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# Appendix A. Glossary

**abundance:** An ecological concept referring to the relative representation of a species in a particular ecosystem.

**anthropogenic:** Originating from man, not naturally occurring.

**assemblage:** An association of interacting populations of organisms in a given waterbody.

**attribute:** Any measurable component of a biological system (Karr and Chu 1999). The BCG describes how ten biological attributes of natural aquatic systems change in response to increasing pollution and disturbance. The ten BCG attributes are in principle measurable, although several are not commonly measured in monitoring programs. The BCG attributes are:

* Historically documented, sensitive, long-lived, or regionally endemic taxa
* Sensitive and rare taxa
* Sensitive but ubiquitous taxa
* Taxa of intermediate tolerance
* Tolerant taxa
* Non-native taxa
* Organism condition
* Ecosystem functions
* Spatial and temporal extent of detrimental effects
* Ecosystem connectivity

**bankfull:** The water level, or stage, at which a stream, river or lake is at the top of its banks and any further rise would result in water moving into the flood plain.

**benthic:** Living in or on the bottom of a body of water.

**best attainable condition:** A condition that is equivalent to the ecological condition of (hypothetical) least disturbed sites where the best possible management practices are in use. This condition can be determined using techniques such as historical reconstruction, best ecological judgment and modeling, restoration experiments, or inference from data distributions.

**biological condition gradient (BCG):** A scientific model that describes how biological attributes of aquatic ecosystems (i.e., biological condition) might change along a gradient of increasing anthropogenic stress.

**biological criteria:** Narrative expressions or numerical values that define an expected or desired biological condition for a waterbody and can be used to evaluate the biological integrity of the waterbody. When adopted by the U.S. jurisdictions, they become legally enforceable standards.

**biological integrity:** The capacity of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

**boatable:** Navigable by boat or non-wadeable on the day of sampling

**calibration:** To adjust the model so that it can be used in an accurate and exact way.

**canal**: An artificial waterway constructed to allow the passage of boats or ships inland or to convey water for irrigation.

**catadromous**: Migrating from fresh water to spawn in the sea, as eels of the genus *Anguilla*.

**channel alterations:** Rivers and their floodplains encased in concrete, often straightening, and narrowing water flows within fixed, manageable courses, or in some cases, burying them underground into sewer networks.

**chironomid:** Chironomidae is a large and diverse family of flies, commonly known as "non-biting midges".

**Clean Water Act (CWA):** An act passed by the U.S. Congress to control water pollution (also known as the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.) [As Amended Through P.L. 107–303, November 27, 2002].

**clinger taxa:** Aquatic insects with behavioral (e.g., fixed retreat construction) and morphological (e.g., long, curved tarsal claws, dorsoventral flattening, and ventral gills arranged as a sucker) adaptations for attachment to surfaces in stream riffles and wave-swept rocky littoral zones of lakes.

**collector-gatherer taxa**: Aquatic insects that collect fine particulate organic matter from the stream bottom.

**community:** All the groups of organisms living together in the same area, usually interacting, or depending on each other for existence.

**condition:** The relative ability of an aquatic resource to support and maintain a community of organisms having a species composition, diversity, and functional organization comparable to reference aquatic resources in the region.

**connectivity:** The demographic linking of local populations through dispersal of pelagic larvae and movement of juveniles or adults (Jones et al. 2009). There are different types of connectivity including: connectivity among populations in the same habitat in different locations; connectivity among marine habitats (e.g., where species use different habitats at different stages in their life history); and connectivity between the land and the sea (Green et al. 2009).

**cyprinid:** Cyprinidaeare the family of freshwater fish that includes the carps, the true minnows, and their relatives. Not all species are small-sized.

**dam:** A structure formed to hold water back, generally built near uncontaminated water collection sources in order to provide a water supply to the surrounding communities, agriculture, or industries.

**decision rules:** Logic statements that experts use to make their decisions.

**discharge**: The volume of water passing through a channel during a given time, usually measured in cubic feet per second.

**diversion:** A structure that redirects water from its natural course.

**ecosystem**: (1) Recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them. (2) Any complex of organisms in an environment considered as a unit for the purpose of study.

**ecosystem functions:** Processes performed by ecosystems, including, among other things, primary and secondary production, respiration, nutrient cycling, and decomposition.

**electrofishing:** A common scientific survey method used to sample fish populations to determine abundance, density, and species composition. Electrofishing establishes an electric field in the water. When exposed to the electric field the fish swim toward it and are captured alive in a dip net. Electrofishing is considered to be size selective, with large fish more susceptible to capture than small ones (Wiley and Tsai 1983).

**EPT:** Three major orders of stream insects that generally have low tolerance to water pollution (E= Ephemeroptera, P= Plecoptera, T= Trichoptera).

**functional feeding group (FFG):** FFG approach categorizes qualitative macroinvertebrate collections according to their morphological-behavioral adaptations for food acquisition (e.g., scrapers that harvest non-filamentous, attached algae from stable surfaces in flowing water).

**habitat:** A place where the physical and biological elements of ecosystems provide a suitable environment including the food, cover, and space resources needed for plant and animal livelihood.

**highly sensitive taxa:** Taxa that naturally occur in low numbers relative to total population density but may make up large relative proportion of richness. May be ubiquitous in occurrence or may be restricted to certain microhabitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or cold-water obligates, commonly k-strategists (populations maintained at a fairly constant level, slower development, longer life-span), may have specialized food resource needs or feeding strategies. Generally intolerant to significant alteration of the physical or chemical environment; are often the first taxa observed to be lost from a community.

**home range:** The area in which an individual organism spends most of its time, and engages in most of its routine activities, such as foraging and resting (Kramer and Chapman 1999).

**human disturbance:** Human activity that alters the natural state and can occur at or across many spatial and temporal scales.

**hydrology:** The scientific study of the movement, distribution, and quality of water on Earth.

**hydropsychidae:** A family of net-spinning caddisflies.

**indicator:** A measured characteristic that indicates the condition of a biological, chemical, or physical system.

**integrity:** The extent to which all parts or elements of a system (e.g., an aquatic ecosystem) are present and functioning.

**intermediate sensitive taxa:** Taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often due to unique life history requirements. May be long-lived, late maturing, low fecundity, limited mobility, or require mutualist relation with other species. May be listed as threatened, endangered (under federal or local threatened and endangered species laws) or species of special concern. Predictability of occurrence often low, therefore, requires documented observation. Recorded occurrence may be highly dependent on sample methods, site selection and level of effort.

**intermediate tolerant taxa:** Taxa that comprise a substantial portion of natural communities, which may increase in number in waters which have moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration. These may be r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), eurythermal (having a broad thermal tolerance range), or have generalist or facultative feeding strategies enabling them to utilize more diversified food types. They are readily collected with conventional sample methods.

**invertebrates**: Animals that lack a spinal column or backbone, including molluscs (e.g., clams and oysters), crustaceans (e.g., crabs and shrimp), insects, starfish, jellyfish, sponges, and many types of worms that live in the benthos.

**least disturbed condition:** The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a waterbody within a class or region. These waters have the least amount of human disturbance in comparison to others within the waterbody class, region, or basin. Least disturbed conditions can be readily found but may depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition may change significantly over time as human disturbances change.

**levee**: An embankment constructed to prevent a river from overflowing (flooding).

**levels:** In the context of this report, levels are the discrete ratings of biological condition along a stressor-response curve (e.g., BCG Level 1 = excellent condition, BCG Level 6 = completely degraded).

**littoral zone:** The part of the river that is close to the shore.

**lotic**: Meaning or regarding things in running water.

**macroinvertebrates:** Animals without backbones of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard No. 30 sieve (28 meshes per inch, 0.595 mm openings).

**metadata:** Structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage data.

**metric**: Measurable quantity of an attribute empirically shown to change in value along a gradient of human influence. A dose-response context is documented and confirmed.

**migration barriers:** Dams, road culverts, levees, and other such structures that impede organisms from moving upstream. Fish need to migrate, or move, to get to habitats where they can spawn, feed, find shelter, and escape extreme temperatures or water flows.

**minimally disturbed condition:** The physical, chemical, and biological conditions of a waterbody with very limited or minimal human disturbance relative to naturally occurring, undisturbed conditions within the waterbody class or region.

**model:** A physical, mathematical, or logical representation of a system of entities, phenomena, or processes (i.e., a simplified abstract view of the complex reality). Meteorologists use models to predict the weather.

**mollusk:** An invertebrate animal with a soft body which typically has a "head" and a "foot" region. Often their bodies are covered by a hard exoskeleton (e.g., clams, scallops, oysters, and chitons).

**monitoring:** A periodic or continuous measurement of the properties or conditions of something, such as a waterbody.

**morphology**: The form, shape, or structure of a stream or organism.

**multimetric index**: An index (expressed as a single numerical value) that integrates several biological metrics to indicate the environmental status of a place.

**native species:** Species that originated in their location naturally and without the involvement of human activity or intervention.

**non-native species:** Any species that is not naturally found in that ecosystem. Species introduced or spread from one region to another outside their normal range are non-native or non-indigenous, as are species introduced from other continents.

**non-wadeable rivers:** Lotic systems more effectively and safely sampled with boat-based field methods than with wading techniques

**nutrients:** Chemicals needed by plants and animals for growth (e.g., nitrogen, phosphorus). In water resources, if other physical and chemical conditions are optimal, excessive amounts of nutrients can lead to degradation of water quality by promoting excessive growth, accumulation, and subsequent decay of plants, especially algae. Some nutrients can be toxic to animals at high concentrations.

**pelagic broadcast spawners:** A reproductive guild of fishes whose eggs and larvae drift laterally and downstream, with drift distances varying depending on channel conditions and flow (Archdeacon et al. 2018).

**piscivore:** A carnivorous animal which eats primarily fish.

**quality assurance (QA):** The process of profiling the data to discover inconsistencies and other anomalies in the data, as well as performing data cleansing activities (e.g., removing outliers, missing data interpolation) to improve the data quality .

**reference condition**: The condition that approximates natural unimpacted conditions (biological, chemical, physical, etc.) for a waterbody. Reference condition (biological integrity) is best determined by collecting measurements at a number of sites in a similar waterbody class or region under undisturbed or minimally disturbed conditions (by human activity). Reference condition is used as a benchmark to determine how much other water bodies depart from this condition due to human disturbance.

**resilience:** The ability of an ecosystem to maintain key functions and processes in the face of human or natural stresses or pressures, either by resisting or adapting to change (Nyström and Folke 2001).

**riffle** - A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

**riparian zone:** The area of vegetation located on the bank of a natural watercourse, such as a river, where the flows of energy, matter, and species are most closely related to water dynamics.

**river:** A stream of water of considerable volume, which travels downhill (from higher altitudes to lower altitudes due to gravity). Rivers carry freshwater to cities and farms, serve as the home to wildlife and fisheries, and provide recreation and natural beauty for people throughout the nation. Rivers are used by humans for irrigation, disposal of waste, to transport people and their manufactured products, to produce hydroelectric power, and to provide habitats for animals.

**scraper taxa:** Aquatic insects that consume algae and associated material.

**sediment:** Particles and/or clumps of particles of sand, clay, silt, and plant or animal matter that are suspended in, transported by, and eventually deposited by water or air.

**seine netting:** Seiningemploys a seine net that hangs vertically in the water with its bottom edge held down by weights and its top edge buoyed by floats. Seine nets can be deployed from the shore as a beach seine or from a boat. Seining is an effective technique for collecting small-sized individuals.

**sensitive taxa:** Taxa that are intolerant to a given anthropogenic stress, often the first species affected by the specific stressor to which they are “sensitive" and the last to recover following restoration.

**sensitive or regionally endemic taxa:** Taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often due to unique life history requirements. May be long lived, late maturing, have low fecundity, limited mobility, or require mutualist relation with other species. May be listed as threatened, endangered, or of special concern. Predictability of occurrence often low, therefore, requires documented observation. Recorded occurrence may be highly dependent on sample methods, site selection, and level of effort.

