	Medium	X	X	X
Eagle Creek	High	Small	X	X	X
Marsh Creek	High	Large	X	X	?
Big Branch	None	Small	X	?	?
Craigs Creek	Low	Small	X	?	?
Mill Creek	Low	Small	X	?	?
Jennys Branch	High	Small	X	?	?
Laurel Creek	Medium	Small	X	?	?
Trammel Branch	None	Small	X	?	?
Rose Branch	Medium	Small	X	?	?
Campbell Branch	None	Small	X	?	?
Beaver Creek Wilderness	High	Medium	X	?	?
Sanders Creek	Low	Small	X	?	?
Mud Creek	None	Small	X	?	?
Ned Branch	High	Small	X	?	?
Kilburn Fork	Medium	Small	X	?	?
Archers Creek	Low	Small	X	?	?
Murphy Creek	None	Small	X	?	?
Brierfield Branch	High	Small	X	?	?
Criscillis Creek	Hgih	Small	X	?	?
Buck Branch	Medium	Small	X	?	?
Big Lick	High	Small	X	?	?
Youngs Creek	None	Small	X	?	?
Indian Creek	High	Medium	X	?	?
Becks Creek	Low	Small	X	?	?
Ryans Creek	Low	Medium	X	?	?
Adams Branch	Low	Small	X	?	?
Bailley Branch	High	Small	X	?	?

	Forest Service Ownership	Fragment Size	Clusters of Organisms/ Unique Species	Unique Habitat	Water Quality
Little Dog Slaughter	High	Small	X	?	?
Calf Pen Fork	Medium	Small	X	?	?
Pigeon Roost Fork	High	Small	X	?	?
Cogur Creek	High	Small	X	?	?
Smith Fork	Low	Small	X	?	?
Rockcastle River Unit					
Cane Creek	High	Medium	?	?	X
Horse Lick Creek	High	Large	X	X	X
Middle Fork	Moderate	Large	X	X	X
Laurel Fork	Moderate	Medium	X	X	X
Sinking Creek	High	Medium	X	X	X
Rockcastle R. (mainstem corridor)	Moderate	Large	X	X	X
Cumberland River-Buck Creek Unit					
Buck Creek	Low	Large	X	X	X
Beaver Creek	High	Medium	X	X	X
Sloans Valley Cave	?	?	X	X	?
Big South Fork Unit					
Rock Creek	High	Large	X	X	X
Little South Fork	Low	Large	X	X	X
Big South Fork	Low	Large	X	X	X

Conserving and Protecting Aquatic Resources on the Daniel Boone National Forest: Recommended Standards and Guidelines

Riparian Prescription Area (RPA)

The primary focus of management prescriptions for riparian areas on the DBNF will be the conservation, restoration and enhancement of riparian-dependent resources and values. Riparian Prescription Areas include all wetlands, ponds, and lakes, as well as perennial streams and adjacent riparian ecosystems. Intermittent and ephemeral streams generally are not included in the RPA, except where they intersect the RPA. Management direction for intermittent and ephemeral streams is addressed as a component of the Streamside Management Zone (SMZ) and by the DBNF's standards and guidelines.

No single feature is used to delineate boundaries of the RPA. The dimensions of the RPA are determined by on-site inspection and analysis using features of soil, landform, and vegetation. The Federal Manual for Identifying and Delineating Jurisdictional Wetlands will be used to delineate wetlands, subject to 404 provisions of the Clean Water Act. Characteristics indicative of the riparian prescription area are:

1. Soils—dark colored alfisols, entisols, inceptisols, and mollisols
2. Landform—the floodplain and first terrace
3. Vegetation—the presence of wetland plants classified as obligates or facultative wetland species.

The RPA is managed to achieve or maintain desired conditions for riparian-dependent ecological processes and species. It is not classified as suitable for timber production. The RPA does not include riparian areas where legal or administrative mandates, e.g., wilderness or research natural area designation, may restrict certain activities.

Proposed facilities, including roads, are located outside of the RPA unless documented on-site analysis indicates no practical alternative exists and appropriate mitigation is possible. Areas of disturbance (e.g. abandoned or poorly maintained roads, trails, or other sites) present opportunities for restoration of riparian characteristics.

Definition of Watercourses

Perennial stream—Any watercourse that contains fish or aquatic insects with multi-year life cycles, and which flows in a well-defined channel that always is at least 90% below the water table. Perennial streams may have segments with subsurface flow. All perennial streams are located entirely within a RPA. Management guidance is provided by RPA standards and guidelines, SMZs, and DBNF-wide standards and guidelines.

Intermittent stream—A watercourse that flows in response to a seasonally fluctuating water table in a well-defined channel. Intermittent streams do not maintain fish or aquatic insects with multi-year life cycles. Intermittent streams not located in the RPA are protected by streamside management zones and DBNF standards and guidelines.

Ephemeral stream —A watercourse that may or may not have a well-defined channel and flows only for short periods during and following precipitation. Ephemeral stream bottoms are usually above the water table and do not contain fish or aquatic insects with multi-year life cycles. Ephemeral streams not located in the RPA are protected by DBNF standards and guidelines.

Desired Condition Objectives

Water quality meets or exceeds Federal, State, and local standards. Desired aquatic habitats maintain biodiversity, as well as water quality, food, and habitat for all life stages of native aquatic life and other riparian-dependent species. There are sufficient amounts and sizes of CWD to provide self-sustaining habitat complexity and diversity. Streams have 78 to 186 pieces of CWD per stream kilometer (125 to 300 per stream mile), temperature does not exceed the critical thermal maximum for aquatic species living in designated cold, cool, and warmwater streams, dissolved oxygen values are greater than 6.0 (mg/l) or at saturation levels, pH values are between 6.0-8.0, and sedimentation rates are in equilibrium with the watershed. Pool habitats occupy about 35 to 65 percent of available habitat. Monitoring is sufficient to detect disturbance to riparian function and water quality.

Vegetation (both living and dead) in these systems is taxonomically diverse, with both horizontal and vertical structural diversity consisting of distinct vegetation layers from the water surface to the canopy top. Rehabilitation of past and future disturbance (both natural and human-caused) may be necessary to protect resource values and facilitate recovery of riparian structure and functions. Geomorphic and soil bioengineering, vegetation management, and other rehabilitation techniques follow ecological principles and emphasize recovery of the diversity and complexity of native vegetative communities.

Standards and Guidelines

The following Standards and Guidelines are recommended for the protection of aquatic and riparian dependent species within the RPA.

1. Streams are managed in a manner resulting in sedimentation rates that stabilize or improve the biological condition category of the stream.

2. Naturally occurring CWD in streams is removed only when it poses a significant risk of damage to facilities or bridges and culverts. The need for removal is determined on a case-by-case basis by the Forest Fisheries Biologist and/or Hydrologist.

3. Stream habitat work is conducted to protect, restore, or enhance native aquatic fauna. Instream use of heavy equipment is limited to the amount of time necessary for completion of the project and must be approved on a site-specific bases by the Forest Fisheries Biologist or Hydrologist.

4. Off-Highway Vehicles (OHV's), bicycles, horses, and other non-pedestrian modes of transportation are prohibited within the RPA except at designated crossings.

5. Activities that may adversely affect aquatic biota are avoided. Consultation with DBNF biologists and hydrologists will be made prior to any instream-disturbance activities.

6. Mitigation of reduced water quality resulting from acid mine drainage, brine pollution, or other point sources is allowed on a site-specific basis for protection or restoration of aquatic species.

7. Vegetation management following both natural and human-caused disturbances enhances recovery of the diversity and complexity of native plant communities.

8. Salvage of dead or dying timber can occur in riparian areas, as long as riparian values are protected and the Desired Condition is maintained or can be met.

9. Corridors for cable logging in areas adjacent to the RPA cross the RPA only after consultation with and approval by DBNF biologists or hydrologists. Full suspension is required when yarding logs across perennial streams.

10. Fish stocking may be permitted as long as populations of native aquatic species are maintained or enhanced.

11. Forest pest management strategies and tools may be used to help achieve the Desired Condition of riparian areas.

12. Drilling pads and production facilities for oil, gas, or mineral extraction are located outside of the RPA. Removal of mineral materials from within the RPA or stream channels is prohibited (see Minerals).

13. Trails, campsites, and dispersed recreation sites are located, constructed, and maintained to minimize impacts to stream and riparian values.

14. Recreational developments causing unacceptable resource damage are closed and/or rehabilitated. Soils are stabilized on eroded recreational sites through revegetation, traffic control, hardening (e.g gravel, mulch), or site closure.

15. Streams are managed in a manner that results in loading of 78 to 186 pieces of CWD per stream kilometer (125 to 300 per stream mile).

16. Streams are managed in a manner that results in dissolved oxygen values of 6.0 mg/l—or at saturation levels.

17. Generally, impoundments are prohibited, but they may be approved on a site-specific basis.

Streamside Management Zone

Definition

A streamside management zone is a designated areas that consist of a stream or other waterbody and an adjacent area where management practices that might affect water quality, fish, or other aquatic and riparian resources are modified and closely monitored (fig. 4). Standards and guidelines for SMZs provide management direction for waterbodies not otherwise included in the RPA. A streamside management zone is designated along perennial watercourses where the RPA width[2] on either side of the channel or bank is 20 m (66 feet) or less. Within a SMZ, areas may be designated to: provide a sediment filtration and absorptive zone; maintain shade for moderation of temperature; protect or enhance stream channels, streambanks, and aquatic and riparian habitats, promote natural floodplain function, and provide a source area for CWD recruitment.

Streamside management zones are demarcated around all perennial and intermittent streams, seeps and springs, sinkholes, and other waterbodies that have the potential to accumulate and transport water and sediment as well as perennial streams where the delineated RPA boundary is narrower than the width of the applicable SMZ. Intermittent and ephemeral channels, although dry for portions of the year, nonetheless have the potential during wet periods to transport sediment and chemicals generated by forest management activities (Lynch and Corbett 1990).

[2]To date, there have been relatively few comprehensive studies of the effectiveness of SMZs of different width in protecting aquatic and riparian dependent resources. As a result, the recommended width of SMZs varies greatly among states and Agencies. The selection of any particular width necessarily involves an assessment of the risk to water quality and other riparian values associated with ground-disturbing activities in the zone adjacent to a water body. Based on their experience and professional judgement, the authors of this Assessment recommend that the DBNF adopt a SMZ of 20 m (66 feet) width.

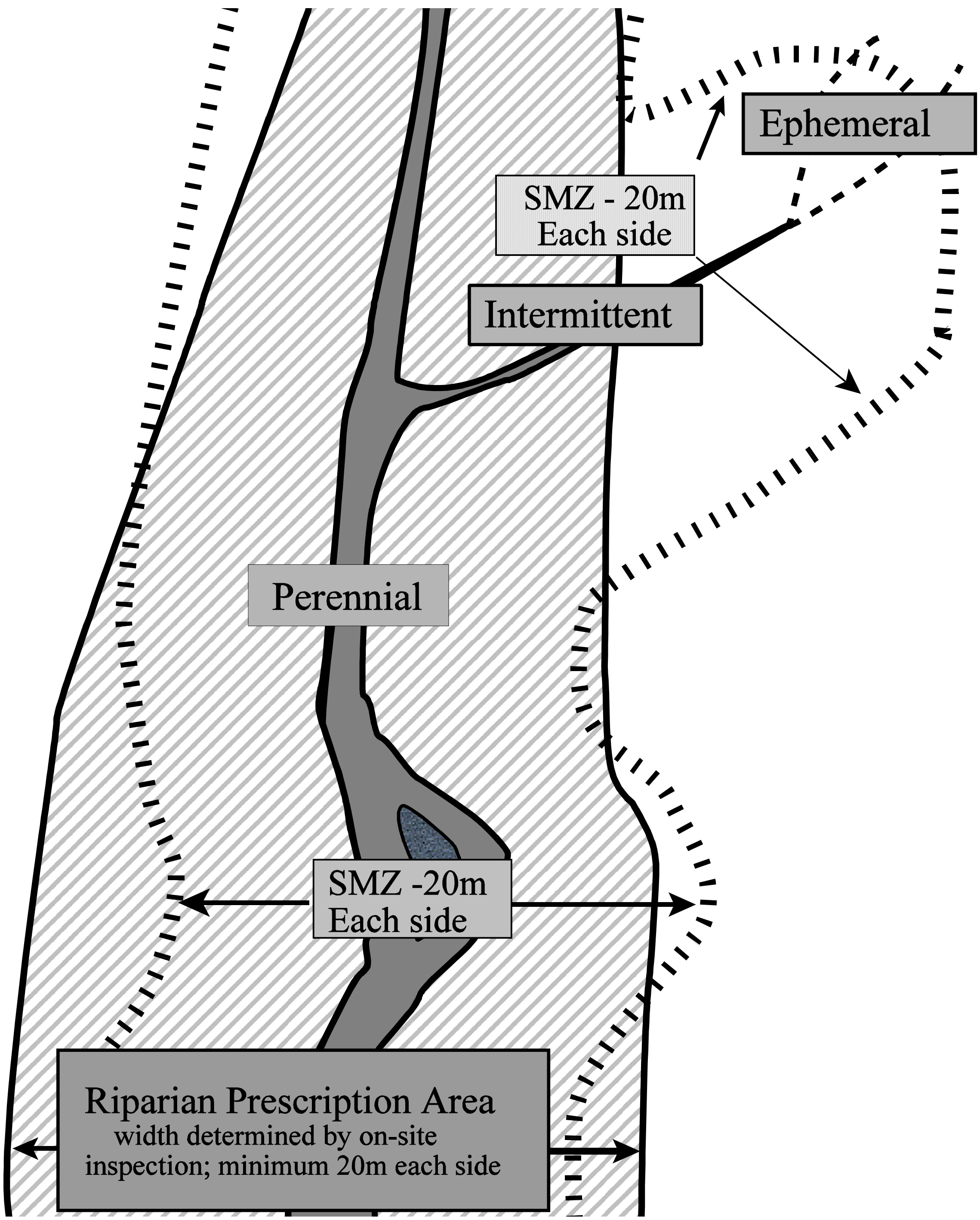

Figure 4. Hypothetical Riparian Prescription Area and Streamside Management Zone in relation to perennial, intermittent, and ephemeral stream channels.

Water quality impacts and benefits

The primary purposes of SMZ's are to maintain, protect, or enhance water quality, riparian and aquatic habitat, and associated ecological communities. They are used to reduce or eliminate management-generated sediment (Everest and others 1987), nutrients (Peterjohn and Correll 1984), logging debris (Dykstra and Froehlich 1976), or chemicals (fertilizers, pesticides, fuels, or lubricants) that might harm aquatic ecosystems. In addition, a properly designed and designated SMZ promotes streambank stability and moderates temperature fluctuations (Beschta and others 1987). Streamside Management Zones are the primary "source areas" for detritus (Gregory and others 1991) and CWD[3] (Maser and Trappe 1984, Harmon and others 1986, Bisson and others 1987, Maser and Sedell 1994), both of which are critical to riparian and aquatic ecosystem function, structure, and health.

Water quality protection begins with land management planning and recognition of SMZ's. However, a comprehensive plan must incorporate additional erosion control and sediment transport-limiting Best Management Practices (BMP's), both within the SMZ and in adjacent sensitive areas. All management within a SMZ should acknowledge the inherent sensitivity and value of riparian areas.

Standards and Guidelines

Specifications for a SMZ, e.g. distance from stream banks, allowable activities, location and size of shade strips, among others, are site-specific and must be explicitly defined before conducting any management activities. Managers must establish clear boundaries in the field, as well as on maps and photos, to guide and alert operators that their activities may impact riparian and aquatic resources.

A SMZ may include an operational limitation zone (OZ), a shade strip (SS), and a filter strip (FS). Operational limitation zones prevent major ground disturbance adjacent to stream channels. Motorized vehicles may be allowed in OZs provided the benefit to riparian dependent resources outweighs the risk of damaging water quality. Shade strips help maintain ambient stream water temperatures, moist habitats, and sources for CWD. Filter strips filter surface runoff, trap sediment, and filter and absorb pollutants.

A. Operational limitation zones protect riparian areas from ground disturbance (Tables 9 and 10).

B. Shade strips maintain ambient water temperature regimes and moist habitats; and they provide sources for CWD and detritus (Tables 9 and 10).

[3] Preliminary analysis of data supplied by USDA Forest Service Forest Inventory and Analysis indicates that at least 20 species of tree common on soils characteristic of riparian areas in Eastern Kentucky will provide at a 10 cm (four-inch) diameter or larger top at heights of 20-21 m (64-67 feet).

C. In shade strips (10 m (33 feet) wide, adjacent to intermittent streams), retain all trees where roots provide structural stability of the streambank and channel. -delete-

D. Filter strips are left between areas of severe soil disturbance (roads, landings, bladed skid trails, and constructions sites) and all perennial and intermittent streams, lakes, wetlands, and sink holes.

Table 9. Streamside Management Zones minimum widths [meters (feet)] required from each bank or edge of *perennial* streams, lakes, and wetlands. Operational limitation Zones (OZ), Shade Strips (SS) and Filter Strips (FS).

Slope	0-10%	11-20%	21-50%	50%+
OZ	20(66)	20(66)	20(66)	20(66)
SS	20(66)	20(66)	20(66)	20(66)
FS	29(95)	35(115)	53(175)	66(215)

Table 10. Streamside Management Zones: Minimum widths [meters (feet)] from each bank of *intermittent* streams for Operational limitation Zones (OZ), Shade Strips (SS), and Filter Strips (FS).

Slope	0-10%	11-20%	21-50%	50%+
OZ	10(33)	10(33)	10(33)	10(33)
SS	10(33)	10(33)	10(33)	10(33)
FS	29(95)	35(115)	53(175)	66(215)

Vegetation Management

Landings

Definition

Landings are cleared areas designed to receive and temporarily store yarded logs. Logs are gathered at landings for storing, handling, and transporting. They may be small areas along skid trails and roads, or large concentration and sorting yards.

Water quality impacts and benefits

Concentrated vehicle traffic on landings may result in soil compaction and rutting. As a result, storm water flows and erosion usually increase and runoff may contain toxic materials from fuels and lubricants in addition to sediment. BMPs should prevent drainage water and associated pollutants from entering streams or affecting subsurface water quality.

Conditions where applied

Standards and Guidelines will apply wherever landings and decks are planned or installed.

Standards and Guidelines

A. *Landing location and size* Landings should be small, located on well-drained stable soils, and not in or near perennial, intermittent, or ephemeral stream channels.

   1. Select sites during pre-harvest planning and prior to road construction. Design roads and skid trail systems around landing locations (Sidle 1980). Locate landings to minimize skid trail distance (Rothwell 1978).

   2. Locate landings outside the RPA and SMZ's, and away from ephemeral drainages. Refer to RPA and SMZ Best Management Practice recommendations. When no alternative to locating a landing in a SMZ is possible, additional mitigating practices will be required. For example, reserve an undisturbed, 50-foot minimum (15 m), forest-floor filter strip between perennial and intermittent stream channels and the downhill edge of the landing disturbance (Swift 1986). Use brush or other barriers to trap sediment.

B. *Landing drainage and soil protection* Select sloping or side-ridge sites that provide drainage from the landing surface. Select and develop landing areas that require the least soil disturbance (Larse 1971, Yee and Roelofs 1980).

   1. Heavy vehicle use on landings compacts soil and increases runoff (Golden and others 1984). Ensure that runoff infiltrates and does not reach stream channels. Disperse storm

water drainage over a convex slope so it does not concentrate in or above ephemeral channels.

2. Design roads, skid trails, and landings to keep surface water away from landings. Install perimeter ditches, as necessary, to intercept and drain any surface and subsurface flow away from the landings.

C. *Seasonal use restrictions* Avoid repeated use of a wet landing or using a landing when the ground is thawing.

1. Grade surfaces to smooth ruts and restore drainage paths (Rothwell 1978).

2. Add gravel or other surfacing materials to problem sites (Arola and others 1991).

D. *Servicing equipment* Service motorized equipment without spilling fuel or oil. Collect and remove waste oil, garbage, and trash (refer to Waste Disposal BMP).

