

GREAT SMOKY MOUNTAINS NATIONAL PARK

FISHERIES DISTRIBUTION MONITORING PROTOCOL



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*Great Smoky Mountains National Park
Resource Management & Science
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Background and Objectives

Background and History

The brook trout (*Salvelinus fontinalis*) is the only trout native to the southern Appalachian Mountains. It was once widespread in Great Smoky Mountains National Park (GRSM), occupying small, swift, high elevation mountain streams as well as larger rivers down to elevations of 1,600 feet. Since 1900, the brook trout has vanished from about 75% of its historical range in GRSM. The initial loss was due to large-scale mechanized logging operations early in the 20th century. Clear cuts and subsequent fires on steep mountainsides led to soil run-off and stream siltation. In addition, trees were cut from stream banks, allowing more sunlight to reach the waterways and raising water temperatures. The brook trout is even less tolerant of warm water than other trout species- it can not survive temperatures above 68°F. (20°C).

As a result of these environmental changes, the brook trout disappeared from all streams in the Smokies below elevations of 3,000 feet. The decline of the brook trout caused displeasure among anglers who longed to trout fish in the mountains. In response, around 1910, logging companies and other entities began stocking streams with non-native rainbow trout from the western United States, brown trout from Europe, and brook trout from the northern United States. Stocking of northern brook trout continued into the 1950s; rainbow trout stocking did not cease until 1975. Competition from the non-native trout, especially rainbows, lead to further declines in the brook trout population. Rainbow trout are larger, more aggressive fish which dominate the prime habitats in streams and eat small brook trout. Biologists believe brook trout range in the Smokies has declined dramatically due to rainbow competition. Most surviving brook trout have become confined to marginal streams above 3,500 feet in elevation.

Stream acidification is an increasingly serious threat to the survival of brook trout. Streams in GRSM naturally become more acidic at higher elevations. However, research shows that areas in the park above 4,800 feet in elevation are receiving some of the highest amounts of acid rain, acid fog, and dry deposition of any monitored site in North America. Consequently, many high elevation streams are becoming increasingly acidic, some to the point that they can no longer support brook trout.

In 1996, genetic research conducted by the University of Tennessee confirmed long-held beliefs that the southern Appalachian brook trout is a distinct subspecies, differing in several ways from the stocked fish native to the northeastern United States and Canada. Only about 15% of park streams are believed to harbor pure strains of truly native fish, undiluted by hybridization with northern brook trout. Since the southern subspecies has such a limited range, and because that range has been diminished drastically in the last 100 years, the southern brook trout is considered a species of

special concern. The Park Service is especially watchful of acidification and competition from rainbow trout in streams where the subspecies currently survives.

Why Monitor Distribution?

It has been determined that native brook trout have lost approximately 75% of their range and that 30 species of non-game fish are missing from the Park as a result of man-induced changes in the landscape. Unfortunately, annual monitoring to assess changes in aquatic communities was not implemented until the mid-1980's. The efforts resulted in the development of standardized sampling protocols for streams in GRSM. The value of these protocols was quickly recognized by state and federal agencies working with trout resources elsewhere in the southeast. The protocols formed the basis of the "Standardized Sampling Guidelines for Wadeable Trout Streams" (Appendix B) which were adopted by the Trout Committee of the Southern Division of the American Fisheries Society. These protocols have been well tested and provide a method that adequately evaluates annual variation in fish communities as well as providing a method to evaluate changes in distribution and community structure.

Fisheries survey work in Great Smoky Mountains National Park (GRSM) has shown that species diversity increases as stream order increases, from headwaters down to Park boundaries. Changes in elevation, stream gradient, physical habitat, and water chemistry naturally affect the distribution of fish populations along the length of streams. Entire aquatic communities are shaped and even changed by species interactions which in turn can regulate the density and integrity of the community. These changes, as well as those associated with abiotic events (drought, flood, etc.), have created the aquatic communities now known. However, in recent history, anthropogenic factors have significantly altered this natural process which has had a tremendous impact on aquatic ecosystems. Changes in species diversity and/or distribution may serve as early warning signals of environmental change resulting from human impacts such as air and water pollution. Scientifically based monitoring programs that continually evaluate aquatic communities are necessary to assess natural variation so that early warning signals of man-induced environmental stresses can be better diagnosed and understood.

Historically, fisheries distribution studies in GRSM have primarily focused on sport fish monitoring, range loss of native brook trout and encroachment of exotic species. However, these efforts largely ignored non-game fish diversity and distribution in many of the park's streams. Efforts to monitor brook trout range have occurred about every 20 years and have not allowed for a reasonable quantification of distributional changes. Likewise, efforts to monitor sportfish populations in larger streams have only occurred periodically and lacked consistency in data collection methods. Data comparisons are very difficult and limited because all of these efforts lack site descriptions and replication through time. Part of the reason for such spacing has been the difficulty

associated with completing parkwide surveys and past emphasis on issues associated with sport fish populations. In addition, the surveys of King, Lennon, Jones, and Kelly were not accomplished using the same techniques, nor were historic sampling sites established. The lack of permanent historic sampling sites made it difficult, if not impossible, to replicate and compare these historic data.

