The Aquatic Species-Specific Protective Measures Guide to Permitted Coal Mining Activities in Virginia

Developed by:

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In consultation with:

U.S. Office of Surface Mining Reclamation and Enforcement
U. S. Fish and Wildlife Service
Virginia Department of Game and Inland Fisheries

February 2009

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ACRONYMS

Acronym	Title
BO	1996 Biological Opinion and Conference Report on the Surface Mining Control and Reclamation Act of 1977
CWA	Clean Water Act
DMLR	Virginia Department of Mines, Minerals and Energy, Division of Mined Land Reclamation
EC	Effects Concentration
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FWCA	Fish and Wildlife Coordination Act
IBI	Index of Biotic Integrity
KIBI	Kentucky Index of Biotic Integrity
KYMBI	Kentucky Macroinvertebrate Biotic Index
LOEC	Lowest Observable Effects Concentration
OSM	U.S. Office of Surface Mining Reclamation and Enforcement
PBC	Probable Biological Consequences
SMCRA	Surface Mining Control and Reclamation Act
SSPM	Species-specific protective measures
TOYR	Time-of-year restrictions
TVA	Tennessee Valley Authority
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VDEQ	Virginia Department of Environmental Quality
VDGIF	Virginia Department of Game and Inland Fisheries
WET	Whole Effluent Toxicity
WQS	Water Quality Standards

1. AQUATIC SPECIES-SPECIFIC PROTECTIVE MEASURES BACKGROUND

This Guide, developed by the Virginia Department of Mines Minerals and Energy, Division of Mined Land Reclamation (DMLR), with input from the U.S. Office of Surface Mining (OSM), the U.S. Fish and Wildlife Service (USFWS) and the Virginia Department of Game and Inland Fisheries (VDGIF), provides measures that coal mining permit applicants may follow to reduce the potential for coal mining activities to:

- adversely affect State and federally listed, proposed, or candidate aquatic species, or
- adversely modify federally designated or proposed critical aquatic habitat in the coal mining region of southwestern Virginia.

In accordance with the 1996 Biological Opinion (BO), titled *Section 7 Formal Consultation and Conference Report on Surface Coal Mining and Reclamation Operations Under the Surface Mining Control and Reclamation Act of 1977*, these measures respond to Term and Condition 1 of the BO. It states "The regulatory authority, acting in accordance with the applicable SMCRA regulatory program, must implement and require compliance with any species-specific protective measures developed by the USFWS field office and the regulatory authority (with the involvement, as appropriate, of the permittee and OSM)." The objective of measures implemented under Term and Condition 1 of the BO is to minimize potential take of federally listed species during lawful mining activity. The measures set forth herein are designed to meet this objective, effectively streamlining the permitting and review process. However, applicants are not bound to implement these measures in all circumstances. Rather, they may choose to develop alternative measures that are tailored to the size, location, and other characteristics of the project area, provided that the measures are at least as protective as those herein. If an applicant elects to implement alternative protective measures, the DMLR and USFWS will determine whether the alternatives are consistent with the objectives of the BO.

To ensure that this Guide continues to reflect the best available science, the DMLR will periodically evaluate the effectiveness of the species-specific protective measures set forth herein, with input from OSM, USFWS and VDGIF, the regulated mining community and other interested stakeholders. They will modify these measures, as appropriate, to reflect any new information available from management experience and scientific monitoring and research.

These protective measures will aid the DMLR, USFWS, VDGIF, coal mine permit applicants and permittees when coordinating on projects involving the following laws pertaining, in part, to surface water or groundwater environments and the species that inhabit those environments:

- Surface Mining Control and Reclamation Act (SMCRA) (30 U.S.C. 1201-1328)
- Virginia Coal Surface Mining Control and Reclamation Act (Title 45.1, Chapter 19, §45.1-226, Code of Virginia)
- Clean Water Act (CWA) (33 U.S.C. 1251-1376)
- Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended, 16 U.S.C. 1531 et seq.)
- Fish and Wildlife Coordination Act (FWCA) (48 Stat.401, as amended; 16 U.S.C. 661 et seq.)
- Virginia Endangered Species Act (Title 29.1, Chapter 5, §29.1-563, Code of Virginia).

OSM, while maintaining oversight authority, has delegated SMCRA regulatory functions to Virginia. Discharges of pollutants to waters of the United States are subject to Section 402 of the CWA, administered nationally by the U.S. Environmental Protection Agency (EPA), with authority for the program delegated to Virginia DMLR for coal mining permits.

2. AQUATIC SPECIES-SPECIFIC PROTECTIVE MEASURES IMPLEMENTATION AND ASSESSMENT

Effects of coal mining can be transferred downstream, beyond project boundaries. Therefore, in Virginia, implementation of appropriate species-specific protective measures is required for any DMLR coal mining permit application, significant revision, or permit renewal area for a preparation plant or slurry impoundment that is in a drainage area upstream and within 10 stream-miles of federally listed species, federally designated critical habitat, or State listed threatened or endangered species. DMLR will use the VDGIF Fish and Wildlife Information System (http://vafwis.org/WIS/asp/default.asp) database to determine point locations of endangered species and federally designated critical habitat within this 10 mile distance. Since the VDGIF database defines areas of interest by using a radius, several trial runs may be required to adjust this radius to be consistent with the 10 stream-mile applicability threshold. Three years after initial implementation of protective measures, the DMLR, USFWS, OSM, VDGIF, the regulated community and other interested stakeholders will assess whether the 10 mile threshold is adequate, too long, or too short to ensure protection of listed aquatic species and designated critical habitats. Alternately for all other coal mining operation such as a surface mine or underground mine a 5 mile limit shall be used and the DMLR will use the same procedures as outlined previously for the 10 mile limit.

3. BEST MANAGEMENT PRACTICES

3.1 Riparian Zones

Undisturbed, forested riparian areas perform several important ecological functions. Riparian forests transfer energy from terrestrial areas to stream food webs as organic matter contained in leaf-fall and micronutrients released through groundwater leachate. In-stream habitat also is affected by forest canopy cover that provides shade and moderates water temperature. Further, large woody debris inputs enhance stream habitat diversity, and root systems along stream banks contribute to channel stability. One of the most important ecological services rendered by healthy riparian forests is the capture and retention of fine sediments eroded during storms. Disturbance of forested riparian zones alters aquatic assemblage composition, contributing to the local loss of sensitive taxa and decreasing diversity (e.g., Jones III et al. 1999; Sutherland et al. 2002).

Since 1977, the SMCRA regulatory program has been administered to authorize various coal mining and reclamation activities through or in stream channels, subject to requirements designed to minimize any disturbance to the prevailing hydrologic balance by (1) preventing to the extent possible additional contributions of suspended solids to stream flow and runoff outside the permit area, and (2) otherwise minimizing disturbances and impacts to fish, wildlife and environmental values.

As described in Wenger's 1999 review of the effectiveness of riparian buffers, we recommend the following measures to provide "…the greatest level of protection for stream corridors, including good control of sediment and other contaminants, maintenance of quality aquatic habitat, and some minimal terrestrial wildlife habitat:"

- *Base width: 100 ft (30.5 m) plus 2 ft (0.61 m) per 1% of slope.*
- *Extend to edge of floodplain.*
- *Include adjacent wetlands. The buffer width is extended by the width of the wetlands, which guarantees that the entire wetland and an additional buffer are protected.*
- *Existing impervious surfaces in the riparian zone do not count toward buffer width (i.e., the width is extended by the width of the impervious surface, just as for wetlands).*
- *Slopes over 25% do not count toward the width.*
- *The buffer applies to all perennial and intermittent streams.*

If a variance to the riparian buffer zone demonstrates listed species will not be jeopardized, federally designated critical habitat will not be adversely modified, and WQS will not be violated, and subsequently is approved, then the applicant should restore the stream channel and riparian buffer zone in accordance with the most current technology available (i.e., natural stream channel design, native tree/shrub plantings, minimize soil compaction). A suitable mine site restoration practice that employs the most current technology available is the Forestry Reclamation Approach (Burger et al., 2005). If the stream and riparian buffer zone cannot be restored onsite, the applicant should provide offsite mitigation in accordance with mitigation guidelines provided by the U.S. Army Corps of Engineers, Norfolk District.

3.2 Road Sumps

DMLR inspectors will monitor haul road sumps. When sumps are approximately 60% full, the permittee shall remove the accumulated sediment for disposal in accordance with the approved plan.

3.3 Miscellaneous

Petroleum and Chemical Handling Practices: Petroleum and chemical products should be stored and handled in accordance with their Material Safety Data Sheets, and any applicable regulatory plans (e.g., Spill Prevention, Control and Countermeasures Plan; Oil Discharge Contingency Plan; Waste Management Plan). In addition, as a species specific protective measure, mine sites (within the 5 or 10 mile limit of listed species or federally designated critical habitat) should handle petroleum and other chemicals (e.g., flocculants, frothing agents, polymers, acids and bases) in the following manner[1]:

- Provide secondary containment, such as reserve sedimentation ponds, for slurry lines.
- Provide secondary containment for all petroleum products.
- Maintain dumpster on site.
- Maintain spill cleanup kit on site.
- Maintain MSDS sheets on site.

[1] These measures are existing DMLR permit conditions for some mine sites located in the Clinch River system.

- Do not store any batteries on the ground on site.
- Require, and document on site, Spill Response Training for mine workers.

3.4 In-stream Work Time-of-Year Restrictions (TOYR)

Many aquatic species' populations are vulnerable to the effects of habitat disturbance during reproduction and early development. Persistence of populations depends on the ability of individuals to reproduce and develop into adults. Therefore, time-of-year restrictions (TOYR) on project activities may need to be established to coincide with the reproductive and early growth periods of each listed species (Tables 1 and 2). Any application of recommended TOYR should be commensurate with the impacts from the proposed project under consideration and may be adjusted after review and in coordination with the VDGIF and the USFWS.

The TOYR described below apply to new permits, significant acreage amendments, and permit renewals within 5 or 10 stream miles (depending upon the type of operation as noted previously) of listed species, or federally designated critical habitat. They are focused on any instream activity necessary for conducting coal mining operations, i.e., access road crossings, etc.