E. *Landing vegetation* Where landings are subject to erosion or are potential sources of sediment, vegetate landing areas immediately after construction, and revegetate as soon as use ends and maintain the site until the site is stable and no longer has the potential for accelerated erosion (Megahan 1983). Use native plants wherever possible.

F. *Site preparation* When necessary**,** rip all landings to ensure soil productivity and the successful reestablishment of vegetation.

Skidding

Definition

Skid trails are bladed or non-bladed travelways that are used to drag or transport trees or logs over forest soil from the stump to a landing. Skid trails may be one-time or temporary-use construction; but primary skid trails may be dedicated for future use.

Water quality impacts and benefits

The careful location, use, protection, and closure of skid trails can significantly reduce soil exposure, soil movement, and sediment delivery to adjacent streams and other water bodies. Repeated traffic over a skid trail system can increase soil exposure, compaction, rutting, and risk of soil movement.

Ruts are depressions caused by the repeated passage of vehicles over roads or trails. Ruts are conduits for water and sediment flow, which may enter streams and other water bodies or impede normal lateral water flow through soils or over the traveled surface. Rutting reduces soil macroporosity and saturated hydraulic conductivity which, in turn, may diminish the infiltration, drainage, and lateral flow capacity of the soil (Dickerson 1976, Tippett 1992).

Decreased infiltration rates due to compaction increase the probability that water will stand on or flow off the soil surface, inhibiting root growth. Less fertile, heavy subsoils can be exposed in a rutted track or deposited over surface horizons as berms (Tippett 1992, Aust and others 1995). Both increased bulk density and soil displacement increase soil exposure and potential erosion, and inhibit revegetation.

Conditions where applied

This practice applies to forest lands where harvesting or thinning operations require transporting trees or logs to landings for loading or processing, and where topography or economics makes ground skidding the most effective means of collecting harvested material.

Standards and Guidelines

A. *Design and Planning*

1. Determine and mark skid trail routes prior to beginning operations, as part of preharvest planning. Avoid wetlands and poorly or somewhat poorly drained soils.

2. To minimize the width and number of skid trails and the area of soil exposed, landing placement and the skid trail system should be planned at the same time (Froelich and others 1981, Haupt and Kidd 1965, Haupt 1960).

3. Skid trails and other ground-disturbing activities should not constitute more than 10 percent of the harvested area.

4. Skid trails should follow contours wherever possible, and skidding should be restricted to marked trails.

5. Generally, skid trails should be diffused and approach landings from downslope, allowing water on trails to disperse onto less-disturbed downslope areas (Nutter 1975). If downhill skidding must be used, design and maintain drainage and dispersal structures to divert flow into undisturbed areas (Megahan 1983)

6. Avoid blading skid trails. Minimize width and depth of blading where it is necessary to remove obstructions and provide safe access for ground-based equipment within the harvest unit.

7. Skid trails should be designed with grades of 15 percent or less. Skidding on steeper grades should only be allowed for short distances (Rothwell 1978). Cable yarding systems

should be used on steeper slopes, or where slope stability or sensitive soils are of concern. Logs should be suspended high enough to prevent damage to soil and water resources.

B. *Use and Protection*

1. Do not skid logs or other materials within perennial, intermittent, or ephemeral stream channels. Skid trails should not cross perennial or intermittent streams. If crossing a perennial stream is unavoidable, use a temporary bridge or other approved method. When crossing intermittent or ephemeral streams, approach at right angles to the channel and implement mitigating measures.

2. To minimize tractor or skidder traffic on the site, directional felling should be used and skidder operators should pull cables to logs rather than driving to each log, (Clayton 1990, Martin 1988).

3. Avoid skidding over saturated soils. Conduct operations in dry seasons or during dry periods whenever possible. Although some rutting may occur under wet conditions, proper layout, use, and maintenance of skid trails reduces and controls traffic on the site, decreasing the probability of severe rutting.

4. Winch felled trees from areas of hydric or poorly drained soils. Avoid gouging or displacing soil.

C. *Closure*

1. Remove and rehabilitate temporary stream crossings.

2. Add waterbars or other dispersal devices to direct storm water off skid trails and reduce potential sediment flow to streams. (Lynch and others 1985, Haupt and Kidd 1965).

3. Stabilize trails by scarifying or ripping, mulching, and seeding or planting. Use native plant species wherever possible.

Site preparation

Definition

Site preparation treatments, mechanical and chemical, are employed to eliminate or suppress competing and undesirable woody and herbaceous vegetation. Such treatments are commonly used to aid in the successful establishment and growth of desired tree species, or to control noxious weeds and other forest pests.

Water quality impacts and benefits

Mechanical site preparation treatments have the potential to cause soil compaction, erosion, and soil displacement; and they may adversely affect water quality by accelerating runoff and increasing sedimentation. Chemical treatments can have direct and indirect effects on fish and other aquatic flora and fauna. Direct effects result from a chemical, in active form and of sufficient concentration, coming in contact with fish or other aquatic biota through water, sediment, or food, causing a biological response.

Indirect effects result from the chemically induced modification of aquatic habitat, rather than the direct interaction between the chemical and aquatic organisms. However, where used appropriately, chemical treatments can yield significant benefits without imposing unreasonable adverse environmental effects. In addition to improving the establishment and growth of new forests, they are valuable in keeping rights-of-way (roads, utility corridors) free of weeds and other vegetation that might affect health and safety. They also contribute to lower maintenance costs and enhanced recreation activities within camping and picnic areas.

Conditions where applied

Mechanical site preparation treatments are used on lands where silviculture or other forestry operations are planned or conducted. They may, for example, be employed to facilitate tree planting or release of young trees from competing vegetation. Chemical treatments are applied to areas along forest roads or utility corridors, on administrative sites, and where release from competing vegetation will help ensure the survival, growth, and establishment of forest plantations.

Standards and Guidelines

A. *Mechanical*

1. Generally, only mowing and scarification are permitted; and then only on slopes with a sustained grade of less than 35 percent, or on sustained grades over 20 percent where there are highly erodible or failure-prone soils. Root-raking, shearing, and drum-chopping are not approved methods. Exceptions may include situations where a change in land use—from forestry to some other purpose—is planned, e.g., construction of developed recreation facilities and administrative sites, construction of wildlife openings, preparation of progeny test plantations, or rehabilitation of storm damaged areas.

2. Ground-based mechanical equipment is not allowed within an RPA, SMZ, or any stream channel except at designated crossings (refer to RPA, SMZ, and Stream Crossing Standards and Guidelines).

B. *Chemical*

1. No herbicide shall be aerially applied within 30 horizontal meters (100 horizontal feet), or ground-applied within 10 horizontal meters (30 horizontal feet) of lakes, wetlands, or perennial or intermittent springs (seeps) and streams; nor shall they be applied within 30 horizontal meters (100 horizontal feet) of any public or domestic water source. Selective treatments (requiring added, site-specific analysis and use of herbicides that have been approved for aquatic use) may occur within such buffers, but only to prevent significant environmental change such as to control noxious weeds. Buffers will be clearly marked before treatments, so applicators can see and avoid them.

2. Application equipment, empty herbicide containers, clothes worn during treatment, and skin shall not be cleaned in open water or wells. Mixing and cleaning water must come from a public water supply and be transported in separate, labeled containers.

3. Aquifers and public water sources will be identified and protected. States will be consulted to ensure compliance with groundwater protection strategies.

4. No herbicide shall be broadcast or spread on rock outcrops or sinkholes. No soil-active herbicide with a half-life longer than 3 months shall be broadcast on slopes greater than 45 percent, erodible soils, or aquifer recharge zones. Such areas will clearly be marked before treatment, so applicators can easily see and avoid them.

5. Herbicide mixing, loading, and cleaning areas in the field shall not be located within 60 m (200 feet) of wells, open water, or other sensitive areas.

6. Accident preplanning and emergency spill plans shall be a part of each site-specific analysis (chapter 30, FSM 2109.12). Spills shall be quickly contained and cleaned up and appropriate agencies and persons promptly notified.

Fire

Fire lines

Definition

A fire line is a barrier constructed to stop the spread of fire. It is constructed by removing fuel and exposing soil, or by rendering fuel nonflammable through use of water or fire retardants.

Water quality impacts and benefits

The purpose of these Standards and Guidelines is to minimize erosion on constructed fire lines and to prevent sediment or fire retardant chemicals from entering streams, water bodies, or ground water.

Conditions where applied

The Standards and Guidelines described here apply to firelines associated with prescribed burning and wildfire.

Standards and Guidelines

A. *Existing barriers* Use existing barriers, e.g., streams, lakes, wetlands, roads, and trails, to reduce the need for fire line construction.

B. *Fire retardants* Fire retardants should not be applied directly over any water bodies. Because they include un-ionized ammonia, retardants can be toxic to aquatic fauna when applied directly to water surfaces. However, an untreated strip along streams or lakes should be sufficient to virtually eliminate movement of retardant to aquatic systems (Norris and others 1983).

C. *Fire lines* Fire lines, particularly those constructed with heavy equipment, should not be located within a RPA or a SMZ. However, if fire lines are needed along perennial and intermittent streams, they should be located along the uphill perimeter of the filter strip to maintain the filtering capacity of the RPA or SMZ.

D. *Fire line size* Constructed fire lines should be only as wide and deep as necessary to contain fire and remove flammable fuels.

E. *Post-fire rehabilitation* Plowed and bladed fire lines will be waterbarred, or turnouts will be constructed as soon as practicable using the maximum spacing guidelines outlined in Table 11. Where fire lines are constructed near streams, additional waterbars are required.

F. *Waterbar construction* Waterbars should be installed by blading or plowing, if possible, when fire lines are constructed.

G. *Waterbar placement* Ensure waterbars and turnouts do not discharge into stream channels or sink holes.

H. *Streamcourse protection (handline construction)* Use hand-constructed fire lines on steep slopes and near stream channels whenever possible.

Table 11. Fire line slope and spacing between waterbars (Kochenderfer 1970)

Fire line grade (%)	Distance between waterbars meters	(feet)
1	120	400
2	76	250
5	38	125
10	23	75
15	18	60
20	15	50
25	12	40
30	10	35
40	9	30

I. *Streamcourse protection (fire line placement)* Fire lines that are built towards watercourses shall be angled to run parallel to the stream—or be constructed with turnout that will allow runoff to be dispersed and infiltrated before reaching a stream.

J. *Streamcourse protection (fire line stream crossings)* During efforts to control wildfire, it may be necessary to construct firelines that cross streams. Such firelines should cross streams at right angles and be stabilized and/or revegetated as soon as possible after the fire is controlled.

K. *Avoiding streamcourses* Fire lines shall not be constructed in stream channels.

Prescribed burning

Definition

Prescribed burning is a technique whereby fire is deliberately set—at a prearranged time and under specific fuel and weather conditions—to accomplish any of a variety of management objectives. Control is maintained until the fire burns out or is extinguished. Objectives in the use of fire include creation and maintenance of plant community composition and structure, control of competing vegetation, fuel reduction, understory reduction prior to harvest, and site preparation following harvest.

Water quality impacts and benefits

Prescribed fire's effects are a function of fire intensity and severity, soil erodibility, rainfall rate and timing, and revegetation rates (Baker 1990, Filipek 1993, Golden and others 1984). Careful location and construction of fire lines can minimize soil movement and prevent sediment from entering streams and other water bodies. Higher fire severity determines the extent to which the litter and humus layers are affected and the degree to which mineral soil is exposed. Erosion and nutrient-loss potential increase with steepness of grade and severity of the fire (Vose and Swank 1993, Wade and Lunsford 1989). Burning at an intensity sufficient to achieve management objectives while minimizing soil exposure and loss of litter and humus reduces the potential for water quality degradation (Robichavd and Waldrop 1994, Swift and others 1993). A properly executed prescribed burn will have low risk of excessive erosion and nutrient and ash movement into streams and water bodies.

Conditions where applied

The practice described here applies to all DBNF lands where prescribed fires are planned or conducted. Adherence to RPA and SMZ Best Management Practice recommendations for streams and water bodies should accompany the use of prescribed fire.

Standards and Guidelines

A. Follow BMP for Fireline Construction.

B. Use existing barriers, e.g., streams, lakes, wetlands, roads, and trails, to reduce the need for fire line construction.

C. Schedule prescribed burns for the appropriate season, weather, fuel, and topographic conditions to achieve management objectives with minimum burn severity and intensity.

D. Burns must not consume all litter and duff or alter the structure and color of mineral soil on more than 20 percent of streamside areas. Steps taken to control soil heating will include the use of backing fires on steep slopes, scattering concentrated fuels, and burning heavy pockets of fuel separately.

E. Low-intensity backing fires may be used in place of constructed fire lines in an SMZ, providing that such fires do not kill trees and shrubs that shade the stream. Such backing fires should burn at an intensity of less than 30 BTU's (British Thermal Units) per second per foot, or with a flame length of under 60 cm (2 feet). Backing fires may be more effective than constructed firelines in reducing the potential for sediment to reach a stream.

F. On severely eroded forest soils, do not burn any area where the average depth of litter-duff is less than 1.25 cm (1/2 inch) or where forest soil depth is less than 50 cm (20 inches).

G. Exercise extreme caution in areas where vegetation has been killed by herbicide treatments, diseases, or pests.

Waste Handling and Disposal

Definition

Best Management Practices for waste handling and disposal are designed to prevent leftover or spilled chemicals (pesticides, fertilizers, and fire retardants), oil, and fuel from reaching surface and ground water. Pesticides include insecticides, herbicides, and fungicides. BMPs include container disposal, wash/rinse procedures, spill management, and equipment maintenance.

Water quality impacts and benefits

Although organic compounds like pesticides, solvents, soil, and fuel generally have a low solubility in water, even small amounts can exceed human or environmental standards. The chemicals used in forest operations often arrive in containers, are mixed on-site, and applied with special equipment. Littering of containers, spills during mixing, and poor cleanup of the mixing and spreading equipment may cause water quality degradation. Similarly, materials that are left behind, e.g., tires, batteries, waste oil, grease and their containers, may cause water pollution.

Conditions where applied

Whenever chemicals or machinery are used in forest operations, proper waste handling and disposal are concerns. Mixing and loading areas, as well as equipment storage and maintenance sites are especially critical because the concentrated materials kept there pose a greater risk of disposal and spillage. In well-drained sandy soils, spills infiltrate deeply, especially when macropores are present; whereas they remain near the surface in organic and clay soils. Steep slopes and wet soils adjacent to open waters are particularly vulnerable to contamination, because surface runoff and flooding may wash pollutants directly into water bodies.

Standards and Guidelines

A. *Training*

1. All operators, handlers, and supervisors must be trained in the transport, use, and disposal of hazardous materials.

2. Procedures for reporting spills and references for waste disposal must be available on site.

B. *Forest chemicals (materials used to control pests or improve site productivity)*

1. When using pesticides, follow the label instructions and immediately report any spills or other threats to the environment to the appropriate State agencies.

2. Triple-rinse containers. Dispose of rinse water and containers according to instructions on container labels.

3. Equipment used in the application of pesticides and fertilizers must be washed and rinsed in areas where runoff will not reach surface and/or ground waters.

C. *Operational materials (gasoline, diesel fuel, hydraulic fluid, oil, grease, and other liquids used in the operation and maintenance of motorized equipment)*

1. Containers of petroleum products are to be closed and delivered to recycling or waste disposal facilities.

2. Petroleum waste materials resulting from the on-site servicing of equipment will be collected for disposal off-site.

3. Dispose of used tires, batteries, and trash at designated facilities.

D. *Accidental spills*

1. Remove fertilizer spills and add spilled material to the spreader or other application device; or, if spilled material is contaminated and unusable, dispose of it using an approved method.

2. Mark any area where significant pesticide spills have occurred. Immediately notify Forest Service personnel and the nearest representative of the responsible State agency.

3. Prominently display at work site(s) appropriate disposal procedures and a list of contacts for reporting spills.

4. Petroleum spills found on open waters or in wet areas shall be contained with surface barriers, skimmed off, and treated with sorptive materials or decontaminant bacteria.

5. Clean and wash application equipment in areas where runoff will not reach surface or ground waters

Transportation System

Roads and road systems

Definition

Forest roads are single- or dual-lane routes used by highway vehicles (including trucks), which have been constructed for continuous, intermittent, or short-term access to DBNF lands. Such roads include unpaved haul roads and limited-use (Hewlett and Douglass 1968) or minimum-standard (Kochenderfer and Helvey 1987) access roads. Roads will have storm drainage structures, may have surfacing, and should receive planned, periodic maintenance. These recommendations apply to all phases of a road's life: design, construction, use, maintenance, reconstruction, and closure. For skid roads and trails and log decks, refer to the Skidding BMP and Landings and Log Decks BMP recommendations.

Water quality impacts and benefits

Roads are a necessary and expensive part of land management activities on the DBNF. They account for 90 percent of the sediment resulting from forestry activities (Eschner and Larmoyeux 1963, Douglass and Swank 1975, Ursic and Douglass 1978, Yoho 1980, Golden and others 1984, Swift 1985, 1993). The construction and use of roads necessitates soil disturbance and creates increased erosion potential. A wide variety of BMP's are available, many of which can reduce erosion potential or prevent sediment from reaching stream channels (Hewlett and Douglass 1968, Kochenderfer and Aubertin 1975, Lynch and others 1985, Swift 1988).

Conditions where applied

Best management practices should be incorporated into all phases of development of a transportation system from road location and design decisions through the life of the road and beyond. Location and design choices determine road cost and serviceability. Soil erosion potential is greatest during construction (Swift 1984b, Vowell 1985) but open roads are chronic sources of erosion and sediment production. Traffic on a road can create new potential for erosion and for release of sediment-laden storm water. The standards and guidelines described here also are appropriate for reconstruction and road closure. Periodic evaluation and maintenance throughout the life of a road are required to ensure that these practices are effective.

Standards and Guidelines

A. *Road Systems* Much of the potential sediment contribution from forest roads can be reduced by careful planning, layout, and design of the road system. Generally, road systems should be located on the most stable terrain and include the smallest-sized and lowest number of log decks, the shortest length of skid trails, and the fewest stream crossings. Roads should be located as close to slope contour as possible, avoiding landslides, springs, and seeps, as well as slopes at or exceeding the angle of repose, rock outcrops, sink holes, old gully systems, and other sensitive areas.

1. The most effective road systems are planned to serve an entire property or watershed. Haphazard road building, i.e., constructing access without planning for future uses, results in reduced water quality. Roads should be located away from stream channels, water bodies, and sink holes and should be constructed on stable benches, sideslopes, and ridges. Road location will determine the placement of log decks and the direction of skidding. When roads are located on high ground or to the sides of ridgelines, it is possible to locate log decks can be separate from water, and skidding will be uphill. By locating a road to one side of a ridgeline, the planner is able to ensure the dispersal of runoff and road drainage to litter-covered slopes, and thereby increase infiltration (refer to SMZ recommendations). In contrast, where roads and decks are located at the base of a slope, downhill skidding is necessary. Such operations concentrate surface runoff and increase the likelihood that eroded soil will be transported to streams.

   In general, new roads should be located outside the RPA and SMZ's. Roads should approach and cross stream channels at right angles, perpendicular to the flow of water, to minimize the amount of bare road surface and cut bank adjacent to the stream channel (refer to SMZ and Stream Crossing BMP recommendations). Because some soils and geologic formations are better suited for roads than others, soil and geologic maps should be used in the location and design process.

2. Planners should recognize a proposed road's potential sediment sources. High-erosion hazard areas include steep, dissected slopes and landslides. Soil and rock characteristics, slope, and local hydrology influence erosion potential. Unless excess excavation is removed to a safe area, building roads across slopes that exceed the angle of repose will result in road fills breaking loose and sliding toward streams. Unless the resulting slide exposes bedrock, the exposed slope will continue to erode into a gully and further add to slope instability and increased sediment transport and deposition. Cutting a road through a landslide can destabilize the slide, resulting in mass movement and sedimentation of streams.