**shifting baseline:** A term used to describe the way significant changes to a system are measured against previous baselines, which themselves may represent significant changes from the original state of the system.

**shredder taxa:** Aquatic insects that consume leaf litter or other coarse particulate organic matter, including wood.

**spawning**: Sexual reproduction in fish.

**species:** A category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding. Also refers to an organism belonging to such a category.

**species composition:** All of the organisms within a specific ecosystem or area; usually expressed as a percent contribution of individual species or species groups.

**species richness:** The number of different species represented in an ecological community, landscape, or region.

**stressors:** Physical, chemical, and biological factors that adversely affect aquatic organisms.

**taxa:** A grouping of organisms given a formal taxonomic name such as species, genus, family, etc.

**taxa richness:** The number of different organism groupings (such as species, family, etc.) represented in an ecological community, landscape, or region.

**taxa of intermediate tolerance:** Taxa thatcomprise a substantial portion of natural communities, which may increase in number in waters which have moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration. These may be r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), eurythermal (having a broad thermal tolerance range), or have generalist or facultative feeding strategies enabling them to utilize more diversified food types. They are readily collected with conventional sample methods,

**taxonomic:** Referring to the science of hierarchically classifying animals by categories (phylum (pl. phyla), class, order, family, genus (pl. genera), species and subspecies) that share common features and are thought to have a common evolutionary descent.

**tolerant taxa:** Taxa that comprise a low proportion of natural communities. Tolerant taxa often are tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution or habitat-induced stress. They may increase in number (sometimes greatly) in the absence of competition. They are commonly r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), able to colonize when stress conditions occur. Last survivors.

**Trichoptera:** The order of insects containing the caddisflies.

**trophic:** Describing the relationships between the feeding habits of organisms in a food chain.

**trophic group:** The organisms within an ecosystem which occupy the same level in a food chain (e.g., piscivore, herbivore, insectivore, omnivore)

**validation:** The set of processes and activities intended to verify that models are performing as expected, in accordance with their objectives, while also identifying potential limitations and assumptions.

**voucher specimens:** Preserved plants or animals collected during a survey.

**water quality:** A term for the combined biological, chemical, and physical characteristics of water with respect to its suitability for a beneficial use.

**water quality criteria:** Elements of state water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use (40 CFR 131).

**water quality standards:** Provisions of state or federal law which consist of a designated use or uses for the waters of the United States. Water quality criteria for such waters are based upon such uses. Water quality standards protect public health or welfare, enhance the quality of the water, and serve the purposes of the Act (40 CFR 131).

**withdrawal**: Water removal from surface and ground water sources for various human uses.

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# Appendix C: New Mexico Large River Classification

While preparing data for review by the fish and macroinvertebrate expert panels, river and sample types were examined to determine whether there were differences in communities due to natural or method effects.

## Benthic Macroinvertebrates

For the macroinvertebrate assemblage, data were limited to 251 samples with abundance data from multiple sources (NMED, NRSA, NM Museum). These were filtered to 205 samples after removing samples with less than three operational taxonomic units (OTU) and same-day replicates.

For the non-metric multi-dimensional scaling (NMS) ordination, taxa occurrences were counted across samples and taxa with less than five occurrences were either removed or re-designated at a higher taxonomic level as an agglomeration of taxa (e.g., all genera re-designated as a family if some genera had less than five occurrences). This process resulted in 122 OTU for the initial ordination, which was run on taxa presence/absence information. The final stress of the 2-dimensional ordination was 20.4, which is very close to the target stress value of less than 20.

When testing for effects of data source, it was apparent that NM Museum samples were substantially different and if analyzed, would require a separate site class (Figure C1). In those samples, organisms were identified only to family level taxonomy, compared to the genus-level taxonomy in other samples. NMED and NRSA samples were somewhat distinct on the second NMS axis.



Figure C1. Initial macroinvertebrate NMS ordination showing data sources. NMED\_2018Dec represent an added data set, but they are otherwise similar to the other NMED samples in terms of source and sampling protocols. NM Museum samples were substantially different from other data sets.

Because the BCG effort was intended to focus on New Mexico rivers and similar rivers in close proximity, the states were highlighted in the ordination to determine whether there were locations with samples that were unlike the New Mexico samples. Texas and Kansas included some samples that were different than samples from other states, as indicated by their position at the top of the diagram and outside of the cloud of NM samples (Figure C2). This difference could also be related to latitude and longitude. Therefore, samples south of latitude 30.0 (Ruidoso, NM and Perdiz, TX) and east of longitude -101.0 (Pampa, TX and Garden City, KS) were removed from subsequent ordinations.



Figure C2. Initial macroinvertebrate NMS ordination showing states.

The second NMS ordination was limited to NMED and NRSA samples and excluded eastern and southern sites. In this second ordination, 151 samples were organized based on taxa occurrence. The resulting ordination had a 3-dimensional solution with a stress of 17.8.

In the second ordination, NRSA and NMED samples were distinguishable (Figure C3). The axis with the most separation of the sources (axis 1) was also related to sample metrics, with more chironomids in the NRSA samples and more EPT in the NMED samples.

Sample year represented as a vector showed that the NRSA samples were collected later than the NMED samples, in general. The sample methods in the ordination diagram indicated there were some distinct methods (Figure C4), especially those collected with a modified Hess method (Ben\_01a). These were mostly collected before 2000.

A picture containing diagram

Description automatically generated



Figure C3. Diagrams of the second macroinvertebrate ordination with vectors of metrics and sample metadata (top) and sources (bottom). NMED\_2018Dec represent an added data set, but they are otherwise similar to the other NMED samples in terms of source and sampling protocols.



Figure C4. Second macroinvertebrate NMS ordination showing sampling methods.

The differences noted by sampling year were further investigated using an indicator species analysis (ISA) using PC-ORD software. The ISA identifies taxa that occur in different occurrence and relative abundance among sample groups. Data were grouped by sample year; pre-2000, 2000-2009, and post-2010. Pre-2000 samples, which were all from NMED, used different taxonomy than the other sample groups. Many chironomid taxa were not identified pre-2000 (Table C1). Of the mayflies, *Acentrella* and *Baetis* were commonly identified in earlier years, though other baetids did not occur earlier. These ISA results suggest that the earlier samples (pre-2000) have some different taxonomic identification standards. It is unlikely that the taxa in question shifted drastically over time in the samples. Based on these ISA results, 38 pre-2000 NMED samples were excluded from subsequent analyses. These excluded samples were mostly from the Lower Rio Grande and from northern non-Rio Grande sites.

Table C1. Macroinvertebrate taxa showing difference before and after year 2000.

|  |  |  |
| --- | --- | --- |
| **Chironomids not occurring before 2000** | **Baetids only occurring after 2000** | **Taxa more common before 2000** |
| *Ablabesmyia* | *Baetodes* | *Heterelmis (*Elmidae*)* |
| *Cladotanytarsus* | *Callibaetis* | *Cinygmula (*Heptageniidae*)* |
| *Cryptochironomus* | *Camelobaetidius* | *Ceratopsyche (*Hydropsychidae*)* |
| *Dicrotendipes* | *Fallceon* |  |
| *Lopescladius* | *Labiobaetis* |  |
| *Paracladopelma* | *Paracloeodes* |  |
| *Pentaneura* | *Pseudocloeon* |  |
| *Phaenopsectra* |  |  |
| *Stictochironomus* |  |  |
| *Tanytarsus* |  |  |
| *Thienemannimyia* |  |  |

A third NMS ordination with 113 samples was conducted. These were limited to NMED and NRSA samples in and around New Mexico after year 1999. In this ordination, sources were distinct (Figure C5). NMED samples generally have more EPT, fewer chironomids, and are collected at higher elevation. Elevation might be a valid classification variable, but the distinction among sources showed a stronger separation than any elevation threshold.



Figure C5. Third macroinvertebrate NMS ordination showing sample sources.

## Fish

Site classification for the fish assemblage included 264 samples with abundance data from throughout New Mexico, with multiple samples for some stations. The data set was limited to fish taxa with greater than five occurrences, for a total of 26 fish taxa. The NMS ordination on presence/absence information resulted in a final stress of 13.9 for a 3-dimensional solution.

MRG samples were most abundant compared to other regions and appeared at the core of the ordination diagram (Figure C6). Samples from the other regions are at the periphery of the diagram, indicating a fish assemblage in those regions that differs from the MRG. Other variables were not obviously biased (date, data source, ecoregion, elevation, etc.). Because there are enough samples in the MRG, and that was the original intent of the effort, subsequent ordinations only used the MRG samples (N = 213).



Figure C6. Initial fish NMS ordination showing sample regions.

In the revised fish NMS ordination of 213 MRG samples and 18 fish taxa, the final stress was 13.7 for a 3-dimensional solution (Figure C7). The ordination of fish taxa presence from abundance samples showed some assemblage structures that varied among samples. Insectivores were at the bottom of the diagram; herbivores were in the upper right; and higher total taxa were in the upper left and central. Environmental variables were not strongly related to the ordination axes, though latitude is weakly correlated with the second axis, southern sites at the top. The sample sources were intermingled, and no source was distinct or suggested that the source should be removed from analysis.



Figure C7. Initial fish NMS ordination showing sample sources and vectors related to fish metrics. Samples in the upper left are 100% Common Carp.

# Appendix D: Assigning Taxa to BCG Attributes

## Evaluating relationships between biological data and top stressors in the region

With input from the work group, top stressors in the region were selected and relationships between individual taxa and these stressors were evaluated. R code was used to generate tolerance values, rankings, and capture probability plots (like in Figure D1) for each taxon and stressor. Outputs were limited to taxa that occurred in ten or more samples.

The outputs from these analyses were provided to the expert panel and helped inform BCG attribute assignments

Chart, scatter chart

Description automatically generatedChart, scatter chart

Description automatically generated

* Points: actual data of relative abundance
* Curve: capture probability (generalized additive model fit and confidence interval)
* 5% capture probability and 50% probability (red dashed lines) represent tolerance and optimum
* Multiple stressors

**Figure D1.** **Examples of capture probability plots.**

## Analytical details

A number of statistical techniques were applied to develop response curves and tolerance values. Those commonly used approaches examine the central location of a species’ niche and its spread in the niche along the environmental gradient. Developing indicator values of biological community to various environmental stressors are mainly focusing on four different statistical approaches i.e., (1) central tendencies, (2) environmental limits, (3) optima, and (4) curve shapes (Yuan 2006). Tolerance values expressed in terms of central tendencies attempt to describe the average environmental conditions under which a species is likely to occur; indicator values expressed in terms of environmental limits attempt to capture the maximum or the minimum level of an environmental variable under which a species can persist; and indicator values expressed in terms of optima define the environmental conditions that are most preferred by a given species. These three types of indicator values are expressed in terms of locations on a continuous numerical scale that represents the environmental gradient of interest. In the meantime, both abundance-based and presence/absence-based models could be built using these three statistical approaches.

A variety of approaches were used to characterize the species-environmental relationship.

1. Weighted averaging (WA) was used to estimate the central tendency of a taxon along an environmental gradient; it computes the mean of product of species abundance and the environmental variable of interest. It could be abundance based or present/absence based. The optima values are often referred as the tolerance values for invertebrates. It is one of the most commonly used approach for characterizing species preference to environmental gradient.
2. When using weighted averages, a normal distribution across the environmental gradient is assumed. The width of the bell shape is often called tolerance which can also be used to characterize the environmental niche for species along the environmental gradient. This statistical tolerance is also used as an indicator value.
3. Environmental limits have also been used to represent the extreme condition a species can tolerate. It can be estimated by computing cumulative percentiles (CPs) from observational data. Most times, the 95th percentile value under which a taxon is observed is usually assumed to be the extreme condition that taxon can tolerate.
4. When using CP, problems arise due to non-uniform distribution (uneven distribution) of samples. This problem can be solved by weight samples within equal width bins and then use these binned data to compute the CPs. This is referred as weighted cumulative distribution function (weighted CDF).
5. We can also use regression estimates of taxon-environment relationships using either linear (LRM), quadratic (QLRM) logistic regression models, or generalized additive models (GAM) to model the relationships. It is more commonly done with presence/absence data to model the binomial distribution. After the models were established, the 95th percentile cumulative probability (area under the curve of models) can be estimated as the environmental limits a taxon can tolerate.
6. Similarly, the central tendency can also be estimated from CPs and regression models using either the median value of the cumulative distribution function or the median cumulative probability of the regression models. The central tendency is thus determined as the optima.