Measurable Objectives

The current distribution monitoring objectives of this program are to:

- (1) Inventory current brook trout distribution in all watersheds (1-2 watersheds per year)
- (2) Establish permanent monitoring sites in selected streams that have brook trout
- (3) Compare current distributions to historical records to determine changes in range
- (4) Establish and monitor permanent sites in each watershed on a rotational basis so that all watersheds are surveyed on a ten year rotation

General Sample Design

Site Selection and Establishment, Population Boundaries, Frequencies and Replications

As of 2007, fish distributions in GRSM have been completed in approximately 80% (1,576 of nearly 2100 miles) of streams, with survey efforts scheduled to occur about every 20 years. Distribution surveys were initially done to determine the ranges of the three trout (salmonid) species found in the park: brook (*Salvelinus fontinalis*), brown (*Salmo trutta*) and rainbow (*Salmo gairdneri*). Emphasis was placed on allopatric versus sympatric brook trout populations, brook trout historical versus current range, and invasive encroachment.

Initial fish distribution surveys also served to 1) establish long-term monitoring sites for the three salmonid species (2-3, 100-200m sites per stream/watershed for a given species/population, with location and number dependent on allopatric versus sympatric zone distribution), 2) to determine the presence of potential barriers to their respective distributions, such as waterfalls and cascades, as well as 3) determine the variety of habitats within potential sites.

A goal of this program is that all permanent brook trout monitoring sites, established during the brook trout distribution surveys (20 watersheds), will be sampled at least once over a ten year rotational cycle (1-2 watersheds per year). Monitoring surveys, along with distribution surveys, are currently used to detect the level of change in the range of brook trout.

Distribution surveys will be conducted from mid-May through mid-October during periods of low to moderate flow (cfs or cms) when fish are most susceptible to the gear. During the period of mid-October through mid-March stream flows are typically high, spawning is ongoing for the three salmonid species, and field conditions are usually not suitable for sampling. However, distribution protocols and procedures remain the same for all park species and populations with the exception of threatened and endangered (T & E) fish species, whose distributions are determined by snorkel surveys.

Sampling Protocol

Field Sampling Procedures and Methods

The watershed to be sampled will be identified by the fishery biologist prior to each field season. The crew (2-3 persons suggested) will begin by filling out the initial information about the watershed on the data sheet (Appendix A- Fish Distribution Data Sheet) and calibrating the altimeter to the benchmark at Park Headquarters (BM 1463') or at a known location in the field. The crew should also record the names of the crew members involved in the survey. All brook trout (or any other species) distribution surveys will begin at points identified in the 1970's survey or at currently known points and proceed upstream to headwater areas. Altimeter checks for accuracy at known points should be periodically taken at tributaries, confluences, trail crossings, etc. The crew will "flag" (place surveyors flagging on a tree or other visible structure) the starting point, mark this point on a GPS unit, record the elevation, time, and physical description of the starting point, then proceed with electroshocking. The crew will shock approximately 100-200m and record all species present. If brook trout are encountered at the initial survey site, the crew must work downstream to identify the downstream limits. The sympatric zone, where brook trout co-exist with rainbow (or other) trout species and eventually 'phase out,' defines these downstream limits. The initial record of species present will serve as the basis for species distribution in the watershed based upon the assumption that species numbers will decline as you move up in stream orders throughout the watershed. The crew will then begin "spot shocking," or moving upstream while periodically shocking 50-75m segments, skipping every other 100m. The crew will continue spot shocking until one of the following seven variables occurs:

- (1) The crew encounters the upper range limit of a species
- (2) The crew encounters the lower range limit of a species
- (3) The crew finds a species not encountered during the initial species records
- (4) The crew encounters a tributary to the stream
- (5) The crew encounters a possible barrier to fish movement (i.e. waterfall, cascade, etc.)
- (6) The crew runs out of usable fish habitat (i.e. the stream ends in a spring, the stream becomes too shallow for fish to inhabit, etc.)
- (7) The crew needs to return to headquarters

Variables Associated with Distribution Surveys

(1) The crew encounters the upper range limit of a species

When the crew spot shocks to a point where a fish species is no longer present, the crew will record both the location and elevation on the quad map, data sheet, and GPS unit. The upper limit will be defined when the last individual of that species is no longer collected in the stream, regardless of its presence in allopatric or sympatric populations. At this time, any other pertinent information should be noted by the crew about characteristics of the stream and of the surrounding area such as substrate, habitat, vegetation types, etc. It is imperative to keep accurate and thorough field notes along with the physical measurements recorded along the way. It should be noted that historically, upper limit of a fish species in a sympatric environment was considered to be the point where 5% or less of the fish population was the species in question.

The crew will then proceed upstream 200-300 meters above the area to ensure that no further individuals of that species are present. If more individuals are found above the point, a new upper range limit should be recorded appropriately. Note that upper ranges of some species may not be distinct due to the natural movement and fluctuation of fish; therefore, careful notes should again be stressed to describe exact segments of the stream where the species numbers begin to thin out and where they are finally absent. As individuals of a species begin to decrease, habitat and substrate types where the fish occur (e.g., pools, riffles, cobble, gravel) should be noted.

When the upper limit of the species range is determined, a 30 meter index site should be installed at that point (see I&M Protocols). A set of stream widths and stream gradients should be recorded according to standardized protocols (AFS Southern Division, Trout Committee 1992). The crew will begin measuring stream widths 30 meters below the upper range limit flag. Mean widths will be measured every 10m upstream from the initial width measurement until four stream widths are recorded. Percent gradient will be measured along the 10m transect between stream width measurements. Mean width and mean percent gradient will be calculated from the

widths and gradients recorded.