3. Preharvest plans should specify periods of use to take advantage of favorable seasons or to avoid wet conditions,. This is particularly important where soil conditions indicate that road, deck, and skid-trail systems will be damaged by traffic during wet conditions. Plans should include preventative actions, such as installing temporary water bars in skid trails when logging operations are suspended because of impending heavy rains.

4. Road system reconstruction also must be planned and scheduled. Many existing roads are major sources of water quality degradation because BMP's were not followed when they were constructed. Such roads must be completely reconstructed, relocated, or closed and stabilized as the sediment transport potential cannot simply be modified by installing

drainage structures or reducing overly steep grades. (refer to Road Construction and Management BMP).

5. Proper planning includes appropriate design of stream crossings and road drainage facilities that will help prevent storm damage. Planners should use risk assessment (stormflow return intervals) and consider watershed area when designing stream crossings (refer to Stream Crossing BMP). Recent studies have shown that timber harvest can result in increased water yields, sometimes changing ephemeral streams into intermittent or intermittent into perennial streams. To handle an expected flow increase, culverts, temporary bridges, or other devices suggested in the BMP's should be installed where roads cross ephemeral channels.

B. *Drainage* Most road construction and management BMP's are techniques for intercepting drainage and sediment originating at roadways to keep it from entering ephemeral, intermittent, and perennial stream channels, rivers, and lakes. The goal is to provide a low-cost, low-maintenance road system that has the least effect on water quality.

1. To ensure good drainage and maintenance of its load-bearing strength, a road should be located on stable slopes, preferably along ridgetops with gentle side slopes. Avoid SMZ's, locations where drainage cannot be provided, and wet floodplain soils (refer to Streamside Management Zone BMP).

2. Select road locations that avoid crossing or coming near streams (including ephemeral streams) or other water bodies, because all are part of the stream system. Although dry most of the time, ephemeral channels have the potential to move substantial amounts of sediment (Miller and others 1985).

3. Do not route roads across perennial, intermittent, or ephemeral channels without providing a crossing structure or other mitigating measures that protect the channel from soil disturbance and the road from stormflow (refer to Stream Crossings BMP).

4. Where roads must approach or cross stream channels, install sediment barriers (including filter strips) (Cook and King 1983) and employ appropriate stream crossing practices (refer to Sediment Barriers and Stream Crossings BMP). Do not locate roads in the floodplain parallel to streams. Approach stream channels on the contour and cross at right angles. Select stable channel-crossing sites.

5. A sloping road approach to any stream crossing should have water-control structures, such as broad-based dips, to divert water from the roadbed and away from the channel (refer to Broad-Based Dips BMP). Alternatively, elevate the grade and create a berm along the shoulders of the roadbed at the crossing to drain surface water away from the stream.

C. *Road Location* Avoid locating roads on steep terrain, especially in areas with sensitive soils and unstable geology. When necessary, use full-bench construction and/or engineered stabilizing techniques when constructing a road across an unstable slope (e.g. slope exceeds the angle of repose for fill material).

1. Avoid steep road grades (percent slope of the road centerline). Locate and design roads as close to the contour as possible.

2. Grades for access roads should be between 2 and 10 percent (Beasley and others 1984), although steeper grades may be allowed for short (less than 200-foot) sections. However, road grades on soils with poor trafficability and high erosion potential should be adjusted downward accordingly (Cook and Hewlett 1979). Switchbacks and frequent changes in grade are better than a sustained grade.

3. Vertical road-cut slopes, which should be less than 3-foot high, can be used where outsloped roadbeds do not have an inside ditch. Vertical cuts in erodible material should not exceed 105 m (5-feet) high (Hewlett and Douglass 1968; Swift 1985). Cut slopes between 1 and 2 m (3-6 feet) high should be constructed at a 3/4:1 grade; cuts higher than 2 m (6 feet) should be sloped to a 1:1 grade and immediately revegetated.

D. *Surfacing and revegetation* Revegetation and roadbed surfacing should be standard practices in construction areas where eroded soil material can reach a stream channel (Swift 1984a,1984b). Immediately following construction on each section of road, all exposed soil in cuts, fills, and roadbeds should be seeded with grass or other recommended vegetation. Exposed soil may be further protected by forest litter and branches resulting from clearing the right-of-way (Hursh 1938, 1939; Cook and King 1983).

1. Until grass and other vegetation are well established, rock, erosion fabric, excelsior blanket, or mulches held by netting can protect temporary erosive fills at dip and cross-drain outlets, and at stream crossings.

2. A soil or gravel berm along the roadbed at the top of new, unprotected fills or at stream crossings can divert, spread, or filter stormwater leaving the roadbed until stabilized by vegetation.

3. Use stone or other stabilizing material to protect roadbeds on erosive soils and on steeper grades. Clean, 8-cm (3-inch) rock applied when the roadbed is soft will become embedded in the soil and provide a pavement for erosion prevention (Kochenderfer and Helvey 1987). A gravel mixture containing sand and smaller sized particles will provide a surface with greater traction and load-bearing capability but will not resist erosion as well (Hewlett and Douglass 1968). A grassed roadbed provides erosion protection for most of the surface, i.e., all but the portion kept bare by light traffic (Swift 1984a, 1985).

E. *Road Drainage* Road design should specify one or more methods of removing water from the roadway (with a minimum amount of erosion) and minimize the amount of sediment delivered to streams or water bodies.

1. Design frequent diversions into the roadway to reduce the erosive power of storm water, and limit chances of off-road damage. Do not run drainage water into landslide-prone areas or onto large, loose fills.

2. Broad-based dips and outsloped roadbeds are commonly used to remove storm water from roads (refer to Broad-based Dips BMP). Inside ditchlines are recommended only to drain crowned roadbeds, to intercept groundwater seeps (Swift 1984a), and to provide a gradient in flat terrain to drain roads (refer to Cross-drain and Turnout BMP recommendations).

3. Where conditions allow, outslope the entire width of a road 3 percent toward the fill slope to obtain best surface drainage. For improved safety, roads may be flat (level graded) or insloped on sharp turns, steep grades, and slick soils; but roadbeds without ditchlines should be outsloped when reconditioned or closed. Broad-based dips spaced at frequent intervals should be used to divert surface water on insloped sections, or such water should be diverted to ditchlines and removed.

F. *Design Strategies* Road design choices may require managers to select among apparently conflicting BMP's. For example, to access a ridgetop tract, a hybrid strategy based on several approaches may pose the least risk of resource damage and sediment delivery to streams. The following three options illustrate the issue.

1. Construct a steeper climbing road, e.g., up to the point of a ridge, and avoid all intermittent and ephemeral stream crossings.

2. Construct a climbing cross-slope road with some crossings on headwater streams.

3. Construct a lower-gradient road where risks of roadbed erosion are less, but stream crossings are more frequent.

G. *Construction Scheduling* If possible, complete road construction at least 1 year before timber harvest is scheduled, so that the roadbed can stabilize before heavy use (Kochenderfer 1970).

1. Avoid construction in wet weather or in seasons when vegetation cannot successfully be established (Swift 1986).

2. Where unsurfaced access roads connect with public highways, sections of gravel or other surfacing must be used to keep mud from being carried onto the pavement or washed into highway drainage.

H. *Maintenance Scheduling* Schedule maintenance so that newly disturbed soils are not exposed during seasons when intense storms are more likely to occur (November 15-April 15). Perform only the maintenance needed to restore roadbed surface and drainage.

1. Revegetate areas disturbed by maintenance.

2. Maintenance of system roads and the application of relevant BMP's should be commensurate with the traffic level on each section of road (Kochenderfer and Helvey 1987). Reid and Dunne (1984) found sediment losses from logging roads were 7.5 times greater during the workweek than on holidays or weekends.

3. Cut vegetation adjacent to the road, i.e., "daylight" the roadbed, so the roadway will dry faster after storms (Kochenderfer 1970). Restrict traffic when roadbed is soft to prevent rutting or breakup of the road surface (Rothwell 1978).

4. Where a section of road is in a poor location or is difficult to maintain, reconstruct the section to improve roadway stability or to direct surface drainage away from a water body.

5. As harvesting operations end, shape and smooth the roadbed as needed, restore function of drainage, and revegetate bare sites on cuts, fills, and ungravelled roadbeds.

I. *Road Closure* Closure of intermittent-use roads includes blocking access, reestablishing outsloping and dip drainage, and revegetating cuts, bed, and fills (Kochenderfer 1970). Native or non-invasive vegetation should be used, and temporary drainage structures should be removed.

1. Deep waterbars (tank traps), which provide greater water diversion than dips, may be used to block access to closed roads.

2. When future use is anticipated, consider leaving culverts in stream crossings to avoid creating additional stream disturbance and sediment source.

3. Where roads have been found to be unnecessary, follow the guidelines in Moll (1996) "A Guide for Road Closure and Obliteration in the Forest Service."

Broad-based dips

Definition

Broad-based dips are surface-runoff diversions that are built into the bed of access roads. The broad-based dip consists of three parts: a long approach section of varying length; a low, outsloped, middle outlet section (throat); and a short terminal section with reverse grade (hump).

The term ‘road’ includes any constructed portion of the transportation system that has a relatively impervious surface. This includes unpaved truck roads and skid roads.

Water quality impacts and benefits

Precipitation falling on compacted road and trail surfaces does not easily infiltrate. Instead, it flows down the road surface to a low point where it will either drain off or pond in a depression. Any moisture that does infiltrate the roadbed will decrease the road's bearing strength, so the road will not support the weight of vehicles. Traffic will rut a soft road surface; ruts, in turn, will concentrate runoff and initiate gully formation.

Precipitation falling on a road surface will dislodge soil that can then be transported by runoff. Where surface runoff is concentrated, e.g., in ruts or ditchlines, it will further erode the road surface or undermine the cut slope. Storm water carried in a roadside ditch may grow to a large volume before the ditch is emptied. Therefore, more erosion occurs following storms, and more sediment is carried away. Ditches usually are designed to empty onto stable slopes in ephemeral channels.

Broad-based dips divert storm water from the road surface without accelerating erosion or delivering sediment to a stream. They are placed at frequent intervals to prevent water accumulation on the road surface and channel runoff to the porous forest floor, where it infiltrates and deposits transported sediment.

The broad-based dip is a self-maintaining, low-cost means of moving water from a road surface and lessening the direct input of sediment to streams.

Conditions where applied

Broad-based dips can be used on unpaved roads that have a gradient of 12 percent or less (Hewlett and Douglass 1968). On steeper grades, the hump and outlet sections of the dip are too short for long wheel-base vehicles to cross without dragging. In addition, the approach grade becomes so steep that erosion actually increases and vehicle traction decreases unacceptably (Cook and Hewlett 1979). Broad-based dips should not be used for cross-draining spring seeps or flowing streams (Swift 1988). They can be built during road rehabilitation or reconstruction, as well as during new construction. However, they are rarely constructed on roads that are crowned and ditched.

Standards and Guidelines

A. *Design* Properly constructed broad-based dips are smooth enough to allow vehicle travel at near-design speeds. Common mistakes are to construct dips too short and steep, or too shallow.

1. The dip should be self cleaning, i.e., sediment that reaches the dip should pass through it and not deposited in the dip outlet.

2. Cross-ditches, water-bars, and open-topped drains are not alternatives to broad-based dips. Such structures require frequent maintenance and when not maintained, they fail to divert storm water from the road surface, which increases road erosion and opportunities for sediment to reach streams.

B. *Installation* With new construction, dips should be built as part of the road surface, NOT cut-in later. “Rough out” broad-based dips during the basic clearing and grading of the roadway.

1. Neither the throat nor the hump should have a sharp, angular break but should be rounded to allow the smooth flow of traffic (Hewlett and Douglass 1968). .

2. The bottom or throat of the dip is outsloped 2 to 3 percent over the total width of the roadway. The throat of the dip should be at a right angle to the road centerline. Cook and Hewlett (1979) recommend a slight slant downslope for dips in erosive, high-clay content soils.

3. In reconstruction, the 20-foot (6 m) (or longer) section, 3-percent reverse grade hump may be built from material excavated from the throat of the dip.

C. *Stabilization* The throat and reverse grade (hump) sections may require armoring with stone to stabilize the dip and reduce rutting.

1. Use larger, clean, open-graded stone, 5 to 8 cm (2 to 3 inches) in diameter, rather than the more erosive "crusher run" material. Typically, dense graded aggregate is recommended for grades steeper than 8 percent or on sites with erosive, soft, or slippery soils.

2. An energy absorber or runoff spreader should be installed below the outlet of the dip to dissipate runoff energy and spread the runoff, particularly where the land slope is steep (Cook and Hewlett 1979).

3. Fillslopes below a dip outlet should be protected with grass, brush, erosion fabric, or rock. Such protection will aid in the infiltration of runoff, deposition of sediment, and prevention of gully formation (refer to Sediment Barriers and Filter Strips BMPs).

4. Sediment barriers below the dip outlet will slow the flow of storm waters and encourage early deposition of sediment on the forest floor.

D. *Proximity to streams* A broad-based dip should not be used to cross stream channels, nor should it drain into any perennial, intermittent, or ephemeral stream. The objective of broad-based dips is to keep storm runoff and sediment out of the stream system (Swift 1988).

E. *Spacing* The spacing of broad-based dips is determined by the character of terrain adjacent to the road and the road centerline gradient (Swift 1985)(Table 11.). On gently sloping ground, broad-based drainage dips generally should not be more than about 60 m (200 feet) apart (Table 11; Cook and Hewlett 1979, Hewlett and Douglass 1968).

1. Always construct dips upslope from steep road grades and stream crossings.

2. Construct dips where the fill slope (distance from the outer edge of a road surface to edge of fill) is short, and where the topography provides surface obstructions and a terrain that will help spread the outflow.

3. Avoid constructing dips in hollows, where fill slopes tend to be longer, and where outflow from the dip could be concentrated at the head of an ephemeral stream.

Table 12. Approximate spacing between broad-based dips based on slope. Actual spacing depends on character of terrain adjacent to the road and other factors such as drainage patterns.

Road grade	Space between dips	
%	meters	(feet)
4	60	(200)
6	50	(165)
8	45	(150)
10	43	(140)
12	40	(135)

Turnouts and cross-drains

Definition

Turnouts, also known as lead-offs or wing ditches, are extensions of road ditches into areas that provide for the dispersion and infiltration of stormwater runoff. Cross-drains are buried pipes (also known as relief culverts) used to convey ditch water from one side of the road to the other, usually from the inside (high side) to the outside (low side) of the road. Turnouts and cross-drains remove runoff from ditches adjacent the road surface and direct it to areas where it will not reach stream channels.

Water quality impacts and benefits

Properly installed turnouts and cross-drains safely route runoff, which accumulates in ditches and at the outlets of waterbars and broad-based dips, away from the road surface. Their purpose is to divert water to where it will infiltrate and drop its sediment load before reaching streams (Swift 1985).

Appropriate installation of these structures will prevent road surface runoff and sediment from reaching streams. Reducing the amount of water that may concentrate on and near the roadbed will help prevent moisture build-up in the roadbed; and a drier roadbed results in an improved traffic surface that will support heavy loads.

Conditions where applied

Turnouts or cross-drains are required wherever the volume and velocity of water flow within ditches is sufficient to erode the ditch line. Installed at proper intervals, they will reduce the volume of runoff and sediment accumulation, and thereby reduce the risk of runoff reaching streams.

Standards and Guidelines

A. *Planning and Design*

1. Turnouts and cross-drains must not empty into any type of stream channel.

2. Cross-drains should not empty onto fill material unless the fill slope is protected from erosion (Hartsog and Gonsior 1973). If cross-drains empty onto fill slopes, drop-outlet structures may be required to safely carry runoff over the fill. Cannon, shotgun, or overhanging culverts should not be installed without an adequate energy dissipator below the outlet of the pipe.

3. Runoff water should be spread, retained, or infiltrated below or beyond the outlet of a turnout or cross-drain. Sediment barriers should be used where runoff volume is large. Logs or brush placed on the ground surface—along the contour of the land—can be used where the expected volume of water and sediment is low (see Sediment Barrier and Filter Strip BMP).

4. Install turnouts and cross-drains at frequent intervals to prevent ditch flows from eroding ditch bottoms (Rothwell 1978, as cited in EPA 1993), cut slopes, or road edges. Refer to Johansen and others (1997) for guidance on spacing cross-drains according to soil types.

5. Use buried pipes for cross-drains. Do not use open-top culverts (wooden box or pole culverts), which require almost constant maintenance. Open-top culverts rapidly fill with gravel and fine sediments and are prone to failure during rainfall events.

B. *Construction*

1. The bottom of turnouts should intersect the ditch bottom at the same elevation.

2. The bottom of turnouts should be steep enough to prevent ponding of runoff and sediment deposition, but be flat enough to prevent erosion of the turnout bottom.

3. Stabilize all disturbed soils around turnouts and cross-drains as soon as practical. Establish vegetation on turnout bottoms only if it will not cause ponding or sediment deposition within the outlet.

4. The bottom of cross-drains should be installed at the same elevation as the ditch bottom.

5. Compact at least the lower portion of fill material surrounding cross-drains to prevent "piping" along the culvert. Cover the pipe with a minimum of 30 cm (12 inches) of soil or half the culvert’s diameter, whichever is greater.

6. Cross-drain outlets or outfalls should have energy dissipators to prevent excessive erosion.

Stream crossings

Definition

Stream crossings are places in the transportation system where roads or trails intersect stream channels. Properly designed stream crossings minimize adverse impacts to streamflow, water quality, and aquatic biota and habitat. There are three principal types of stream crossings: fords, culverts (pipes), and bridges (including pipe arches), any of which may be installed permanently or temporarily, e.g., for the life of a project.

Water quality impacts and benefits

Stream crossings are the most critical element of a transportation system. Improperly designed or constructed crossings can significantly increase sediment loading. If road runoff, sediment, or other pollutants enter the stream system, crossings also may become chronic point sources. The failure of a stream crossing is often catastrophic, causing extensive local and downstream erosion and sediment production or deposition (Furniss and others 1991). Improperly installed stream crossings may also impede or preclude movements that may be essential to complete the life-history requirements of certain aquatic organisms.

Condition where applied

Stream crossing BMP's should be followed wherever a road or skid trail crosses any perennial, intermittent, or ephemeral stream.

Standards and Guidelines

Design specifications for a stream crossing are determined by a number of factors, including type of road and road-use pattern, channel characteristics, stream flow regime, and sensitivity of the aquatic ecosystem.

A. *Planning*

1. Minimize the number of stream crossings.

2. Locate stream crossings to minimize channel change and the amount of fill material needed. (Furniss and others 1991)

3. Select channel sections that are relatively straight (both above and below the crossing) and have stable banks and bottom.

4. Avoid construction during spawning seasons of sensitive aquatic species such as trout and mussels, or any threatened or endangered species.

B. *Design (all types of crossings)*

1. To minimize the length of streamside disturbance, align roadway approach sections with the stream channel at or near a right angle; cross the stream in the shortest possible distance.

2. Design the crossing to maintain stream hydraulics/turbulence. Minimize channel gradient changes, widening, or constriction.

3. Use crossings that do not disturb the bottom of streams, e.g., bridges or pipe arches, to minimize effects on fish or other aquatic organisms. (U.S. EPA 1993).

4. For temporary roads, favor temporary bridges over culverts or fords.

5. Design structures to accommodate storm flows expected to occur while the structures will be in place. Use regionally accepted methods for calculating expected stormflows.

6. Design crossings so streamflow does not pond above the structure during normal or high flows. This reduces sediment deposition immediately above the crossing and maintains the channel's ability to safely pass high storm flows.

7. Design crossings to minimize the amount of road runoff that enters the stream. Design structures so that precipitation falling on the roadbed drains away from the stream. Divert surface runoff from crossing approaches as near to the crossing as possible without causing runoff to enter the stream.

8. Design crossings to allow passage of floating debris and bedload.

9. Design the crossing so that streamflow will not be diverted along the road if the crossing fails, plugs with debris, or is over-topped (Furniss and others 1991).