Table 1. Listed State and Federal aquatic mollusks and time of year restrictions (TOYR)

Long-term Brooders: TOYR 15 April – 15 June; 15 August – 30 September		
Common Name	**Scientific name**	**Status**
Birdwing pearlymussel	*Lemiox rimosus*	Federal Endangered
Black sandshell	*Ligumia recta*	State Threatened
Cumberlandian combshell	*Epioblasma brevidens*	Federal Endangered
Deertoe	*Truncilla truncata*	State Endangered
Dromedary pearlymussel	*Dromus dromas*	Federal Endangered
Fanshell	*Cyprogenia stegaria*	Federal Endangered
Fluted kidneyshell	*Ptychobranchus subtentum*	Federal Candidate
Fragile papershell	*Leptodea fragilis*	State Threatened
Littlewing pearlymussel	*Pegias fabula*	Federal Endangered
Oyster mussel	*Epioblasma capsaeformis*	Federal Endangered
Purple lilliput	*Toxolasma lividus*	State Endangered
Slippershell	*Alasmidonta viridis*	State Endangered
Snuffbox	*Epioblasma triquetra*	State Endangered
Spectaclecase	*Cumberlandia mondonota*	State Endangered
Tan riffleshell	*Epioblasma walkeri*	Federal Endangered
Tennessee heelsplitter	*Lasmigona holstonia*	State Endangered

Table 1. continued

Long-term Brooder: TOYR 15 Feb. - 15 June; 15 August - 30 September		
Purple bean	*Villosa perpurpurea*	Federal Endangered
Short-term Brooders: TOYR 15 May – 31 July		
Appalachian monkeyface	*Quadrula sparsa*	Federal Endangered
Cracking pearlymussel	*Hemistena lata*	Federal Endangered
Cumberland monkeyface	*Quadrula intermedia*	Federal Endangered
Elephant ear	*Elliptio crassidens*	State Endangered

Fine-rayed pigtoe	*Fusconaia cuneolus*	Federal Endangered
Ohio pigtoe	*Pleurobema cordatum*	State Endangered
Pimpleback	*Quadrula pustulosa pustulosa*	State Threatened
Pyramid pigtoe	*Pleurobema rubrum*	State Endangered
Sheepnose	*Plethobasus cyphyus*	State Endangered
Shiny pigtoe	*Fusconaia cor*	Federal Endangered
Slabside pearlymussel	*Lexingtonia dolabelloides*	State Threatened
Rough pigtoe	*Pleurobema plenum*	Federal Endangered
Rough rabbitsfoot	*Quadrula cylindrica strigillata*	Federal Endangered
Snails: TOYR 1 April – 15 June		
Spider elimia	*Elimia arachnoidea*	State Endangered
Spiny riversnail	*Io fluvialis*	State Threatened

Table 2. Listed State and Federal fishes and corresponding time of year restrictions (TOYR)

Common Name	**Scientific Name**	**TOYR**	**Status**
Blackside dace	*Phoxinus cumberlandensis*	01 April - 01 August	Federal Threatened
Slender chub	*Erimystax cahni*	01 April - 01 July	Federal Threatened
Golden darter	*Etheostoma denoncourti*	01 May - 31 August	State Threatened
Variegate darter	*Etheostoma variatum*	15 March - 31 July	State Endangered
Yellowfin madtom	*Noturus flavipinnis*	15 May - 31 July	Federal Threatened

4. BIOLOGICAL AND CHEMICAL MONITORING

Pre-project (baseline) and permit phase biological and chemical monitoring will enable evaluation of potential ecosystem changes over time in response to mining activities. In general, monitoring stations should be sited downstream from the permitted areas in each sub-basin to document cumulative impacts to the aquatic biota.

4.1 Probable Biological Consequences

Applicants should include a Probable Biological Consequences (PBC) statement. The PBC should include an evaluation of macroinvertebrate and fish biomonitoring, as well as in-stream chemistry data. Monitoring regimes for biological and chemical parameters are provided (Table 3) to account for natural seasonal variability. If no adverse ecological impacts are detected, or identified stressor sources are eliminated during the initial 5 years of mining activity, then monitoring frequency may be reduced during the remainder of the life of the permit. If no adverse impacts are detected in years 0-5, subsequent monitoring for renewed permits should be required only during the Mid-term Permit Review year, as specified in Table 3. The monitoring plan may be amended by the permitting agency, if operational and/or treatment processes and/or conditions change significantly during the life of a permit.

Table 3. Monitoring program for each new coal mine permit or initial permit renewal following adoption of species specific protective measures.

Monitoring target	Years/ Frequency/ Seasonal window(s)[1]	Method(s)[2]	Location(s)
Invertebrates	0 – 5/ twice per year / Feb. 15 – May 15 and Sep. 15 – Nov. 15	KYMBI,	Fish IBI site plus one site below the downstream-most NPDES outfall. Applies to intermittent and perennial streams.
Fish	0, 2, 4/ once per year / July 15 – November 15	TVA IBI for UTRB streams (Appendix 1) KIBI for Big Sandy R. Basin streams	Below point where all drainage from the permit area passes. Perennial streams only.
In-stream surface water chemistry.	Years 0 – 5, twice per year at invert. sites; and years 0, 2, 4, once per fish-sampling year	EPA (Appendix 3)	Fish & invertebrate Sites

1. Year 0 is baseline, pre-project. If no adverse impacts to streams are detected during the initial 5 yr. monitoring period and the permit is renewed, fish, invertebrate, and in-stream surface chemistry monitoring should be repeated at the appropriate frequency only during the year of the mid term review.
2. Acronyms identified below

4.1.1 Macroinvertebrate Biomonitoring:

Macroinvertebrate sampling and index scoring should follow the Kentucky Department of Environmental Protection, Division of Water protocols (Mills *et al*. 2002; Pond and McMurray 2002; Pond *et. al.* 2003). The Kentucky Macroinvertebrate Index (KYMBI) is based partly on a large sample size of streams that are in the same ecoregion as the Virginia coalfields and includes versions for application to either headwater or larger streams. The KYMBI relies on invertebrates identified to the highest practicable level of taxonomic resolution[2], thereby providing a means to more accurately detect responses related to environmental alterations, as well as subtle changes that may go undetected using family-only taxonomy. In addition to conducting the habitat assessments that are part of the KYMBI protocol, instantaneous flow should be measured at the most downstream macroinvertebrate site during both the winter-spring and fall sampling foray. After two consecutive declines in MBI scores, the DMLR, USFWS and DGIF will confer to determine if any permit modifications or remedial actions are needed to address the declines.

[2] Although the KYMBI was developed to utilize genus/species level identification of Chironomidae (midges), in the Virginia coalfields Chironomidae need only be identified to the family level. This will increase the speed at which macroinvertebrate bioassessments can be accomplished and address uncertainty in identifications due to the limited pool of competent midge taxonomists.

4.1.2 Fish Biomonitoring:

To monitor fish assemblages in Tennessee River Basin streams, the Tennessee Valley Authority's (TVA) Index of Biotic Integrity (IBI) should be calculated after application of counterpart sampling protocols (Appendix 1). Over the past 20-plus years, the TVA fish IBI has been developed and refined based on a large number of samples in streams of the Tennessee River Valley, including Virginia. The TVA IBI metrics account for inherent variance in fish assemblage composition due to ecoregion and watershed size effects. Monitoring fish assemblages should be done during the baseline, pre-project year and then every other year through year 5. If no impacts are identified, monitoring would be repeated only during the year of the subsequent Mid-term Permit Review. Fish IBI sampling stations will be located immediately downstream of the confluence of tributaries draining the permit area. Some sampling stations may receive drainage from more than one permit. Therefore, if significant changes or declines occur at a fish IBI station, DMLR may revise the biological and/or chemical monitoring to isolate the specific stressor source(s).

For mine sites in the Big Sandy River Basin within 5 or 10 stream miles (depending upon the type of operation as noted previously) of a State listed aquatic species, fish assemblages should be monitored using the Kentucky Index of Biotic Integrity (KIBI, Compton *et al.* 2003) and associated sampling protocols. As with the TVA IBI, the KIBI is adjustable to ecoregion and watershed size and should be measured during years 0, 2, and 4. A spreadsheet template for calculating KIBI scores is available at http://www.water.ky.gov/sw/swmonitor/sop/. Both the KIBI and TVA IBI require measurement of the watershed area extending upstream from the point where sampling begins. To adjust metric scoring criteria for watershed size using the TVA IBI, trisected plots (Appendix 1) should be used. Instead of the trisected plot method, the KIBI incorporates watershed size (as Log_{10} catchment area) in spreadsheet equations provided to calculate metric scores.

4.1.3 Blackside Dace Surveys:

The federally listed threatened blackside dace (*Phoxinus cumberlandensis*) has recently been introduced from its native range in the Cumberland River system (Skelton and Strange 2003) to the Powell River system. It has been found in North Fork Powell River tributaries along and close to the Black Mountain drainage divide. USFWS requests for blackside dace surveys will be restricted to the North Fork Powell River watershed, unless specimens are found elsewhere in the Virginia coalfields. In the North Fork Powell drainage, if a project is to occur within 2 miles upstream of a DGIF record for blackside dace, SSPM (provided herein or an alternative approved by DMLR and USFWS) must be implemented for the dace. If an occurrence for the blackside dace is known within 10 miles of the project, then a survey should be conducted within appropriate stream habitat in this area. If the blackside dace is found during the survey, approved SSPM should be implemented.

4.1.4 In-Stream Chemistry:

Surface water chemistry should be monitored concurrent with sampling at biomonitoring sites. It is likely the composition and concentration of chemicals will vary differently in response to seasonal flow changes. Surface water sampling should be conducted at all biomonitoring sites. As samples are collected for laboratory analyses, instantaneous pH, temperature, dissolved oxygen, and specific conductance should be measured in the field, contemporaneously with all fish and macroinvertebrate sampling events. Total dissolved solids should be determined through laboratory testing until such time as a correlation can be established between specific conductance and total dissolved solids.

4.1.4.1 Surface Water:

In-stream inorganic water chemistry should be taken concurrently with each macroinvertebrate and fish IBI sample. Surface water samples should be collected and analyzed for the presence of the following constituents or water quality properties: dissolved aluminum, antimony, arsenic, beryllium, cadmium, chromium VI, copper, dissolved iron, lead, dissolved manganese, magnesium, mercury, nickel, selenium, silver, thallium, and zinc, ammonia, pH, hardness, alkalinity, sulfate, acidity, sodium, potassium, chloride. Approved methods are in Appendix 3. *Interim Chemical/Biological Monitoring Protocol for Coal Mining Permit Applications* (USEPA 2000, http://www.epa.gov/region3/mtntop/pdf/interim_monitorprotocol.pdf), recommends that each of these parameters be monitored to provide useful information upon which Clean Water Act permit decisions can be made.

4.1.4.2 In-Stream Sediment Monitoring:

DMLR will:

- implement a pilot program to characterize in-stream sediment in the Indian Creek watershed, Tazewell County
- develop a sediment monitoring plan for Indian Creek with input from DGIF, OSM, USFWS, and interested stakeholders in the Indian Creek watershed.

5. PILOT PROGRAM FOR WHOLE EFFLUENT TOXICITY (WET) TESTING

Duration: 2.5 years

In coordination with the regulated community, the DMLR will select three permittees, each with at least one of the following types of discharges within 5 stream miles of listed species (sampling to be conducted at end-of-pipe):

- Chemically-treated sedimentation pond effluents
- Deep mine water discharges
- Effluents from ponds receiving coal pile runoff

Quarterly, DMLR will request whole effluent toxicity tests using the effluent from these sources on fathead minnow, a cladoceran, and amphipod following American Society for Testing and Materials E729-96 (2002): *Standard Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians.* Lowest Observable Effects Concentrations (LOEC) and Effects Concentrations (EC) shall be determined. Permittees, OSM, DMLR, VDGIF, and USFWS may split samples and conduct parallel tests.

Following completion of the Pilot Program, the four agencies will review the results and determine whether whole effluent toxicity testing is warranted on a routine basis.

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Appendix 1

Draft TVA Protocol for Conducting an Index of Biotic Integrity
Biological Assessment, Updated 2005

DRAFT

TVA PROTOCOL FOR CONDUCTING AN INDEX OF BIOTIC INTEGRITY BIOLOGICAL ASSESSMENT, UPDATED 2005

Introduction

The index of biotic integrity (IBI) is an environmental assessment of a stream based on ecological metrics applied to the resident fish community (Karr, 1981). Twelve metrics address species richness and composition, trophic structure, fish abundance, and fish condition (Table 1). Each metric reflects the condition of one aspect of the fish community and is scored against expectations under reference conditions. Potential scores are 1-poor, 3-intermediate, or 5-the best to be expected. Scores for the 12 metrics are summed to produce the IBI for the site. The IBI is then classified using the system developed by Karr et al. (1986) rating the site from “Very poor” to “Excellent” (Table 2). Additional information on the strategies underlying the methodology and individual metrics is presented by Plafkin et. al. (1989).