In summary, indicator values developed from above approaches can be considered as either optima (central tendency, WA or 50th percentile) or tolerance (limits, 95th percentile). All these methods have their own pros, cons, and limitations but indicator values developed from these statistical methods are generally correlated or similar to each other. Variations due to statistical approaches can be minimized by either taking average or selecting the most consistent results from these methods.

Output from a total of 16 parametric models (both optima and tolerances) were gathered for taxa that occurred in at least ten samples, though cautions have to be made to use any tolerance values with less than 20 samples. If genera occurred in at least ten samples, results were generated for those taxa. Higher-level identifications were analyzed using the identification in the database. Genera were not collapsed to family to run the family level analyses.

## Results

There were 210 NRSA sites in the states neighboring NM with stream orders greater than 4. These were mostly from xeric and SPL regions (81 and 75 sites, respectively), but also included sites from WMT (N = 30), TPL (N = 13), CPL (N = 9), and SAP (N = 2). Limitation to ecological regions was considered but would result in few samples for analysis.

The stressors that were readily available with the NRSA data set included those related to water quality, intensive land uses, and habitat quality (Table D1). Natural variables (discharge, watershed area, channel width, and channel slope) were also included in the analysis so that responses to natural settings could also be detected.

***Table D1.***

|  |  |  |
| --- | --- | --- |
| **Variable code** | **Type** | **Description** |
| COND | Stressor | Conductivity |
| NTL | Stressor | Total nitrogen |
| PTL | Stressor | Total phosphorus |
| pctCropHayGrssWS | Stressor | % of the watershed with crops, hay, or grass cover (StreamCat) |
| pctCropHayWS | Stressor | % of the watershed with crops or hay cover (StreamCat) |
| pctUrbOpnWS | Stressor | % of the watershed with urban or open land uses (StreamCat) |
| pctUrbWS | Stressor | % of the watershed with urban land uses (StreamCat) |
| W1\_HALL | Stressor | Riparian anthropogenic disturbance |
| PCT\_SAFN | Nat/Strs | % sand and fines substrate |
| CFS | Natural | Discharge (cubic feet/second) |
| WSAREA\_KM2 | Natural | Watershed area in square kilometers (StreamCat) |
| XBKF\_W | Natural | Average bankfull channel width |
| XSLOPE | Natural | Average water surface slope |

## Fish:

There are 118 taxa in the taxa list provided by NMED and updated with unique taxa occurring in NRSA river samples. The NMED list includes some taxa that do not occur in the MRG sites. The taxa list with representative in the current data set includes 69 taxa. This includes two taxa at higher taxonomic levels (*Lepomis* and Cyprinidae), two identifications indicating life stage (e.g., Rainbow Trout (<200 mm TL)), and one hybrid (Cutbow). Of the 69 taxa, 54 occur in more than one sample and 27 occur in ten or more samples.

In the NRSA data set from large lotic southwest U.S. systems, there are 179 fish taxa, 59 of which correspond to those observed in the MRG data set. Of the 59 taxa in both data sets, 29 occur in more than ten NRSA sites, which would be minimal for deriving tolerance indications from GAM plots (20 samples would be preferred). There are three taxa that occur commonly in the BCG data set that are not in the NRSA regional data set, including the Rio Grande Silvery Minnow, Speckled Chub, and Rio Grande Bluntnose Shiner.

There were 73 fish taxa displayed by occurrence in Southwest sandy-bottomed rivers (File Attachments: Fish\_Distrib\_AllYrs.pdf). The stressor-response analysis for 42 fish taxa is displayed in plots (example, Figure D2) and tabulated statistics (File Attachments: fish.SR.plots.zip; GAM.output.20180807.xlsx).

Diagram

Description automatically generated

Figure D2. Example of a fish distribution map showing the Rio Grande Silvery Minnow in sampled river sites in and around NM.

## Macroinvertebrates

There were 470 macroinvertebrate taxa in the NRSA data limited to this study, including identifications at genus, family, and higher levels. Of those, about 165 taxa were represented in ten or more samples and were included in analyses. At the genus level alone, there were 301 taxa displayed by occurrence in Southwest sandy-bottomed rivers (File Attachment: Bugs\_Distrib\_Genus\_All.pdf). The stressor-response analysis for 165 benthic macroinvertebrate taxa is displayed in plots (example, Figure D3) and tabulated statistics (File Attachments: bugs.SR.plots.zip; GAM.output.20180807.xlsx).

Graphical user interface, diagram

Description automatically generated

Figure 3. Example of a benthic macroinvertebrate distribution map, showing Tricorythodes in sampled river sites in and around NM.

## Review

The tables (GAM.output.20180807.xlsx) list each taxon by stressor, with multiple columns of model results. Each column shows the stressor magnitude for the labelled statistic. While multiple models were available, it was recommended that a few statistics be favored, such as the GAM 50th, GAM 95th, Opt WA, and Tol WA. These were ranked to suggest relative tolerance of taxa and possible BCG attributes, as shown in the far-right columns of each spreadsheet. The tables could be filtered by stressor or by taxon to reduce the number of results to interpret simultaneously.

The figures were in pdf files, one for each assemblage and stressor, with taxa displayed in alphabetical order (File Attachments: bugs.SR.plots.zip and fish.SR.plots.zip). The slopes of the GAM curves were interpreted as increasing or decreasing taxa occurrence as stressors increase.