C. *Construction (all types of crossings)*

1. Plan construction so it can be completed in the shortest practicable time. Have all necessary materials on the site before starting or ensure that they will be delivered and ready to use as soon as the site is prepared.

2. All suitable excavated material shall be used as backfill or embankment. Dispose of all surplus material in a stable, protected area outside the floodplain.

3. Avoid operating machinery in any waterbody, including streams, whenever possible.

4. Do not place erodible fill material below the normal high water line unless the material can be stabilized. Stabilize erodible fill with material that will not be moved by normal or high streamflows.

5. Construct (install) crossings during dry weather and at times that are not critical for the aquatic ecosystem.

6. Use silt fences or other sediment barriers along the fill to minimize soil loss from the construction site.

7. Immediately stabilize all exposed soils.

8. Unless it is to be incorporated into a brush barrier, remove construction debris and other newly generated roadside slash away from streams and outside the SMZ. Take such material to a location mutually agreed upon by a DBNF hydrologist or fisheries biologist.

9. Appropriate State or Federal permits may be required, if spoil or imported material is to be used as fill within the floodway or channel of a perennial stream.

D. *Pipe culverts and pipe arches*

1. Under most conditions, culverts should be considered permanent installations and not removed after use. If culverts must be removed, stream banks and channel must be restored to their original contour (size and shape) and all disturbed soil stabilized.

2. Use one large culvert rather than two or more smaller ones whenever possible. Larger pipes pass water more efficiently than small pipes and the latter are more easily plugged by floating debris. Individual crossings should be constructed for each channel of a braided stream or across broad flats. Additional culverts may be needed to maintain proper flow distribution on wet sites.

3. Align the pipe with stream direction and gradient to ensure that sediment passes through the pipe and that water is not directed against the streambank.

4. Install the culvert bottom at the same level as the stream bottom. Where fish passage is a concern, use a pipe-arch culvert. If a pipe-arch culvert is not available, install the culvert with a gradient of 1 percent or less, unless special features are included to facilitate fish passage. If the pipe cannot be bedded using on-site material, excavate at least 20 cm (8 inches) and backfill to the natural level of the channel with approved material.

5. Inlet and outlet ends of the pipe must extend beyond the fill.

6. To prevent flow blockage or erosion and scour, protect pipe entrance and embankments with riprap, gabions, headwalls, drop inlets or other inlet structures.

7. Control outlet scour below pipe culverts with energy dissipators that are compatible with fish passage requirements or movement of aquatic fauna.

8. Culverts should be sized and installed to accommodate a minimum 20-year flood. Roadways must be protected from washout when overtopped by a flood event.

9. Place culverts and culvert fills to prevent "piping" along the length of the culvert. Cover the culvert with a minimum of 30 cm (12 inches) or half the culvert's diameter of soil, whichever is greater.

E. *Fords*

1. Fords should be considered only where roads will receive minimum or intermittent use; and such use should be restricted to low-flow periods. Use fords only on service and minor collector roads, not arterials and major collector roads.

2. When creating approach sections, select locations with stable and relatively low stream banks that will require minimal excavation and earth movement.

3. Select only locations with bottom conditions that will support the designed use. Geo-textile fabrics, precast concrete planks, or additional rock may be added to strengthen or armor the crossing bottom, if such materials will provide for acceptable movement of fish and other aquatic fauna. All BMPs should facilitate conformance with the contour and grade of the stream channel substrate.

4. Harden road approach sections within 8 m (25 feet) of the stream to prevent erosion and sediment delivery directly into the stream channel.

5. Construct the ford bottom so it is low in the stream center, rather than flat. This will concentrate the water for fish passage when the stream flow is low, rather than thinly spreading it over the whole crossing width.

F. *Bridges (permanent and temporary)*

1. Consider temporary bridges when addressing management objectives for the road, cost considerations, and on-the-ground conditions. Temporary bridges may include timber/log construction, metal grate crossings, and portable bridge decks such as flatbed trailers.

2. Discourage the use of low-water bridges, i.e., bridges that are above water during normal flows but are submerged during high flows because they can preclude movement of fish and other aquatic species.

3. Place abutments on firm material where they will not obstruct stream flow or reduce channel capacity.

4. To avoid unnecessary site disturbance and soil erosion, remove only the stringers and decking after using temporary bridges. Do not remove abutments from temporary bridge installations even when the road is closed, obliterated, and reclaimed.

Sediment barriers

Definition

Sediment barriers are a temporary, mitigating practice used trap and hold sediment until areas producing the sediment are treated and stabilized. They may be human-made structures or natural terrain features. Such barriers may include filter strips, brush barriers and brush piles, hay or straw bales, silt fences, rock dikes, and retention basins. Filter strips are areas of land that infiltrate surface runoff and trap sediment and associated pollutants.

Water quality impacts and benefits

Forestry activities such as road and trail construction can disturb the soil surface and initiate erosion, causing sediment to move downslope to drainage paths and streams. Barriers can intercept sediment and help protect water quality. Surface obstructions and ground vegetation in filter strips trap or filter eroded soil particles and allow runoff to infiltrate porous forest soils. Roots and soils in a filter strip can intercept nutrients carried by subsurface soil moisture.

Conditions where applied

Sediment barriers are used on sites where soil has eroded as a result of management activities, or where excess fertilization could reach a stream channel or waterbody. To increase the effectiveness of a filter strip, sediment barriers should be placed in the pathway of runoff. Barriers can also be used to keep sediment out of other sensitive management areas.

Standards and Guidelines

A. *Barrier types and materials* A wide variety of designs and materials may be used to construct effective sediment barriers. The specific choice will be determined by the estimated amount of sediment that will be produced and the distance between the sediment source and the waterbody that would be affected, the availability of materials, cost, and the efficiency of use.

B. *Planning* Plan roads, landings, or other potential sources of soil disturbance so that sediment is released as far upslope from stream channels as possible. Select and design runoff outlets that will disperse water and sediment over the terrain and allow it to infiltrate (Swift 1986).

C. *Multiple barriers* The use of one or more sediment barriers, including brush, will increase the sediment trapping capacity of a filter strip.

D. *Traps (hay or straw)* Concentrated flows of sediment and water from dips, culverts, and turnouts can be delayed and spread by traps constructed with hay or straw bales that are held in place by stakes. To be effective, bales must fit tight and close together on the forest floor or ditch surface.

E. *Dikes (rock, riprap, brush, logs)* Dikes of rock or layers of riprap, brush, or logs can be used to break the force of flowing water in ditches and at outlets of culverts and crossdrains.

F. *Silt fences* Fences of human-made fabrics provide nearly total trapping of sediments, but are prone to failure by overtopping or the collapse of supporting stakes.

    1. Install fence with stakes on the downslope side. The number of stakes will depend on specific circumstances but in general more is better, to help hold the fabric and reduce the weight on each individual stake. Additional support of wire fencing may be necessary.

2. Lay fabric against the upslope side of brush barriers to seal openings in the brush.

3. The bottom strip of all silt fences must be dug into the soil, facing upslope, or otherwise tightly attached to the soil surface along the full length of fence.

4. Position fences along the contour with ends turned upslope beyond the level where flow could bypass the barrier.

G. *Soil surface protection* The soil surface can be protected from erosion by layers of excelsior blanket or other erosion-preventing fabrics, mulches, or rock layers. This practice is most appropriate where the volume or velocity of water discharged onto bare soil or the forest floor exceeds the ability of the surface to resist erosion.

H. *Retention basins* Retention basins can be constructed to trap storm water and sediment. Preconstruction planning must consider the volume of water and material that will be retained, as well as the need for periodic cleaning of the basin to maintain its capacity (Burns 1996).

I. *Timing* All barriers must be in place before the first erosion-causing storm following soil disturbance.

Recreation

Trails

Definition

A trail is a path or travelway of varying width, which is commonly used by and maintained for hikers, horse riders, mountain bikers, or for motorized vehicles with a total width of 125 cm (50 inches) or less. Sidewalks and paths within a recreation development are not considered as trails. Travelways greater than 125 cm (50 inches) that are constructed to serve vehicles (including off-road vehicles) are roads, not trails, and are addressed under Road BMP's.

Water quality impacts and benefits

Dispersed recreation activities, including trail use in popular areas that receive a lot of traffic, can cause considerable damage to soil, water, and aquatic fauna. Sensitive soils, riparian areas, and stream banks are particularly susceptible to damage and need special attention during construction and maintenance. Trails on steep slopes also are susceptible to erosion from runoff, especially when users make "shortcut" trails between switchbacks. A variety of techniques can be used to harden trails and reduce the effects of erosion to negligible levels.

Conditions where applied

The practices described here apply to all trail types; including hiking, mountain biking, horseback riding and OHV trails.

Standards and Guidelines

A. Obliterate user-constructed trails whose continued use would not be consistent with management objectives.

B. For new construction, give priority consideration to “loop” trails that will serve to lessen the need for user-developed trails.

C. Designate and design trails for specific uses, e.g., hiking, horseback riding, mountain biking, and OHV use.

D. Develop management objectives for all trails. Regularly inspect all trail and associated structures, such as bridges, culverts, and stream approaches.

E. Promote partnerships with user groups to aid in such activities as trail maintenance, construction, and visitor information.

F. Divert water runoff from trails to reduce erosion. Provide drainage either by rolling the trail grade, outsloping the tread, or establishing cross drains. Table 11 shows spacing requirements for various soil types and trail grades (refer to Stream Crossing Standards and Guidelines).

G. Minimize the number of stream crossings. To reduce erosion, harden crossings or use bridges on larger streams.

H. Design trails on sideslopes of less than a 40-percent grade and avoid sensitive soil types whenever possible.

I. Design turns to minimize excavation and cutbank exposure. This may be accomplished by using climbing turns and avoiding switchbacks whenever possible.

J. Hardening of climbing turns, switchbacks, and stream approaches is recommended.

K. Locate stream crossings in areas that have as many of the following features as possible:

    1. a well-defined stream channel
    2. inimal channel width
    3. a flat stream gradient
    4. stable approaches on both sides of the crossing

L. Restrict traffic on trails to meet trail management objectives and minimize resource damage. This may include seasonal closures.

M. Horse-trail and OHV stream crossings and approaches will be hardened (refer to Stream Crossing Standards and Guidelines).

N. Avoid locating stream crossings in areas with Protected, Endangered, Threatened, and Sensitive (PETS) species.

Dispersed recreation

Definition

Dispersed recreation occurs outside of developed sites and includes activities such as picnicking, fishing, and camping at undeveloped sites. Trail use, a major form of dispersed recreation, is covered in its own section.

Water quality impacts and benefits

Dispersed recreation often occurs near streams and lakes and has the potential to adversely affect water quality, riparian vegetation, stream and lake banks, and aquatic habitat. As dispersed recreation sites become concentrated and overused, erosion and runoff often increase, particularly on sensitive soils and in riparian areas. Impacts to aquatic resources can be minimized by dispersing use and hardening heavily used or sensitive sites.

Conditions where applied

These standards apply to all dispersed recreation that occurs within Streamside Management Zones (SMZ's).

Standards and Guidelines

A. Camping in dispersed recreation areas is not allowed within 30 m (100 feet) of perennial streams or lakes.

B. Areas having aquatic resource damage, erosion, or excess vegetative damage because of overuse will either be hardened or closed and rehabilitated.

C. Tethering or corralling of horses or other livestock is not allowed within 30 m (100 feet) of perennial streams or lakes.

Fish, Wildlife and Range Management

Fish and wildlife management

Definition

Wildlife management encompasses many activities primarily related to habitat, including habitat protection, restoration, rehabilitation, and creation. Species of concern include both game species including deer, turkey, quail, grouse, trout, and bass, and many non-game species, including neo-tropical migratory birds, salamanders, reptiles, fish, and mussels.

Water quality impacts and benefits

Habitat projects for aquatic or riparian-dependent fauna should have minimal short-term effects on water quality. Such effects may occur when project work is in or near a stream or its tributaries. Sedimentation typically results from such activities as installation of stream channel structures, restoration of eroding stream banks, or modification of stream crossings. Typical habitat enhancement structures that have no foreseeable impact on water quality include wood duck or bat houses and artificial reefs for lake fish. The benefits of wildlife habitat management are both direct and indirect. A few of the benefits derived from such management include: enhancement of habitat for species whose populations are declining on private lands adjacent to the DBNF, a decrease in sediment loading in streams, and increases in biodiversity.

Standards and Guidelines

A. Any habitat management within a stream channel or a RPA must benefit aquatic or riparian-dependent species.

B. Each site-specific environmental analysis will include a Biological Assessment (BA) to determine if and how a management project may affect species listed or proposed for listing by the Federal Government as endangered or threatened. In addition, each site-specific environmental analysis will include a Biological Evaluation (BE) to determine if and how a project would affect species designated by the Regional Forester as sensitive.

C. A DBNF-wide BA or BE can be used to cover routine activities such as stocking non-native trout, provided that such activities have previously been approved by the forest biologist, and that they will contribute to attainment of the desired condition.

D. Habitats of rare and sensitive plants found within riparian areas, for example, white fringeless orchid, may benefit from restoration activities. Examples include removal of mid-story vegetation, felling of individual trees within the area, or the in-stream use of log jams to create sediment traps. Specific projects may be approved on a case-by-case basis when accompanied by a BA or BE.

E. Wildlife ponds (including constructed wetlands) within the RPA are generally discouraged, but may be approved on a site-by-site basis. The DBNF hydrologist and fisheries biologist must be involved in such projects.

F. Generally, impoundments are prohibited, although they may be approved on a site-by-site basis.

G. Woody debris naturally occurring in streams will be removed only when it has demonstrably degraded habitat for riparian-dependent species, or when it poses a direct threat to private property or DBNF infrastructures, e.g., bridges. The need for removal must be determined on a case-by-case basis following consultation with the forest hydrologist and fisheries biologist.

H. Stream structures may be used to enhance habitat for trout or native aquatic species. Structures will be designed to mimic the appearance and function of natural habitat features. Heavy equipment use in streams is permitted but should be kept to a minimum and supervised by the forest hydrologist and fisheries biologist. Appropriate permits must be obtained.

I. Streams will be managed in a manner that results in 78 to 186 pieces of CWD per stream kilometer (125 to 300 per stream mile) or loadings typical for streams on the DBNF.

J. From February through July, which is the spawning period or juvenile rearing time for most rare and other aquatic species, the DBNF fisheries biologist and/or State biologists must be consulted before instream disturbance activities are approved.

K. Fish stocking may be permitted as long as populations of native aquatic species are maintained or enhanced. The potential impact of any non-indigenous species on the native aquatic fauna will be evaluated by the Forest Fisheries Biologist. Fish stocking will be coordinated through a Memorandum of Understanding among State, the Forest Service, and other interested groups.

L. Restoration efforts for any species will be initiated through the NEPA process and will include consultation with State Fish and Game and the U.S. Fish and Wildlife Service.

Range

Definition

Range is land designated for growing herbaceous vegetation as forage for livestock.

Water quality impacts and benefits

Bank erosion, sedimentation, and nutrient levels may rise to unacceptable levels where livestock has unlimited access to streams and adjacent riparian areas.

Standards and Guidelines

A. Appropriate NEPA documentation is a necessary part of designating grazing areas. Such documents will include approved grazing plans and analyses that show how many animals can be supported without exceeding the land's carrying capacity.

B. Perennial and intermittent streams channels will be fenced to exclude animals. Crossings and other access sites will be hardened.

C. Feeding troughs, watering troughs, and salt and mineral blocks will be placed outside of the RPA and SMZ's.

Minerals

Definition

Exploration and extraction of minerals, coal, oil, and gas are carried out by individuals and firms through leasing and/or exercise of outstanding or reserved rights. About 70 percent of subsurface rights on the DBNF are either outstanding in third-party agreements or reserved under various rules and regulations administered by the Secretary of Agriculture. Non-energy related minerals include limestone, sand and gravel, sandstone, and refractory clays. Limestone is the only mineral currently being quarried on the DBNF by means of an underground operation.

Water quality impacts and benefits

Mineral extraction activities can adversely affect water quality, aquatic habitats, species richness, and the diversity of aquatic flora and fauna communities and may cause fragmentation of aquatic communities. Erosion and sedimentation, acid mine drainage, release of brine waste water, and oil spills are leading causes of problems associated with mining and mineral extraction.

Remediation of land and water resources degraded by past mineral operations will be accomplished through the DBNF Watershed Improvement Program, which is being conducted in partnership with other Federal and State agencies, clubs and organizations, industry, and individuals within the scientific community. Benefits to aquatic resources can also be achieved by reclaiming lands that were mined for coal prior to acquisition by the DBNF and where reclamation was either inadequately accomplished or not accomplished at all. Reclamation will provide an opportunity to accelerate restoration of degraded watersheds by enhancing natural recovery processes.

Similar benefits can be gained in areas where past oil and gas operations were conducted under rules and regulations less stringent than those now in effect. Restoration of oil and gas drilling sites may be accomplished using improved technologies and methods.

Conditions where applied

Mineral (coal, oil, and gas) exploration and development require compliance with the National Environmental Policy Act of 1969 (NEPA); although some outstanding mineral rights remain exempt. Consultation with the U.S. Department of the Interior Bureau of Land Management, and Office of Surface Mining, as well as responsible State agencies, is also required. Where surface occupancy is judged to be in the best interest of the United States, the DBNF may choose to lease access to federally controlled minerals. Extraction of minerals through privately held mineral rights provisions is subject to deed rights or stipulations, as well as applicable Federal and State rules and regulations. Reserved rights are subject to stipulations of the deed, as well as rules and regulations administered by the Secretary of Agriculture.

Mining of privately owned coal from beneath National Forest System lands is subject to a determination of Valid Existing Rights (Surface Mining Control and Reclamation Act, P.L. 95-87), and all other Federal and State rules and regulations dealing with mineral exploration and mining.

Standards and Guidelines

A. *Federally controlled minerals*

1. Surface occupancy is prohibited within the Riparian Prescription Area.

2. Mineral exploration and production activities shall be planned, managed, and coordinated with regard for other natural resources; including those activities that potentially could affect riparian areas and aquatic habitats. Following exploration and production operations, the permittee is responsible for reclaiming disturbed sites in accordance with an approved reclamation plan. Reclamation plans will consider opportunities to meet or exceed the Desired Condition of the management area in which operations were conducted.

3. Where mineral mining operations are conducted adjacent to seeps, springs, and karst features (sink holes) found outside the RPA, implement prescribed mitigation measures (see SMZ Standard and Guidelines).

   Coal - Follow Federal and State rules and regulations promulgated to establish performance standards for protecting soil, water and aquatic resources and values; and for restoration and reclamation of areas affected by mining activities. Such rules and regulations include requirements for protection of surface and groundwater quantity and quality; prevention and control of acid mine drainage, erosion, and sediment deposition; and protection of streams and hydrologic balance.

Oil And Gas –

a. A permitted operation may be temporarily suspended due to wet weather when unacceptable resource damage is anticipated or may be occurring.

b. All mud pits, disposal pits, and auxiliary pits will be lined with an appropriate, impermeable liner. All drilling fluids and cuttings must be captured in a pit and removed from the DBNF as soon as possible and taken to an approved disposal site.

c. To ensure that pollutants are contained on a site, drainage on the drill pad will be contained behind a berm constructed around the pad's perimeter.

d. Any brine resulting from the operation will be transported for disposal away from National Forest lands.

e. All petroleum and brine spills, regardless of quantity, will be reported promptly to the district ranger, forest hydrologist, and fisheries biologist, as well as other appropriate State and Federal officials.

f. Transportation system roads with adequate drainage structures and rock surfacing will be maintained to their standard and not allowed to deteriorate. Erosion problems resulting from poorly drained and inadequately surfaced roads will be remedied by upgrading those roads, e.g., eliminating erosion, gullying, and stream sedimentation.

g. Oil storage tanks shall be enclosed by a berm large enough to contain one and one-half times the capacity of the largest tank in the tank battery. All valves leading from oil storage tanks will be locked. Berms will have a clay core or other, similarly impermeable material. The berm's top will be level and maintained at the elevation at which it was constructed.

h. Any liquids collected within a berm, including liquids that may be rainwater, will not be drained off the site. Drains will not be installed. Liquids will be removed by vacuum truck to an approved disposal or injection facility. A representative from the DBNF may approve the siphoning-off of rainwater if the facility has no history of saltwater contamination, or if the water has been tested and found free of contaminants.

i. After production operations have been completed, tank batteries, flow lines, and related facilities will be removed. The disturbed area will be reclaimed to prevent erosion and stream sedimentation. It will then be re-shaped to produce a smooth, uniform slope with all holes and depressions filled. Where the DBNF representative deems it necessary, the area shall be scarified (ripped) to provide a good seedbed prior to liming, fertilizing, seeding (preferably with native plant materials) and mulching.