Site Selection

There are two steps in sample site selection. Use a 7.5 minute topographic map(s) to locate the study area and potential stream access points which may serve as sampling sites. Secondly, visit potential access points to select sampling sites and get property owner permission, if necessary. Sample site selection is governed primarily by study objectives, stream physical features, and stream access.

Study Objectives

To monitor a point source discharge, sample sites should be located upstream (control site) and downstream (study site) of the point source to isolate and measure potential effects. If possible, sample sites should be located to avoid having other potential sources of pollution contribute to the stream between the sampling sites and the targeted point source. Such extraneous influences can distort results and, if they can not be avoided, may also need to be assessed to help explain results. Another concern is locating the study site downstream of the mixing zone of the point source effluent. It is important that all fish and all habitats within the stream channel be exposed to the effluent. Identifying the mixing zone is usually more of a problem in larger streams, generally greater than 10 m wide. These situations may require selection of more than one study site. To characterize non-point source run-off within a watershed, sites should be located in the lower end of sub-watersheds and/or periodically on the mainstream of the watershed to reflect cumulative effects from activities upstream. Localized non-point source run-off can be monitored with the same strategy used to monitor point source discharge.

Stream Physical Features

Three basic stream habitats which characterize streams are riffle, run, and pool. The presence of these basic habitats at a site is essential to obtaining an accurate assessment. Exceptions to this rule are when the study objective is to assess the loss of one or more of these habitats or when streams in the surrounding eco-region typically lack one of the basic habitats.

Sampling

Ideally sampling should produce a representative sample of the fish community and an estimate of fish relative abundance (catch rate). The number of species collected in a sample is largely dependent on the number of different habitats sampled. Basic habitats (usually riffle, run, pool, and shoreline) that are characteristic of the subject stream should be targeted for sampling. More specific habitats (usually a variation of basic habitat by substrate or cover) are often associated with higher species diversity in medium to large rivers. The need to target these additional habitats for sampling should be determined by someone familiar with the regional fish fauna.

In most streams, multiple sampling techniques are necessary, including boat shocking in pool habitat too deep to wade. In small streams (5 ft or less in average width) backpack shocking alone may be sufficient. Sampling requires at least five people (one person recording data, two people working the seine, one person operating the backpack shocker, and one person carrying a dip net and bucket). If a major portion of the stream habitat is deep pool, two additional people are needed to boat shock this habitat. Field equipment required to collect an IBI are listed in Table 3.

Sampling protocol depletes species from dominant habitats, usually riffle, run, pool, and shoreline. In large rivers additional dominant habitats, based on substrate type (e.g., gravel run), may be targeted for species depletion. With the exception of shoreline, habitats are sampled until three consecutive units of sampling effort produce no additional species for that habitat. Shoreline, which often over-laps the other three habitats, is sampled until an effort produces no new species for the site. A unit of sampling effort covers 300 square feet (e.g. 15 ft by 20 ft) in streams averaging more than 15 feet in width. In narrower streams each sample effort should cover an area 10 feet times the average width (e.g. 10 ft by 8 ft for a stream averaging 8 ft wide). Additional sampling in minor habitats may be done if deemed necessary by the crew leader.

Spring and summer are recommended sampling seasons. Sampling during fall and winter can be complicated by the prevalence of young of the year (YOY) fish which are not considered in IBI analysis but complicate sample processing. Also, decreasing water temperatures during late fall and winter cause some fish species to hide in heavy cover where they are more difficult to capture. If sampling must be done during fall, YOY may be partially avoided by using a larger mesh (1/4”) seine.

Young-of-year (YOY) fish are omitted from the analysis because they have not been subjected to conditions at the sample site for an adequate period of time to fully reflect those conditions (Karr, 1981). They are, however, noted in the comments section of the field sheet because they may provide additional insight on the health of the sample site.

Seining

Two techniques are used, seine hauling and backpack shocking into the seine. Seine hauling is used to sample shallow pool and run habitats that are relatively free of boulders, snags, or other obstacles that may foul the seine. Two people haul (actually pull) an open seine through the water to herd and trap fish. A haul may be terminated by beaching the seine on shore or by rapidly lifting the seine at midstream. (Sampling efficient is much reduced if the seine is hauled against the current).

Backpack shocking into the seine is used in riffle and run habitats. This is accomplished by positioning the seine perpendicular to the stream flow and shocking a predefined area downstream to the seine. Stunned fish drift downstream and into the seine. An additional person dip netting stunned fish caught in snags or boulders may be needed. With both seining techniques, it is imperative that the lead line of the seine be kept as close to the substrate as possible to contain fish.

The area sampled by either technique is calculated as a rectangular transect, the width of the seine times distance hauled or shocked. The seine width may be adjusted by rolling-up seine on the brails. Transect length may be measured with a measured length of rope, hip chain, loggers tape, or other device with similar accuracy.

Shoreline Shocking

A backpack shocker and dip net are used to collect fish from around logs, boulders, undercut banks, and brush piles in shallow water. During sampling, fish caught should be frequently transferred from the dip net to a bucket of water to reduce fish mortality and escapement. Collections should proceed in an upstream direction to avoid reduce visibility due to turbidity caused by sampling. The area sampled is calculated by multiplying the length (ft) of the shocking run times the effective width sampled (we use two feet). A hip chain or range finder is recommended as devices for measuring run length.

Boat Shocking

A boat-mounted, 230 volt DC generator is used to sample deep pool areas. A ten-minute shocking run is made in a downstream direction which allows stunned fish to rise to the surface in front of the boat. Sampling efforts are alternated between midchannel and shoreline habitat. This allows deep pool areas to be treated as a single habitat when depleting species. If possible, avoid resampling an area. However, when deep pool habitat is limited it may be necessary to resample one or more areas to achieve species depletion. Fish captured in resampled areas should be excluded from catch rate and proportional metrics.

Boat shocking appears to have a much lower catch rate per area than shoreline shocking or seining. In relatively health rivers, approximately five minutes of boat shocking are required to catch the average number of fish taken by other methods from a 300 square feet area. Until boat shocking effort can be better quantified, five minutes of boat shocking will be considered equivalent to the effort spent sampling 300 square feet area (each 10 minute boat shocking run is considered equivalent to two units of effort).

Sample Processing

After each seine haul or shocking run, fish captured are sorted by species, counted, and examined for anomalies. This information, along with habitat type and dimensions of the area sampled, is recorded on the field sheet or data logger. Voucher specimens, especially of unusual species, should be retained to verify identification. Subsamples may also be retained for laboratory processing when fish become too numerous to work efficiently in the field or when quality assurance is being applied to sampling. Voucher specimens and subsamples should be preserved in a jar containing 10 percent formalin and labeled with location, date, and crew leader. Each subsample should be labeled and preserved separately from other specimens. This is done by placing the subsample and label in a perforated zip-lock bag before being preserved with other specimens or subsamples. Fish not retained should be released in a manner which will prevent their recapture, off-site or after sampling is done.

IBI Analysis

Metrics

The 12 metrics used for the Tennessee Valley streams (Table 1) are based on Karr (1981). Most Tennessee Valley streams support a greater diversity of fish than the midwestern streams studied by Karr and metrics have been modified to accommodate this difference. Metric 6 (proportion of individuals as green sunfish) has been modified to include other designated tolerant species. Metric 8 (proportion of individuals as insectivorous minnows) has been modified to include fish designated as specialized insectivores-darters, madtoms, and selected minnow species. Metric 7 (proportion of individuals as omnivores) has been modified to include stoneroller species, who's increased numbers are usually associated with nutrient enrichment.

Alternate metrics for metrics 2, 3, 4, and 11 (see Table 1) are prescribed for use in perennial headwater streams located at elevations under 1,800 feet. Headwater streams are defined as: Ridge and Valley Ecoregion and Interior Plains Ecoregion streams having less than 5 square mile drainage areas, Blue Ridge Ecoregion streams having less than 10 square mile drainage areas, and Southwestern Appalachian Ecoregion streams having less than 100 square mile drainage areas. Naturally low fish diversity found in these streams reduces the accuracy of the four original metrics. Alternate metrics 2, 3, and 11 measure ecological parameters comparable to those measured by the original metrics. Alternate metric 4 (percent compositions by the two most dominant species) was taken from Kearns et al. (1994) and can be considered a more sensitive version of metric 7 (percentage of fish as tolerant species). It was chosen as an alternate metric because disturbed fish communities in headwater streams are sometimes dominated by opportunistic species (*Cottus* sp., *Rhinichthys* sp., *Campostoma* sp., etc.) rather than designated tolerant species.

A 12 metric IBI apparently reaches the limit of its utility in headwater streams of the Blue Ridge Mountain and Southwestern Appalachian ecoregions. Blue Ridge Mountain streams draining less than 10 MI^2 and located at elevations greater than 1800 Ft. are naturally coldwater and usually support no more than four native species. Increases in native fish diversity in these streams appear to be associated with increases in land use and subsequent warming of the stream. Consequently, most of the 12 IBI metrics will not accurately measure the ecological health of fish communities in these streams. Alternate metrics and indices for coldwater streams have been proposed by Steedman (1988), Lyons (1995), and Williams (1996). More work needs to develop metrics and indices for fish bioassessment in this ecoregion. Headwater streams in the Southwestern Appalachian Ecoregion are even more limited for use of IBI. Fish diversity is naturally low and seems to vary with the degree of intermittence exhibited by these streams. IBI is not recommended for streams draining less than 10 MI^2 in the Southwestern Appalachian Ecoregion.

Scoring Criteria

Metric scoring criteria are illustrated graphically (Figures 1a-4q) for four of the eight ecoregions indicated for the State of Tennessee and the Tennessee Valley (EPA, 1995). Each graph consists of values derived from IBI samples taken by TVA from streams with conditions ranging from very degraded to nearly pristine (potential reference condition). Graphs were also examined for major watersheds within each ecoregion. Symbols on figures 1a-4q are used to distinguish among watersheds. In some cases, watershed specific scoring criteria were necessary. Criteria were set using the trisection method described by Karr (1981) or the flat trisection method presented by OEPA (1987).

Species Designation

Designations for tolerance, trophic guilds, and spawning guild are essential for scoring metrics 5 through 9, and 11. Recommended designations (table “Fish _Species.xls”) are based on ecological information presented by Balon (1975), Pflieger (1975), Smith (1979), Lee et. al. (1980), Etnier and Starnes (1994), and on professional judgment of TVA biologist. Some designations may change as our knowledge of species ecology increases.

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Table 1. List of metrics used in calculating Index of Biotic Integrity*

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1. Number of native species

2. Number of native darter species
   or (headwater streams)** Number of riffle species

3. Number of native sunfish species (less Micropterus sp.)
   or (headwater streams) Number of pool species

4. Number of native sucker species
   or (headwater streams) Percent composition by two most dominate species

5. Number of intolerant species
   or (headwater streams) Number of headwater intolerant species

6. Percentage of fish as tolerant species

7. Percentage of fish as omnivores and stoneroller species

8. Percentage of fish as specialized insectivores

9. Percentage of fish as piscivores

10. Catch rate (average number/300 Sq. Ft. or 5 minutes of boat shocking)

11. Percentage of fish as hybrids
    or (headwater streams) Percentage of fish as simple lithophilic spawners

12. Percentage of fish with disease, tumors, fin damage, and other anomalies

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*Each is assigned a value as follows: 1-poor, 3-intermediate, 5-the best to be expected. The IBI for a given site is the sum of those values.

**Headwater streams include perennial streams with drainage areas of <five to one square miles (Central Appalachian Ridges and Valleys, and Interior Plateau Ecoregions), <10 to one square miles (Blue Ridge Mountains Ecoregion), or <100 to 10 square miles (Southwestern Appalachians Ecoregion).