# Appendix E: Benthic Macroinvertebrate Taxa Attribute Assignments

| **Taxa Name** | **BCG Attribute** | **Family** | **FFG** | **Habit** |
| --- | --- | --- | --- | --- |
| Annelida | Hirudinea |  |  |  |
| Hirudinea | 5 |  | Predator | Sprawler |
| Erpobdella | 5 | Erpobdellidae | Predator | Sprawler |
| Branchiobdellida | 5 | Cambarincolidae | Collector |  |
| Myzobdella | 5 | Piscicolidae |  |  |
| Glossiphoniidae | 5 | Glossiphoniidae | Predator | Sprawler |
| Helobdella | 5 | Glossiphoniidae | Predator | Sprawler |
| Annelida | Oligochaeta |  |  |  |
| Oligochaeta | 5 |  | Collector | Burrower |
| Cambarincolidae | 5 | Cambarincolidae |  |  |
| Enchytraeidae | 5 | Enchytraeidae | Collector | Burrower |
| Enchytraeus | 5 | Enchytraeidae |  |  |
| Haplotaxida | 5 |  | Collector |  |
| Lumbricina | 5 |  |  |  |
| Chaetogaster | 5 | Naididae |  |  |
| Dero | 5 | Naididae |  |  |
| Naididae | 5 | Naididae | Collector | Burrower |
| Naididae (Naidinae) | 5 | Naididae |  |  |
| Naididae (Tubificinae) | 5 | Naididae |  |  |
| Nais | 5 | Naididae | Collector | Burrower |
| Ophidonais | 5 | Naididae |  |  |
| Pristina | 5 | Naididae |  |  |
| Slavina | 5 | Naididae | Collector |  |
| Aulodrilus | 5 | Tubificidae |  |  |
| Branchiura | 5 | Tubificidae |  |  |
| Limnodrilus | 5 | Tubificidae | Collector | Clinger |
| Rhyacodrilus | 5 | Tubificidae |  |  |
| Tubificidae | 5 | Tubificidae | Collector | Burrower |
| Tubificinae | 5 | Tubificidae |  |  |
| Lumbriculidae | 5 | Lumbriculidae | Collector | Burrower |
| Allonais | 5 | Naididae |  |  |
| Paranais | 5 | Naididae |  |  |
| Potamothrix | 5 | Tubificidae |  |  |
| Arthropoda | Arachnida |  |  |  |
| Acarina | 4 |  | Predator |  |
| Arachnida | 4 |  |  |  |
| Hydracarina | x |  | Predator |  |
| Atractides | 4 | Hygrobatidae | Predator |  |
| Corticacarus | 4 | Hygrobatidae |  |  |
| Lebertia | 4 | Lebertiidae | Predator |  |
| Protzia | 4 | Protziidae | Predator |  |
| Sperchon | 4 | Sperchonidae | Predator |  |
| Sperchonopsis | x | Sperchonidae | Predator |  |
| Testudacarus | 3 | Torrenticolidae | Predator |  |
| Torrenticola | 4 | Torrenticolidae | Predator |  |
| Oribatei | 4 | Oribatidae | Predator |  |
| Arrenurus | 4 | Arrenuridae | Predator |  |
| Hydrachnidae | 4 | Hydrachnidae | Predator |  |
| Hygrobates | 4 | Hygrobatidae | Predator |  |
| Krendowskia | x | Krendowskiidae |  |  |
| Limnesia | 4 | Limnesiidae |  |  |
| Tyrrellia | x | Limnesiidae |  |  |
| Mideopsis | 4 | Mideopsidae |  |  |
| Koenikea | x | Unionicolidae |  |  |
| Neumania | 4 | Unionicolidae | Predator |  |
| Arthropoda | Branchiopoda |  |  |  |
| Cladocera | x | Cladocera | Filterer | Sprawler |
| Arthropoda | Collembola |  |  |  |
| Collembola | x |  |  |  |
| Entomobryidae | x | Entomobryidae |  |  |
| Hypogasturidae | x | Hypogasturidae |  |  |
| Arthropoda | Insecta | Coleoptera |  |  |
| Coleoptera | x |  |  |  |
| Amphizoidae | 2 | Amphizoidae | Predator |  |
| Carabidae | x | Carabidae |  |  |
| Helichus | 3 | Dryopidae | Shredder | Clinger |
| Postelichus | 4 | Dryopidae | Shredder | Clinger |
| Copelatus | 4 | Dytiscidae | Predator | Swimmer |
| Dytiscidae | 4 | Dytiscidae | Predator | Climber |
| Hygrotus | 4 | Dytiscidae | Predator | Swimmer |
| Laccophilus | x | Dytiscidae | Predator | Swimmer |
| Liodessus | 4 | Dytiscidae | Predator | Swimmer |
| Rhantus | 4 | Dytiscidae | Predator | Swimmer |
| Cleptelmus addenda | 3 | Elmidae | Scraper | Clinger |
| Dubiraphia | 4 | Elmidae | Collector | Clinger |
| Elmidae | 3 | Elmidae | Collector | Clinger |
| Heterelmis | 4 | Elmidae | Collector | Clinger |
| Heterlimnius corpulentus | 3 | Elmidae | Collector | Clinger |
| Hexacylloepus | 4 | Elmidae |  | Clinger |
| Macrelmis | x | Elmidae | Scraper | Clinger |
| Macronychus | x | Elmidae |  |  |
| Microcylloepus | 4 | Elmidae | Scraper | Clinger |
| Narpus | 3 | Elmidae | Shredder | Clinger |
| Optioservus | 4 | Elmidae | Scraper | Clinger |
| Stenelmis | 4 | Elmidae | Scraper | Clinger |
| Zaitzevia | 3 | Elmidae | Scraper | Clinger |
| Zaitzevia parvulus | 3 | Elmidae | Scraper |  |
| Dineutus | 4 | Gyrinidae | Predator | Swimmer |
| Gyretes | 4 | Gyrinidae | Predator | Sprawler |
| Gyrinus | 3 | Gyrinidae | Predator | Swimmer |
| Peltodytes | 4 | Haliplidae | Shredder | Climber |
| Heteroceridae | x | Heteroceridae |  |  |
| Hydraena | x | Hydraenidae |  |  |
| Ochthebius | 4 | Hydraenidae | Scraper | Clinger |
| Berosus | 4 | Hydrophilidae | Collector | Swimmer |
| Enochrus | 4 | Hydrophilidae | Collector | Burrower |
| Hydrochus | 4 | Hydrophilidae | Collector | Swimmer |
| Hydrophilidae | 4 | Hydrophilidae | Predator | Swimmer |
| Laccobius | 4 | Hydrophilidae | Predator |  |
| Tropisternus | 5 | Hydrophilidae | Collector | Climber |
| Lutrochus | x | Lutrochidae |  |  |
| Psephenus | 3 | Psephenidae | Scraper | Clinger |
| Scirtidae | 4 | Scirtidae | Scraper | Climber |
| Sphaeriusidae | x | Sphaeriusidae |  |  |
| Staphylinidae | x | Staphylinidae |  |  |
| Arthropoda | Insecta | Diptera |  |  |
| Diptera | x |  | Collector | Climber |
| Atherix | 3 | Athericidae | Predator | Sprawler |
| Atherix pachypus | 3 | Athericidae | Predator |  |
| Blephariceridae | 2 | Blephariceridae | Scraper | Clinger |
| Atrichopogon | 4 | Ceratopogonidae | Predator | Sprawler |
| Bezzia/Palpomyia | 3 | Ceratopogonidae | Predator | Sprawler |
| Ceratopogonidae | 4 | Ceratopogonidae | Predator | Sprawler |
| Ceratopogoninae | 4 | Ceratopogonidae | Predator | Burrower |
| Dasyhelea | 5 | Ceratopogonidae | Collector | Sprawler |
| Dasyheleinae | 5 | Ceratopogonidae |  |  |
| Forcipomyia | 3 | Ceratopogonidae | Scraper | Burrower |
| Stilobezzia | 3 | Ceratopogonidae | Predator | Sprawler |
| Ablabesmyia | 5 | Chironomidae | Predator | Sprawler |
| Apedilum | 5 | Chironomidae |  | Clinger |
| Axarus | 4 | Chironomidae |  |  |
| Brillia | 3 | Chironomidae | Shredder | Burrower |
| Cardiocladius | 3 | Chironomidae | Predator | Clinger |
| Chaetocladius | 4 | Chironomidae | Collector | Sprawler |
| Chernovskiia | x | Chironomidae |  |  |
| Chironomidae | 4 | Chironomidae | Collector | Burrower |
| Chironomini | 5 | Chironomidae | Collector | Burrower |
| Chironomus | 5 | Chironomidae | Collector | Burrower |
| Cladotanytarsus | 3 | Chironomidae | Filterer | Climber |
| Coelotanypus | 4 | Chironomidae | Predator | Burrower |
| Conchapelopia | 4 | Chironomidae | Predator | Sprawler |
| Constempellina | 4 | Chironomidae | Collector | Climber |
| Corynoneura | 3 | Chironomidae | Collector | Sprawler |
| Cricotopus | 4 | Chironomidae | Shredder | Clinger |
| Cricotopus (Cricotopus) | 4 | Chironomidae |  |  |
| Cricotopus (Cricotopus) Bicinctus | 5 | Chironomidae |  |  |
| Cricotopus (Cricotopus) Trifascia | 4 | Chironomidae |  |  |
| Cricotopus (Isocladius) | 4 | Chironomidae |  |  |
| Cricotopus (Nostococladius) Nostocicola | 3 | Chironomidae | Shredder |  |
| Cricotopus bicinctus | 5 | Chironomidae | Shredder | Burrower |
| Cricotopus bicinctus Gr. | 5 | Chironomidae | Shredder |  |
| Cricotopus trifascia | 3 | Chironomidae |  |  |
| Cricotopus trifascia Gr. | 3 | Chironomidae | Shredder |  |
| Cricotopus/Orthocladius | 4 | Chironomidae | Shredder | Sprawler |
| Cryptochironomus | 5 | Chironomidae | Predator | Sprawler |
| Cryptotendipes | 5 | Chironomidae | Collector | Burrower |
| Cyphomella | x | Chironomidae |  | Burrower |
| Diamesa | 3 | Chironomidae | Collector | Sprawler |
| Dicrotendipes | 4 | Chironomidae | Filterer | Burrower |
| Djalmabatista | x | Chironomidae | Predator | Sprawler |
| Endochironomus | 4 | Chironomidae | Shredder | Clinger |
| Endotribelos | x | Chironomidae | Collector | Burrower |
| Eukiefferiella | 4 | Chironomidae | Collector | Sprawler |
| Eukiefferiella brehmi Gr. | 4 | Chironomidae | Mixed |  |
| Eukiefferiella devonica Gr. | 3 | Chironomidae | Mixed |  |
| Eukiefferiella gracei Gr. | 4 | Chironomidae | Mixed |  |
| Eukiefferiella pseudomontana Gr. | 4 | Chironomidae | Mixed |  |
| Gillotia | x | Chironomidae |  | Burrower |
| Glyptotendipes | 4 | Chironomidae | Collector | Burrower |
| Goeldichironomus | 5 | Chironomidae | Collector | Burrower |
| Labrundinia | 4 | Chironomidae | Predator | Sprawler |
| Larsia | 4 | Chironomidae | Predator | Sprawler |
| Limnophyes | 4 | Chironomidae | Collector | Sprawler |
| Lopescladius | 4 | Chironomidae | Shredder | Sprawler |
| Microchironomus | x | Chironomidae | Collector | Burrower |
| Micropsectra | 3 | Chironomidae | Collector | Climber |
| Microtendipes | 4 | Chironomidae | Collector | Clinger |
| Microtendipes pedellus Gr. | 4 | Chironomidae | Filterer |  |
| Microtendipes rydalensis Gr. | 4 | Chironomidae |  |  |
| Monodiamesa | 4 | Chironomidae | Collector | Sprawler |
| Nanocladius | 4 | Chironomidae | Collector | Sprawler |