4. Common Variety Materials (Salable) - Sale or removal of mineral materials from stream channels or RPA's, such as sand and gravel, is prohibited. Such activities are not compatible with the Desired Condition for riparian or aquatic habitats.

B. *Private Minerals*

Reserved rights - The exercise of reserved rights shall be in accordance with applicable State and Federal laws, rules, and regulations administered by the Secretary of Agriculture, and made a part of the mineral reservation within a deed, and other county and municipal laws, ordinances or regulations which are applicable to the area of a specific permitted operation.

Outstanding Rights - The exercise of outstanding rights shall be in accordance with terms of the deed of separation, as well as applicable State and Federal laws and regulations.

Restoration and Recovery of Threatened or Endangered Species

The purpose of a recovery plan for threatened or endangered species is to ". . .delineate reasonable actions which are believed to be required to recover and/or protect the species" (Biggins 1989). Over half of the action strategies thought to be necessary for restoration and recovery of aquatic species on the DBNF are very general and vague. For some species, life histories and/or life cycles are well described, but for many others virtually nothing is known. Most species found on the DBNF are the latter. Viable key actions, which can be implemented today, include:

(1) acquire land known to be occupied by such species,
(2) restore riparian and aquatic habitats that are critical to life histories, and
(3) ensure that BMP's are followed when conducting any activities that may affect aquatic resources.

In addition, surveys of current populations and of habitats suitable for species restoration must be continued and expanded. As required by federal mandates, i.e., the Endangered Species Act, highest priority should be given those fish and mussel species identified in Tables 3 and 5 as federally endangered or threatened. Other species with conservation status should also be given high priority for restoration of populations and habitat. These species are the pool from which federal listings are often drawn; conservation actions by the DBNF may help prevent future listings. Most of these would benefit Forest Service acquisition and management of the habitats in which they are found. Although some of the fish species may benefit from the creation or modification of habitat, e.g., deep pools, root wads, and CWD, for mussels there is insufficient information about basic life history and distribution to recommend habitat improvement procedures.

Inventory of Fauna and Habitat Conditions

Inventory is essential for establishing baseline data on the biotic and abiotic components of aquatic systems; and it is therefore a critical step in the monitoring process. Habitats in all streams on the DBNF should be inventoried to assess current conditions. Reliable inventory techniques should be used to collect baseline data on appropriate physical, chemical, and biological parameters.

Water quality —Inventory protocols should follow standard Forest Service methods.

Sediment transport—Inventory protocols should follow Dissmeyer 1994.

Stream inventory—The basic principles of Basinwide Visual Estimation Techniques (BVET) (Hankin and Reeves 1988) should be followed for all stream habitat and fish population inventory and monitoring. Specifically, sample sites should be selected from naturally occurring habitat, e.g., pools, riffles, according to a random-systematic design (Dolloff and others 1993).

Ultimately, complete basinwide surveys should be conducted on all DBNF streams. These surveys should collect baseline data and be used to support project-level analyses and monitoring. Habitat and aquatic biota components should be selected to address clearly defined objectives such as guidelines identified in the revised Forest land Resource Management Plan.

Habitat inventories should include variables such as: habitat type, (pool, riffle), length, width, area, maximum depth, average depth, residual volume (pools only), dominant substrate, and CWD loading.

Pieces or volume of CWD should be counted or measured. The location of wood can be identified through the use of hipchain or a global positioning system (GPS). Pool-riffle ratio should be calculated from the habitat-area data collected during the BVET.

Because the cost of stream surveys must be considered, stream inventory and monitoring should be based on clearly defined needs and priorities. A hierarchical approach should be used to determine sampling strategy and intensity. A hierarchical strategy for inventorying and monitoring streams on the DBNF is given in Appendix 3.

Protocols for freshwater mussel population inventories are being developed by Warren and Haag of the USDA Forest Service Southern Research Station. As they become available, these methods should be adopted to inventory mussels on the DBNF.

Monitoring and Evaluation

Introduction

With passage of the NFMA, Congress required the Forest Service to monitor the effects of all its activities. Monitoring provides direct information about 1) how well the desired resource objectives identified in the planning process were met during project implementation, 2) whether necessary resource protection measures were applied, and 3) how effective these measures were.

Monitoring of Operational Standards and Guidelines

This section addresses implementation and effectiveness monitoring of the Standards and Guidelines outlined in the Aquatic Conservation Assessment (ACA). Both physical and biological attributes of aquatic systems are addressed. Most of the information was compiled from various published and unpublished documents that are currently used on the DBNF and in other Region 8 national forests, as well as the Center for Aquatic Technology Transfer (CATT).

Implementation Monitoring

Purpose: Implementation monitoring will focus on determining whether the Standards and Guidelines and BMP’s outlined in the DBNF Aquatic Conservation Strategy are employed during on-the-ground management activities.

Methods: Implementation monitoring will follow procedures established for the DBNF. Before beginning any on-the-ground activity, project managers will prepare a checklist developed from forest-wide and project-specific standards and guidelines and BMP's and the Aquatic Conservation Strategy. Project reviewers will visit each site and mark a "yes" or "no" for each attribute on the list and will sign and date each list. The lists will be filed both in the Ranger District project file and at the Forest Supervisors Office. Other documents to be filed with the monitoring checklist will include contract officer/inspector daily diaries, photographs, and specialists' field review reports.

Frequency of monitoring: Monitoring to verify the use of best management practices will begin at the start of all activities and continue until activities cease. The consistency of implementation monitoring will be reviewed on a minimum of two new management activities per ranger district each fiscal year. The projects that are selected will represent a sample of timber harvest, road construction/reconstruction, recreation development, wildlife/fisheries habitat improvement, and other projects that are undertaken by the ranger districts. Staff from the DBNF, ranger district personnel, and line officers jointly will select the projects and sites for review.

Data analysis: Compliance or non-compliance with Standards and Guidelines and BMP's will be determined by tallying the number of "yes" responses on completed checklists. A minimum of 90 percent "yes" checkmarks will indicate satisfactory implementation of resource protection measures.

Responsible person(s) and reporting requirements: Soil and water staff resource specialists from the DBNF Supervisors Office, ranger district resource specialists, timber sale administrators, engineering contract inspectors, and other personnel will be responsible for on-site field inspections of the individual management activities. The ranger district aquatic resource specialist will maintain a copy of implementation monitoring records, and the Supervisors Office soil and water staff will maintain the DBNF file. Some implementation reviews may involve interdisciplinary field visits associated with specific projects.

Effectiveness monitoring

Purpose: Determine if BMP's, Standards and Guidelines, and other resource protection measures are effective in meeting the Desired Future Condition.

Methods: Standard methods and procedures will be used to assess changes in soil and water movement, water quality, and aquatic biota. Sampling methods will include (but nort be limited to): channel cross-sections, physical and chemical analyses, basin-wide habitat and fish population surveys (BVET) methods, mussel monitoring methods, and random surveys of aquatic biota. Monitoring sites will be associated with ongoing and completed activities. Baseline (pre-project implementation) monitoring data will be collected for all proposed activities.

Frequency of monitoring: Monitoring of affected resources will occur at selected sites or watersheds during intervals established in the DBNF Annual Monitoring Plan. All activities with the potential to increase the transport of sediment to water-bodies also will be monitored during or following storm (bankfull) events.

Data analysis and interpretation: Qualitative and quantitative methods both will be used to analyze collected data. The data will be compared with established Desired Conditions and displayed in figures for qualitative analysis and interpretation. Depending on monitoring objectives, study design, and sample size, either parametric or non-parametric statistical methods may be applied to help determine the effectiveness of resource protection measures.

Responsible persons/reporting requirements: As identified in the DBNF Annual Monitoring Plan, staff from the ranger districts and the forest supervisors office will be responsible. Ranger district personnel will retain the data, although both offices will contribute to data analysis and preparation of the annual monitoring report. A copy of the report will be kept at the ranger station and with the Supervisors Office aquatic resource staff.

Glossary

Abutment: Foundation at the edge of a stream crossing which supports the ends of a bridge.

Arch pipe: A culvert section, usually formed of bolted plates, that is an arc of a circle (usually one-half or less); a bottomless culvert.

Best Management Practices (BMP's): Methods, measures, or practices that prevent or reduce water pollution; including but not limited to, structural and nonstructural controls, operation and maintenance procedures and other requirements, and scheduling and distribution of activities. Usually BMP's are applied as a system of practices rather than a single practice.

Biological Agent: Any predator, pathogen, or parasite that can be used to maintain another organism's population density at a lower average level than would occur in its absence.

Broad-Based Dip: Surface runoff diversions built into the bed of a forest road; consisting of a long approach section, a low, out-sloped middle section, and a short terminal section with a reverse grade.

Brush Barrier: A linear pile of tree limbs, tops, logs, and other forest debris which is arranged along the lower edge of a road, landing, or site-prepared area to slow, diffuse, or intercept sediment moving off a disturbed site. Sediment trapping efficiency can be increased by placing solid material in contact with the ground surface.

Buffer: An area of land established between two separate and distinct land use regimes, which serves to modify the effects of one land use on the other.

Channel: A water-bearing trough eroded vertically into low areas of the land surface. Also, a ditch or canal excavated for the flow of water.

Coarse Woody Debris: Pieces of wood (branches, whole trees, root wads) that are at least 10 cm (4 inches) in diameter and 1 meter (3 feet) long.

Cross Drain: Culverts that convey ditch water from one side of a road to the other.

Culvert: A metal, plastic, or concrete pipe installed to allow surface water to flow under roads or trails.

Effectiveness monitoring: The means by which managers determine if implemented plans and prescriptions achieve project objectives or other design criteria.

Ephemeral stream: A watercourse that may or may not have a well-defined channel, and which flows only for short periods during and following precipitation. Ephemeral stream bottoms are usually above the water table and do not contain fish or aquatic insects with larvae that have multi-year life cycles. Ephemeral streams not located in the RPA are protected by DBNF-wide Standards and Guidelines.

Erosion: The process of detachment, transport, and deposition of soil material.

Filter Strip: Area of land that infiltrates surface runoff and traps sediment and associated pollutants.

Fire Intensity: The rate of heat release per unit of time per unit length of fire front. Numerically, it is the product of the heat yield, the quantity of fuel consumed in the fire front, and the rate of fire spread.

Fire Severity: A measure of the amount of organic material consumed from the soil surface and the degree to which soil is exposed and its mineral composition altered.

Gabion: Wire baskets filled with stone and placed to armor streambanks or cut banks against erosion.

Headwall: A wall built around the inlet opening of a culvert.

Implementation monitoring: The means by which managers determine if plans and prescriptions are implemented as designed.

Infiltration: Movement of surface water into the soil.

Intermittent stream: A watercourse that flows in response to a seasonally fluctuating water table in a well-defined channel. Intermittent streams do not maintain fish or aquatic insects with larvae that have multi-year life cycles. Intermittent streams not located in the RPA are protected by a SMZ and DBNF-wide Standards and Guidelines.

Landing/Deck: Areas that are cleared for holding, storing, handling, and loading logs.

Large Woody Debris: See coarse woody debris.

Logging Slash: Logging residue composed of trees, tops and branches.

Outslope: The feature of a road surface, established during construction or maintenance, that slants the roadbed to the outer or downhill side to facilitate drainage of storm runoff from the road in more diffuse flow than occurs at dips and waterbars. Outsloped road designs contrast to crowned roadbeds or to insloped surfaces angled toward a ditchline.

Perennial stream: Any watercourse that contains fish or aquatic insects with larvae that have multi-year life cycles, and which flows in a well-defined channel that always is below the water table. Perennial streams may have subsurface flow. All perennial streams are located entirely within the RPA. Management guidance is provided by RPA, SMZ, and DBNF-wide Standards and Guidelines.

Pipe arch: A pipe that has been deformed from a circular shape, such that the width (or span) is larger than the vertical dimension (or rise).

Prescribed Burning: The planned, controlled use of fire to accomplish a variety of management objectives.

Riparian Prescription Area (RPA): Riparian areas on the DBNF are managed as a separate prescription area where riparian-dependent resources and values are given priority. Riparian ecosystems have variable widths that are determined by ecologically significant boundaries rather than arbitrary distances. The RPA includes all wetlands, ponds, lakes, and perennial streams and adjacent riparian ecosystems

Riprap: Rock or other large aggregate that is placed to protect streambanks, bridge abutments, or other erodible sites from runoff or wave action.

Road crown: The elevated centerline portion of a road. Its purpose is to promote lateral surface drainage and prevent ponding on the roadbed.

Sedimentation: The deposition of eroded soil material (sediment) into an ephemeral, intermittent, or perennial stream, lake, or other waterbody.

Sinkhole: A geologic feature, typically within karst topography, that may provide a direct connection between the land surface and groundwater.

Site preparation: Any planned action that is taken to prepare a site for natural or artificial regeneration. The three major types of site preparation; mechanical treatments, prescribed burning, and chemical application; may be used alone or in combination.

Skid road: An unsurfaced single-lane path constructed for heavy or off-road vehicles to transport or drag logs to a landing.

Skid trail: A temporary, unbladed, unsurfaced pathway on forest litter and soil, over which felled trees or logs are dragged to a landing.

Stormflow/runoff: Water from a precipitation event that does not penetrate the soil and flows off the site.

Streamside Management Zone (SMZ): A designated area that consists of the stream itself and an adjacent area of varying width (riparian area) where management practices that might affect water quality, fish or other aquatic resources are modified. The SMZ is an area of closely managed activity, not an area of exclusion. It may provide an effective filter and absorptive zone for sediments, nutrients and pesticides; maintain streamside shade; protect channels, streambanks and maintain aquatic habitats; and promote floodplain stability.

Subsurface filter strip: An area of land in which soil water moves, and where chemicals are removed from interflow by soil adsorption and plant uptake.

Turnout: Extensions of a road ditch into a vegetated area that provide for the dispersion and infiltration of stormwater runoff.

Understory: Trees and other woody species growing under a more or less continuous cover of branches and foliage formed collectively by the upper portion of adjacent trees and other woody growth.

Waterbar: A mound or ridge of soil built across a light-duty road, skid road or trail, or fireline, for the purpose of diverting water off the surface and onto porous forest soil.

Waterbody: Any river, creek, slough, canal, lake, reservoir, pond, sinkhole, or other natural or artificial watercourse that flows within a defined channel or is contained within a discernable shoreline.

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Appendix 1. Fish and Mussel Sensitive Species Accounts

In each account, the scientific name (common name in parentheses) is followed by the status designation, where, E is endangered, T, threatened, SC, of special concern, X, considered extirpated, S, sensitive species (Regional Forester's list), and CS, conservation species. The sources of the status designations are: United States Fish and Wildlife Service (FWS), American Fisheries Society (AFS), Kentucky State Nature Preserves Commission (KNP), and Daniel Boone National Forest (DB). The habitat section includes a description of the most-frequented habitat of each species followed by the placement of the species into a habitat classification scheme following Burr and Warren (1986) as modified from Cowardin et al. (1979) (Appendix Table 1).

Appendix Table 1. Outline classification of major ichthyofaunal habitats of Daniel Boone National Forest with physiographic provinces, sections, subsections, and major drainages of occurrence (modified from Burr and Warren 1986).

I. Lacustrine System
- (A) Reservoir subsystem-forestwide
- (B) Sinkhole Pond subsystem
  - (1) Highland Rim Section

II. Palustrine System
- (A) Pond Subsystem-forestwide

III. Riverine System
- (A) Cave Stream Subsystem
  - (1) Highland Rim Section
- (B) Spring Subsystem-forestwide
- (C) Upland Headwater Creek Subsystem
  - (1) Appalachian Plateaus
  - (2) Highland Rim Section
- (D) Upland Stream and River Subsystem
  - (1) Appalachian Plateaus
  - (2) Highland Rim Section

The Reproductive Habits section for fishes and Known Hosts and Reproduction sections for mussels are described in following paragraphs. The Hydrologic Units section denotes those drainages within the forest in which each species occurs. The Status section contains a concise statement regarding the current or former distribution of the species in the DBNF. Use of the terms "generally distributed," "occasional," or "sporadic" follow Burr and Warren (1986) and Cicerello et al. (1991) for fishes and mussels, respectively.

In the Reproductive Habits (Appendix Table 2) section of the fish accounts, each sensitive fish species is classified according to its known reproductive strategy. Summaries or original information on reproductive habits were used from Scott and Crossman (1973), Pflieger (1975), Trautman (1981), Becker (1983), Etnier and Starnes (1993), and Jenkins and Burkhead (1994). Original references are cited for information not included in or published subsequent to these works.

~~Appendix Table 2. Outline classification of reproductive habits of fishes of Kentucky modified~~ from Balon (1975).

I. Nonguarder
  - A. Open spawner
    - 4. Pelagic spawner
    - 5. Benthic
      - a. Coarse substrate spawner
      - b. Fine substrate spawner
      - c. Plant spawner
  - B. Brood hider
    - 1. Benthic
      - a. Coarse substrate spawner
      - b. Fine substrate spawner
    - 2. Crevice spawner

II. Guarder/Nester
  - A. Coarse substrate nest
  - B. Fine substrate nest
  - C. Plant-material nest

D. Cavity nest

III. Bearer

A. Gill-chamber brooder

B. Livebearer

For further explication of definitions, the reader is referred to Balon (1975) and Winemiller and Rose (1992). The outline contains three major headings: nonguarder, guarder/nester, and bearer. Nonguarders include fishes that do not protect their eggs and young upon completion of spawning and may be classified into two groups: open spawners or brood hiders. Open spawners scatter their eggs in the environment, either in the water column (pelagic spawners) or on the bottom over rocks, sand, or plants (benthic spawners). Brood hiders conceal their eggs during spawning either by burying them in the substrate (benthic spawners), or by depositing them in crevices of rocks or logs (crevice spawners). Brood hiders may prepare spawning sites (e.g., trout redds) but do not guard the site once spawning is completed. Coarse substrate includes gravel and larger size categories, and fine substrate, sand and mud. Plant spawners deposit eggs on or over living plants or organic debris. Guarder/nesters build a nest and guard the embryos until they hatch and may continue guarding the larval or even juvenile stages. Nests may be constructed of coarse or fine substrate, of plant-material, or in cavities formed by rocks, logs, old muskrat burrows, or discarded cans (cavity nests). Bearers carry the eggs or young with them. Gill-chamber brooders are fishes in which fertilization is external, but after spawning, eggs are taken through the mouth and incubated in the gill chamber until hatching. Livebearers are fertilized internally and females carry the developing embryos internally until they are born as well-developed juveniles.

At the end of the Reproductive Habits section for each sensitive fish species, parenthetical descriptive terms (Page 1985, Johnston and Page 1992) are used to describe egg-placement strategies and prespawning substrate preparation. The use of the nests or redds of other genera by species known to be nest associates also are given. There is a degree of overlap in the classification terms and the parenthetical descriptors, but both are useful in comparing reproductive habits among species.

Six descriptors are used to describe modes of egg deposition: broadcaster, strander, egg-burier, egg-attacher, egg-clumper, and egg-clusterer. For the first four, no parental care is given the eggs, but in egg-clumpers and egg-clusterers, usually one parent, most often the male, guards the eggs until hatching (Page 1985). Broadcasters scatter eggs over the surface of the substrate. Standers encase eggs in long gelatinous strands. Egg-buriers release eggs just below the substrate or cover the eggs with bottom material in the course of spawning activities. Egg-attachers place eggs singly or in groups of two to three on rocks, plants, logs, or other debris. Egg-clumpers deposit eggs in multi-layered clumps between the substrate and an overlying object (e.g., rock, log). Egg-clusterers deposit eggs in a single layer on the underside of rocks, logs, or other objects.