Table 2. Biotic integrity classes used in assessing fish communities along with general descriptions of their attributes (Karr et al. 1986).

Class	Attributes	IBI Range
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.	58-60
Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare.	40-44
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-34
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22
No fish	Repetitive sampling fails to turn up any fish.	

Table 3. IBI field equipment.

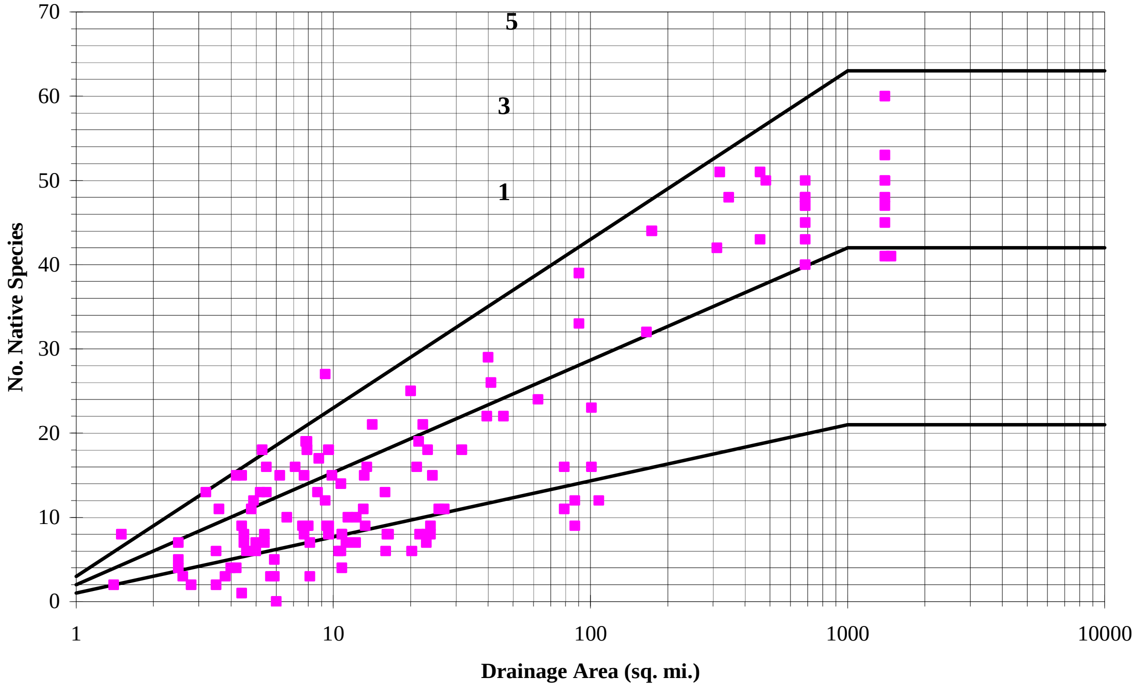
Wade sampling (all streams):

1-first aide kit
1-20’ X 6’, 3/16” mesh seine
1-10’ X 6’, 3/16” mesh seine (for small streams)
2-backpack shocker (one backup)
2-pairs of shocker gloves
1-dip net
1-clip board
Field sheets
Pencils
Distance measuring device (measuring tape, loggers tape, range finder, or hip chain)
1-bucket
1-camera with close-up lens
1-pack 8 X 8” zip-lock freezer bags
Quart collection jars
Formalin
Label paper
Chest waders

Deep pool sampling (rivers and large creeks):

1-boat mounted electrofishing unit
2-life vests
1-long-handled dip net
2-pairs of shocker gloves
1-clip board
Field sheets
Pencils
Distance measuring device (range finder or global positioning system)
1-large cooler or boat mounted fish holding tank
1-fish holding net
1-gallon collection jar
Formalin
Label paper

Figure 1



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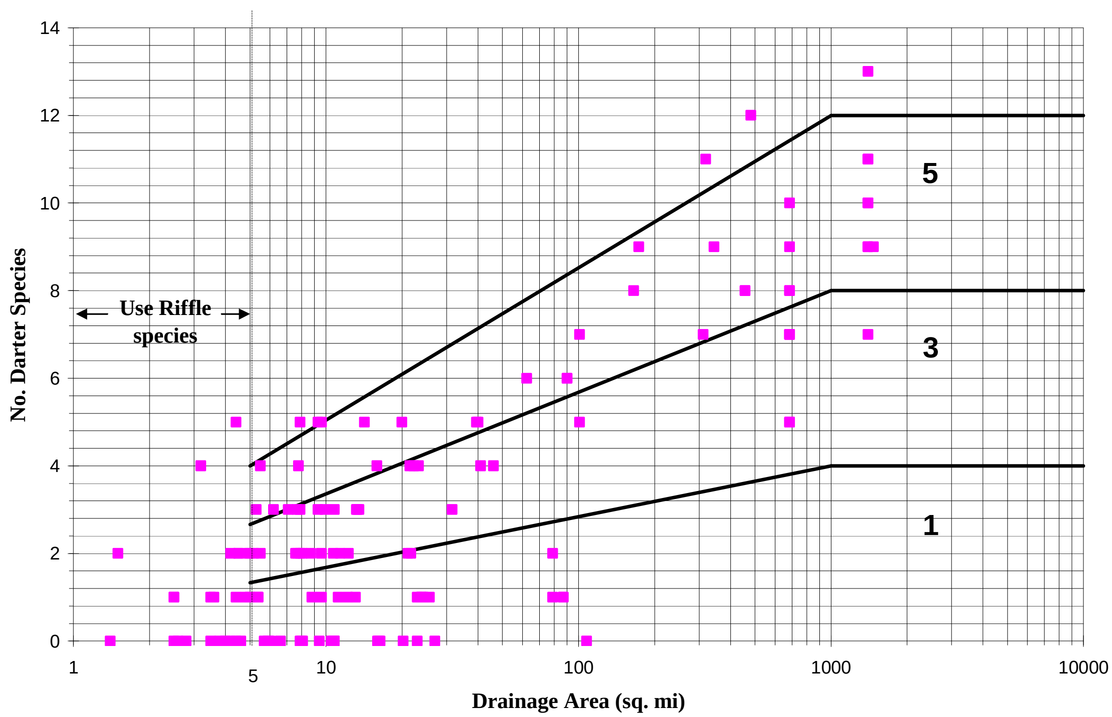

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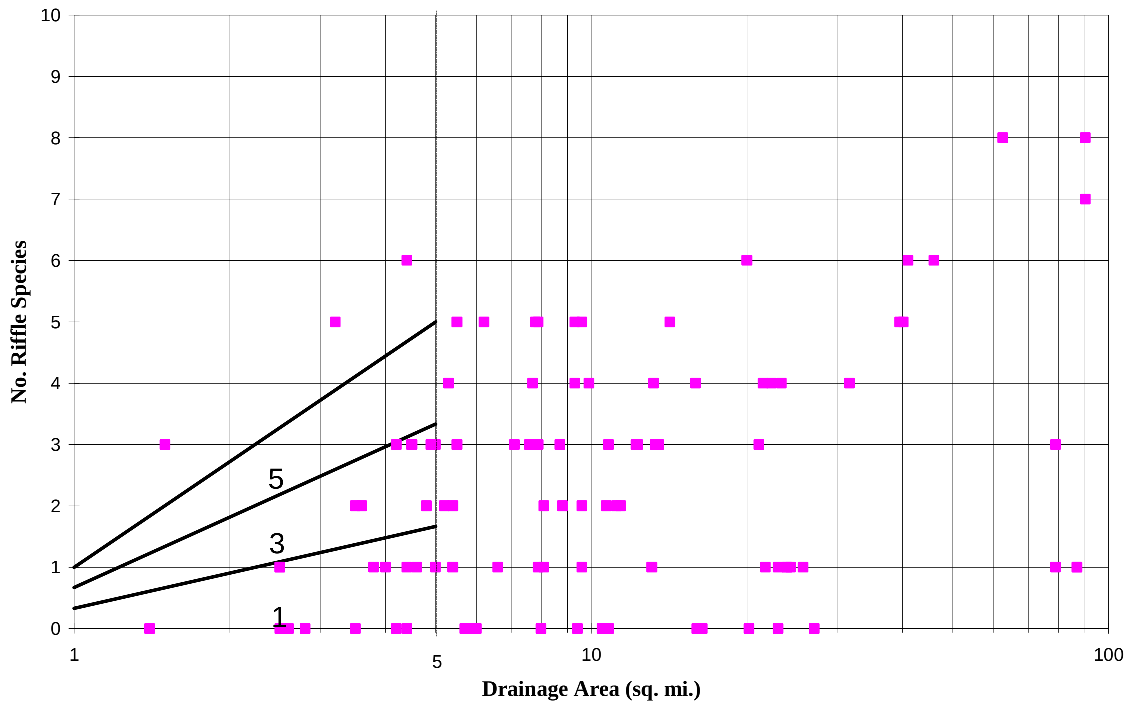

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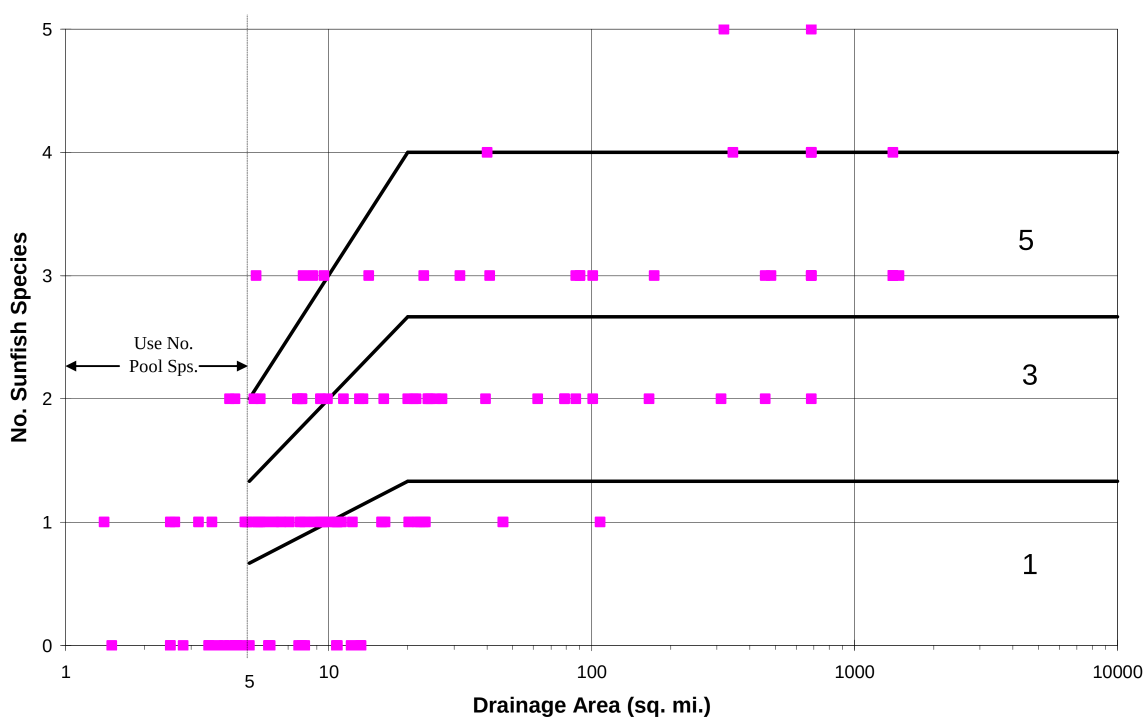

