**Supplemental Appendix S6-- Extirpation concentration (XC95) values: Step-by-Step Calculation and Spreadsheet Tools for Predicting Stressor Levels that Extirpate Genera and Species**

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Appendix S6: Extirpation concentration (XC95) values have potential uses beyond the development of water quality criteria, which have only recently been studied (Coffey et al. 2013; Cormier et al. 2012). Because some scientists may wish to explore a variety of possible applications, the specific conductivity XC95 values are provided here for stream benthic macroinvertebrates derived from the combined data sets (Appendix S5) from Ecoregions 69 and 70 (Omernik, 1987)

XC95 values are expressed as µS/cm. The 95% CI were estimated using a bootstrapping method described in USEPA (2011) using a more powerful R-script than available in the XC95 BEAT. Methods are described in Cormier et al., [a] and USEPA (2011, 2016). The symbol column contains designations for XC95, equal to (=), approximate (~) or greater than (>) the calculated value. The extirpation of taxa with > designation cannot be reliably estimated with the tested SC range. Predictions of the proportion of a distribution of XC95 values (XCD) in the SC range where taxa are identified as > may not be reliable. In this particular example, the XC95 designations were estimated using a software script in *R* (R Core Team 2014) (USEPA 2011, USEPA 2016). However, these designations can also be estimated by examining plots of the probability of observing a taxon over a range of SC (Supplemental Appendix S7).