Four descriptors are used for fishes that prepare the substrate prior to spawning: saucer-builder, pit-builder, pit-ridge-builder, and mound-builder (Johnston and Page 1992). The distinction between saucer-builders and pit-builders is often arbitrary because both may prepare circular or semi-circular depressions for spawning activities that may be rimmed with a lip of displaced substrate. The term pit-builder is used for fishes that primarily use the mouth or snout to dig the depression and saucer-builder for those that mostly rely on fin-waving for excavation. Pit-ridge-builders excavate stones with their mouths and pile them immediately upstream. Spawning occurs in the pit, the eggs are covered, and with continued spawning, the pit is extended downstream. Eventually, a longitudinal ridge of gravel is constructed as the location of the spawning pit moves downstream. Mound-builders move stones with their mouths into piles or mounds extending some 19 cm above the stream bottom; they then spawn on the sides or tops of the mounds, and cover the eggs with stones.

Mussel reproductive traits are classified according to the period in which female mussels release larvae and the strategy by which females may facilitate successful larval parasitization of appropriate host fishes. Freshwater mussels are unique among bivalves in undergoing a brief parasitic stage as larvae during which time the larvae (glochidia) live on the gills of a fish host (or, for one species, a salamander) and derive nutrition for development from the fish's blood. Mussel/fish host relationships are often specific, and parasitization of the proper fish species is required for transformation of glochidia to juvenile mussels. Glochidia are brooded by the female mussel in the gills until they are mature and able to parasitize fish. North American mussels show two distinct modes of brooding, long-term and short-term brooding. <u>Long-term brooders</u> fertilize eggs in the summer or fall and brood glochidia over the winter and release glochidia in the spring. <u>Short-term brooders</u> fertilize eggs in the spring or summer and release glochidia in the summer or fall. Mussel species have at least three distinct strategies to facilitate glochidial parasitization of the proper fish host. <u>Generalists</u> are mussel species that use a wide variety of fish species as hosts and often release glochidia in long, stringy masses of mucous that ensnare fish indiscriminately. <u>Displaying specialists</u> use only one or a few closely related fish species and females display modified anatomical structures that resemble small fish or other prey items and attract potential fish to the female mussel. Similarly, <u>non-displaying specialists</u> use only a narrow range of hosts, but have no specialized structures to attract host fishes to the female; rather, these species release glochidia in small packages that resemble insect larvae, larval fish, fish eggs, or other food items of small fishes.

For many species, reproductive activities are unknown, and these are indicated in the accounts. For others, reproductive habits have been judged from indirect or circumstantial evidence or extrapolated from reproductive strategies of putative relatives. These cases are indicated by including "needs confirmation" in parentheses following the account. Even with the seeming wealth of literature on reproduction in southeastern United States fishes, for most of the Kentucky fish fauna many details of reproductive habits are lacking, are entirely anecdotal, are based on one or few observations of spawnings, or are laboratory studies without field confirmation. Reproduction in mussels is even less well documented.

Fishes: United States Fish and Wildlife Service

Notropis albizonatus (palezone shiner): USFWS-E; AFS-T; KNP-E; DB-E.
Habitat: Occurs in upland streams on the eastern edge of the Highland Rim and Cumberland Plateau that have permanent flow, clean, clear water and substrates of mixed with cobble, pebble, gravel, and sand bottoms. Primarily inhabits transitional areas between pools and riffles (Poly 1997). Riverine System-upland stream and river subsystem. Substrate-cobble, pebble, gravel, and sand.
Reproductive Habits: Nonguarder, open, benthic, coarse or fine substrate spawner (unconfirmed).
Hydrologic Units: Big South Fork.
Status: Cumberland-Tennessee River endemic. Sporadic, but locally common, in Little South Fork Cumberland River. This population represents one of only two extant populations in the world with the other two known historical populations being extirpated (Warren et al. 1994).

Phoxinus cumberlandensis (blackside dace): USFWS-T; AFS-E; KNP-T; DB-T.
Habitat: Confined to small, upland creeks (usually 300-500 m in elevation), 2-5 m wide in the southern Cumberland Plateau and Cumberland Mountains. Typically in sluggish pools, 0.3-1.0 m deep, with bedrock, gravel, or sand and detritus substrates, often in association with undercut banks, brush, or slab rocks. Streams inhabited are shaded and cool, seldom exceeding 23C. Riverine System-upland headwater creek subsystem. Substrate-bedrock, cobble, pebble, gravel, sand, and organic debris. Vegetation/Cover: instream shelter.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate spawner (nest associate of Campostoma and Semotilus)(Starnes and Starnes 1981, Cicerello and Laudermilk 1996).
Hydrologic Units: Upper Cumberland River, Rockcastle River, Cumberland River-Buck Creek.
Status: Cumberland River endemic. Occasional, but can be locally common in isolated headwater streams, with most populations above Cumberland Falls.

Etheostoma percnurum (duskytail darter): USFWS-E; AFS-T; DB-E.

Habitat: Primary habitat includes clear, silt-free rocky pools above riffles with cover of cobbles and slabrocks (Burr and Eisenhower 1996). Riverine System-upland stream and river subsystem. Substrate-boulder, cobble, pebble, and gravel.
Reproductive Habits: Guarder/nester, cavity nester (egg-clusterer)(Layman 1984, 1991).
Hydrologic Units: Big South Fork.
Status: Cumberland-Tennessee River endemic. The Big South Fork harbors the only known population of this species in the entire Cumberland River drainage. In the Big South Fork the species is sporadic but occurs in greatest numbers from about the mouth of Difficulty Creek downstream to the mouth of Oil Well Branch (Burr and Eisenhower 1996).

Fishes: American Fisheries Society

Acipenser fulvescens (lake sturgeon): AFS-T; KNP-E; DB-S.
Habitat: Little is known of the habitat of this species in Kentucky, except that it occurs in big, flowing rivers with a firm sand/gravel bottom. Riverine System: upland stream and river subsystems. Substrate: cobble, pebble, gravel, and sand.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate spawner.
Hydrologic Units: Upper Cumberland River (below the Falls).
Status: Considered extirpated and known only from a specimen taken in 1954 from the Cumberland River, McCreary County.

Polyodon spathula (paddlefish): AFS-SC; DB-CS.
Habitat: Requires quiet or slow-moving waters rich in zooplankton on which it feeds. Large flowing rivers and big rivers with oxbows and backwaters are characteristic habitats; must have access to gravel bars subject to sustained flooding during spring months for spawning. Also in backwaters and embayments of man-made impoundments. Lacustrine System- reservoir and floodplain lake and oxbow subsystems. Riverine System- upland stream and river subsystems. Substrate-pebble, gravel, sand, and mud.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate spawner.
Hydrologic Units: Licking River, Kentucky River-Red River, Upper Cumberland River (below the Falls).
Status: Sporadic and rare, but may be taken in spring from the mainstems of rivers.

Hemitremia flammea (flame chub): AFS-SC; KNP-X.
Habitat: Little is known of the habitat of this fish in Kentucky waters, although it was apparently restricted to spring-fed creeks and streams of the Cumberland Plateau. Riverine System-spring, upland headwater creek, and upland stream and river subsystems. Substrate- gravel, sand, mud, and organic debris. Vegetation/Cover- aquatic bed and instream shelter.
Reproductive Habits: Unknown.
Hydrologic Units: Upper Cumberland River.

Status: Considered extirpated. Reported to be abundant in Big Laurel River, Laurel County, and also collected in Clear Fork and Wolf Creek near Pleasant View, Whitley County in the 1880s. There are no reports of this species in Kentucky since that time (Burr and Warren 1986).

Ammocrypta pellucida (eastern sand darter): AFS-T; KNP-S; DB-S.
Habitat: Primarily occurs in upland streams and rivers where it is most often taken in moderate current over small gravel and sand substrates. Usually avoids the swiftest portions of riffles and heavily silted substrates, frequenting the less turbulent, but clean-swept margins of the main current. Riverine System- upland/lowland stream and river and big river subsystems. Substrate- gravel and sand.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse or fine substrate spawner (egg-burier).
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River, Kentucky River-Red River.
Status: Sporadic and rare in most drainages; occasional and locally common in Middle Fork and South Fork Kentucky River (R. R. Cicerello, personal communication, Kentucky State Nature Preserves Commission).

Crystallaria asprella (crystal darter): AFS-SC; KNP-X.
Habitat: Little is known of the habitat of this species in Kentucky. Riverine System- upland stream and river and big river. Substrate-gravel and sand.
Reproductive Habits: Unknown (but see George et al. 1996).
Hydrologic Units: Big South Fork.
Status: May be extirpated. Not collected in Kentucky since 1929 (Green River drainage)(Burr and Warren 1986); represented in the Big South Fork by an unsubstantiated record from the 1800s (Starnes and Etnier 1993, Brooks M. Burr, personal communication, Southern Illinois University). Potential habitat exists for the species in the Big South Fork mainstem of Kentucky.

Etheostoma cinereum (ashy darter): AFS-SC; KNP-T*; DB-S.
Habitat: Primarily occurs in clear, upland streams and rivers on the Highland Rim and along the Pottsville Escarpment bordering the western margin of the Cumberland Plateau. Individuals are most often taken near shore in slow to moderate current, above or below riffles and associated with cover in the form of boulders, tree snags, or stands of water willow with substrates of sand and gravel mixed with organic debris. Riverine System- upland stream and river subsystem. Substrate- gravel, sand, and organic debris. Vegetation/Cover: emergent and instream shelter.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate or plant spawner (egg-attacher).
Hydrologic Units: Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland-Tennessee River endemic. Occasional and locally common in Rockcastle River and Big South Fork; sporadic and rare in Buck Creek, where it was recently rediscovered

(P. Ceas and G. Schuster, Eastern Kentucky University, personal communication) after an absence from collections in that drainage since the late 1960s (Shephard and Burr 1984; Cicerello and Butler 1985; Burr and Warren 1986). *Reclassified as special concern as this report was in late stages of preparation (Kentucky State Nature Preserves Commission. 1997.)

Etheostoma maculatum (spotted darter): AFS-SC; KNP-T; DB-S.
Habitat: Primarily inhabits large streams and rivers of the Highland Rim and Cumberland Plateau. Occurs in riffles and shoals with rapid flow and substrates of boulder, cobble, and pebble. Riverine System-upland stream and river subsystem. Substrate-boulder, cobble, pebble, and gravel.
Reproductive Habits: Guarder/nester, cavity nest (egg-clumper).
Hydrologic Units: Middle Fork Kentucky River.
Status: May be extirpated. Sporadic and rare in upper Kentucky River; discovered in the 1980s in North Fork Kentucky River lending credence to unsubstantiated records from the Middle Fork Kentucky River in the late 1950s (Clay 1975).

Etheostoma nigrum susanae (Cumberland johnny darter): AFS-T; KNP-T; DB-S.
Habitat: Most frequently associated with sand or sand-laden bedrock substrates in headwater creeks or streams in areas of slow to moderate current. Riverine System-upland headwater creek and upland stream and river subsystem. Substrate-gravel and sand.
Reproductive Habits: Guarder/nester, cavity nester (egg-clusterer).
Hydrologic Units: Upper Cumberland River (above the Falls).
Status: Cumberland River endemic. Sporadic and rare and only known from above Cumberland Falls.

Percina burtoni (blotchside logperch): AFS-SC; KNP-X; DB-S.
Habitat: Usually associated with clear streams harboring a diverse ichthyofauna, implying near pristine conditions may be necessary for its survival. Occurs over clean gravel in areas of slow to moderate current. Riverine System-upland stream and river subsystem. Substrate-boulder, cobble, pebble, and gravel.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse substrate spawner (egg-burier)(needs confirmation).
Hydrologic Units: Big South Fork.
Status: Cumberland-Tennessee River endemic. Considered extirpated. Known only from the Little South Fork Cumberland River, where its presence has not been confirmed in over 100 years.

Percina macrocephala (longhead darter): AFS-T; KNP-T; DB-S.
Habitat: Clear, upland streams and rivers of the Highland Rim and Appalachian Plateaus. Often associated with boulder and cobble-strewn flowing pools and the areas above and below deep, fast

riffles underlain with cobble. Riverine System-upland stream and river subsystem. Substrate-boulder, cobble, and pebble.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse substrate spawner (egg-burier)(needs confirmation).
Hydrologic Units: South Fork Kentucky River, Big South Fork.
Status: Considered extirpated. Not collected in forest waters since the turn of the century.

Fishes: Kentucky State Nature Preserves Commission

Ichthyomyzon fossor (northern brook lamprey): KNP-T; DB-CS.
Habitat: Adults and ammocoetes occur in small and medium-size upland streams of the Appalachian Plateaus. Adults require clean, clear riffles and glides with sand/gravel bottoms for spawning; ammocoetes require quiet water with a mixture of sand, silt, and debris-ridden substrates. Riverine System-upland stream and river subsystem. Substrate-pebble, gravel, sand, mud, and organic debris.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse substrate spawner (pit-builder)(pit associate of other Ichthyomyzon spp.).
Hydrologic Units: Middle Fork Kentucky River, South Fork Kentucky River, Kentucky River-Red River.
Status: Glacial Relict. Occasional and uncommon in upper Kentucky River drainages.

Ichthyomyzon greeleyi (mountain brook lamprey): KNP-T; DB-S.
Habitat: Adults and ammocoetes occur in small and medium-size upland streams of the Appalachian Plateaus. Adults require clean, clear riffles and glides with sand/gravel bottoms for spawning; ammocoetes require quiet water with a mixture of sand, silt, and debris-ridden substrates. Riverine System-upland stream and river subsystem. Substrate-pebble, gravel, sand, mud, and organic debris.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse substrate spawner (pit-builder).
Hydrologic Units: Rockcastle River, Big South Fork.
Status: Sporadic and rare in Rockcastle River, occasional in Little South Fork.

Lampetra appendix (American brook lamprey): KNP-T; DB-CS.
Habitat: Adults inhabit glides, riffles, and flowing margins of medium to large-size upland streams and rivers with permanent flow and clear water, and bottoms of mixed gravel, sand, and sediment. Ammocoetes occur in pools and backwater areas where they bury themselves in sand and sediment. Riverine System-upland stream and river subsystem. Substrate-pebble, gravel, sand, mud, and organic debris.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse substrate spawner (pit-builder).
Hydrologic Units: Licking River (potential), Middle Fork Kentucky River, South Fork Kentucky River (potential), Kentucky River-Red River.

Status: Sporadic and rare and only represented in the entire Kentucky River by populations within forest proclamation boundaries.

Clinostomus funduloides (rosyside dace): KNP-SC.
Habitat: Frequents small, upland headwater creeks and streams of the Highland Rim with clear cool waters and a variety of bottom types including cobble, pebble, gravel, and sand. Generally in pools with moderate current, especially those pools with undercut banks or tangled roots. Riverine System-upland headwater creek and upland stream and river subsystems. Substrate-cobble, pebble, gravel, and sand.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate spawner (nest associate of *Campostoma* and *Nocomis*).
Hydrologic Units: Big South Fork (suspected introduction).
Status: Introduced or native status in Big South Fork (Little South Fork and Rock Creek), where the species is rare, is equivocal (Burr et al. 1990).

Erimystax insignis (blotched chub): KNP-E; DB-CS.
Habitat: Occupies medium to large-size streams and rivers primarily on the Highland Rim where there is continuous flow, clear water, and gravel or rocky bottoms. Generally found in pools above or below riffles (sometimes in the riffles themselves) in water less than 1-m deep. Riverine System-upland stream and river subsystem. Substrate-cobble, pebble, gravel, and sand.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate spawner (Harris 1986).
Hydrologic Units: Big South Fork.
Status: Cumberland-Tennessee River endemic. Known from one population in Big South Fork (Little South Fork) where the species is sporadic and uncommon. Of five drainages harboring the species historically in Kentucky, only two, including the Little South Fork continue to support the species.

Notropis sp. cf. *spectrunculus* (sawfin shiner): KNP-E; DB-S.
Habitat: Inhabits clear, cool, upland streams on the eastern edge of the Highland Rim and Cumberland Plateau, occurring in pools with noticeable current or glides over a rocky bottom. Riverine System-upland stream and river subsystem. Substrate-cobble, pebble, gravel, and sand.
Reproductive Habits: Unknown.
Hydrologic Units: Big South Fork.
Status: Cumberland-Tennessee River endemic. Sporadic and rare and known from two populations in Big South Fork (Little South Fork and Rock Creek). Formerly common in Little South Fork, but recent surveys indicate the species has declined precipitously (Poly 1997). These represent two of three known populations in Kentucky.

Phenacobius uranops (stargazing minnow): KNP-SC.

Habitat: Occupies streams of moderate to high gradient, permanent flow, clear water, and bottoms of clean pebble and gravel on the Highland Rim and Cumberland Plateau. Invariably in riffles or runs at depths of 15-50 cm. Young often near beds of water willow or in the margins of flowing pools. Riverine System-upland stream and river subsystem. Substrate-pebble and gravel.
Reproductive Habits: Unknown.
Hydrologic Units: Rockcastle River.
Status: Cumberland-Tennessee-Green River endemic. May be extirpated. Sporadic and rare in Rockcastle River where it was last taken in 1955.

Moxostoma lacerum (harelip sucker): KNP-X.
Habitat: Inhabited pools in clear waters of upland streams and rivers with silt-free, rocky substrates. Riverine System-upland stream and river subsystem. Substrate-cobble, pebble, and gravel.
Reproductive Habits: Unknown.
Hydrologic Units: Rockcastle River, Big South Fork.
Status: Extinct. Known from two localities each in the Big South Fork (Little South Fork) and Rockcastle River. Last taken in forest waters in 1891.

Noturus exilis (slender madtom): KNP-E.
Habitat: Occupies riffles and flowing pools of small to medium-size streams and rivers over a pebble and gravel bottom. Riverine System-upland stream and river subsystem. Substrate-cobble, pebble, and gravel.
Reproductive Habits: Guarder/nester, cavity nest.
Hydrologic Units: Big South Fork (potential).
Status: Known only from the Tennessee portion of the Big South Fork (Etnier and Starnes 1993), where the species is rare and may be extirpated.

Noturus stigmosus (northern madtom): KNP-SC; DB-CS.
Habitat: Characteristic of large streams and rivers where it frequents areas of moderate to swift current over a gravel/sand bottom. In these habitats, sometimes associated with pondweed and accumulated debris. Riverine System-upland stream and river subsystem. Substrate-pebble, gravel, sand, and organic debris.
Reproductive Habits: Guarder/nester, cavity nest.
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River.
Status: Occasional and locally common in Licking River; sporadic and uncommon in Middle Fork and South Fork Kentucky River (R. R. Cicerello, personal communication, Kentucky State Nature Preserves Commission). Most known localities for the species in the Licking and Kentucky river drainages are within or near forest proclamation boundaries.

Percopsis omiscomaycus (trout-perch): KNP-SC.

Habitat: Frequently captured from clear, deep pools and glides over a sand or mixed sand/gravel substrate in upland streams. Moves from pools into shallow water at night. Riverine System-upland stream and river subsystem. Substrate-gravel and sand.
Reproductive Habits: Nonguarder, open, benthic, coarse or fine substrate spawner.
Hydrologic Units: Licking River.
Status: Glacial relict. May be extirpated. Known from two records from the late 1930s in the Licking River (North Fork Triplett and Slate Lick creeks) but has not been reported from these drainages since that time although potential habit exists in the drainage.