| Natarsia | 5 | Chironomidae | Predator | Sprawler |
| Nilothauma | 4 | Chironomidae |  |  |
| Odontomesa | 4 | Chironomidae | Scraper | Sprawler |
| Oliveiriella | x | Chironomidae |  |  |
| Orthocladiinae | 4 | Chironomidae | Collector | Burrower |
| Orthocladius | 4 | Chironomidae | Collector | Sprawler |
| Orthocladius (Euorthocladius) | 4 | Chironomidae |  |  |
| Orthocladius (Euorthocladius) Rivulorum | 4 | Chironomidae |  |  |
| Orthocladius complex | 4 | Chironomidae |  |  |
| Pagastia | 3 | Chironomidae | Collector | Sprawler |
| Parachironomus | 5 | Chironomidae | Predator | Sprawler |
| Paracladius | 4 | Chironomidae |  | Sprawler |
| Paracladopelma | 4 | Chironomidae | Collector | Sprawler |
| Parakiefferiella | 4 | Chironomidae | Collector | Sprawler |
| Paralauterborniella | 4 | Chironomidae | Collector | Burrower |
| Parametriocnemus | 4 | Chironomidae | Collector | Sprawler |
| Paraphaenocladius | 4 | Chironomidae | Collector | Sprawler |
| Paratanytarsus | 4 | Chironomidae | Collector | Sprawler |
| Paratendipes | 4 | Chironomidae | Collector | Burrower |
| Pentaneura | 4 | Chironomidae | Predator | Sprawler |
| Phaenopsectra | 4 | Chironomidae | Scraper | Burrower |
| Platysmittia | x | Chironomidae |  |  |
| Polypedilum | 4 | Chironomidae | Shredder | Climber |
| Potthastia | 3 | Chironomidae | Collector | Sprawler |
| Potthastia longimana gr. | 3 | Chironomidae |  |  |
| Procladius | 5 | Chironomidae | Predator | Sprawler |
| Prodiamesinae | 4 | Chironomidae |  |  |
| Pseudochironomini | x | Chironomidae |  |  |
| Pseudochironomus | 4 | Chironomidae | Collector | Burrower |
| Pseudosmittia | x | Chironomidae | Collector | Sprawler |
| Radotanypus | 4 | Chironomidae | Predator |  |
| Rheocricotopus | 4 | Chironomidae | Collector | Sprawler |
| Rheotanytarsus | 4 | Chironomidae | Collector | Clinger |
| Robackia | 4 | Chironomidae | Collector | Burrower |
| Saetheria | 4 | Chironomidae | Collector | Burrower |
| Saetheria tylus | 4 | Chironomidae |  |  |
| Smittia | x | Chironomidae | Collector | Burrower |
| Stempellinella | 3 | Chironomidae | Collector | Clinger |
| Stenochironomus | 4 | Chironomidae | Cg,Sh | Burrower |
| Stictochironomus | 5 | Chironomidae | Collector | Burrower |
| Sublettea | 4 | Chironomidae | Collector |  |
| Synorthocladius | 3 | Chironomidae | Collector |  |
| Tanypodinae | 4 | Chironomidae | Predator | Burrower |
| Tanypus | 5 | Chironomidae | Predator | Sprawler |
| Tanytarsini | 4 | Chironomidae | Filterer | Burrower |
| Tanytarsus | 4 | Chironomidae | Collector | Climber |
| Telopelopia | 4 | Chironomidae | Predator | Sprawler |
| Thienemanniella | 4 | Chironomidae | Collector | Sprawler |
| Thienemannimyia | 4 | Chironomidae | Predator | Sprawler |
| Thienemannimyia genus Gr. | 4 | Chironomidae |  |  |
| Thienemannimyia Gr. | 4 | Chironomidae | Predator | Sprawler |
| Tribelos | 4 | Chironomidae | Collector | Burrower |
| Tvetenia | 3 | Chironomidae | Collector | Sprawler |
| Tvetenia bavarica Gr. | 3 | Chironomidae | Collector |  |
| Tvetenia discoloripes Gr. | 3 | Chironomidae | Collector |  |
| Tvetenia tshernovskii | 3 | Chironomidae |  |  |
| Tvetenia vitracies | 3 | Chironomidae |  |  |
| Xenochironomus | 2 | Chironomidae |  |  |
| Xestochironomus | x | Chironomidae | Predator | Burrower |
| Dolichopodidae | x | Dolichopodidae | Predator | Sprawler |
| Chelifera | 4 | Empididae | Predator | Sprawler |
| Empididae | 4 | Empididae | Predator | Sprawler |
| Hemerodromia | 4 | Empididae | Predator | Sprawler |
| Neoplasta | 3 | Empididae | Predator | Sprawler |
| Ephydridae | 5 | Ephydridae | Collector | Burrower |
| Limnophora | 4 | Muscidae | Predator | Burrower |
| Muscidae | 4 | Muscidae | Predator | Sprawler |
| Maruina | 3 | Psychodidae | Scraper | Clinger |
| Pericoma | 3 | Psychodidae | Collector | Burrower |
| Psychodidae | 3 | Psychodidae | Collector | Burrower |
| Sciomyzidae | 4 | Sciomyzidae | Predator | Burrower |
| Simuliidae | 4 | Simuliidae | Collector | Clinger |
| Simulium | 4 | Simuliidae | Collector | Clinger |
| Nemotelus | x | Stratiomyidae | Collector | Sprawler |
| Odontomyia | 4 | Stratiomyidae | Collector | Sprawler |
| Stratiomyidae | x | Stratiomyidae | Collector | Sprawler |
| Stratiomys | 4 | Stratiomyidae | Collector | Sprawler |
| Atylotus/Tabanus | 4 | Tabanidae | Predator |  |
| Chrysops | 4 | Tabanidae | Predator | Sprawler |
| Tabanidae | 4 | Tabanidae | Predator | Sprawler |
| Tabanus | 4 | Tabanidae | Predator | Sprawler |
| Antocha | 3 | Tipulidae | Collector | Clinger |
| Antocha monticola | 3 | Tipulidae | Collector |  |
| Cryptolabis | 2 | Tipulidae | Predator | Burrower |
| Dicranota | 3 | Tipulidae | Predator | Sprawler |
| Erioptera | 4 | Tipulidae | Collector | BU,SP |
| Hexatoma | 3 | Tipulidae | Predator | Burrower |
| Limonia | 4 | Tipulidae | Shredder | Burrower |
| Rhabdomastix | 3 | Tipulidae | Predator | Sprawler |
| Tipula | 4 | Tipulidae | Shredder | Burrower |
| Tipulidae | 4 | Tipulidae | Shredder | Burrower |
| Arthropoda | Insecta | Ephemeroptera |  |  |
| Ameletus | 2 | Ameletidae | Collector | Swimmer |
| Acentrella | 3 | Baetidae | Collector | Swimmer |
| Acentrella insignificans | 4 | Baetidae | Collector | Swimmer |
| Apobaetis | x | Baetidae |  |  |
| Baetidae | 4 | Baetidae | Collector | Swimmer |
| Baetis | 4 | Baetidae | Collector | Swimmer |
| Baetis flavistriga | 4 | Baetidae | Collector | Clinger |
| Baetis notos | 4 | Baetidae |  |  |
| Baetis tricaudatus | 4 | Baetidae | Collector | Swimmer |
| Baetodes | 3 | Baetidae | Scraper | Clinger |
| Baetodes edmundsi | x | Baetidae |  |  |
| Callibaetis | 5 | Baetidae | Collector | Swimmer |
| Camelobaetidius | 4 | Baetidae | Collector | Swimmer |
| Camelobaetidius musseri | 4 | Baetidae |  |  |
| Camelobaetidius warreni | 4 | Baetidae |  |  |
| Centroptilum | x | Baetidae | Collector | Clinger |
| Diphetor hageni | 3 | Baetidae | Collector | Clinger |
| Fallceon | 4 | Baetidae | Collector | Swimmer |
| Fallceon quilleri | 4 | Baetidae | Collector | Clinger |
| Labiobaetis | 4 | Baetidae | Collector | Swimmer |
| Paracloeodes | 4 | Baetidae | Scraper | Swimmer |
| Paracloeodes minutus | 4 | Baetidae | Scraper |  |
| Procloeon | x | Baetidae | Collector | Swimmer |
| Pseudocloeon | x | Baetidae | Sc,Sh | Swimmer |
| Caenidae | x | Caenidae | Collector | Sprawler |
| Caenis | 4 | Caenidae | Collector | Sprawler |
| Cercobrachys | 4 | Caenidae |  |  |
| Drunella doddsi | 3 | Ephemerellidae | Scraper | Clinger |
| Drunella grandis | 2 | Ephemerellidae | Scraper | Clinger |
| Ephemerella | 3 | Ephemerellidae | Scraper | Clinger |
| Ephemerella excrucians | 3 | Ephemerellidae |  | Clinger |
| Ephemerella inermis | 3 | Ephemerellidae | Shredder | Clinger |
| Ephemerella inermis/infrequens | 3 | Ephemerellidae |  | Clinger |
| Ephemerella infrequens | 3 | Ephemerellidae | Shredder | Clinger |
| Ephemerellidae | 3 | Ephemerellidae | Collector | Clinger |
| Serratella micheneri | 3 | Ephemerellidae |  |  |
| Hexagenia | x | Ephemeridae | Collector | Burrower |
| Cinygmula | 3 | Heptageniidae | Scraper | Clinger |
| Epeorus | 3 | Heptageniidae | Scraper | Clinger |
| Epeorus margarita | 3 | Heptageniidae | Scraper |  |
| Heptagenia | 4 | Heptageniidae | Scraper | Clinger |
| Heptageniidae | 3 | Heptageniidae | Scraper | Clinger |
| Nixe | 3 | Heptageniidae | Scraper | Clinger |
| Rhithrogena | 3 | Heptageniidae | Scraper | Clinger |
| Isonychia | 3 | Isonychiidae | Filterer | Swimmer |
| Asioplax | 4 | Leptohyphidae |  | Sprawler |
| Homoleptohyphes | 3 | Leptohyphidae |  |  |
| Leptohyphes | 4 | Leptohyphidae | Collector | Clinger |
| Leptohyphidae | 4 | Leptohyphidae | Collector |  |
| Tricorythodes | 4 | Leptohyphidae | Collector | Sprawler |
| Vacupernius | x | Leptohyphidae |  |  |
| Choroterpes | 4 | Leptophlebiidae | Cg,Pr | Clinger |
| Leptophlebia | 4 | Leptophlebiidae | Collector | Swimmer |
| Leptophlebiidae | 4 | Leptophlebiidae | Collector | Swimmer |
| Neochoroterpes | 4 | Leptophlebiidae |  | Clinger |
| Neochoroterpes oklahoma | 4 | Leptophlebiidae |  |  |
| Paraleptophlebia | 4 | Leptophlebiidae | Collector | Swimmer |
| Thraulodes | 4 | Leptophlebiidae | Collector | Clinger |
| Thraulodes brunneus | 4 | Leptophlebiidae |  |  |
| Traverella | 4 | Leptophlebiidae | Filterer | Clinger |
| Traverella albertana | x | Leptophlebiidae |  |  |
| Homoeoneuria | 2 | Oligoneuriidae | Cf,Cg | Burrower |
| Siphlonurus | 3 | Siphlonuridae |  | Swimmer |
| Arthropoda | Insecta | Hemiptera |  |  |
| Abedus | 5 | Belostomatidae | Predator | Climber |
| Belostomatidae | 4 | Belostomatidae | Predator | Climber |
| Corixidae | 5 | Corixidae | Predator | Swimmer |
| Graptocorixa | 4 | Corixidae | Predator | Swimmer |
| Hesperocorixa | 4 | Corixidae | Piercer-Predator | Swimmer |