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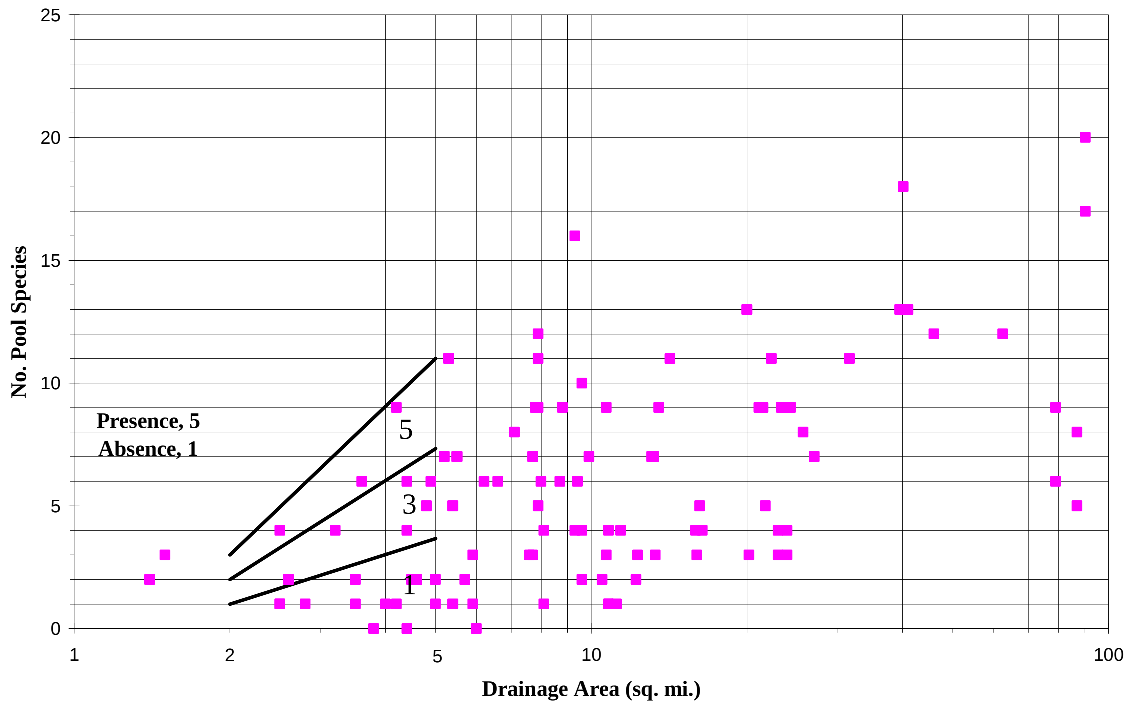

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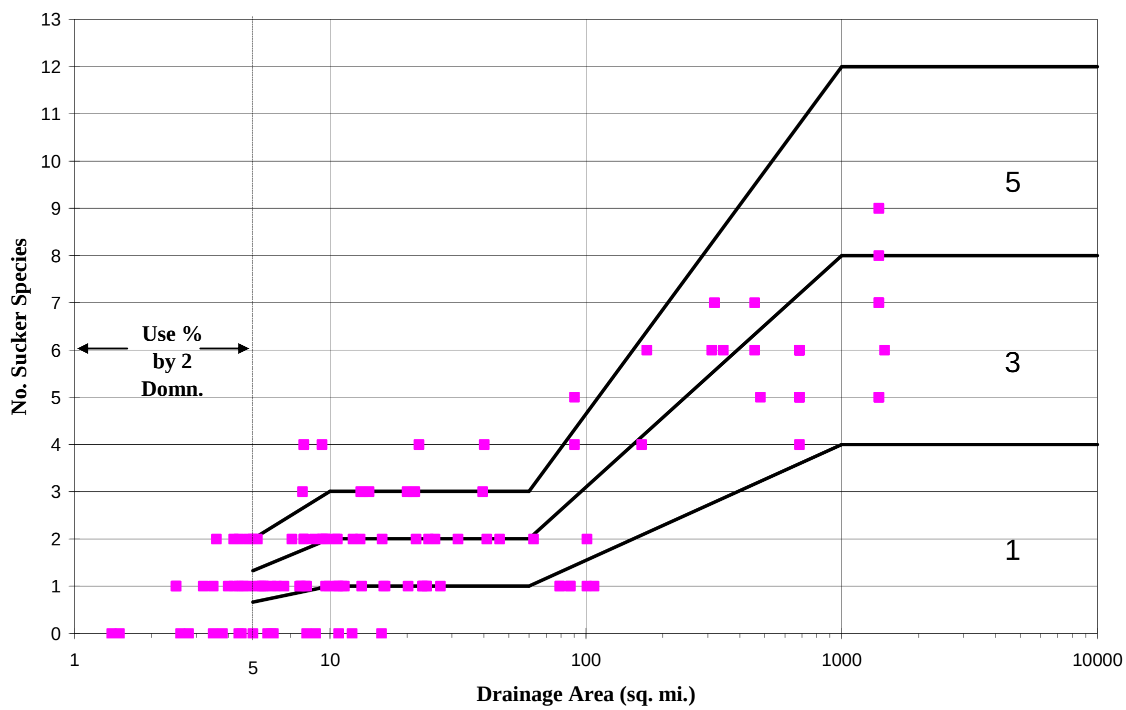

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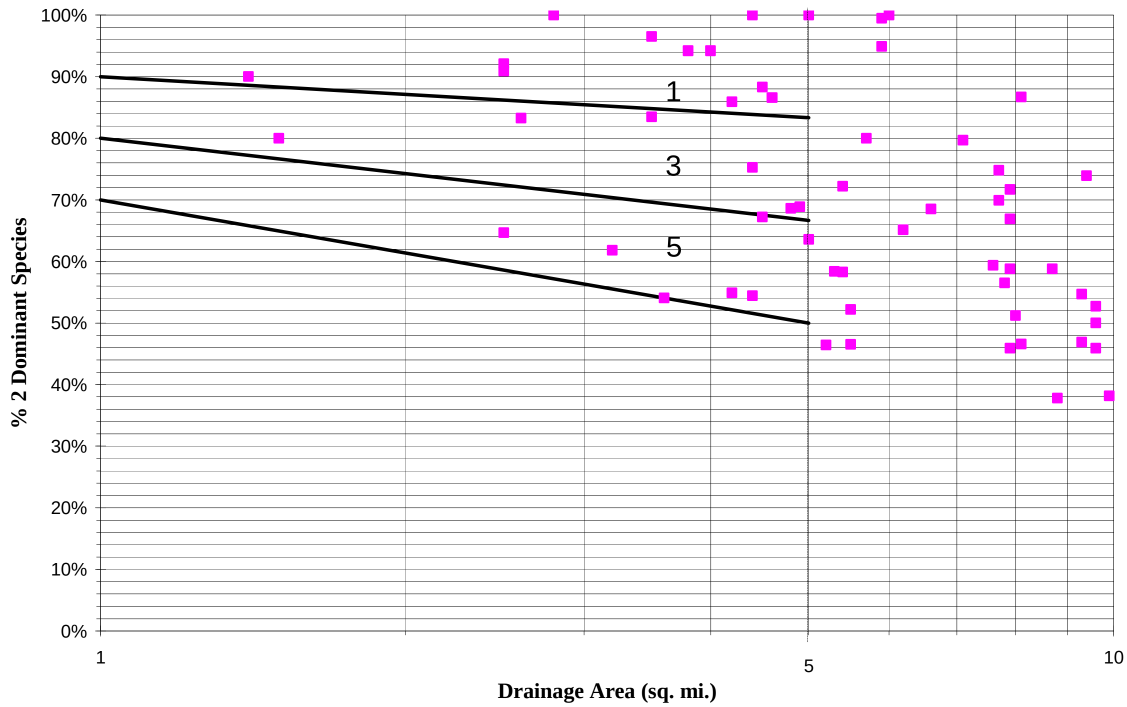

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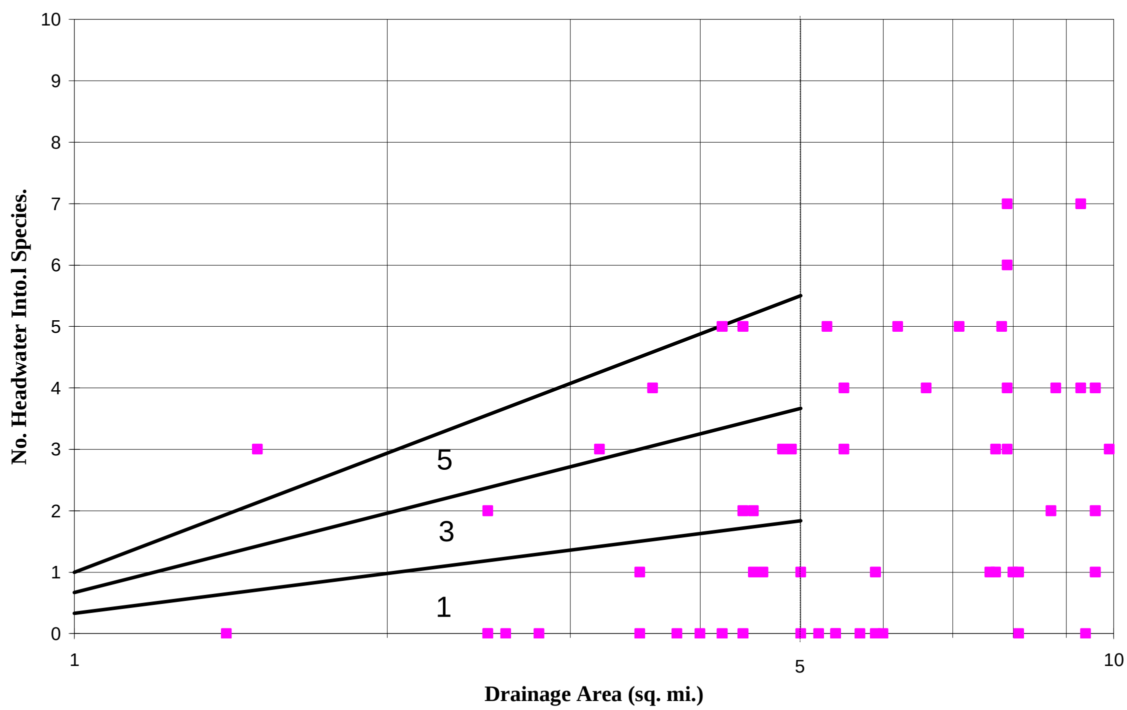