Dominant substrate, or the stream substrate most frequent at that point in the stream, will be visually classified at the upper range flagging. To determine the dominant substrate for that area, the crew will visually classify the substrate (Hamilton and Bergersen 1984) in a five meter square area of the stream at the flagging based upon the following size parameters:

Substrate Type	Size (mm)
fine (silt, detritus, etc.)	
small gravel	< 2 mm
large gravel	3-10 mm
cobble	1-10 cm
small boulder	11-30 cm
large boulder	30-60 cm
bedrock	

Table SP-1

The crew will record the three dominant substrate types in order of magnitude on the data sheet. Crew members should confer with one another to reach a mutual decision about the order of dominance of the substrate types.

Spot shocking will continue upstream until all species are absent, or one of the other variables mentioned are encountered.

(2) The crew encounters the lower range limit of a species

As a species lower range is found, the species will be recorded on the data sheet, the elevation recorded, and the area should be referenced on the data sheets, quad map, and GPS unit. The crew will then continue upstream to determine the upper limit of the species. If the lower limit of a species occurs within a sympatric population zone, a 30 meter index site should be installed (see I & M Protocols).

(3) The crew finds a species not encountered during the initial species records

Some species will be limited to the upper elevation headwater areas and therefore may not be found near the Park boundaries. When a new species is encountered, the lower range limit should be determined, either from the initial upstream survey or by spot shocking downstream until it is no longer found. The species should be recorded on the data sheet, the area flagged, an elevation recorded, and the area referenced on the data sheets, quad map, and GPS unit. Water quality parameters such as pH,

temperature, and conductivity will be recorded at the same location as the flagging. Dominant substrate types should be recorded according to the table under Variable (1). Spot shocking will continue upstream until the upper range limit of all species are found, or one of the other variables mentioned are encountered.

(4) The crew encounters a tributary to the stream

Tributaries will be sampled exactly the same as the main stream. Upon arriving at a tributary, the confluence will be flagged, the elevation recorded, and the data recorded and indexed on the data sheets, quad map, and GPS unit. If the tributary is shown on the quad map, the altimeter should be calibrated as close as possible according to the contour lines on the map. If the tributary is not located on the quad map, draw the tributary freehand on the map and record any appropriate data on the data sheet¹ and GPS unit. Any discrepancies between the quad map and the altimeter should be noted. If the tributary is unnamed, an index name (i.e. Trib A, Trib 1, etc.) should be given to the tributary and this name marked on the map, data sheets, and GPS unit in order to keep all tributaries separate. Water quality parameters such as pH, temperature, and conductivity will be measured at the tributary and recorded.

Tributaries which do not support salmonids will not be surveyed for non-game fish distributions. To ensure that the tributary does not support salmonids, spot shocking should continue at least 200m up the tributary. If no salmonids are found in this reach, the crew may return to the main stream and proceed with the survey. Species present in the tributary will be recorded and the distance shocked up the tributary should be noted. Spot shocking will then continue upstream until one of the other variables is encountered.

(5) The crew encounters a possible barrier to fish movement (i.e. waterfall, etc.)

Frequently, in headwater streams, crews will encounter waterfalls, cascades, logjams, or other habitat features which may or may not impede fish migration above that point. Upon reaching obstructions of this nature that are at least 5.5 feet in vertical height, the elevation will be recorded on the data sheet and quad map. This point should also be marked on the GPS unit. Pictures of these obstructions should be taken and photo numbers recorded on the data sheet. At least one photo should include a crew member for scale. Once completed, spot shocking should continue to determine if the fish species is present above the barrier. If non-native fish are collected, the crew should look for and document the presence of roads and railroad grades alongside the stream. If only native fish are encountered, electrofishing should continue until no fish are

¹Tributaries found during the survey not previously mapped on the quad map should be noted and this information passed to the data management specialist at Twin Creeks research lab.

found. If no fish are found, the crew should proceed back to the barrier and collect the appropriate data.

(6) The crew runs out of usable fish habitat (i.e. the stream ends in a spring, the stream becomes too small for fish to inhabit, etc.)

Some streams support fish populations up to the headwaters until it becomes uninhabitable. Such areas may exist where the stream becomes too shallow, the stream ends in a spring or other subterranean flow, or the stream just becomes void of fish for other, unknown reasons.

Upon reaching a point where fish are no longer present, the area should be flagged, the elevation recorded, and appropriate notes made on the data sheets, quad maps, and GPS unit. Specifically, be sure to note any possible habitat restrictions which may account for the upper range limit of the population. Take a photo of the area and index it to the upper limit on the data sheets, quad map, and GPS unit. Record pH, temperature, and conductivity at the upper limit, as well as any other appropriate data.

(7) The crew needs to return to headquarters or camp

Surveys may be cut short due to time constraints, weather, light, or a variety of other situations. Before the crew leaves a site which is not yet completed, several steps must be taken to ensure the next crew knows where to resume the survey and to not exclude parts or re-survey segments of the stream.

When the crew reaches an endpoint, the location should be flagged, the elevation recorded and the location noted on the data sheets, quad map, and GPS unit. It is imperative that the location be recorded on the quad map and GPS unit to ensure the next crew can pick up where the previous crew left off. Any other pertinent information, such as trail crossings, historical features, etc., related to the ending point, should also be recorded on the data sheet and GPS unit to assist the next crew in finding the site location.