| Sigara | 5 | Corixidae | Predator | Swimmer |
| Trichocorixa | 5 | Corixidae | Predator | Swimmer |
| Gerridae | x | Gerridae |  |  |
| Macrovelia | x | Macroveliidae | Predator | Climber |
| Ambrysus | 4 | Naucoridae | Predator | Clinger |
| Ambrysus mormon | 4 | Naucoridae | Predator |  |
| Limnocoris | x | Naucoridae |  |  |
| Naucoridae | 4 | Naucoridae | Predator | Clinger |
| Pelocoris | x | Naucoridae |  |  |
| Ranatra | x | Nepidae | Predator | Climber |
| Notonectidae | 5 | Notonectidae | Predator |  |
| Neoplea | x | Pleidae |  |  |
| Microvelia | x | Veliidae | Predator | Skater |
| Veliidae | x | Veliidae |  |  |
| Arthropoda | Insecta | Lepidoptera |  |  |
| Petrophila | 3 | Crambidae | Shredder | Climber |
| Petrophilia | 3 | Pyralidae | Scraper | Clinger |
| Arthropoda | Insecta | Megaloptera |  |  |
| Corydalidae | 3 | Corydalidae | Predator | Clinger |
| Corydalus | 3 | Corydalidae | Piercer-Predator | Clinger |
| Corydalus cornutus | 3 | Corydalidae | Predator | Clinger |
| Sialis | 3 | Sialidae | Predator | Burrower |
| Arthropoda | Insecta | Odonata |  |  |
| Anisoptera | x |  | Predator |  |
| Aeshnidae | 4 | Aeshnidae | Predator | Climber |
| Calopterygidae | 4 | Calopterygidae | Predator | Climber |
| Hetaerina | 4 | Calopterygidae | Predator | Climber |
| Argia | 4 | Coenagrionidae | Predator | Clinger |
| Coenagrion/Enallagma | x | Coenagrionidae | Predator | Climber |
| Coenagrionidae | 4 | Coenagrionidae | Predator | Climber |
| Enallagma | 4 | Coenagrionidae | Predator | Climber |
| Macromia | x | Corduliidae | Predator | Sprawler |
| Erpetogomphus | 4 | Gomphidae | Predator | Burrower |
| Gomphidae | 4 | Gomphidae | Predator | Burrower |
| Gomphus | x | Gomphidae | Predator | Burrower |
| Ophiogomphus | 4 | Gomphidae | Predator | Burrower |
| Progomphus | 4 | Gomphidae | Predator | Burrower |
| Stylurus | 4 | Gomphidae | Predator | Sprawler |
| Libellula | 4 | Libellulidae | Predator | Sprawler |
| Libellulidae | 4 | Libellulidae | Predator | Sprawler |
| Arthropoda | Insecta | Plecoptera |  |  |
| Plecoptera | 3 |  | Predator | Clinger |
| Capniidae | 3 | Capniidae | Shredder | Sprawler |
| Chloroperlidae | 3 | Chloroperlidae | Predator | Clinger |
| Zapada | 3 | Nemouridae | Shredder | Sprawler |
| Acroneuria | 3 | Perlidae | Predator | Clinger |
| Claassenia sabulosa | 3 | Perlidae | Predator | Clinger |
| Hesperoperla pacifica | 3 | Perlidae | Predator | Clinger |
| Perlidae | 3 | Perlidae | Predator | Clinger |
| Cultus | 3 | Perlodidae | Predator | Clinger |
| Isogenoides | 3 | Perlodidae | Predator | Clinger |
| Isogenoides elongatus | 3 | Perlodidae | Predator |  |
| Isoperla | 3 | Perlodidae | Predator | Clinger |
| Megarcys signata | 3 | Perlodidae | Predator |  |
| Perlodidae | 3 | Perlodidae | Predator | Clinger |
| Perlodinae | 3 | Perlodidae | Predator |  |
| Skwala | 3 | Perlodidae | Predator | Clinger |
| Pteronarcella badia | 3 | Pteronarcyidae | Shredder | Clinger |
| Pteronarcys | 3 | Pteronarcyidae | Shredder | Clinger |
| Taeniopteryx | 3 | Taeniopterygidae | Scraper | Sprawler |
| Arthropoda | Insecta | Thysanoptera |  |  |
| Thysanoptera | x |  |  |  |
| Arthropoda | Insecta | Trichoptera |  |  |
| Trichoptera | x |  | Collector | Sprawler |
| Brachycentrus | 3 | Brachycentridae | Filterer | Clinger |
| Brachycentrus (Oligoplectrodes) Americanus | 3 | Brachycentridae | Filterer |  |
| Brachycentrus (Sphinctogaster) Occidentalis | 3 | Brachycentridae | Filterer | Clinger |
| Brachycentrus occidentalis | 3 | Brachycentridae | Filterer | Clinger |
| Micrasema | 3 | Brachycentridae | Shredder | Clinger |
| Anagapetus | 2 | Glossosomatidae | Scraper | Clinger |
| Culoptila | 3 | Glossosomatidae | Scraper | Clinger |
| Glossosoma | 3 | Glossosomatidae | Scraper | Clinger |
| Glossosomatidae | 3 | Glossosomatidae | Scraper | Clinger |
| Protoptila | 3 | Glossosomatidae | Scraper | Clinger |
| Helicopsyche | 4 | Helicopsychidae | Scraper | Clinger |
| Helicopsyche (Feropsyche) Borealis | 4 | Helicopsychidae | Scraper |  |
| Arctopsyche grandis | 3 | Hydropsychidae | Filterer | Clinger |
| Ceratopsyche oslari | 3 | Hydropsychidae | Filterer |  |
| Ceratopsyche venada | 2 | Hydropsychidae | Filterer |  |
| Cheumatopsyche | 4 | Hydropsychidae | Filterer | Clinger |
| Hydropsyche | 4 | Hydropsychidae | Filterer | Clinger |
| Hydropsyche occidentalis | 4 | Hydropsychidae | Filterer |  |
| Hydropsychidae | 4 | Hydropsychidae | Filterer | Clinger |
| Smicridea | 4 | Hydropsychidae | Filterer | Clinger |
| Hydroptila | 4 | Hydroptilidae | Scraper | Clinger |
| Hydroptilidae | 4 | Hydroptilidae | Scraper | Clinger |
| Ithytrichia | 4 | Hydroptilidae | Scraper | Clinger |
| Leucotrichia | 3 | Hydroptilidae | Scraper | Clinger |
| Mayatrichia | 4 | Hydroptilidae | Scraper | Clinger |
| Metrichia | x | Hydroptilidae | Scraper | Clinger |
| Neotrichia | 4 | Hydroptilidae | Scraper | Clinger |
| Ochrotrichia | 4 | Hydroptilidae | Collector | Clinger |
| Oxyethira | 4 | Hydroptilidae |  | Clinger |
| Stactobiella | 2 | Hydroptilidae | Collector | Climber |
| Zumatrichia notosa | 3 | Hydroptilidae |  |  |
| Lepidostoma | 3 | Lepidostomatidae | Shredder | Climber |
| Ceraclea | 3 | Leptoceridae | Shredder | Sprawler |
| Leptoceridae | 4 | Leptoceridae | Collector | Climber |
| Nectopsyche | 4 | Leptoceridae | Shredder | Climber |
| Oecetis | 4 | Leptoceridae | Predator | Clinger |
| Oecetis avara | 4 | Leptoceridae | Predator | Clinger |
| Oecetis disjuncta | 4 | Leptoceridae |  |  |
| Ylodes | x | Leptoceridae |  |  |
| Limnephilidae | 3 | Limnephilidae | Shredder | Climber |
| Limnephilus | 4 | Limnephilidae | Shredder | Climber |
| Psychoglypha | 3 | Limnephilidae | Collector | Clinger |
| Psychoronia | 2 | Limnephilidae | Shredder | Sprawler |
| Chimarra | 4 | Philopotamidae | Filterer | Clinger |
| Polycentropodidae | 3 | Polycentropodidae | Filterer | Clinger |
| Polycentropus | 3 | Polycentropodidae | Predator | Clinger |
| Psychomyia | 3 | Psychomyiidae | Collector | Clinger |
| Rhyacophila coloradensis Gr. | 2 | Rhyacophilidae | Predator | Clinger |
| Oligophlebodes | 2 | Uenoidae | Scraper | Clinger |
| Arthropoda | Malacostraca | Amphipoda |  |  |
| Amphipoda | x |  |  |  |
| Crangonyctidae | 4 | Crangonyctidae |  |  |
| Crangonyx | 4 | Crangonyctidae |  |  |
| Hyalella | 4 | Hyalellidae | Collector | Sprawler |
| Hyalella azteca | 4 | Hyalellidae | Collector | Sprawler |
| Arthropoda | Malacostraca | Decapoda |  |  |
| Cambaridae | x | Cambaridae | Collector | Sprawler |
| Orconectes | x | Cambaridae | Collector | Sprawler |
| Orconectes virilis | 6 | Cambaridae | Collector |  |
| Procambarus | x | Cambaridae | Collector |  |
| Macrobrachium | x | Palaemonidae |  |  |
| Palaemonidae | x | Palaemonidae |  |  |
| Arthropoda | Malacostraca | Isopoda |  |  |
| Isopoda | x |  | Collector |  |
| Caecidotea | 4 | Asellidae | Collector | Sprawler |
| Arthropoda | Malacostraca | Mysida |  |  |
| Americamysis | x | Mysidae |  |  |
| Mysidae | x | Mysidae |  |  |
| Taphromysis | x | Mysidae |  |  |
| Arthropoda | Other |  |  |  |
| Copepoda | x |  | Filterer | Clinger |
| Ostracoda | 4 |  | Filterer |  |
| Cnidaria |  |  |  |  |
| Cnidaria | x |  |  |  |
| Mollusca | Bivalvia |  |  |  |
| Corbicula | 6 | Corbiculidae | Filterer | Burrower |
| Corbicula fluminea | 6 | Corbiculidae | Filterer | Burrower |
| Eupera | x | Pisidiidae | Filterer |  |
| Musculium transversum | x | Pisidiidae | Filterer |  |
| Pisidiidae | 4 | Pisidiidae | Filterer |  |
| Pisidium | 4 | Pisidiidae | Filterer | Burrower |
| Sphaerium | x | Pisidiidae | Cf,Cg | Burrower |
| Mollusca | Gastropoda |  |  |  |
| Rissooidea | x | Hydrobiidae |  |  |
| Ancylidae | 4 | Ancylidae | Scraper | Climber |
| Ferrissia | 4 | Ancylidae | Scraper | Clinger |
| Hebetoncylus | 4 | Ancylidae |  |  |
| Fossaria | 4 | Lymnaeidae | Cg,Sc | Climber |
| Galba | x | Lymnaeidae |  |  |
| Lymnaea | 4 | Lymnaeidae | Scraper | Climber |
| Lymnaeidae | 4 | Lymnaeidae | Scraper | Climber |
| Physa | 5 | Physidae | Scraper |  |
| Physella | 5 | Physidae | Scraper | Climber |
| Physidae | 5 | Physidae | Scraper | Climber |
| Gyraulus | 4 | Planorbidae | Scraper | Climber |
| Planorbella | x | Planorbidae | Scraper | Climber |
| Melanoides | 6 | Thiaridae |  |  |
| Hydrobiidae | x | Hydrobiidae | Scraper | Climber |
| Other |  |  |  |  |
| Nemata | 4 |  | Predator |  |
| Nematoda | 4 |  |  |  |
| Nematomorpha | 4 |  | Predator | Burrower |
| Gordius | x | Gordiidae | Predator |  |
| Prostoma | 4 | Tetrastemmatidae | Predator |  |
| Trepaxonemata | 4 |  |  |  |
| Turbellaria | 4 |  | Predator | Sprawler |
| Tricladida | x |  | Collector |  |
| Polycelis coronata | x | Planariidae | Collector |  |
| Rotifera | x |  |  |  |