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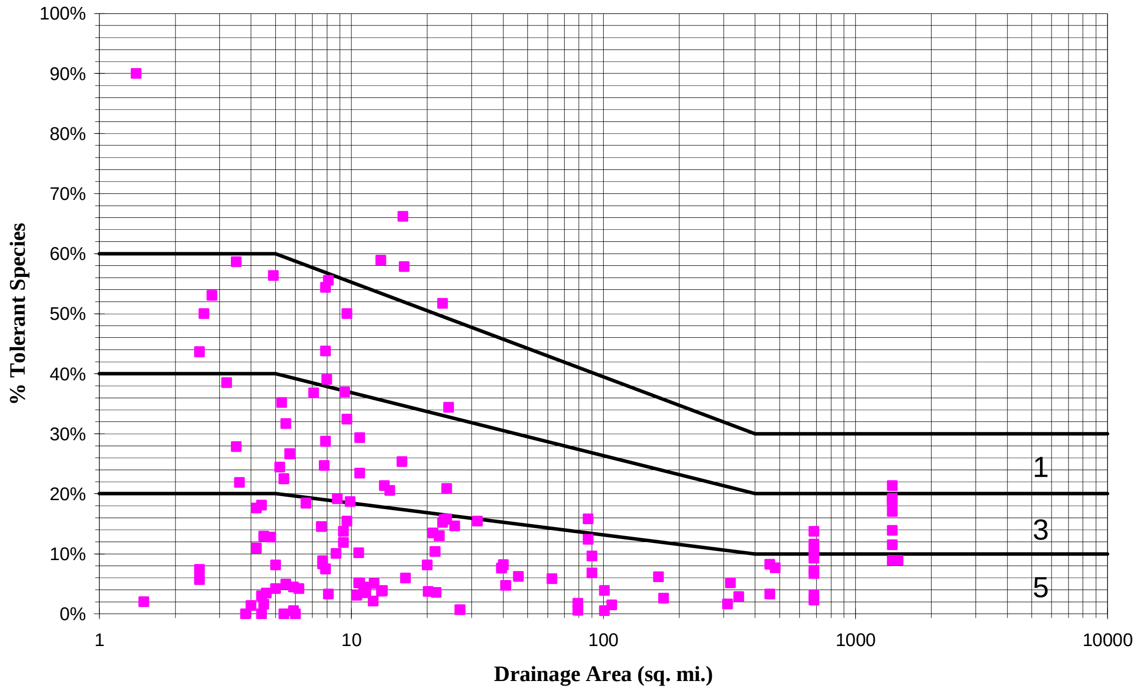

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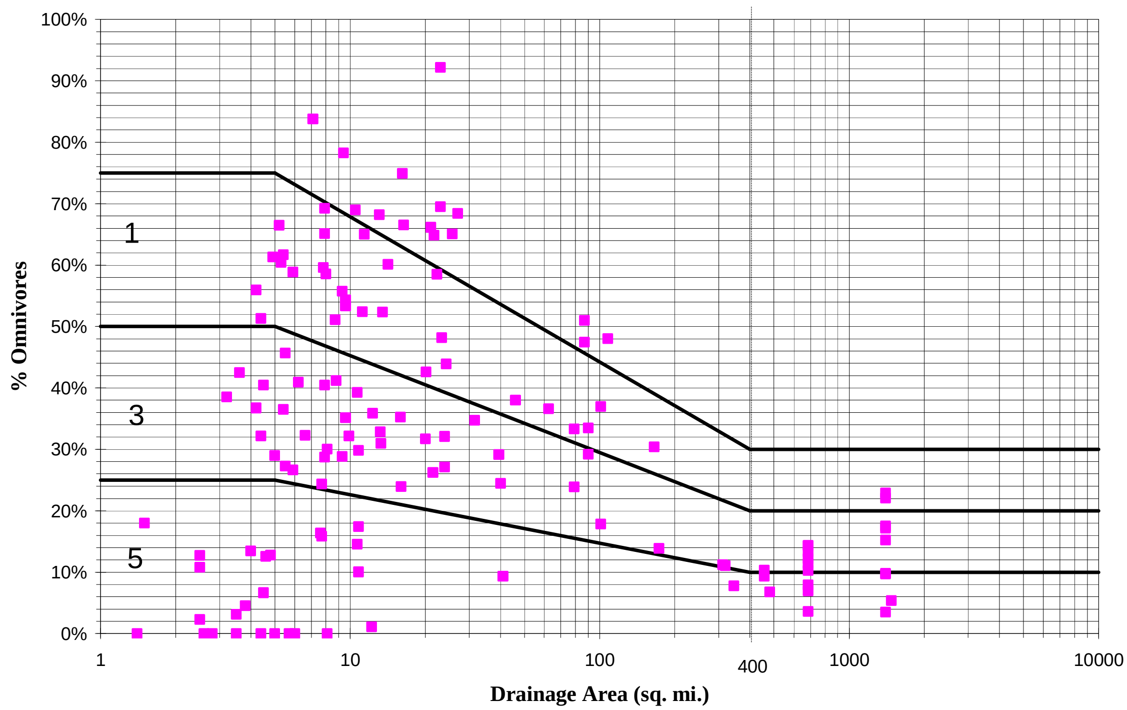

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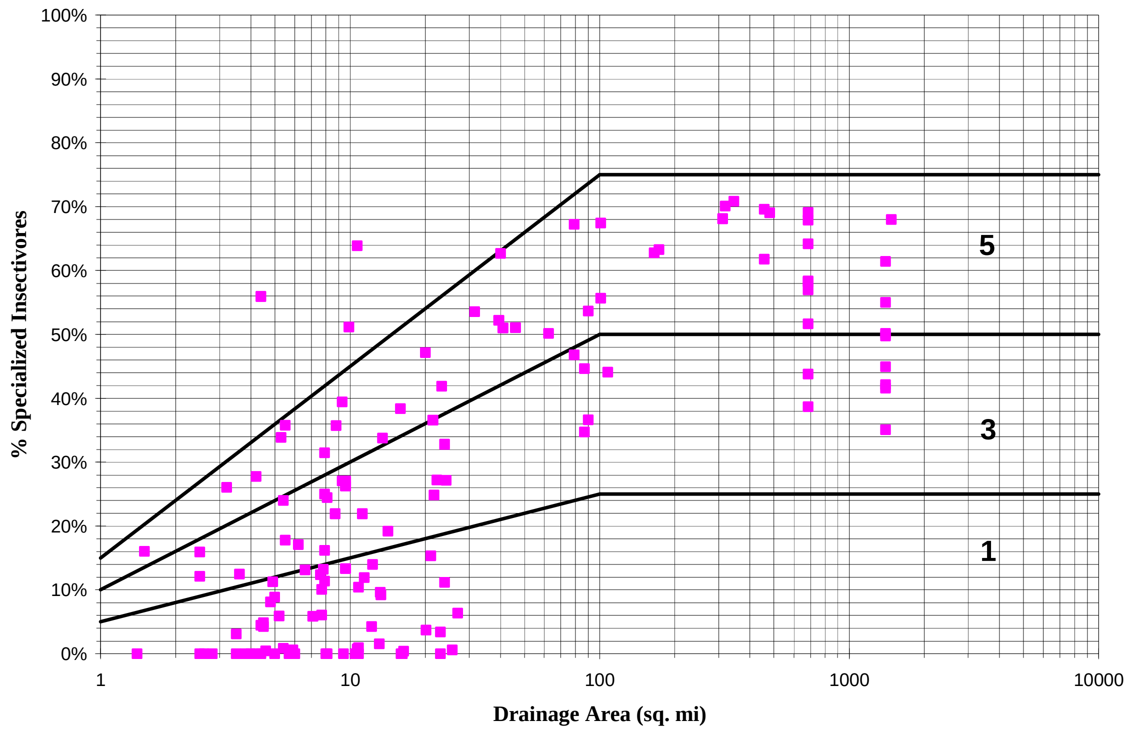

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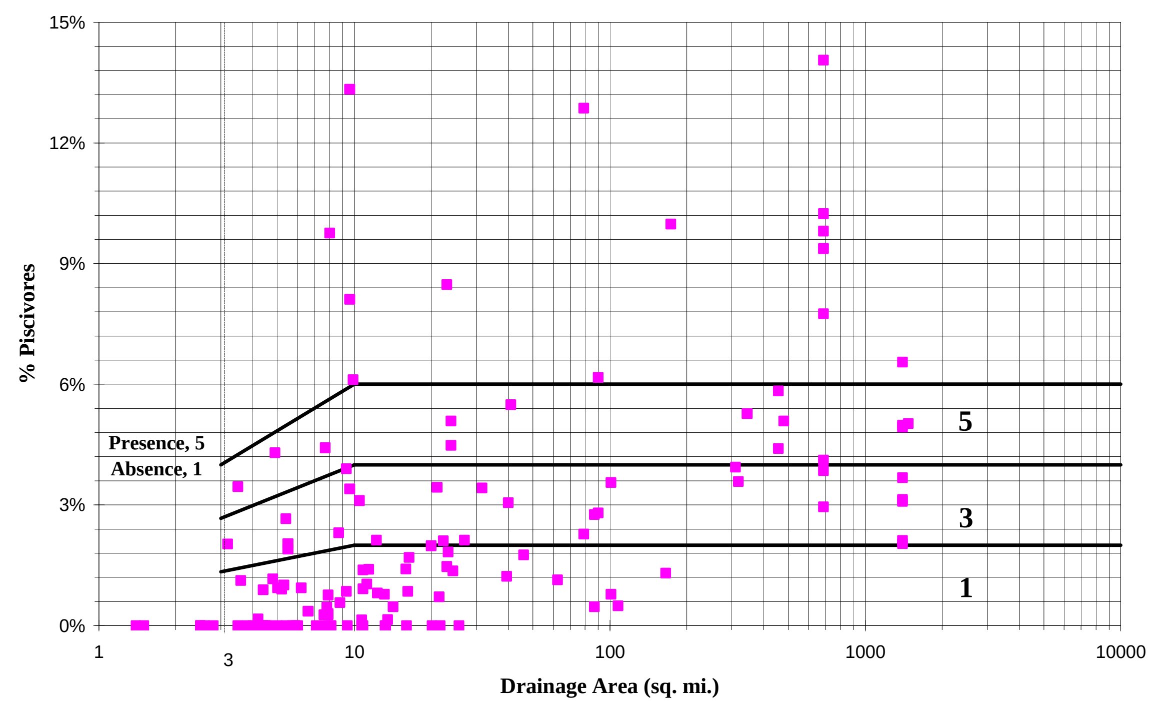

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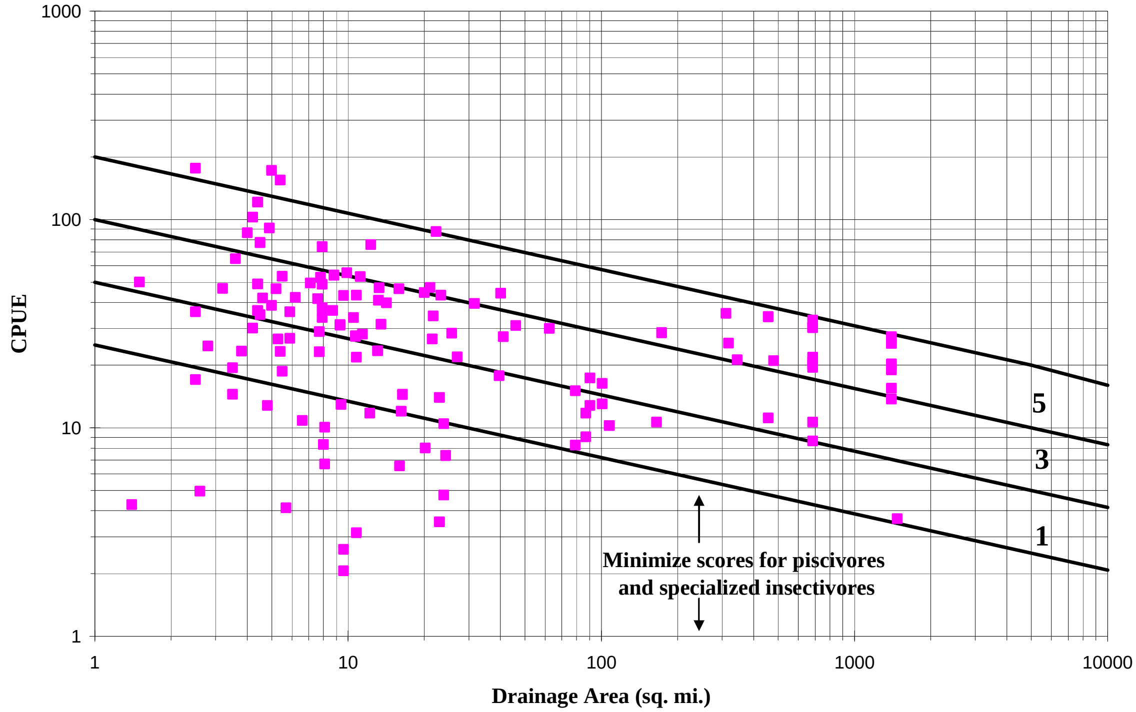