Operational Requirements

Equipment and Gear

Consistency in data collection is a necessity when engaging in surveys of this magnitude. Therefore, all crews will be supplied with identical sets of distribution gear consisting of the following equipment:

- backpack electrofishing unit (battery or AC unit)
- electroshocking probes (two per shocker)
- electrical gloves (two pair per shocker)
- 1-2 extra batteries per shocker
- waders/wading boots
- data board
- distribution data sheets (use waterproof paper only!) (see Appendix C)
- USGS Quadrangle topo maps
- daypack (to carry food/waders)
- altimeter
- clinometer
- GPS unit
- camera
- measuring tape
- radio (NPS two way, for safety purposes)
- surveyors flagging
- pack covers
- water filter
- small diameter nylon rope
- shocker repair kit
- first aid kit
- black Sharpie marker
- SCT meter

Data Management

Data Handling, Entry, Editing, and Analysis

The importance of data accuracy and thoroughness cannot be overstated. All data sheets should be recorded legibly such that any other member of the crew could pick up the datasheet and understand the interpretation of the data. All crewmembers will be held individually responsible for the data that they record and should therefore make every effort possible to record clear, concise, and thorough notes which are easily

understood by the fishery biologists. All raw data, field notes, and datasheets should be filled out completely, checked, and entered into the GRSM fisheries database for the corresponding year at the conclusion of each distribution survey. It is important to back up the database on a daily basis and archive periodically to prevent data loss. Distribution data should be immediately transcribed to the appropriate USGS quadrangle map (to display range changes) and is then available to the fishery biologists for various analyses and incorporation into annual fisheries reports, maps, figures, tables, and/or summaries.

Data entry and database maintenance for fish distribution surveys will be conducted at the fisheries office in park headquarters. Physiographic natural obstructions (waterfalls, cascades, etc.) and permanent monitoring sites will be incorporated into a fish distribution layer as point references using ARC GIS to map them. Upper and lower range data (elevations) for all fish species will be entered directly from the USGS quadrangle maps via a digitizer, then incorporated into the ARC GIS distribution layer (see Appendix C- example distribution map). Population data from historical monitoring sites located within the same watershed, for all fish species, will be incorporated into the GIS layer. All site, location, and stream feature information (points) stored on the GPS unit must be downloaded to the ARC GIS fish distribution layer. Brook trout and other fish population data will be entered into the MICROFISH 3.0 program (vanDeventer and Platts 1989) in the fisheries office. Stream chemistry data (i.e. pH, conductivity, discharge, etc.) will be recorded on field data sheets and entered on the GRSM fisheries database in the fisheries office at the end of each survey. Data will be entered by NPS fishery biologists or NPS biological science technicians who have considerable knowledge of fisheries data programs, and all digitizing will be done by NPS personnel who have been trained in the use of GIS digitizing techniques and ARC GIS software.

Quality Control and Quality Assurance

All data will be collected by either NPS fisheries biologists, NPS biological science technicians, or NPS volunteers. Each crew will have at least one NPS employee who has previously completed watershed surveys and is experienced in all aspects of the distribution surveys. Crews will work together and confer amongst each other to compile field notes that ensure accurate data is being recorded. All data sheets will be visually checked and re-checked by the crew leader at the end of each day to ensure no recording errors in the field and to keep all data sheets together.

Data entry will be completed by NPS fishery biologists or NPS biological science technicians who have considerable knowledge of the database programs used in the fisheries office. All GIS data entry will be completed by those NPS employees who have undergone sufficient training and demonstrated proficiency in the use of GIS software, a digitizing table, and a GPS unit. All data is edited immediately after entry to correct

errors. Data entry and edit status is recorded by stream name in the database, and all datasheets should be initialed, for reference purposes, by whoever enters them.

Comparison Protocols

Historical salmonid distributions will be entered onto GIS using historical range maps and previous distribution surveys (King 1937; Lennon 1967; Jones 1978; Kelly et al. 1980; Bivens et al. 1985). Once current salmonid distributions are established and entered onto the GIS system, comparisons between current and historic distributions can be made using the GIS program, data summaries, or statistical analyses to detect range changes. Losses or gains in brook trout range will be reported in total stream miles/km and percent (%) by stream and watershed when possible. Long term distribution analysis is possible for a given watershed after either annual rotation or 10 year cyclic sampling is completed.

Personnel

Requirements, Qualifications, and Training

Crew members will consist of the staff fishery biologists, seasonal biological science technicians, and NPS volunteers/SCAs. Biological science technicians and volunteers will be selected from those who have an educational background in wildlife and fishery sciences from an accredited university. NPS technicians and volunteers will have taken either college courses in fisheries management or ichthyology or will undergo a short training period of fish identification and field sampling techniques from NPS biologists (Appendix C- GRSM Stream Sampling Training Program). This training will serve as a refresher for returning field staff. Each crew member will undergo a minimum of 40 hours of training in the following areas: the use, maintenance, repair, and safety aspects of electroshocker units; the use and maintenance of all water quality instruments; the use of a flow meter to measure stream discharge; the identification of and sampling procedures for salmonids and other game and non-game species; the recognition and measurement of representative stream sample sites; recording of data in the field; and, data entry and editing using computer databases. All trainees are provided with *Standardized Sampling Guidelines for Wade able Trout Streams* (American Fisheries Society Southern Division Trout Committee 1992) to supplement their training (Appendix D). These guidelines were developed primarily in Great Smoky Mountains National Park and expanded to include situations throughout the southeast.

All training is conducted under the supervision of the fishery biologists. Additional training and support will be provided by senior crew members who have worked for a

minimum of one summer (5 months). Any trainee who is experiencing difficulty with a procedure or sampling protocol is mentored by a crew leader until the trainee is proficient with the protocol.