# Appendix F: Fish Attribute Assignments

LLNLB = Long-lived native large-bodied fish; trophic group codes: H – herbivore; I – invertivore; O – omnivore; P – piscivore; PL – planktivore. Pelagic broadcast spawners = a specialized reproductive category that is dependent on channel conditions and flow.

| **Species Common Name** | **Species Scientific Name** | **LLNLB1** | **Trophic Group** | **Family** | **Pelagic Broadcast Spawner** |
| --- | --- | --- | --- | --- | --- |
|  | **Attribute I: Historically documented, sensitive, long-lived, or regionally endemic taxa** | | | | |
| Beautiful Shiner | *Cyprinella formasa* |  | I | Cyprinidae |  |
| Colorado pikeminnow | *Ptychocheilus lucius* | Yes | P | Cyprinidae |  |
| Humpback Chub | *Gila cypha* | Yes | I | Cyprinidae |  |
| Phantom Shiner | *Notropis orca* |  |  | Cyprinidae |  |
| Razorback Sucker | *Xyrauchen texanus* | Yes | O | Catostomidae |  |
| Rio Grande Bluntnose Shiner | *Notropis simus simus* |  |  | Cyprinidae | Yes |
| Rio Grande Cutthroat Trout1 | *Oncorhynchus clarki virginalis* |  | I | Salmonidae |  |
| Rio Grande Shiner | *Notropis jemezanus* |  | I | Cyprinidae | Yes |
| Roundnose Minnow | *Dionda episcopa* |  | H | Cyprinidae |  |
| Speckled Chub | *Macrhybopsis aestivalis* |  | I | Cyprinidae | Yes |
| Virgin Chub | *Gila seminuda* |  | O | Cyprinidae |  |
| Woundfin | *Plagopterus argentissimus* |  | O | Cyprinidae |  |
|  | **Attribute II: Highly sensitive taxa** | | | | |
| Bridgelip Sucker | *Catostomus columbianus* |  | H | Catostomidae |  |
| Brook Silverside | *Labidesthes sicculus* |  | I | Atherinidae |  |
| Freckled Madtom | *Noturus nocturnus* |  | I | Ictaluridae |  |
| Mimic Shiner | *Notropis volucellus* |  | O | Cyprinidae |  |
| Rio Grande Chub | *Gila pandora* |  | I | Cyprinidae |  |
| Rio Grande Silvery Minnow (Att2 outside of Middle Rio Grande) | *Hybognathus amarus* |  | H | Cyprinidae | Yes |
| Rio Grande Sucke1 | *Catostomus plebeius* | Yes | O | Catostomidae |  |
| Shovelnose Sturgeon | *Scaphirhynchus platorynchus* | Yes |  | Acipenseridae |  |
| Tadpole Madtom | *Noturus gyrinus* |  | I | Ictaluridae |  |
| Torrent Sculpin | *Cottus rhotheus* |  | I | Cottidae |  |
|  | **Attribute III: Intermediate sensitive taxa** | | | | |
| Arkansas Darter | *Etheostoma cragini* |  | I | Percidae |  |
| Blacktail Redhorse | *Moxostoma poecilurum* |  | I | Catostomidae |  |
| Chiselmouth1 | *Acrocheilus alutaceus* |  | H | Cyprinidae |  |
| Chub Shiner | *Notropis potteri* |  | I | Cyprinidae |  |
| Dusky Darter | *Percina sciera* |  | I | Percidae |  |
| Harlequin Darter | *Etheostoma histrio* |  | I | Percidae |  |
| Iowa Darter | *Etheostoma exile* |  | I | Percidae |  |
| Largescale Sucker | *Catostomus macrocheilus* | Yes | O | Catostomidae |  |
| Logperch | *Percina caprodes* |  | I | Percidae |  |
| Longnose Dace | *Rhinichthys cataractae* |  | I | Cyprinidae |  |
| Longnose Sucker1 | *Catostomus catostomus* | Yes | I | Catostomidae |  |
| Mississippi Silvery Minnow | *Hybognathus nuchalis* |  |  | Cyprinidae |  |
| Mountain Sucker | *Catostomus platyrhynchus* |  | H | Catostomidae |  |
| Peamouth1 | *Mylocheilus caurinus* |  | I | Cyprinidae |  |
| Pirate Perch | *Aphredoderus sayanus* |  | I | Aphredoderidae |  |
| Prairie Chub | *Macrhybopsis australis* |  | O | Cyprinidae |  |
| Prickly Sculpin | *Cottus asper* |  | I | Cottidae |  |
| Redfin Pickerel | *Esox samericanus americanus* |  | P | Esocidae |  |
| Rio Grande Silvery Minnow (Att3 in the Middle Rio Grande only) | *Hybognathus amarus* |  | H | Cyprinidae | Yes |
| Sauger | *Sander canadensis* |  | P | Percidae |  |
| Scaly Sand Darter | *Ammocrypta vivax* |  | I | Percidae |  |
| Shoal Chub | *Macrhybopsis hyostoma* |  | O | Cyprinidae |  |
| Shorthead Redhorse | *Moxostoma macrolepidotum* | Yes | O | Catostomidae |  |
| Silver Chub | *Macrhybopsis storeiana* |  | I | Cyprinidae |  |
| Slenderhead Darter | *Percina phoxocephala* |  | I | Percidae |  |
| Slim Minnow | *Pimephales tenellus* |  | I | Cyprinidae |  |
| Spotted Sucker | *Minytrema melanops* |  | I | Catostomidae |  |
| Threespine Stickleback | *Gasterosteus aculeatus* |  | I | Gasterosteidae |  |
|  | **Attribute IV: Intermediate tolerant taxa** | | | | |
| Bigmouth Shiner | *Notropis dorsalis* |  | O | Cyprinidae |  |
| Blackstripe Topminnow | *Fundulus olivaceus* |  | O | Fundulidae |  |
| Blacktail Shiner | *Cyprinella venustus* |  | I | Cyprinidae |  |
| Blue Catfish | *Ictalurus furcatus* | Yes | P | Ictaluridae |  |
| Bluegill X Longear Sunfish | *Lepomis mcarochirus x megalotis* |  | I | Centrarchidae |  |
| Bluehead Sucker | *Catostomus discobolus* |  | H | Catostomidae |  |
| Bluehead Sucker X Flannelmouth Sucker | *Catostomus x Catostomus latipinnis* |  |  | Catostomidae |  |
| Bluehead Sucker X White Sucker | *Catostomus discobolus x commersoni* |  | O | Catostomidae |  |
| Brassy Minnow | *Hybognathus hankinsoni* |  | O | Cyprinidae |  |
| Creek chub | *Semotilus atromaculatus* |  | I | Cyprinidae |  |
| Emerald Shiner | *Notropis atherinoides* |  | O | Cyprinidae |  |
| Flannelmouth Sucker | *Catostomus latipinnis* |  | O | Catostomidae |  |
| Flathead Chub | *Platygobio gracilis* |  | I | Cyprinidae |  |
| Freshwater Drum | *Aplodinotus grunniens* | Yes |  | Sciaenidae | Yes |
| Ghost Shiner | *Notropis buchanani* |  | I | Cyprinidae |  |
| Johnny Darter | *Etheostoma nigrum* |  | I | Percidae |  |
| Mud Darter | *Ethostoma asprigene* |  | I | Percidae |  |
| Northern Pikeminnow | *Ptychocheilus oregonensis* | Yes | P | Cyprinidae |  |
| Orangespotted Sunfish | *Lepomis humilus* |  | I | Centrarchidae |  |
| Orangethroat Darter | *Ethostoma spectabile* |  | I | Percidae |  |
| Plains Minnow | *Hybognathus placitus* |  | H | Cyprinidae | Yes |
| Plains Topminnow | *Fundulus sciadicus* |  | I | Fundulidae |  |
| Pugnose Minnow | *Opsopoeodus emiliae* |  | O | Cyprinidae |  |
| Pumpkinseed | *Lepomis gibbosus* |  | I | Centrarchidae |  |
| Quillback1 | *Carpioides cyprinus* | Yes | O | Catostomidae |  |
| Red River Shiner | *Notropis bairdi* |  | I | Cyprinidae |  |
| Redbreast Sunfish | *Lepomis auritus* |  | I | Centrarchidae |  |
| Redfin Shiner | *Lythrurus umbratilis* |  | I | Cyprinidae |  |
| Redspotted Sunfish | *Lepomis miniatus* |  | I | Centrarchidae |  |
| Ribbon Shiner | *Lythrurus fumeus* |  | I | Cyprinidae |  |
| Rio Grande Cichlid | *Cichlasoma cyanoguttatum* |  | P | Cichlidae |  |
| River Carpsucker | *Carpiodes carpio* | Yes | O | Catostomidae |  |
| River Goby | *Awaous banana* |  | P | Gobiidae |  |
| River Shiner | *Notropis blenniuis* |  | I | Cyprinidae |  |
| Sabine Shiner | *Notropis sabinae* |  | I | Cyprinidae | Yes |
| Sacramento Pikeminnow | *Ptychocheilus grandis* | Yes | P | Cyprinidae |  |
| Sacramento Sucker | *Catostomus occidentalis* | Yes | O | Catostomidae |  |
| Sand Shiner | *Notropis stramineus* |  | O | Cyprinidae | Yes |
| Silverband Shiner | *Notropis shumardi* |  | I | Cyprinidae |  |
| Slough Darter | *Etheostoma gracile* |  | I | Percidae |  |
| Speckled dace | *Rhinichthys osculus* |  | I | Cyprinidae |  |
| Spotted Bass | *Micropterus punctulatus* |  | P | Centrarchidae |  |
| Stonecat | *Noturus flavus* |  | P | Ictaluridae |  |
| Striped Mullet | *Mugil cephalus* |  | P | Mugilidae |  |
| Tule Perch | *Hysterocarpus traskii* |  | I | Embiotocidae |  |
| Weed Shiner | *Notropis texanus* |  | H | Cyprinidae |  |
| White Perch | *Morone americana* |  | P | Moronidae |  |
| Wiper | *Morone chrysops x saxatilis* |  | P | Moronidae |  |
| Yellow Bass | *Morone mississippiensis* |  | P | Moronidae |  |
|  | **Attribute V: Tolerant taxa** | | | | |
| Bigmouth Buffalo | *Ictiobus cyprinellus* | Yes | O | Catostomidae |  |
| Bluegill | *Lepomis macrochirus* |  | I | Centrarchidae |  |
| Bluntnose Minnow | *Pimephales notatus* |  | O | Cyprinidae |  |
| Bowfin | *Amia calva* |  | P | Amiidae |  |
| Fathead Minnow | *Pimephales promelas* |  | O | Cyprinidae |  |
| Gizzard Shad | *Dorosoma cepedianum* |  | H | Clupeidae |  |
| Green Sunfish X Longear Sunfish | *Lepomis cyannelus x megalotis* |  | P | Centrarchidae |  |
| Longnose Gar | *Lepisosteus osseus* | Yes | P | Lepisosteidae |  |
| Northern Plains Killifish | *Fundulus kansae* |  | O | Fundulidae |  |
| Red River Pupfish | *Cyprinodon rubrofluviatilis* |  | O | Cyprinodontidae |  |
| Red Shiner | *Cyprinella lutrensis* |  | O | Cyprinidae |  |
| Shortnose Gar | *Lepiosteus platostomus* | Yes | P | Lepisosteidae |  |
| Smallmouth Buffalo | *Ictiobus bubalus* | Yes | O | Catostomidae |  |
| Spotted Gar | *Lepiosteus oculatus* | Yes | P | Lepisosteidae |  |
| Western Mosquitofish | *Gambusia affinis* |  | I | Poeciliidae |  |
| White Catfish | *Ameiurus catus* | Yes | O | Ictaluridae |  |
|  | **Attribute VI: Non-native or intentionally introduced species – moderate tolerance to stress2** | | | | |
| Brook Stickleback | *Culaea inconstans* |  | I | Gasterosteidae |  |
| Bullhead Minnow | *Pimephales vigilax* |  | I | Cyprinidae |  |
| Central Stoneroller | *Campostoma anomalum* |  | H | Cyprinidae |  |
| Common sunfishes | *Lepomis* |  |  | Centrarchidae |  |
| Crappie | *Pomoxis* |  |  | Centrarchidae |  |
| Flathead Catfish | *Pylodictus olivaris* |  | P | Ictaluridae |  |
| Gray Redhorse | *Scartomyzon congestum* | Yes | I | Catostomidae |  |
| Longear Sunfish | *Lepomis megalotis* |  | I | Centrarchidae |  |
| Mexican Tetra | *Astyanax mexicanus* |  | P | Characidae |  |
| Muskellunge | *Esox masquinongy* |  |  | Esocidae |  |
| Northern Pike | *Esox lucius* |  | P | Esocidae |  |
| Redear Sunfish | *Lepomis microlophus* |  |  | Centrarchidae |  |
| Redside Shiner | *Richardsonius balteatus* |  |  | Cyprinidae |  |
| Smallmouth Bass | *Micropterus dolomieu* |  | P | Centrarchidae |  |
| Sonora Sucker | *Catostomus insignis* |  | O | Catostomidae |  |
| Tench | *Tinca tinca* |  |  | Cyprinidae |  |
| Threadfin Shad | *Dorosoma petenense* |  | PL | Clupeidae |  |
| Walleye | *Stizostedion vitreum* |  | P | Percidae |  |
| White Bass | *Morone chrysops* |  | P | Percichthyidae |  |
| Yellow Perch | *Perca flavescens* |  | I | Percidae |  |
| Yellowfin Goby | *Acanathogobius flavimanus* |  | P | Gobiidae |  |
|  | **Attribute VI - T: Non-native or intentionally introduced species –tolerant to stress2** | | | | |
| Black Bullhead | *Ameiurus melas* |  | I | Ictaluridae |  |
| Black Crappie | *Pomoxis nigromaculatus* |  | I | Centrarchidae |  |
| Blue Tilapia | *Oreochromus Aureus* |  | O | Cichlidae |  |
| Brown bullhead | *Ameiurus nebulosus* |  |  | Ictaluridae |  |
| Bullhead | *Ameiurus* |  |  | Ictaluridae |  |
| Channel Catfish | *Ictalurus punctatus* |  | I | Ictaluridae |  |
| Common Carp | *Cyprinus carpio* |  | O | Cyprinidae |  |
| Golden Shiner | *Notemigonus crysoleucas* |  | O | Cyprinidae |  |
| Goldfish | *Carassius auratus* |  | O | Cyprinidae |  |
| Grass Carp | *Ctenopharyngodon idella* |  | I | Cyprinidae | Yes |
| Green Sunfish | *Lepomis cyanellus* |  | I | Centrarchidae |  |
| Largemouth Bass | *Micropterus salmoides* |  | P | Centrarchidae |  |
| Longfin Dace | *Agosia chrysogaster* |  | O | Cyprinidae |  |
| Plains Killifish | *Fundulus zebrinus* |  | I | Fundulidae |  |
| Rainwater Killifish | *Lucania parva* |  | I | Fundulidae |  |
| Sailfin Molly | *Poecilia latipinna* |  | H | Poeciliidae |  |
| Warmouth | *Chaenobryttus gulosus* |  | I | Centrarchidae |  |
| White Crappie | *Pomoxis annularis* |  | P | Centrarchidae |  |
| White Sucker | *Catostomus commersonii* |  | O | Catostomidae |  |
| Yellow Bullhead | *Ameiurus natalis* |  | O | Ictaluridae |  |
|  | **Attribute VI -S: Non-native or intentionally introduced species – sensitive to stress2** | | | | |
| Bigscale Logperch | *Percina macrolepida* |  | I | Percidae |  |
| Brown Trout | *Salmo trutta* |  | I | Salmonidae |  |
| Cutbow | *Oncorhynchus clarki x mykiss* |  | I | Salmonidae |  |
| Desert Sucker | *Catostomus clarki* |  | H | Catostomidae |  |
| Rainbow Trout | *Oncorhynchus mykiss* |  | I | Salmonidae |  |
| Snake River Cutthroat Trout | *Oncorhynchus clarki ssp.* |  | I | Salmonidae |  |
|  | **Attribute X: Ecosystem Connectivity3** | | | | |
| American Eel | *Anguilla rostrata* |  | I | Anguillidae |  |
|  | **Attribute x: No attribute assignment (insufficient data)** | | | | |
| Arkansas River Shiner | *Notropis girardi* |  | I | Cyprinidae | Yes |
| Arkansas River Speckled Chub | *Macrhybopsis aestivalis tetranemus* |  | I | Cyprinidae | Yes |
| Atlantic Needlefish | *Strongylura marina* |  | P | Belonidae |  |
| Bigmouth Sleeper | *Gobiomorus dormitor* |  | P | Elotridae |  |
| Blue sucker | *Cycleptus elongatus* | Yes | I | Catostomidae |  |
| Brook Trout | *Salvelinus fontinalis* |  | I | Salmonidae |  |
| Chihuahua Chub | *Gila nigrescens* |  | I | Cyprinidae |  |
| Chinook Salmon | *Oncorhynchus tshawytscha* |  | I | Salmonidae |  |
| Coho Salmon | *Oncorhynchus kisutch* |  | I | Salmonidae |  |
| Common Snook | *Centropomus undecimalis* |  | P | Centropomidae |  |
| Cutbow | *Oncorhynchus clarki x mykiss* |  | I | Salmonidae |  |
| Cyprinidae | *Cyprinidae* |  |  | Cyprinidae |  |
| Fat Snook | *Centropomus parallelus* |  | P | Centropomidae |  |
| Gila Chub | *Gila intermedia* |  | I | Cyprinidae |  |
| Gila Trout | *Oncorhynchus gilae* |  | I | Salmonidae |  |
| Golden Redhorse | *Moxostoma erythrurum* |  |  | Catostomidae |  |
| Greenthroat Darter | *Etheostoma lepidum* |  | O | Percidae |  |
| Gulf Killifish | *Fundulus grandis* |  |  | Fundulidae |  |
| Headwater Catfish | *Ictalurus lupus* |  | I | Ictaluridae |  |
| Headwater Chub | *Gila nigra* |  | I | Cyprinidae |  |
| Hybrid Lepomis | *Lepomis sp.* |  | P | Centrarchidae |  |
| Inland Silverside | *Menidia beryllina* |  | PL | Atherinidae |  |
| Kokanee Salmon | *Oncorhynchus nerka* |  | PL | Salmonidae |  |
| Lake Trout | *Salvelinus namaycush* |  | P | Salmonidae |  |
| Lamprey Ammocoete | *Lamprey* |  | O | Petromyzontidae |  |
| Loach Minnow | *Rhinichthys cobitis* |  | I | Cyprinidae |  |
| Mottled Sculpin | *Cottus bairdi* |  | I | Cottidae |  |
| Mountain Whitefish | *Prosopium williamsoni* |  | I | Salmonidae |  |
| Pecos Bluntnose Shiner | *Notropis simus pecosensis* |  | I | Cyprinidae | Yes |
| Pecos Gambusia | *Gambusia nobilis* |  | I | Poeciliidae |  |
| Pecos Pupfish | *Cyprinodon pecosensis* |  | O | Cyprinodontidae |  |
| Rainbow Trout | *Oncorhynchus mykiss* |  | P | Salmonidae |  |
| Rock Bass | *Ambloplites rupestris* |  | I | Centrarchidae |  |
| Roundtail Chub | *Gila robusta* |  | O | Cyprinidae |  |
| Sand Roller | *Percopsis transmontana* |  | I | Percopsidae |  |
| Santa Ana Sucker | *Catostomus santaanae* |  | H | Catostomidae |  |
| Sheepshead Minnow | *Cyprinodon variegatus* |  |  | Cyprinodontidae |  |
| Snake River Cutthroat Trout | *Oncorhynchus clarki ssp.* |  | P | Salmonidae |  |
| Southern Redbelly Dace | *Phoxinus erythrogaster* |  | H | Cyprinidae |  |
| Spikedace | *Meda fulgida* |  | I | Cyprinidae |  |
| Striped Bass | *Morone saxatilis* |  | P | Percichthyidae |  |
| Suckermouth Minnow | *Phenacobius mirabilis* |  | I | Cyprinidae |  |
| Unknown Campostoma | *Campostoma* |  |  | Cyprinidae |  |
| Unknown Fundulus | *Fundulus* |  |  | Fundulidae |  |
| Unknown Notropis | *Notropis* |  |  | Cyprinidae |  |
| Unknown Temperate Bass | *Perciformes* |  |  |  |  |
| White Mullet | *Mugil curema* |  | O | Mugilidae |  |
| White Sands Pupfish | *Cyprinodon tularosa* |  | O | Cyprinodontidae |  |
| Yellowfin Mojarra | *Gerres cinereus* |  | P | Gerridae |  |
| Zuni Bluehead Sucker | *Catostomus discobolus yarrowi* |  | H | Catostomidae |  |