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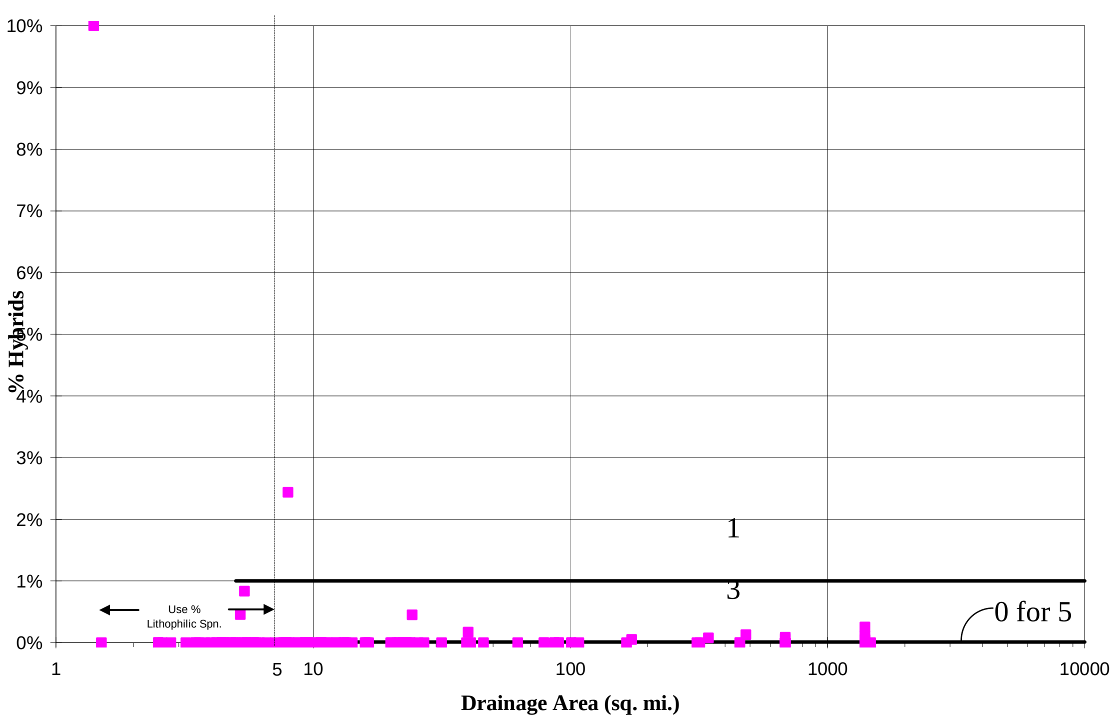

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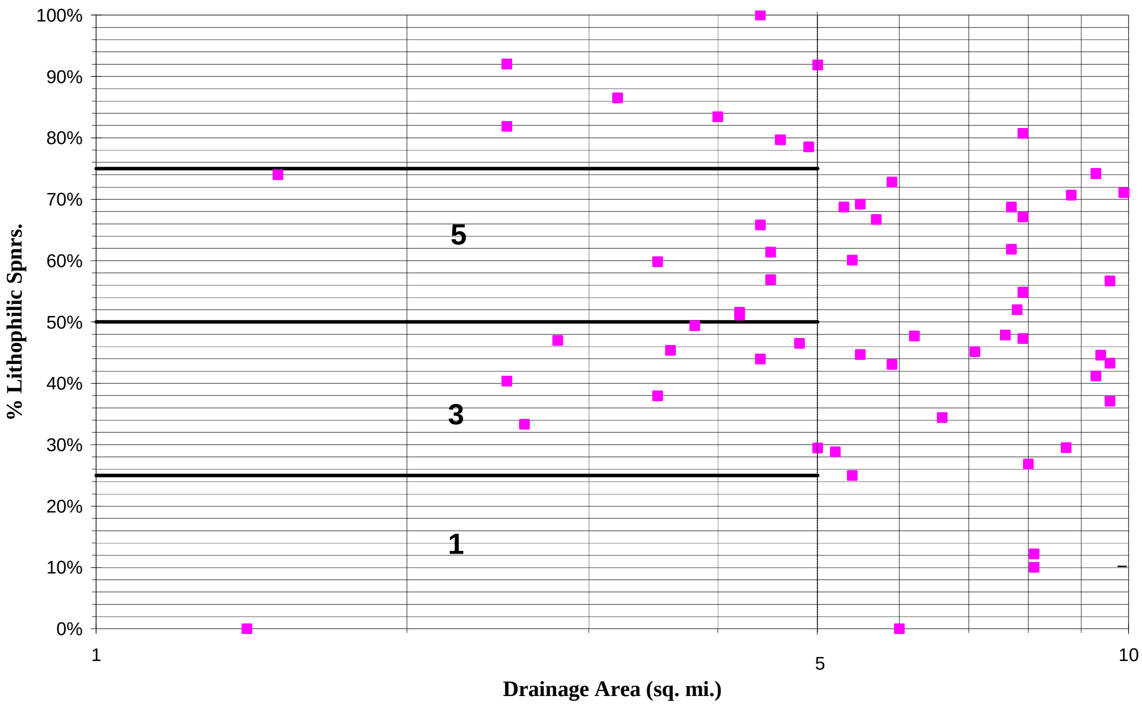

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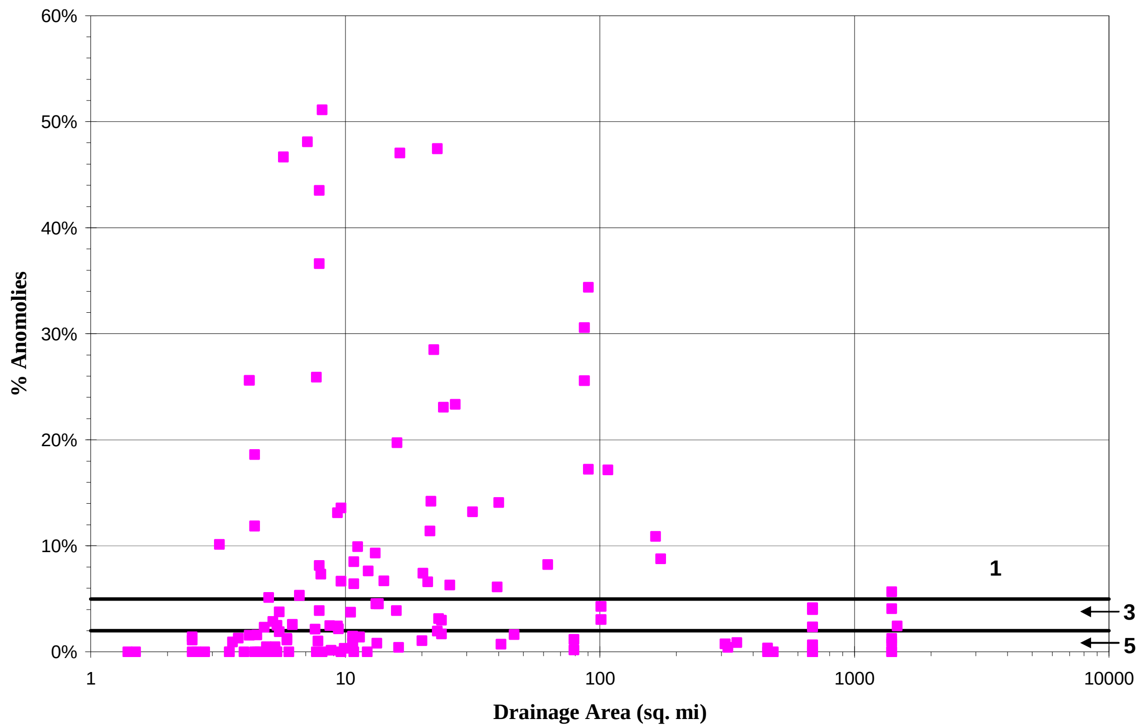

Appendix 2

Ecological Guilds of Upper Tennessee River Basin Fishes for Application to the TVA IBI

TOLERANCE	COM NAME	SCI NAME	FOOD SOURCE	REPROD GUILD	HDWTR HAB	NATIVE
	Alewife	*Alosa pseudoharengus*	PK			never
INT	Rock bass	*Ambloplites rupestris*	TC		P	always
HI	Rock bass < 5 in.	*Ambloplites rupestris* < 5 in.	TC		P	always
TO	Black bullhead	*Ameiurus melas*	OM		P	always
TO	Yellow bullhead	*Ameiurus natalis*	OM		P	always
TO	Brown bullhead	*Ameiurus nebulosus*	OM		P	always
	Unidentified bullhead	*Ameiurus* sp.	OM			always
	Western sand darter	*Ammocrypta clara*	SP	L	P	always
	American eel	*Anguilla rostrata*	TC		P	always
	Freshwater drum	*Aplodinotus grunniens*	IN		P	always
	Central stoneroller	*Campostoma anomalum*	OM			always
TO	Goldfish	*Carassius auratus*	OM			never
	River carpsucker	*Carpiodes carpio*	OM		P	always
	Quillback	*Carpiodes cyprinus*	OM		P	always
	Highfin carpsucker	*Carpiodes velifer*	OM		P	always
TO	White sucker	*Catostomus commersoni*	OM	L	P	always
INT	Rosyside dace	*Clinostomus funduloides*	SP	L	P	always
	Clinch sculpins	*Cottus* (undescribed)	IN			always
	Black sculpin	*Cottus baileyi*	IN		R	always
	Mottled sculpin	*Cottus bairdi*	IN		R	always
	Banded sculpin	*Cottus carolinae*	IN		R	always
	Unidentified sculpin	*Cottus* sp.	IN		R	always
	Grass carp	*Ctenopharyngodon idella*	HB			never
	Blue sucker	*Cycleptus elongatus*	IN	L	P	always
	Whitetail shiner	*Cyprinella galactura*	IN		P	always
TO	Spotfin shiner	*Cyprinella spiloptera*	IN		P	always
	Steelcolor shiner	*Cyprinella whipplei*	IN		P	always
TO	Common carp	*Cyprinus carpio*	OM			never
TO	Gizzard shad	*Dorosoma cepedianum*	OM		P	always
	Threadfin shad	*Dorosoma petenense*	HB		P	some
	Slender chub	*Erimystax cahni*	SP	L	R	always
INT	Streamline chub	*Erimystax dissimilis*	SP	L	R	always
	Blotched chub	*Erimystax insignis*	OM	L	R	always
	Grass pickerel	*Esox americanus vermicalutus*	TC		P	always
	Muskellunge	*Esox masquinongy*	TC		P	always
	Chain pickerel	*Esox niger*	TC		P	always
	Duskytail darter	*Etheostoma* (undescribed)	SP		P	always
	Greenside darter	*Etheostoma blennioides*	SP	L	R	always
	Rainbow darter	*Etheostoma caeruleum*	SP	L	R	always
INT	Bluebreast darter	*Etheostoma camurum*	SP	L	R	always
	Greenfin darter	*Etheostoma chlorobranchium*	SP	L	P	always
	Ashy darter	*Etheostoma cinereum*	SP	L	P	always
INT	Fantail darter	*Etheostoma flabellare*	SP		R	always
	Redline darter	*Etheostoma rufilineatum*	SP	L	R	always
	Snubnose darter	*Etheostoma simoterum*	SP	L	R	always
INT	Speckled darter	*Etheostoma stigmaeum*	SP	L	P	always
HI	Swannanoa darter	*Etheostoma swannanoa*	SP	L	R	always
INT	Tippecanoe darter	*Etheostoma tippecanoe*	SP	L	R	always
	Wounded darter	*Etheostoma vulneratum*	SP		P	always
	Banded darter	*Etheostoma zonale*	SP	L	R	always
HI	Northern studfish	*Fundulus catenatus*	SP	L	R	always