Roles and Responsibilities

A minimum of three crews consisting of 2-3 people per crew is recommended for the completion of distribution surveys in a given watershed during the lower summer and fall stream flows. Greater than three crews will be utilized depending upon watershed size, number of trained crew members available, and time constraints. On each crew, one crew member will electrofish while the other crew member(s) will record all data.

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APPENDIX A

GRSM Fish Distribution Data Sheet

GREAT SMOKY MOUNTAINS NATIONAL PARK FISH DISTRIBUTION DATA

Begin point (Elev.\ Descrip.) _____
 Watershed _____ Stream _____ Quadrangle _____ Date _____
 Surveyed by _____ State _____ County _____ sheet ____ of ____

[illegible]

NOTES:

30 METER SITE DATA

APPENDIX B

Standardized Sampling Guidelines for Wadeable Trout Streams

AMERICAN FISHERIES SOCIETY SOUTHERN DIVISION, TROUT COMMITTEE

Standardized Sampling Guidelines for Wadeable Trout Streams

August 1992

The following guidelines for standardized sampling methods in wadeable trout streams are based on the recommendations of the Standardized Trout Stream Sampling sub-committee of the American Fisheries Society, Southern Division Trout Committee. Wadeable trout streams, exclusive of tailwaters, are defined as those that can be waded and sampled with backpack electrofishing gear. Southeastern trout streams are the primary focus of these guidelines, although they may be used (with or without modification) in other geographical regions. The objectives of these guidelines are:

1. Establishment of standardized sampling procedures that will provide a mechanism by which data can be more readily compared among various streams
2. Provision of standardized trend data on population changes (e.g., density, standing crop, species composition, size and age structure, etc.) through time as they relate to various abiotic effects (e.g., droughts, floods, regulation differences or changes, etc.)

Recommended Sampling Protocol

Station Selection

1. Since complete electrofishing surveys of even the smallest streams are usually impractical, fish stock assessments must be based on a sample of stream reaches (Bohlin et al. 1982). The recommended procedure for selecting these sampling sections (also referred to as stations or sites) for monitoring purposes is to use "representative" stream reaches that contain the major habitat types or units present, such as pools, riffles, runs, etc. If possible, streams should be traversed prior to station selection to ensure that major habitat types are included in proportion to their occurrence. Representative reaches can be chosen randomly or sited using specific criteria as project needs dictate. Bovee (1982) and Hamilton and Bergersen (1984) provide additional information regarding habitat-based site selection. Non-contiguous habitat units may also be sampled if "representative" reaches are unavailable or lack the desired level of precision for specific studies. Representative reaches are, however, recommended for long-term monitoring stations.
2. Minimum recommended station length is 100 m in streams ≤ 10 m in mean width as this length typically provides for the inclusion of at least one cycle of the basic stream habitat units present. The recommended station length in streams with mean widths exceeding 10 m is 200 m since it is difficult to include all major habitat types in 100-m stations in these larger streams. In practice, these station length recommendations should be used as points of reference since actual station lengths will often require adjustment to avoid habitat unit fragmentation and to make use of any fish passage obstructions present.

Sampling Techniques

1. Backpack electrofishing is the most commonly used, non-lethal means for sampling trout population in relatively small streams (Armour et al. 1983) and is recommended here. Other sampling techniques, such as ichthyocides and explosives, may be necessary under specific circumstances and are described in Armour et al. (1983) and Platts et al. (1983). Removal-depletion and mark-recapture population estimation techniques are typically employed with backpack electrofishing gear. The removal-depletion method, however, is strongly recommended because of its overall efficiency (Armour et al. 1983) and because its associated assumptions (see Section 2 below) are more easily met. For example, behavioral responses of trout released after capture by

electrofishing and marking may be such that the assumption of equal catchability (among marked and unmarked fish) is violated (Mesa and Schreck 1989). Little change in the behavior of trout remaining in stream sections following successive removal-depletion electrofishing passes has been noted (Mesa and Schreck 1989).

Two to four removal passes, made in the upstream direction only, may be used in removal-depletion sampling (Armour et al. 1983), although three passes are ideal in nearly all situations (Figure 1). Bohlin (1982) and Bohlin et al. (1982) recommend three removal passes where capture probabilities (catchabilities) are ≥ 0.50 , although they note that two passes may be sufficient where large populations are present (Figure 1).

Catchability refers to a fish's estimated probability of capture on a given pass of a removal-depletion sample and characterizes the sample's reliability (Armour et al. 1983). Electrofishing catchabilities ranging from 0.50 to 0.70 are considered typical for stream salmonids (Bohlin 1982). In samples from Southeastern streams, catchabilities have averaged near 0.60 for adult trout (Figures 2 and 3). Catchabilities ≥ 0.50 will provide reliable population estimates.

The small size of young-of-the-year (YOY) trout tends to lower the catchability of this group. Field observations indicate that part of this lowered catchability may be due, in part, to the tendency of netters to first capture the larger individuals (adults) in a group of stunned fish. When relatively large numbers of YOY are present, the overall catchability estimate for the sample may be lowered into the 0.40 to 0.50 range if YOY data are not treated separately.