*1 - Long-lived native large-bodied fish (LLNLB) are important keystone species and indicators of ecosystem connectivity.*

*2 - The experts broke the non-native fishes into three categories: those that were sensitive to anthropogenic stress (VI-S), those that were tolerant of anthropogenic stress (VI-T) and those with moderate tolerance (VI).*

*3 - Attribute X species are indicative of ecosystem connectivity.*

# Appendix G: Benthic Macroinvertebrate Indicators Used in Developing BCG Rules

| **Indicator** | **Description** | **Ecological Rationale** |
| --- | --- | --- |
| Taxa richness | # taxa of all taxonomic groups | Total taxa richness is progressively higher in better biological conditions. Observations of macroinvertebrate taxa richness as an indicator of community integrity is well-established in primary bioassessment literature and experience (Barbour et al. 1999). |
| Richness of EPT species | # taxa | High EPT taxa richness is indicative of the best conditions. EPT taxa are generally sensitive to environmental degradation such as reduced dissolved oxygen, unstable substrates, reduced food quality, and contamination due to heavy metals and other pollutants (Angradi 1999, Barbour et al. 1999, Yuan and Norton 2003, Hutchens et al. 2009). As environmental conditions become worse, the sensitive and specialist taxa of these groups will emigrate or perish. |
| Richness of non-hydro Trichoptera | # taxa | Trichoptera richness (not counting Hydropsychidae) is indicative of the best conditions. For large, sandy-bottom rivers, Trichoptera are generally sensitive to environmental degradation such as reduced dissolved oxygen, unstable substrates, reduced food quality, and contamination due to heavy metals and other pollutants. The Hydropsychidae family of Trichoptera are somewhat more tolerant than other families. |
| EPT composition | % of counted individuals that are EPT | Relative abundance of EPT individuals is progressively higher in better conditions (Angradi 1999, Barbour et al. 1999, Yuan and Norton 2003, Hutchens et al. 2009). |
| Chironomid composition (individuals) | % of counted individuals that are chironomids | Chironomids should not be too dominant in better conditions (dependent on richness). |
| Richness of chironomids | # taxa that are chironomids | If chironomids are dominant, they can indicate better conditions if they are diverse. |
| Native mollusks | # taxa | Native mollusks require relatively undisturbed conditions. |
| Composition: non-insects | % of counted individuals that are non-insects | Non-insects indicate poor conditions if relative abundance is too high. Non-insects (primarily gastropods, bivalves, crustaceans, and worms) can be tolerant or take advantage of stresses, and therefore, an increase in relative abundance indicates the presence of disturbance. |
| Functional feeding group: shredder | # taxa | Shredder taxa richness indicates better conditions and high shredder richness can outweigh negative indications from other rules. Shredders are more sensitive to urban disturbances than to agricultural disturbances (Paul et al. 2006). |
| Functional feeding group: scraper | # taxa | Scraper taxa should be diverse in better sites and at least represented in good sites. Scrapers are known to be sensitive to metal contaminants (Carlisle and Clements 1999) and can respond positively to nutrient enrichment (Camargo et al. 2004). |
| Habit: clinger taxa | # taxa | Clinger taxa richness is indicative of progressively better biological conditions. Increases in deposited sediment have been related to decreases in clinger taxa richness (Rabeni et al. 2005). |
| Functional feeding group: collector-gatherers | % individuals | Collector-gatherers should not dominate in better sites. Percent collector-gatherers can respond positively to nutrient enrichment (Camargo et al. 2004, Lawrence and Gresens 2004). |
| Density: % of target | % of target # of individuals | Low macroinvertebrate density indicates poor conditions. |
| Sensitive species | # attribute I, II, and III taxa | Sensitive and specialist taxa indicate better conditions. |
| Tolerant species | % attribute V individuals | Tolerant taxa should not be abundant in better conditions. |

# Appendix H: Macroinvertebrate Metric Box Plots by Median Rating

Metric naming conventions

att BCG attribute

nB no Baetidae

nH no Hydropsychidae

nt number of taxa

pct percent

pi percent individuals

pt percent of taxa

Plotted sample size by rated BCG level

3 14

34tie 2

4 18

45tie 2

5 8



























































































































































# Appendix I - Fish Indicators Used in Developing BCG Rules

| **Indicator** | **Description** | **Ecological Rationale** |
| --- | --- | --- |
| Long-lived native large-bodied fish (LLNLB) | # of individuals | Long-lived native large-bodied fish are important components of good-condition fish assemblages. Large freshwater fish assemblages often show deterministic distributions of individuals among body size classes, with decreasing abundance in relation to increasing body size (Reiss 1989; Kerr and Dickie 2001; Brown and Gillooly 2003; Allan et al.2005; White et al. 2007; Clement et al. 2015). Many of these species require a large, uninterrupted river that flows throughout the year so they can migrate and spawn. The removal of long-lived large-bodied fish changes the fish community structure, causing a trophic cascade, reduced biodiversity, and loss of ecosystem function (Duffy 2002; Humphries and Winemiller 2009). |
| Sensitive and intermediate tolerant species (Attributes I-IV) | % of species | The BCG attributes respond to stressors in distinctly different ways, so they are predictive, quantitative measures along the full range of stress levels. A high percentage of sensitive and intermediate tolerant species (Attributes I, II, III, and IV) indicates a system with minimal-moderate stress pressure. Moderate pollution can produce changes in taxa so that diversity remains similar to natural but species composition shifts (e.g., numbers of sensitive forms decrease while numbers of tolerant species increase (Odum 1985; Rapport and Whitford 1999; EPA 2016; Weijermann et al. 2018). |
| Native Attribute I-IV cyprinid taxa | # of species | Cyprinidae is the largest family of freshwater fishes found in North America (Nelson 1994). Cyprinids are integral to freshwater food chains, converting certain small aquatic plants and animals (algae, insects, fish, etc.) into protein available to larger fish and fish-eating birds. The Rio Grande fish community was once dominated by a cyprinid assemblage including the federally endangered Rio Grande Silvery Minnow *Hybognathus amarus*. Native cyprinid species are reported to be sensitive to degraded habitat and water quality (Linam et al. 2002). |
| Rio Grande Silvery Minnow | # of species | Historically, the Rio Grande Silvery Minnow was one of the most abundant species in the Rio Grande, found from northern New Mexico to the Gulf of Mexico, but is now present only in the MRG (Bestgen and Platania 1991; Cowley et al. 2007; Sallenave et al. 2018). The Rio Grande Silvery Minnow was listed as an endangered species in 1994 and is also listed as endangered under New Mexico state law. |
| Pelagic broadcast spawners | # of individuals | Pelagic broadcast spawners are a reproductive guild of fishes whose eggs and larvae drift laterally and downstream (Archdeacon et al. 2018). Pelagic-broadcast spawning is uncommon in freshwater ecosystems but is employed in rivers on the Great Plains, North America (Hoagstrom and Turner 2013). They are good indicators of ecosystem condition because they have specific wetted habitat requirements; sufficient connected river habitat must be available for the species to complete its life cycle, some portion of the upstream end of that habitat must continually remain wet even during deep drought, and downstream individuals must be able to reach upstream spawning places (Cowley 2002). |
| Number of trophic groups present | # of trophic groups | The trophic groups represent the various feeding categories in the fish assemblage (Karr 1981; Schlosser 1982). Alterations in water quality, hydrologic regime, or other habitat conditions due to anthropogenic activities can cause shifts in the trophic structure (Karr et al. 1985; Poff and Allan 1995; Goldstein and Meador 2004; Higgins 2009). Therefore, trophic groups are a proven indicator of ecosystem condition. |
| Non-native species | # of species | Non-native fish species can have severe negative impacts in freshwater ecosystems (Casal 2006; Galiana et al. 2014). Non-natives can adversely affect native species by decreasing their abundance through predation, by displacing them from optimal habitats, or by outcompeting them for food (Cucherousset and Olden 2011). Many of the fishes in the Rio Grande are now non-native; of the 27 species of fish historically native to the Rio Grande in New Mexico, only 14 remain (Rinne and Platania 1994; Cowley 2006; Sallenave et al. 2010). |
| Non-native piscivores | # of species | Non-native piscivores can adversely affect native species by decreasing their abundance through predation or by outcompeting them for food (Rinne and Platania 1994; Cucherousset and Olden 2011). For example, on the Rio Grande, non-native salmonids outcompete the native Rio Grande Cutthroat Trout and the non-native White Sucker outcompetes the native Rio Grande Sucker (Rinne and Platania 1994). |
| Number of individuals | # of individuals | While the number of individuals was generally not a useful indicator, it did illustrate a clear change in condition when the number fell below a minimal threshold. |

# Appendix J: Fish Distributions by Rated BCG Level

Metric naming conventions

att BCG attribute

LLNLB Long-lived native large body

natv native

ni number of individuals

nt number of taxa

pct percent

pi percent individuals

pt percent of taxa

Plotted sample size by rated BCG level

4 13

5 39

6 6

























































