TOLERANCE	COM NAME	SCI NAME	FOOD SOURCE	REPROD GUILD	HDWTR HAB	NATIVE
TO	Western mosquitofish	*Gambusia affinis*	IN		P	some
TO	Unidentified mosquitofish	*Gambusia* sp.	IN		P	never
	Hybrid shad	Hybrid *Dorosoma*	PK			always
	Hybrid darter	Hybrid *Etheostoma*	SP			never
	Hybrid sunfish	Hybrid *Lepomis* spp.	IN			never
	Hybrid bass	Hybrid *Micropterus* sp.	TC			never
	Hybrid white x yellow bass	Hybrid *Morone* (*chrysops* x *miss*)	TC			never
	Hybrid striped x white bass	Hybrid *Morone* (*chrysops* x *sax*)	TC			never
	Hybrid redhorse	Hybrid *Moxostoma*	IN			never
	Hybrid shiner	Hybrid *Notropis*	IN			never
	Hybrid darter	Hybrid *Percina*	SP			never
	Hybrid crappie	Hybrid *Pomoxis*	TC			never
	Hybrid walleye x sauger	Hybrid *Sander*	TC			never
HI	Northern hog sucker	*Hypentelium nigricans*	IN	L		always
	Ohio lamprey	*Ichthyomyzon bdellium*			P	always
HI	Mountain brook lamprey	*Ichthyomyzon greeleyi*	HB		P	always
	Unidentified lamprey (I)	*Ichthyomyzon* sp.			P	always
	Bullhead or madtom	Ictaluridae (bullhead/madtom)				always
	Blue catfish	*Ictalurus furcatus*	OM		P	always
	Channel catfish	*Ictalurus punctatus*	OM		P	always
	Brook silverside	*Labidesthes sicculus*	IN		P	always
	Harelip sucker	*Lagochila lacera*	IN			always
	Least brook lamprey	*Lampetra aepyptera*	HB		P	always
HI	American brook lamprey	*Lampetra appendix*	HB		P	always
	Unidentified lamprey (L)	*Lampetra* sp.	HB		P	always
TO	Longnose gar	*Lepisosteus osseus*	TC		P	always
	Redbreast sunfish	*Lepomis auritus*	IN			never
TO	Green sunfish	*Lepomis cyanellus*	IN		P	always
	Pumpkinseed	*Lepomis gibbosus*	IN			never
	Warmouth	*Lepomis gulosus*	IN		P	always
	Orangespotted sunfish	*Lepomis humilis*	IN		P	always
	Bluegill	*Lepomis macrochirus*	IN		P	always
HI	Longear sunfish	*Lepomis megalotis*	IN		P	always
	Redear sunfish	*Lepomis microlophus*	IN		P	always
	Crappie or sunfish	*Lepomis* or *pomoxis*				always
	Unidentified sunfish	*Lepomis* sp.	IN		P	always
TO	Striped shiner	*Luxilus chrysocephalus*	OM	L	P	always
HI	Warpaint shiner	*Luxilus coccogenis*	SP	L	P	always
HI	Mountain shiner	*Lythrurus lirus*	SP	L	P	always
	Scarlet shiner	*Lythrurus fasciolaris*	SP	L	P	always
	Inland silverside	*Menidia beryllina*	IN			always
	Smallmouth bass	*Micropterus dolomieu*	TC		P	always
	Spotted bass	*Micropterus punctulatus*	TC		P	always
	Largemouth bass	*Micropterus salmoides*	TC		P	always
	Unidentified bass	*Micropterus* sp.	TC		P	always
	Unidentified temperate bass	*Morone* (not *saxatilis*)	TC		P	some
	White bass	*Morone chrysops*	TC	L	P	some
	Yellow bass	*Morone mississippiensis*	TC	L	P	some
	Striped bass	*Morone saxatilis*	TC	L	P	never
	Silver redhorse	*Moxostoma anisurum*	IN	L	P	always
	River redhorse	*Moxostoma carinatum*	IN	L	P	always
INT	Black redhorse	*Moxostoma duquesnei*	IN	L	P	always

TOLERANCE	COM NAME	SCI NAME	FOOD SOURCE	REPROD GUILD	HDWTR HAB	NATIVE
	Golden redhorse	*Moxostoma erythrurum*	IN	L	P	always
	Shorthead redhorse	*Moxostoma macrolepidotum*	IN	L	P	always
	Unidentified redhorse	*Moxostoma* sp.	IN		P	always
	No species found	No species present				never
	River chub	*Nocomis micropogon*	OM		P	always
TO	Golden shiner	*Notemigonus crysoleucas*	OM		P	some
	Sawfin shiner	*Notropis* (undescribed)	SP	L	R	always
HI	Bigeye chub	*Notropis amblops*	SP	L	P	always
INT	Popeye shiner	*Notropis ariommus*	SP	L	P	always
	Emerald shiner	*Notropis atherinoides*	SP	L	P	always
	Tennessee shiner	*Notropis leuciodus*	SP	L	P	always
	Silver shiner	*Notropis photogenis*	SP	L	P	always
	Rosyface shiner	*Notropis rubellus*	SP	L	P	always
HI	Saffron shiner	*Notropis rubricroceus*	SP	L	P	always
	Unidentified shiner	*Notropis* sp.				always
	Mirror shiner	*Notropis spectrunculus*	SP	L	P	always
	Weed shiner	*Notropis texanus*	SP			always
	Mimic shiner	*Notropis volucellus*	SP	L	P	always
	Unidentified madtom	*Noturus*	SP			always
INT	Mountain madtom	*Noturus eleutherus*	SP		R	always
	Yellowfin madtom	*Noturus flavipinnis*	SP		P	always
HI	Stonecat	*Noturus flavus*	SP		P	always
	Pygmy madtom	*Noturus stanauli*	SP		R	always
	Rainbow trout	*Oncorhynchus mykiss*	IN			never
	Yellow perch	*Perca flavescens*	IN			never
	Unidentified perch	*Perca* sp.				never
	Tangerine darter	*Percina aurantiaca*	SP	L		always
	Blotchside logperch	*Percina burtoni*	SP	L	P	always
	Logperch	*Percina caprodes*	SP	L	P	always
	Channel darter	*Percina copelandi*	SP	L	P	always
INT	Gilt darter	*Percina evides*	SP	L	R	always
	Longhead darter	*Percina macrocephala*	SP	L	P	always
	Blackside darter	*Percina maculata*	SP	L	P	always
	Dusky darter	*Percina sciera*	SP	L	P	always
	Fatlips minnow	*Phenacobius crassilabrum*	SP	L	R	always
	Suckermouth minnow	*Phenacobius mirabilis*	SP	L	R	always
	Stargazing minnow	*Phenacobius uranops*	SP	L	R	always
	Blackside dace	*Phoxinus cumberlandensis*	HB	L		never
HI	Southern redbelly dace	*Phoxinus erythrogaster*	HB	L	P	always
HI	Undescribed redbelly dace	*Phoxinus* sp. cf. *saylori*	IN	L	P	always
	Mountain redbelly dace	*Phoxinus oreas*	HB	L		never
HI	Tennessee dace	*Phoxinus tennesseensis*	HB	L	P	always
	Bluntnose minnow	*Pimephales notatus*	OM		P	always
	Fathead minnow	*Pimephales promelas*	OM		P	never
	Unidentified minnow	*Pimephales* sp.				always
	Bullhead minnow	*Pimephales vigilax*	SP		P	always
	Paddlefish	*Polyodon spathula*	PK	L	P	always
	White crappie	*Pomoxis annularis*	TC		P	always
	Black crappie	*Pomoxis nigromaculatus*	TC		P	always
	Unidentified crappie	*Pomoxis* sp.	TC		P	always
	Flathead catfish	*Pylodictis olivaris*	TC		P	always

TOLERANCE	COM NAME	SCI NAME	FOOD SOURCE	REPROD GUILD	HDWTR HAB	NATIVE
	Blacknose dace	*Rhinichthys atratulus*	IN	L		always
HI	Longnose dace	*Rhinichthys cataractae*	SP	L	R	always
	Brown trout	*Salmo trutta*	TC			never
INT	Brook trout	*Salvelinus fontinalis*	IN		P	always
TO	Creek chub	*Semotilus atromaculatus*	IN		P	always
	Sauger	*Sander canadense*	TC	L	P	always
	Walleye	*Sander vitreum*	TC	L	P	always
	Central mudminnow	*Umbra limi*	IN		P	always
	Unidentified chub	Unidentified chub				always
	Unidentified dace	Unidentified dace				always
	Unidentified darter	Unidentified darter	SP			always

Abbreviations: HI - headwater intolerant, INT - intolerant, TO - tolerant, F - false, IN - insectivore, SP - specialized insectivore, OM - omnivore, TC - top carnivore, PK - planktivore, HB - herbivore, L - simple lithophilic spawner, P - pool species, R

Appendix 3

Surface Water Chemistry Methods and Detection Limits

Parameters, Methods, and Detection Limits		
Parameter	Method	Detection Limits (ug/L)
Temperature (EC), Dissolved Oxygen (mg/l), pH (su), Conductivity (uS/cm)	multiparameter field meter, *in situ*.	NA
Total Suspended Solids	EPA 160.2	4000
Total Dissolved Solids	EPA 160.1	10,000
Acidity	EPA 305.1	10,000
Alkalinity	EPA 310.1	2,000
Sulfate	EPA 300.0	20
Chloride	EPA 300.0	20
Nitrate	EPA 300.0	2.0
Nitrite	EPA 300.0	4.0
Hardness	Calculate using calcium and magnesium - SM 2340B	30
Dissolved Organic Carbon	EPA 415.1	1,000
Dissolved Aluminum	EPA 200.7 (ICP optical)	20
Antimony	EPA 200.9 (Graphite furnace)	0.8
Arsenic	EPA 200.9	0.5
Beryllium	EPA 200.7 **************************** EPA 200.9	0.3 ******************* 0.02
Cadmium	EPA 200.7 **************************** EPA 200.9	1.0 ******************* 0.05
Calcium	EPA 200.7	10

Parameters, Methods, and Detection Limits, continued		
Parameter	Method	Detection Limits (ug/L)
Chromium VI	EPA 218.6	0.3
Copper	EPA 200.7	2.0
Dissolved Iron	EPA 200.7	30
Lead	EPA 200.9	0.7
Dissolved Manganese	EPA 200.7	1.0
Magnesium	EPA 200.7	20
Mercury	EPA 245.1	0.2
Nickel	EPA 200.7	5.0
Potassium	EPA 200.7	300
Selenium	EPA 200.9	0.6
Silver	EPA 200.7 EPA 200.9	2.0 0.5
Sodium	EPA 200.7	30
Thallium	EPA 200.9	0.7
Zinc	EPA 200.7	2.0