2. Three important assumptions apply if reliable electrofishing data are to be obtained using the removal-depletion method: (1) no fish may enter or leave the study site during sampling; (2) each fish has an equal chance of being captured; and (3) catchability remains constant with each removal (Armour et al. 1983; Van Deventer and Platts 1983). The use of block nets is necessary to meet the first assumption, particularly at the downstream end of sampling sites. The upstream boundary of sampling sites can often be located where fish passage is obstructed (e.g., by small waterfalls or cascades), thus making a block net unnecessary. The other two assumptions can be reasonably met by maintaining uniform sampling effort and equipment settings (e.g., current and voltage) among the removal passes. One netter per electrofishing unit (in addition to the operator) per pass is recommended and the availability of a back-up electrofishing unit will permit equal effort among passes should a unit fail during the sample.
3. Alternating current (AC) is recommended for sampling the softwater streams typically encountered in the Southeast since it has proven to be more effective than direct current (DC). The most suitable voltages appear to be 300-700 VAC in streams with conductivities of $\leq 50 \mu\text{S}$ (μmhos). Battery-powered (DC) electrofishing units can be used if desired where conductivity is higher ($> 50 \mu\text{S}$) and may be necessary in wilderness areas where internal-combustion engines are prohibited. Information regarding the current and voltage used should always be recorded on the appropriate field data sheets.
4. Unpublished data from Great Smoky Mountains National Park and Cherokee National Forest (Tennessee) indicate that one electrofishing unit will provide reliable quantitative data from streams up to 4 m in mean width (Figure 3). Additionally, Habera et al. (1992) and Russell (1992) found that many streams with a mean width of 4.5-6 m can also be adequately sampled with one electrofishing unit. The results of Habera et al. (1992) and Russell (1992) also indicate, however, that site-specific decisions should be made where mean stream width are in the 4.5- to 6-m range. Higher-gradient streams with distinct habitat units can often be sampled more easily with one unit than lower-gradient streams without distinct habitat units.

Electrofishing effort (in terms of electrofishing units) must be increased in wider streams if assumptions associated with the removal-depletion method are to be met. As a general rule, one electrofishing unit per 3 m of mean stream width has provided reliable data in streams over 4 m wide (Figure 3) and is, therefore, recommended. Other stream features such as channel morphology and habitat types present may also affect the number of electrofishing units required. Therefore, decisions regarding the use of an additional electrofishing unit in situations where mean width suggests this may be necessary (i.e., > 4 m) should be based on these factors as well.

Sample Timing

1. The recommended stream sampling period is summer and early fall (June - October), primarily because this time frame coincides with the period of lowest stream flows in the Southeast. Stream flow rates have a marked effect on electrofishing efficiency; therefore, avoid sampling during high flow conditions (e.g., those typically occurring in the winter and early spring or after storm events). Sampling during summer and early fall also permits collection of YOY trout and subsequent assessment of year-class strength. Disadvantages associated with winter and early spring sampling, notwithstanding high stream flows, may include safety hazards (e.g., anchor ice) and lowered fish catchability related to extremely cold water and the tendency for trout to enter the substrate and not float well when stunned (Armour 1983). Sampling during the period of peak leaf fall may present problems with keeping block nets in place and with seeing and retrieving stunned fish.
2. Temporal differences in trout life-history parameters at higher elevations (e.g., spawning dates) may necessitate delaying sampling to late summer if YOY assessments are to be made.
3. Individual streams should be sampled at approximately the same time each year, particularly if the stream is part of a long-term monitoring program.

Data Collection and Analysis

1. Mean stream width based on multiple measurements (a minimum of 10 per sample site) should be determined as this is necessary for calculating the surface area of the site. Other physicochemical features such as gradient, elevation, substrate composition, discharge, basic water quality parameters, etc. can be measured or characterized as needed. These data may greatly enhance comparisons between streams by helping to explain part of the observed variability.
2. Minimum data to be collected from individual adult and YOY trout (and other game fish) include total length (mm) and weight (g). Total number and total weight by species may be recorded for non-game species if desired. Electronic scales expedite the handling of large numbers of specimens. Hand-held spring scales are highly accurate if maintained and are easily carried to remote sampling locations (Jennings 1989).

3. The recommended computer software for processing electrofishing data acquired using the removal-depletion method is MicroFish 3.0 (Van Deventer and Platts 1989). This software uses the maximum-likelihood method (Carle and Strub 1978; Van Deventer and Platts 1983) to calculate population estimates and provides various other population statistics such as mean length, weight, and condition factors. MicroFish 3.0 output can be used, along with surface area measurements for each sampling station, to calculate fish densities and standing crops. Densities and standing crops serve as basic means for comparing trout populations among sites, streams, or years. It is recommended that adult and YOY trout population estimates (and other statistics) be calculated separately since YOY catchabilities tend to be lower than those for adults.

Summary

These guidelines constitute an attempt to standardize trout stream sampling procedures and promote data exchange among the various natural resource management agencies represented by members of the American Fisheries Society, Southern Division Trout Committee. Compliance with these guidelines is strictly voluntary, although it is anticipated that widespread acceptance of the concept of standardized trout stream sampling procedures will provide the basis for a sound regional coldwater fisheries database. Such a database would enable more accurate assessments of trout population responses to various environmental and management changes within and across the Southeast region and might eventually decrease the amount of sampling necessary in the future.