Typhlichthys subterraneus (southern cavefish): KNP-SC; DB-S.
Habitat: An obligate cave dweller in the karst region of the Highland Rim, inhabiting cool (10-14C), lentic cave waters over mixed gravel, sand, and mud substrates. Riverine System-cave stream subsystem. Substrate-gravel, sand, and mud.
Reproductive Habits: Bearer, gill-chamber brooder (needs confirmation).
Hydrologic Units: Cumberland River-Buck Creek.
Status: Known from a single cave system in Pulaski County, Kentucky. This population differs in a number of features from populations to the southeast in Tennessee and may represent an undescribed taxon.

Etheostoma sagitta spilotum (Kentucky arrow darter): KNP-SC; DB-CS.
Habitat: Restricted to upland creeks and streams of the Cumberland Plateau. Generally a headwater creek inhabitant, but juveniles and occasionally adults may be taken in streams. Occupies sluggish pools or areas above and below riffles over substrates of bedrock, cobble, and pebble; avoids rapid currents. Riverine System-Upland headwater creek and upland stream and river subsystems. Substrate-bedrock, cobble, and pebble.
Reproductive Habits: Unknown (but see Lowe 1979).
Hydrologic Units: Middle Fork Kentucky River, South Fork Kentucky River, and Kentucky River-Red River.
Status: Kentucky River endemic. Occasional and locally common in Middle and South Forks Kentucky River; sporadic and rare in Kentucky River-Red River, where it is known only from Red River. About half of the entire range of this endemic lies within forest proclamation boundaries.

Etheostoma tippecanoe (Tippecanoe darter): KNP-SC*; DB-CS.
Habitat: Inhabitant of upland rivers of the Highland Rim and Cumberland Plateau. Occurs in moderate to rapid currents of long, shallow gravel riffles. Riverine System-Upland stream and river subsystems. Substrate-pebble and gravel.
Reproductive Habits: Nonguarder, brood hider, benthic coarse substrate spawner (egg-burier)(Warren et al. 1986).

Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River, and Big South Fork.
Status: Sporadic and generally uncommon in Big South Fork; occasional and may be seasonally common in Licking River; occasional and locally common in Middle Fork and South Fork Kentucky River. *Considered currently stable in Kentucky and was delisted during late stages of preparation of this report (Kentucky State Nature Preserves Commission. 1997.)

Percina evides (gilt darter): KNP-SC*; DB-CS.
Habitat: Occurs primarily in upland streams, rivers, and big rivers of the Highland Rim, and Appalachian Plateaus. Adults are often taken in riffles of rapid current over cobble, pebble, and gravel substrates; young frequently dwell in shallow riffles of slow to moderate current with gravel substrates. Riverine System-Upland stream and river subsystems. Substrate-cobble, pebble, and gravel.
Reproductive Habits: Nonguarder, brood hider, benthic coarse substrate spawner (egg-burier).
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River, and Big South Fork.
Status: Sporadic in occurrence in most DBNF waters; occasional and locally common in Middle Fork and South Fork Kentucky River.
*Considered currently stable and was delisted during late stages of preparation of this report (Kentucky State Nature Preserves Commission. 1997.)

Fishes: Daniel Boone National Forest

Ichthyomyzon bdellium (Ohio lamprey): DB-CS.
Habitat: Parasitic adults frequent medium to large-size streams and rivers but may be found in small streams depending on the host to which they are attached. Small to medium-size streams are ascended by adults for spawning. Ammocoetes occur in pools and backwaters of the spawning streams in mud covered with sticks, branches, and other debris. Lacustrine System-Reservoir subsystem. Riverine System-Upland stream and river subsystems. Substrate-cobble, pebble, gravel, sand, mud, and organic debris.
Reproductive Habits: Nonguarder, brood hider, benthic, coarse substrate spawner (pit-builder).
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River, Kentucky River-Red River (potential), Rockcastle River, Cumberland River-Buck Creek, and Big South Fork.
Status: Sporadic and uncommon in the Cumberland, Kentucky, and Licking river units; appears to be most common in some Cumberland and Kentucky river units but is seldom taken in numbers.

Clinostomus elongatus (redside dace): DB-CS.

Habitat: Restricted primarily to small, upland headwater creeks of the Appalachian Plateaus with clear, cool water and cobble, pebble, gravel, and sand substrates. Pools less than 2 m deep with moderate current and cover in the form of brush, roots, and undercut banks are frequented. Riverine System-upland headwater creek subsystem. Substrate-cobble, pebble, gravel, and sand.
Reproductive Habits: Nonguarder, open, benthic, coarse substrate spawner (nest associate of *Nocomis, Semotilus*, and *Luxilus*).
Hydrologic Units: Licking River, Kentucky River-Red River units.
Status: Glacial relict. Occasional and locally common in North Fork Red River and tributaries of the Licking River (Meade et al. 1986). Most known populations of this species within Kentucky occur within the DBNF proclamation boundaries

Mussels: United States Fish and Wildlife Service

Alasmidonta atropurpurea (Cumberland elktoe): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Found in shallow, low gradient pools with silt and sand (Rock and Marsh creeks) or in riffles with sand and gravel (Rock Creek, Big South Fork). Riverine System-upland headwater creek and stream and river subsystem.
Known Hosts: *Hypentelium nigricans* (northern hogsucker)(Gordon and Layzer 1993).
Reproduction: Long-term brooder, generalist (needs confirmation).
Hydrologic Units: Upper Cumberland River, Big South Fork.
Status: Cumberland River endemic. Generally distributed in Marsh Creek (Upper Cumberland River unit) and Rock Creek (Big South Fork unit); sporadic in Big South Fork mainstem.

Epioblasma brevidens (Cumberland combshell): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Occurs in riffles or pool margins in sand and gravel. Riverine System-upland stream and river subsystem.
Known Hosts: *Etheostoma blennioides* (greenside darter), *E. rufilineatum* (redline darter), E. simoterum (Tennessee snubnose darter), *E. vulneratum* (wounded darter), *Percina caprodes* (logperch), *Cottus carolinae* (banded sculpin)(Yeager and Saylor 1996).
Reproduction: Long-term brooder, Displaying host-specialist (needs confirmation).
Hydrologic Units: Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland-Tennessee River endemic. Occasional in Big South Fork mainstem and Buck Creek. Considered extirpated from Rockcastle and Upper Cumberland (below the Falls) river mainstems.

Epioblasma capsaeformis (oyster mussel): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Found in riffles or in water willow (Justicia americana) beds adjacent to riffles in sand and gravel. Riverine System-upland stream and river subsystem.

Known Hosts: *Etheostoma rufilineatum* (redline darter), *E. vulneratum* (wounded darter), *Percina sciera* (dusky darter), *Cottus carolinae* (banded sculpin)(Yeager and Saylor 1996).
Reproduction: Long-term brooder, Displaying host-specialist.
Hydrologic Units: Upper Cumberland (below the Falls) River, Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland/Tennessee River endemic. Occasional in Big South Fork mainstem; sporadic in Buck Creek. Considered extirpated from Rockcastle and Cumberland river mainstems.

Epioblasma torulosa rangiana (northern riffleshell): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Found in riffles in sand and gravel. Riverine System-upland stream and river subsystem.
Known Hosts: *Etheostoma zonale* (banded darter), *E. camurum* (bluebreast darter), *Salmo trutta* (brown trout), *Cottus carolinae* (banded sculpin)(Watters 1996).
Reproduction: Long-term brooder, Displaying host-specialist (needs confirmation).
Hydrologic Units: No records.
Status: There are no recent or historical records for this species in the Forest proclamation boundaries. However, this species is known historically from the upper Kentucky River drainage and the Licking River downstream of the Forest. This species likely occurred in the upper Licking and Kentucky river drainages and the absence of records in these areas is probably due to the lack of surveys that took place before alteration of these streams. Suitable habitat may exist for re-introduction.

Pegias fabula (little-wing pearlymussel): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Found in riffles in sand and gravel, often one or more individuals found under large, flat rocks. Riverine System-upland headwater creek and upland stream and river subsystems.
Known Hosts: *Etheostoma blennioides* (greenside darter), *E. baileyi* (emerald darter)(J. Layzer, Tennessee Technological University, unpublished data).
Reproduction: Long-term brooder, mode of glochidial release unknown.
Hydrologic Units: Rockcastle, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland/Tennessee River endemic. Occasional in Horse Lick Creek (Rockcastle River unit), Big South Fork mainstem, and Little South Fork; sporadic or extirpated in Rockcastle River mainstem and Buck Creek.

Pleurobema clava (clubshell): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Found in riffles in sand and gravel. Riverine System-upland stream and river subsystem.
Known Hosts: Unknown.
Reproduction: Short-term brooder, Nondisplaying host-specialist (needs confirmation).
Hydrologic Units: No records.

Status: The historical range of this species probably overlapped closely with Epioblasma torulosa rangiana. Similarly, there are no recent or historical records for this species within the Forest proclamation boundaries. However, this species is known historically from the upper Kentucky River drainage and the Licking River downstream of the Forest. This species likely occurred in the upper Licking and Kentucky river drainages and the absence of records in these areas is probably due to the lack of surveys that took place before alteration of these streams. Suitable habitat may exist for re-introduction.

Villosa trabalis (Cumberland Bean): USFWS-E; AFS-E; KNP-E; DB-E.
Habitat: Found in riffles in sand and gravel or slow-moving shallow pools in sand and silt. Riverine System-upland stream and river subsystem.
Known Hosts: *Etheostoma flabellare* (fantail darter), *E. virgatum* (striped darter), *E. obeyense* (barcheek darter), and *E. kennicotti* (stripetail darter)(J. Layzer, Tennessee Technological University, unpublished data).
Reproduction: Long-term brooder, Displaying host-specialist (needs confirmation).
Hydrologic Units: Upper Cumberland (below the Falls) River, Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland-Tennessee River endemic. Generally distributed in Buck Creek; occasional in Big South Fork, Little South Fork (Big South Fork unit), and Horse Lick Creek (Rockcastle River unit); sporadic in Rockcastle mainstem.

Mussels: American Fisheries Society, Kentucky State Nature Preserves Commission, and Daniel Boone

Anodontoides denigratus (Cumberland papershell): KNP-E; DB-PS.
Habitat: Found in shallow, low gradient pools with silt and sand. Riverine System-upland headwater creek subsystem.
Known Hosts: Unknown.
Reproduction: Long-term brooder, generalist (needs confirmation).
Hydrologic Units: Upper Cumberland (above the Falls) River.
Status: Cumberland River endemic. Generally distributed in Marsh Creek.

Alasmidonta marginata (elktoe): AFS-SC; KNP-T; DB-C.
Habitat: Riverine System-upland stream and river subsystem.
Known Hosts: *Hypentelium nigricans* (northern hogsucker); *Moxostoma macrolepidotum* (shorthead redhorse); *Catostomus commersoni* (white sucker); *Ambloplites rupestris* (rock bass); *Lepomis gulosus* (warmouth)(all need confirmation) (Howard and Anson 1923).
Reproduction: Long-term brooders, generalist.

Hydrologic Units: Licking River, Kentucky River-Red River, Upper Cumberland (below the Falls) River, Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: generally distributed in the Red River; occasional in Horse Lick Creek (Rockcastle River unit); sporadic in the Little South Fork (Big South Fork unit); sporadic or extirpated in the Rockcastle and Cumberland river mainstems and the upper Licking River.

Epioblasma triquetra (snuffbox): AFS-T; KNP-SC; DB-S.
Habitat: Found in riffles or pool margins in sand and gravel. Riverine System-upland stream and river subsystem.
Known Hosts: *Percina caprodes* (logperch), *Cottus carolinae* (banded sculpin)(Yeager and Saylor 1995).
Reproduction: Long-term brooder, Displaying host-specialist (needs confirmation).
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River,Kentucky River-Red River, Cumberland River-Buck Creek, Big South Fork.
Status: Occasional to sporadic in all units except Big South Fork where it is considered extirpated.

Fusconaia subrotunda (long-solid): AFS-SC; KNP-T; DB-C.
Habitat: Found in deep, swift riffles and shoals in sand and gravel substrate. Riverine System-upland stream and river subsystem.
Known Hosts: Unknown.
Reproduction: Short-term brooder, Nondisplaying host-specialist (needs confirmation).
Hydrologic Units: South Fork Kentucky River, Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Rare in South Fork Kentucky River; considered extirpated in Rockcastle River, Cumberland River-Buck Creek, and Big South Fork units.

Plethobasus cyphyus (sheepnose): AFS-T; KNP-SC; DB-E.
Habitat: Found in deep, swift riffles and shoals in sand and gravel substrate. Riverine System-upland stream and river subsystem.
Known Hosts: *Stizostedion canadense* (sauger)(needs confirmation) (Surber 1913; Wilson 1916).
Reproduction: Short-term brooder, Nondisplaying host-specialist (needs confirmation).
Hydrologic Units: Licking River.
Status: Sporadic in the Licking River.

Pleurobema oviforme (Tennessee clubshell): AFS-SC; KNP-E; DB-S.
Habitat: Found in riffles in sand and gravel or slow-moving shallow pools in sand and silt. Riverine System-upland stream and river subsystem.

Known Hosts: *Campostoma anomalum* (central stoneroller), *Luxilus chrysocephalus* (striped shiner), *Nocomis micropogon* (river chub), *Cyprinella galactura* (whitetail shiner), *Etheostoma flabellare* (fantail darter)(Weaver et al. 1991).
Reproduction: Short-term brooder, Nondisplaying host-specialist.
Hydrologic Units: Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland-Tennessee River endemic. Occasional to sporadic in Horse Lick Creek (Rockcastle River unit), Buck Creek, Big and Little South Forks; sporadic or extirpated in Rockcastle River mainstem.

Ptychobranchus subtentum (fluted kidneyshell): AFS-SC; KNP-T; DB-C.
Habitat: Found in riffles in sand and gravel or slow-moving shallow pools in sand and silt. Riverine System-upland stream and river subsystem.
Known Hosts: Unknown.
Reproduction: Long-term brooder, Nondisplaying host-specialist.
Hydrologic Units: Upper Cumberland (below the Falls) River, Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Cumberland-Tennessee River endemic. Generally distributed in Little South Fork and Rock Creek (Big South Fork unit); occasional in Horse Lick Creek (Rockcastle River unit) and Buck Creek; sporadic in Big South Fork; sporadic or extirpated in Rockcastle and Cumberland river mainstems.

Simpsonaias ambigua (salamander mussel): AFS-SC; KNP-T; DB-S.
Habitat: Found in deep riffles or flowing pools, usually under large, flat rocks. Riverine System-upland stream and river subsystem.
Known Hosts: *Necturus maculosa* (mudpuppy) (Howard 1915, Arey 1932).
Reproduction: Long-term brooder (needs confirmation), mode of glochidial release unknown.
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River, Kentucky River-Red River.
Status: Sporadic to occasional in all units. Status difficult to ascertain because difficulty in locating individuals under rocks.

Toxolasma lividus (purple lilliput): AFS-SC; KNP-E; DB-S.
Habitat: Found in riffles in sand and gravel or slow-moving shallow pools in sand and silt. Riverine System-upland stream and river subsystem.
Known Hosts: *Lepomis cyanellus* (green sunfish) and *L. megalotis* (longear sunfish) (Gooch 1986).
Reproduction: Long-term brooder, Displaying host-specialist.
Hydrologic Units: Rockcastle River, Cumberland River-Buck Creek, Big South Fork.
Status: Occasional in Horse Lick Creek (Rockcastle River unit), Buck Creek, and Little South Fork; sporadic or extirpated in Rockcastle River mainstem.

Villosa lienosa: AFS-CS; KNP-SC; DNF-C.
Habitat: Found in riffles in sand and gravel or slow-moving shallow pools in sand and silt. Riverine System-upland stream and river subsystem.
Known Hosts: *Lepomis cyanellus* (green sunfish), *L. macrochirus* (bluegill), *Micropterus salmoides* (largemouth bass) (Keller and Ruessler 1997).
Reproduction: Long-term brooder, Displaying host-specialist.
Hydrologic Units: Licking River, Middle Fork Kentucky River, South Fork Kentucky River.
Status: Sporadic in all units.

Appendix 2.Riparian-dependent species found on or near the Daniel Boone National Forest[1.]

Animals

Gastropods

Campeloma decisum	*Campeloma crassula*	*Elimia plicata-striata*
Elimia semicarinata	*Elimia laqueata*	*Elima ebenum*
Ferrissia fragilis	*Ferrissia rivularis*	*Gyraulus parvus*
Helisoma triovlis	*Helisoma anceps*	*Leptoxis praerosa*
Lithasisa obovata	*Lithasia armigera*	*Physella virgata*
Physella heterostropha	*Physella gyrina*	*Physella integra*
Pleurocera curtum	*Pleurocera canaliculatum*	*Pomatiopsis lapidaria*
Rhodacmea elatior		

Decapods

Cambarus bartonii bartonii	*Cambarus diogenes diogenes*	*Cambarus distans*

Cambarus dubius	*Cambarus ortmanni*	*Cambarus parvoculus*
Cambarus robustus	*Cambarus striatus*	*Cambarus tenebrosus*
Cambarus veteranus	*Orconectes australis packardi*	*Orconectes putnami*
Orconectes placidus	*Orconectes rusticus*	*Orconectes bisectus*

Amphibians - Salamanders

Ambystoma barbouri Streamside salamander	*Ambystoma jeffersonianum* Jefferson salamander	*Ambystoma maculatum* Spotted salamander
Ambystoma opacum Marbled salamander	*Ambystoma t. tigrinum* Eastern tiger salamander	*Cryptobranchus alleganiensis* Hellbender (introduced)
Desmognathus fuscus Northern dusky salamander	*Desmognathus monticola* Seal salamander	*Desmognathus ochrophaeus* Mountain dusky salamander
Desmognathus welteri Black Mountain salamander	*Eurycea cirrigera* Southern twoline salamander	*Eurycea longicauda* Longtail salamander
Eurycea lucifuga Kentucky spring salamander	*Gyrinophilus porphyriticus duryi* Cave salamander	*Hemidactylium scutatum* Four-toed salamander
Necturus maculosus Mudpuppy	*Notophthalmus v. viridescens* Spotted newt	*Pseudotriton montanus diastictus* Midland mud salamander
Pseudotriton r. ruber Northern red salamander		

Amphibians - Frogs and Toads

Acris crepitans blanchardi Blanchard's cricket frog	*Bufo a. americanus* American toad	*Bufo woodhousei fowleri* Fowler's toad
Gastrophryne carolinensis Eastern narrowmouth toad	*Hyla chrysoscelis* Cope's gray treefrog	*Pseudacris brachyphona* Mountain chorus frog

Pseudacris c. crucifer Northern spring peeper	*Pseudacris triseriata feriarum* Upland chorus frog	*Rana catesbeiana* Bullfrog
Rana clamitans Green frog	*Rana palustris* Pickerel frog	*Rana sylvatica* Wood frog
Rana utricularia Southern leopard frog	*Scaphiopus holbrookii* Eastern spadefoot	

Reptiles - Snakes

Nerodia s. sipedon Northern water snake	*Thamnophis sauritus* Eastern ribbon snake	*Regina septemvittata* Queen snake

Reptiles - Turtles

Apalone s. spinifer Eastern spiny softshell	*Chelydra s. serpentina* Common snapping turtle	*Chrysemys picta marginata* Midland painted turtle
Graptemys geographica Common map turtle	*Graptemys ouachitensis* Ouachita map turtle	*Pseudemys concinna* River cooter
Sternotherus odoratus Common musk turtle	*Trachemys scripta elegans* Red-eared slider	

Mammals

Castor canadensis Beaver	*Lutra canadensis* River otter	*Mustela vison* Mink
Myotis grisescens Gray bat	*Myotis lucifugus* Little brown bat	*Ondatra zibethicus* Muskrat