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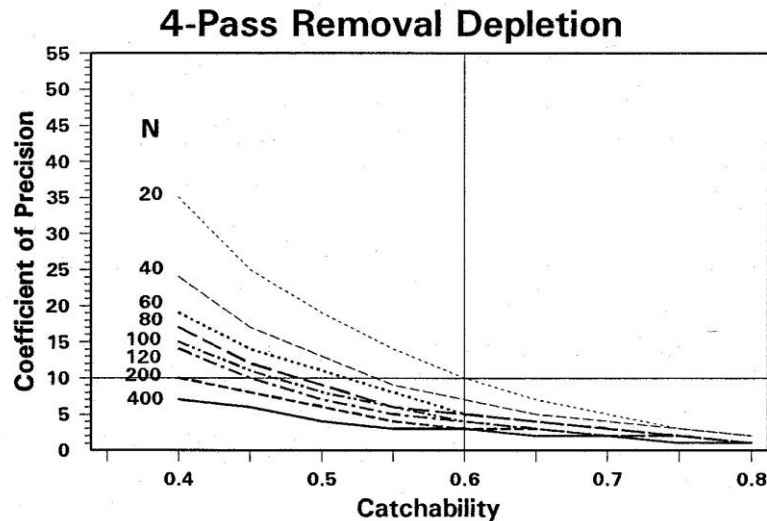
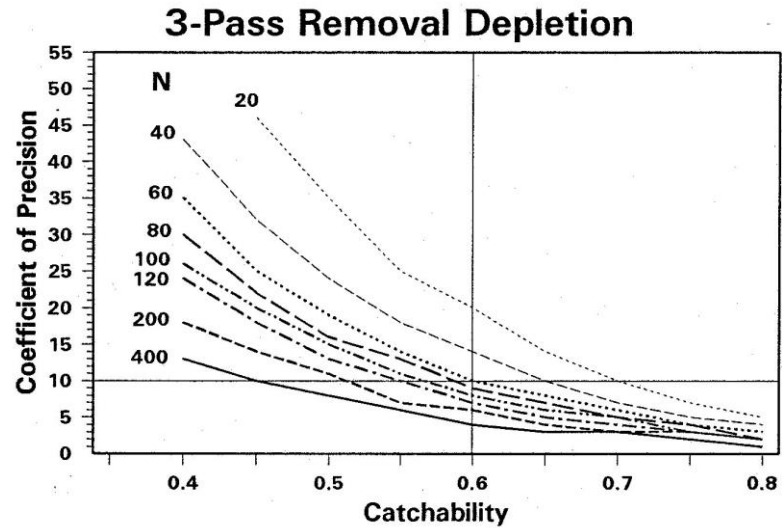
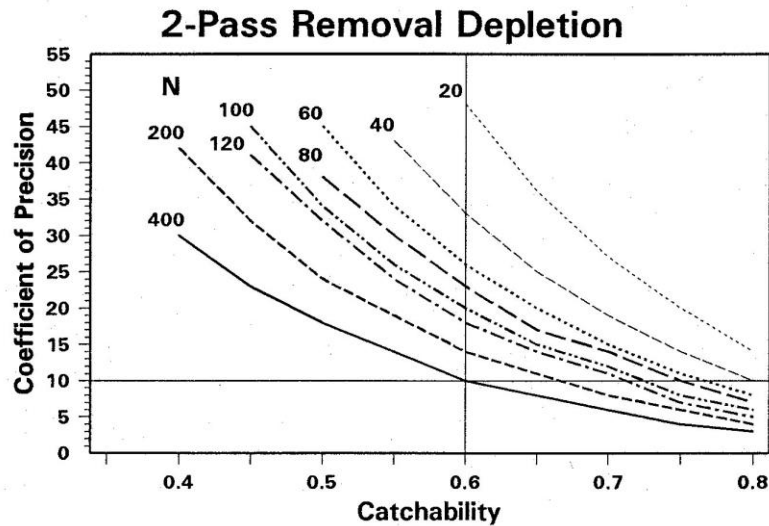


Figure 1. Coefficient of precision (Van Deventer and Platts 1989) vs. catchability curves for population sizes (N) ranging from 20-400 with 2-, 3-, and 4-pass removal depletions. The coefficient of precision, $CP(N)$, is a measure of the difference between N (actual population size) and the corresponding population estimate ($\hat{N}$). For example, a $CP(N)$ of 10% means that $\hat{N}$ will be within 10% of N at the 95% confidence level. The graphs indicate that to maintain a given level of precision (e.g., 10%), catchability must increase as N decreases since the effect of capturing (or not capturing) a given fish on a given pass becomes increasingly important when N is relatively small and each fish represents a larger proportion of N . Using a reference catchability of 0.60, which the literature (Bohlin 1982) and data (unpublished) from GSMNP indicate is average, it is apparent that a 10% level of precision is possible only when sampling the largest populations ($N \geq 400$) with 2-pass removal depletions. Catchabilities of >0.75 must be achieved when sampling small populations ($N < 50$) using 2-pass depletions if a 10% level of precision is to be obtained. Conversely, catchability need not exceed 0.60 for population sizes as low as 20 to achieve a 10% level of precision with 4-pass depletion samples. However, the additional effort required for four removal passes often would not justify any added precision. Three-pass depletions with catchabilities near 0.60 permit high levels of precision ($\leq 10\%$) for populations where $N \geq 60$. Where $N < 60$, somewhat higher catchabilities are necessary (0.65-0.70) but not unrealistic. Graphs are adaptations of those presented in Van Deventer and Platts (1989).

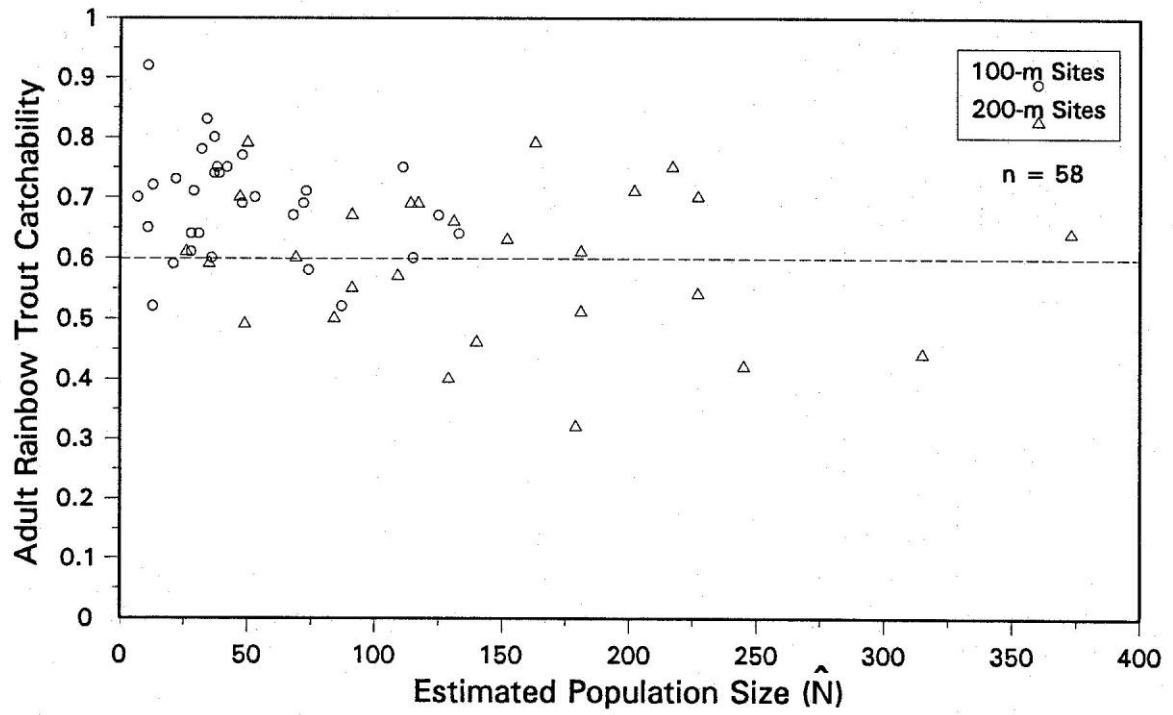


Figure 2. Adult rainbow trout catchabilities for 3-pass depletion samples from 58 Tennessee and North Carolina populations (100-200 m sites). Catchabilities averaging near 0.60 were achieved over a range of population sizes.

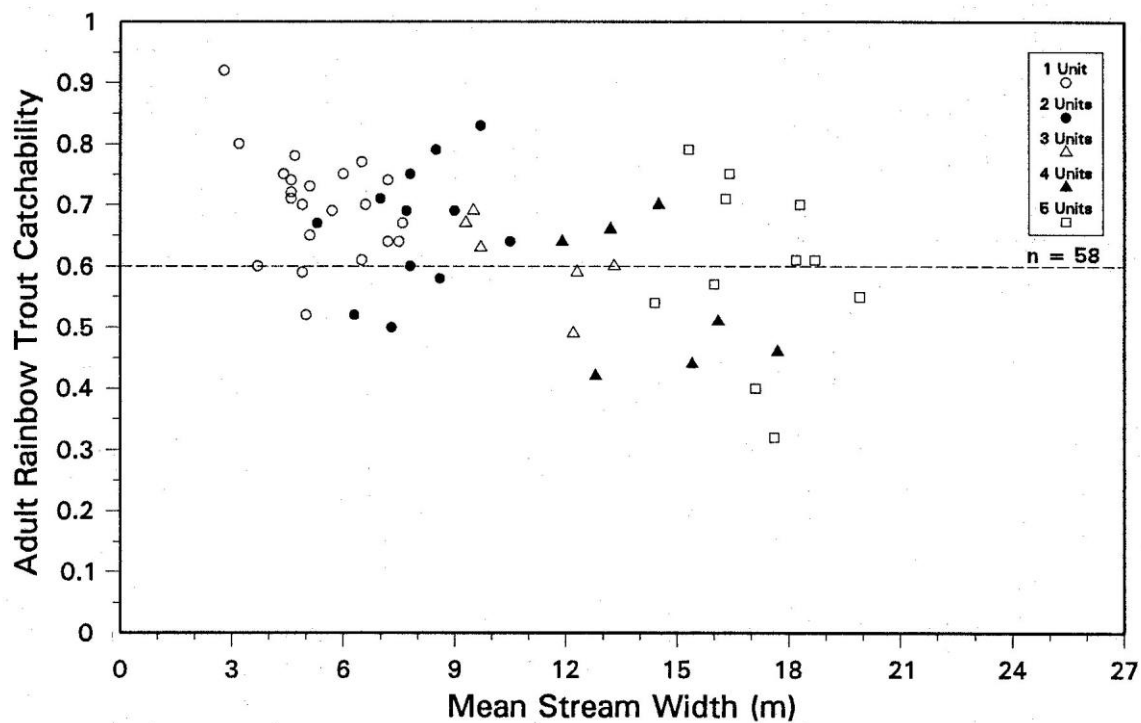


Figure 3. Adult rainbow trout catchabilities for 3-pass depletion samples of 58 Tennessee and North Carolina populations from a range of stream sizes. Catchabilities averaging near 0.60 were achieved in wider streams by employing additional electrofishing units, typically at the rate of one unit per 3 to 4 m of mean stream width.

APPENDIX C

Example Distribution Map