Birds

Protonotaria citrea	*Seiurus noveboracensis*	*Seiurus motacilla*

Prothonotary Warbler	Northern Waterthrush	Louisana Waterthrush
Podilymbus podiceps Pied-billed Grebe	*Ardea berodias occidentalis* Great Blue Heron	*Casmerodius albus* Great Egret
Bubulcus ibis Cattle Egret	*Aix sponsa* Wood Duck	*Anas platyrhynchos* Mallard
Lophodytes cucullatus Hooded Merganser	*Pandion haliaetus* Osprey	*Haliaeetus leucocephalus* Bald Eagle
Rallus limicola Virginia Rail	*Porzana carolina* Sora	*Limnothlypis swaninsonii* Swainson's Warbler
Butorides striatus Little-green Heron	*Phalacrocorax auritus* Double-crested Cormorant	*Gallinula chloropus* (?) Common Moorhen
Fulica americana American Coot	*Charadrius semipalmatus* Semipalmated. Plover	*Tringa melanoleuca* Greater Yellowlegs
Tringa solitaria Solitary Sandpiper	*Actitis macularia* Spotted Sandpiper	*Calidris minutilla* Least Sandpiper
Calidris melanotos Pectotral Sandpiper	*Larus philadelphis* Bonaparte's Gull	*Larus delanarensis* Ring-billed Gull
Larus argentatus Herring Gull	*Sterna caspia* Caspian Tern	*Sterna forstri* Forster's Tern
Megaceryle alcyon Belted Kingfisher	*Empidonax alnorum* Alder Flycatcher	*Empidonax traillii* Willow Flycatcher
Iridoprocne bicolor Tree Swallow	*Stelgidopteryx ruficollis* Northern Rough-winged Swallow	*Riparia riparia* Bank Swallow
Anthus spinoletta Water Pipit	Vireo gilvus Warbling Vireo	

Plants[2]

Acorus calamus	Agalinis purpurea	Alisma subcordatum
Apios americana	Arenaria fontinalis	Asclepias incarnata
Aster saxicastellii	Aster prenanthoides	Aster umbellatus
Bartonia paniculata	Bartonia virginica	Bidens aristosa
Bidens cernua	Bidens coronata	Bidens frondosa
Bidens laevis	Bidens tripartita	Bidens vulgata
Boehmeria cylindrica	Boykinia aconitifolia	Calamagrostis cinnioides
Callitriche heterophylla	Callitriche terrestris	Campanula aparinoides
Cardamine bulbosa	Cardamine douglassii	Cardamine pensylvanica
Cardamine rotundifolia	Carex amphibola	Carex baileyi
Carex bromoides	Carex caroliniana	Carex conjuncta
Carex crinita	Carex cristatella	Carex davisii
Carex debilis var. debillis	Carex debilis var. rudgei	Carex festucacea
Carex flaccosperma	Carex frankii	Carex gracillima
Carex granularis	Carex gynandra	Carex intumescens
Carex joorii	Carex laevivaginata	Carex leptalea
Carex louisianica	Carex lupulina	Carex lurida
Carex prasina	Carex scabrata	Carex scioaria
Carex shortiana	Carex squarrosa	Carex stipata

Carex torta	Carex tribuloides	Carex typhina
Carex vulpinoidea	Ceratophyllum demersum	Chelone glabra
Chelone obliqua	Chrysosplenium americanum	Cicuta maculata
Commelina virginica	Cyperus bipartitus	Cyperus esculentus
Cyperus flavescens	Cyperus odoratus	Cyperus pseudovegetus
Cyperus strigosus	Cyperus tenuifolius	Diodia virginiana
Dulichium arundinaceum	Echinochloa colonum	Echinochloa crusgalli
Eclipta prostrata	Eleocharis elliptica	Eleocharis erythropoda
Eleocharis ovata	Eleocharis quadrangulata	Eleocharis verrucosa
Epilobium coloratum	Equisetum hyemale var. affine	Eragrostis hypnoides
Erianthus giganteus	Eupatorium fistulosum	Eupatorium perfoliatum
Fimbristylis autumnalis	Galium obtusum	Galium tinctorium
Glyceria melicaria	Glyceria septentrionalis	Glyceria striata
G ratiola neglecta	Gratiola virginiana	Gratiola viscidula
Helenium autumnale	Helenium flexuosum	Heteranthera limosa
Hibiscus laevis	Hibiscus moscheutos	Hydrocotyle americana
Hymenocallis caroliniana	Hypericum mutilum	Hypericum walteri
Impatiens capensis	Impatiens pallida	Iris virginica
Isoetes engelmannii	Juncus acuminatus	Juncus articulatus
Juncus brachycarpus	Juncus bufonius	Juncus canadensis

Juncus coriaceus	Juncus debilis	Juncus diffusissimus
Juncus dudleyi	Juncus effusus var. solutus	Juncus marginatus
Juncus scirpoides	Juncus torreyi	Juncus americana
Lathyrus palustris	Leersia oryzoides	Leersia virginica
Leptochloa filiformis	Lindernia dubia var. anagallidea	Lindernia dubia var. dubia
Linum striatum	Lippia lanceolata	Lobelia cardinalis
Lobelia nuttallii	Lobelia puberula	Lobelia siphilitica
Lorinseria areolata	Ludwigia alternifolia	Ludwigia decurrens
Ludwigia palustris	Ludwigia peploides ssp. peploides	Lycopus americanus
Lycopus uniflorus	Lycopus virginicus	Lysimachia ciliata
Lysimachia hybrida	Lysimachia lanceolata	Lysimachia nummularia
Lysimachia quadrifolia	Lythrum alatum var. alatum	Mecardonia acuminata
Mentha citrata	Mentha piperita	Mentha spicata
Mimulus alatus	Mimulus ringens	Murdannia keisak
Myosotis laxa	Myosotis scorpioides	Myosurus minimus
Myriophyllum aquaticum	Najas guadalupensis	Nasturtium officinale
Nuphar lutea ssp. macrophylla	Nymphaea odorata	Onoclea sensibilis
Orontium aquaticum	Osmunda cinnamomea	Osmunda regalis var. spectabilis
Oxypolis rigidior	Panicum anceps	Panicum rigidulum

Panicum verrucosum	Parnassia asarifolia	Parnassia grandifolia
Penthorum sedoides P	halaris arundinacea	Physostegia virginiana
Pilea pumila	Platanthera ciliaris	Platanthera clavellata
Platanthera cristata	Plantanthera flava	Platanthera integrilabia
Pluchea camphorata	Podostemum ceratophyllum	Polygonum amphibium var. emersum
Polygonum caespitosum var. longisetum	Polygonum hydropiperoides	Polygonum lapathifolium
Polygonum pensylvanicum	Polygonum punctatum	Polygonum sagittatum
Potamogeton crispus	Potamogeton diversifolius	Potamogeton foliosus
Potamogeton nodosus	Potamogeton pectinatus	Potamogeton pulcher
Proserpinaca palustris	Ranunculus abortivus	Ranunculus ambigens
Ranunculus bulbosus	Ranunculus hispidus	Ranunculus pusillus
Rhynchospora capitellata	Rhynchospora corniculata	Rhynchospora globularis var. gobularis
Rhynchospora glomerata	Rorippa palustris var. fernaldiana	Rorippa sylverstris
Rotala ramosior	Rumex verticillatus	Sabatia angularis
Sabatia campanulata	Sagittaria australis	Sagittaria brevirostra
Sagittaria calycina	Sagittaria latifolia	Samolus parviflorus
Saururus cernuus	Saxifraga michauxii	Scirpus atrovirens var. atrovirens
Scirpus atrovirens	Scirpus cyperinus	Scirpus expansus

var. georgianus

Scirpus pendulus	Scirpus polyphyllus	Scirpus pungens
Scirpus purshianus	Scirpus validus	Scutellaria lateriflora
Selaginella apoda	Sparganium americanum	Sparganium androcladum
Spirodela polyrrhiza	Stachys tenuifolia var. tenuifolia	Teucrium canadense
Thelypteris palustris var. pubescens	Tragiola pilosa	Trautvetteria caroliniensis
Typha latifolia	Utricularia gibba	Veratrum viride
Verbena hastata	Veronica anagallis-aquatica	Veronica peregrina
Viola affinis	Viola cucullata	Viola lanceolata
Viola primulifolia	Viola sagittata	Wolffia brasiliensis
Wolffia columbiana	Xyris torta	Platanus occidentalis
Ilex opaca	Vitas riparia	Vitas rupestris
Salix nigra	Acer negundo	Fraxinus pennsylvanica
Ulmus alata	Ulmus fulva	Cornus amoemum
Cornus alternifolia	Tsuga canadensis	Liriodendron tulipifera
Acer saccharinum	Acer rubrum	Carpinus caroliniana
Ilea virginica	Rhododendron maximum	Rhododendron vaseyi
Dirca palustris	Ilex verticillata	Calycanthus fertilis
Lindera benzoin		

[1]This list is very dynamic; species may be added or deleted over a period of time as new information becomes available.
[2]Some of these plants are not associated entirely with a riparian area but are associated with stream corridors on cliff faces.(i.e. Waterfalls, seeps on cliffs, etc.)

Appendix 3. Aquatic Biota Inventory protocol.

All streams on the DBNF should be inventoried to assess how closely current conditions approximate desired conditions. Reliable inventory techniques should be used to collect baseline data on appropriate physical, chemical, and biological parameters. Because the cost of stream surveys must be considered, stream inventory and monitoring should be based on clearly defined needs and priorities

Water quality - inventory protocols should follow standard Forest Service methods.

Sediment transport - inventory protocols should follow Dissmeyer 1994.

Stream inventory - Follow established inventory protocols such as Basinwide Visual Estimation Techniques (BVET; Hankin and Reeves 1988) for all stream habitat and fish population inventory and monitoring. Specific sample sites should be selected from naturally occurring habitat (e.g. pools, riffles) within stream reaches according to a random-systematic design (see Dolloff et al. 1993).

Ultimately, complete surveys should be conducted on all DBNF streams. These surveys should consist of baseline data and be used to support project level analyses and monitoring. Habitat and aquatic biota components should be selected to address clearly defined objectives such as guidelines identified in the revised forest plan.

Habitat inventories should include variables such as: habitat type (e.g. pool, riffle), length, width, area, maximum depth, average depth, residual pool volume (pools only), dominant substrate, and coarse woody debris loading.

Coarse woody debris should be counted. The location of wood can be identified by hipchain or global positioning system (GPS). Pool-riffle ratio should be calculated from the habitat-area data collected during the inventory.

Protocols for freshwater mussel population inventories are currently being developed by Warren and Haag of the USDA Forest Service Southern Research Station. These methods should be adopted to inventory mussels on the DBNF as they become available.

Fish biodiversity - Historical fish distributions should be collected from appropriate sources and compiled in a geographical information systems (GIS) compatible format. Fish distribution records should be reviewed before conducting new fish inventories to identify streams and sites likely to contain species of conservation interest.

For larger streams, select 1 to 2 % of the pool-riffle combinations within the stream (i.e. one out of 20 pool- riffle combinations for a 5 % sample) for one pass electrofishing surveys. Plot cumulative number of species captured (*y* - axis) by cumulative pool-riffle combination area (*x* - axis) to determine if the sample size is adequate for a cursory estimate of the total fish community. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five habitat-units sampled with no previous unsampled species in the catch). When appropriate, seining techniques, following the protocol of Jenkins and Burkhead (1994) should replace electrofishing in streams suspected of containing threatened or endangered species.

More intensive sampling (see below) should be employed when negative changes in the fish community are detected or when species of conservation interest appear to be absent from a stream or stream section in which they historically occurred.

Fish inventory - A hierarchical approach should be used to determine sampling strategy and intensity. Below is an example outline of a hierarchical strategy for inventorying and monitoring streams on the DBNF.

1) Watersheds Not Containing Species Of Conservation Interest

Systematically select 1 to 2 % of the pool-riffle combinations within the stream (i.e. one out of 20 pool- riffle combinations for a 5 % sample). Collect measurements of the minimum habitat characteristics (see above) and locate sample-sites by hip-chain measurement and physical landmarks or GPS.

In each selected unit use one-pass electrofishing to survey the fish community.

Plot cumulative number of species captured (*y* - axis) by cumulative pool-riffle combination area (*x* - axis) to determine if the sample size is adequate for an acceptable estimate of the total fish community. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five habitat-units sampled with no previous unsampled species in the catch).

2) Watersheds that do not contain Species Of Conservation Interest But Receive High Recreational Use Or Where Management Activities Are Planned

Recommended effort

Complete habitat survey following the protocol of Dolloff et al. (1993). Collect measurements of the minimum habitat characteristics (see above) and locate sample-sites by hip-chain measurement and physical landmarks or GPS.

Conduct three-pass electrofishing removal techniques to inventory fish populations in 20 random-systematically selected pool-riffle combinations.

Summarize population data to be sure population estimates are within two standard deviations of the mean; if not, increase the sample size.

Plot cumulative number of species captured (*y* - axis) by cumulative pool-riffle combination area (*x* - axis) to determine if the sample size is adequate for an acceptable estimate of species richness. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five habitat-units sampled with no previous unsampled species in the catch).

Minimum effort

From a random starting point in the target stream, systematically select 10 pool-riffle combinations. Locate sample-sites by hip-chain measurement and physical landmarks or GPS.

In each selected unit, record the minimum habitat characteristics (see above). Summarize habitat data to be sure observations are within two standard deviations of the mean for each variable; if not, increase the sample size.

In each selected unit use one-pass electrofishing to survey species richness.

Plot cumulative number of species captured (*y* - axis) by cumulative pool-riffle combination area (*x* - axis) to determine if the sample size is adequate for an acceptable estimate of the total fish community. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five habitat-units sampled with no previous unsampled species in the catch).

3) Watersheds Containing Species Of Conservation Interest

From a random starting point in the target stream, systematically select 50 of each habitat type. In each selected unit record the minimum habitat characteristics (see above), plus additional habitat characteristic specific to the target species, and count fish by underwater observations. Locate sample sites by hip-chain measurement and physical landmarks or GPS.

Summarize habitat data to be sure observations are within two standard deviations of the mean for each variable; if not, increase the sample size.

Use underwater observation to assess the risk of electrofishing on the target species population before the technique is employed (see Leftwich et al. in review). Limit the use of electrofishing to minimize injurious effects on the target species populations.

Systematically select 10 of each habitat type from the units characterized for habitat (i.e. 10 of the 50 pools and 10 of the 50 riffles selected for underwater observation) for three-pass removal electrofishing.

4) Watersheds Containing Species Of Conservation Interest That Receive High Recreational Use Or Where Management Activities Are Planned

Recommended effort

Complete habitat and fish-population inventory and data analysis, following the protocol BVET of Dolloff et al. (1993), prior to management activity.

The minimum habitat characteristics (see above) should be recorded, plus additional habitat characteristic specific to the target species.

Fish population inventory, as outlined by Dolloff et al. (1993), may need to be modified to effectively sample target species while minimizing impact on their populations (see Leftwich et al. in review).

Minimum effort

From a random starting point in the target stream, systematically select 50 units of each habitat type. In each selected unit record relevant habitat characteristics and count fish by underwater observations. Locate sample-sites by hip-chain measurement and physical landmarks or geographic positioning system (GPS).

Summarize habitat data to ensure observations are within two standard deviations of the mean for each variable; if not, increase the sample size.

Systematically select 10 of each habitat type (e.g. 10 of the 50 pools and 10 of the 50 riffles selected for underwater observation) for three-pass removal electrofishing.

Use underwater observations to assess the risk of electrofishing on the target species population before the technique is employed (see Leftwich et al. in review).

Appendix 4. Aquatic Biota and T/E/S Species Monitoring Protocol

Aquatic habitat and fish population monitoring

Habitat monitoring should be conducted on each inventoried stream every 5 years or following management activities in the watershed or natural (e.g. floods, tornados, etc.) and human-caused (e.g. road failures) events. Monitoring protocols should be compatible with the inventory protocol.

A hierarchical approach to monitoring should be used to determine sampling strategy and intensity. Below is an outline of a hierarchical strategy for monitoring streams on the DBNF. Data collected during monitoring should be compared with the respective inventory to evaluate changes in fish populations. When negative changes are detected in a stream, the stream should be resurveyed using the appropriate inventory protocol.

1) Watersheds Not Containing Species Of Conservation Interest

Systematically select 5 pool-riffle combinations within the stream.

Collect measurements of minimum habitat characteristics (see Appendix 3) and locate sample-sites by hip-chain measurement and physical landmarks or GPS.

In each selected unit use one-pass electrofishing to survey the fish community.

Plot cumulative number of species captured (y - axis) by cumulative pool-riffle combination area (x - axis) to determine if the sample size is adequate for an acceptable estimate of species richness. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five pool-riffle combinations sampled with no previous unsampled species in the catch).

Sampling Schedule

Monitoring should be conducted once every 5 years during periods of low flow.

Repeat survey following management activities within the watershed and following damaging natural (i.e. floods, tornados) and human-caused (i.e. chemical spills, road failures) events.

2) Watersheds Not Containing Species Of Conservation Interest But Receive High Recreational Use Or Where Management Activities Are Planned

Systematically select 5 pool-riffle combinations within the stream.

Collect measurements of the minimum habitat characteristics and locate sample-sites by hip-chain measurement and physical landmarks or GPS.

In each selected unit use one-pass electrofishing to survey the fish community.

Plot cumulative number of species captured (y - axis) by cumulative pool-riffle combination area (x - axis) to determine if the sample size is adequate for an acceptable estimate of species richness. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five pool-riffle combinations sampled with no previous unsampled species in the catch).

Sampling Schedule

Monitoring should be conducted once every 3 years during periods of low flow.

Repeat survey following management activities within the watershed and following damaging natural (i.e. floods, tornados) and human-caused (i.e. chemical spills, road failures) events.

3) Watersheds Containing Species Of Conservation Interest

Systematically select 10 pool-riffle combinations within the stream.

Collect measurements of the minimum habitat characteristics plus habitat characteristics specific to the target species and locate sample-sites by hip-chain measurement and physical landmarks or GPS.

Summarize habitat data and compare to previous basinwide inventory. Estimates should fall within two standard deviations of the mean basinwide estimates for each variable; if not, increase the sample size. If estimates still exceed two standard deviations, repeat basinwide sampling at comparable flow.

Where applicable, use underwater observations to assess relative abundance of target species (see Leftwich et al. in review).

Electrofishing surveys maybe necessary when turbid stream conditions prevent reliable underwater observations or when objectives require precise estimates of population size with known confidence intervals. Electrofishing surveys should be designed to minimize injurious effects on the target species populations.

Species Richness

Plot cumulative number of species captured or observed (y - axis) by cumulative pool-riffle combination area (x - axis) to determine if the sample size is adequate for an acceptable estimate of species richness. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five habitat-units sampled with no previous unsampled species in the catch).

Sampling Schedule

Monitoring should coincide with the life cycle of the target species (e.g. once every three years for blackside dace) or following damaging natural (i.e. floods, tornados) and human-caused (i.e. chemical spills, road failures) events. Monitoring should be conducted during periods of low flow following the spawning season of the target species.

Repeat survey following management activities within the watershed.

4) Watersheds Containing Species Of Conservation Interest That Receive High Recreational Use Or Where Management Activities Have Been Implemented

Systematically select 20 pool-riffle combinations within the stream.

Collect measurements of the minimum habitat characteristics plus habitat characteristics specific to the target species and locate sample sites by hip-chain measurement and physical landmarks or GPS.

Summarize habitat data and compare to previous basinwide inventory. Estimates should fall within two standard deviations of the mean basinwide estimates for each variable; if not, increase the sample size. If estimates still exceed two standard deviations, repeat basinwide sampling at comparable flow.

Where applicable, use underwater observations to assess relative abundance of target species (see Leftwich et al. In review).

Electrofishing surveys maybe necessary when turbid stream conditions prevent reliable underwater observations or when objectives require precise estimates of population size with known confidence intervals. Electrofishing surveys should be designed to minimize injurious effects on the target species populations.

Species Richness

Plot cumulative number of species captured or observed (y - axis) by cumulative pool-riffle combination area (x - axis) to determine if the sample size is adequate for an acceptable estimate of species richness. The sample size should be acceptable when the curve through the data reaches a stable asymptote (e.g. about five habitat-units sampled with no previous unsampled species in the catch).

Sampling Schedule

Monitoring should coincide with the life cycle of the target species or following damaging natural and human-caused events. Monitoring should be conducted during periods of low flow following the spawning season of the target species.