| **Order** | **Family** | **Genus** | **Symbol** | **XC95** | **95% CI** | ***N*** |
| --- | --- | --- | --- | --- | --- | --- |
| Plecoptera | Perlodidae | *Remenus* | = | 108 | 86−259 | 63 |
| Ephemeroptera | Ephemerellidae | *Timpanoga* | = | 138 | 108−383 | 33 |
| Plecoptera | Taeniopterygidae | *Strophopteryx* | = | 159 | 115−392 | 29 |
| Trichoptera | Lepidostomatidae | *Lepidostoma* | ~ | 183 | 104−392 | 170 |
| Plecoptera | Chloroperlidae | *Utaperla* | = | 231 | 184−300 | 48 |
| Ephemeroptera | Leptophlebiidae | *Leptophlebia* | = | 235 | 185−387 | 115 |
| Ephemeroptera | Ephemerellidae | *Drunella* | = | 243 | 172−408 | 295 |
| Plecoptera | Peltoperlidae | *Tallaperla* | = | 243 | 156−589 | 121 |
| Plecoptera | Chloroperlidae | *Alloperla* | = | 245 | 210−301 | 131 |
| Ephemeroptera | Heptageniidae | *Cinygmula* | = | 281 | 227−348 | 224 |
| Plecoptera | Perlodidae | *Clioperla* | = | 299 | 117−1,590 | 27 |
| Ephemeroptera | Heptageniidae | *Heptagenia* | = | 301 | 215−356 | 113 |
| Ephemeroptera | Heptageniidae | *Nixe* | = | 316 | 273−394 | 219 |
| Diptera | Ceratopogonidae | *Bezzia* | = | 324 | 226−528 | 70 |
| Plecoptera | Taeniopterygidae | *Taeniopteryx* | = | 331 | 223−1,076 | 44 |
| Diptera | Chironomidae | *Constempellina* | = | 333 | 211−857 | 25 |
| Ephemeroptera | Ephemerellidae | *Ephemerella* | = | 335 | 277−381 | 683 |
| Trichoptera | Limnephilidae | *Pycnopsyche* | = | 343 | 164−534 | 93 |
| Ephemeroptera | Heptageniidae | *Epeorus* | = | 345 | 278−453 | 752 |
| Trichoptera | Uenoidae | *Neophylax* | = | 356 | 265−566 | 282 |
| Ephemeroptera | Ameletidae | *Ameletus* | = | 360 | 259−4,884 | 390 |
| Diptera | Chironomidae | *Platysmittia* | = | 387 | 127−702 | 35 |
| Ephemeroptera | Leptophlebiidae | *Paraleptophlebia* | = | 389 | 349−492 | 675 |
| Plecoptera | Perlodidae | *Diploperla* | = | 391 | 287−631 | 201 |
| Diptera | Chironomidae | *Demicryptochironomus* | = | 393 | 259−689 | 120 |
| Ephemeroptera | Heptageniidae | *Leucrocuta* | = | 396 | 320−536 | 369 |
| Plecoptera | Nemouridae | *Prostoia* | = | 401 | 272−508 | 35 |
| Trichoptera | Glossosomatidae | *Agapetus* | = | 404 | 210−487 | 41 |
| Plecoptera | Perlodidae | *Yugus* | = | 408 | 202−794 | 150 |
| Plecoptera | Chloroperlidae | *Haploperla* | = | 410 | 347−497 | 445 |
| Plecoptera | Capniidae | *Paracapnia* | = | 419 | 243−572 | 50 |
| Ephemeroptera | Ephemerellidae | *Eurylophella* | = | 434 | 348−574 | 289 |
| Ephemeroptera | Ephemerellidae | *Serratella* | = | 449 | 360−655 | 148 |
| Trichoptera | Psychomyiidae | *Lype* | = | 450 | 301−741 | 32 |
| Coleoptera | Elmidae | *Promoresia* | = | 456 | 320−931 | 128 |
| Plecoptera | Perlodidae | *Isoperla* | = | 468 | 396−578 | 868 |
| Diptera | Tipulidae | *Brachypremna* | = | 474 | 239−556 | 26 |
| Ephemeroptera | Ephemeridae | *Ephemera* | = | 478 | 350−1,693 | 220 |
| Plecoptera | Pteronarcyidae | *Pteronarcys* | ~ | 525 | 212−2,768 | 211 |
| Diptera | Chironomidae | *Conchapelopia* | = | 544 | 328−1,175 | 155 |
| Diptera | Chironomidae | *Stempellina* | = | 563 | 268−713 | 60 |
| Ephemeroptera | Baetidae | *Diphetor* | = | 611 | 528−705 | 249 |
| Ephemeroptera | Baetidae | *Procloeon* | = | 657 | 537−730 | 145 |
| Plecoptera | Perlidae | *Eccoptura* | ~ | 681 | 418−939 | 99 |
| Diptera | Chironomidae | *Zavrelia* | = | 704 | 297−1,837 | 93 |
| Ephemeroptera | Baetidae | *Acerpenna* | = | 710 | 453−1,036 | 63 |
| Trichoptera | Goeridae | *Goera* | ~ | 723 | 530−745 | 34 |
| Plecoptera | Peltoperlidae | *Peltoperla* | > | 746 | 547−1,349 | 188 |
| Plecoptera | Perlodidae | *Cultus* | = | 771 | 276−1,398 | 33 |
| Plecoptera | Perlodidae | *Malirekus* | ~ | 771 | 261−913 | 45 |
| Ephemeroptera | Heptageniidae | *Maccaffertium* | = | 779 | 680−851 | 793 |
| Plecoptera | Nemouridae | *Amphinemura* | = | 798 | 520−3,725 | 1,054 |
| Coleoptera | Dytiscidae | *Hydroporus* | = | 822 | 346−822 | 37 |
| Ephemeroptera | Baetidae | *Plauditus* | = | 843 | 723−1,176 | 716 |
| Ephemeroptera | Heptageniidae | *Stenacron* | ~ | 843 | 629−996 | 479 |
| Diptera | Dixidae | *Dixa* | > | 844 | 434−1,831 | 95 |
| Ephemeroptera | Heptageniidae | *Stenonema* | = | 845 | 712−937 | 1,218 |
| Ephemeroptera | Baetiscidae | *Baetisca* | = | 851 | 555−1,016 | 70 |
| Trichoptera | Philopotamidae | *Wormaldia* | ~ | 861 | 508−1,979 | 117 |
| Trichoptera | Psychomyiidae | *Psychomyia* | > | 895 | 608−1,388 | 58 |
| Diptera | Chironomidae | *Krenosmittia* | ~ | 913 | 235−1,540 | 32 |
| Diptera | Chironomidae | *Stempellinella* | > | 920 | 675−2,768 | 424 |
| Ephemeroptera | Baetidae | *Acentrella* | = | 947 | 712−2,087 | 1,291 |
| Isopoda | Asellidae | *Asellus* | = | 960 | 342−1,014 | 33 |
| Trichoptera | Philopotamidae | *Dolophilodes* | > | 1,036 | 599−7,053 | 564 |
| Ephemeroptera | Baetidae | *Centroptilum* | = | 1,101 | 600−1,175 | 104 |
| Ephemeroptera | Isonychiidae | *Isonychia* | = | 1,146 | 1,017−1,303 | 1,303 |
| Diptera | Chironomidae | *Parachaetocladius* | > | 1,183 | 600−2,768 | 232 |
| Isopoda | Asellidae | *Lirceus* | = | 1,190 | 784−1,347 | 153 |
| Diptera | Chironomidae | *Diplocladius* | = | 1,249 | 241−1,340 | 26 |
| Decapoda | Cambaridae | *Cambarus* | > | 1,311 | 1,028−1,994 | 658 |
| Diptera | Chironomidae | *Rheopelopia* | > | 1,341 | 435−2,523 | 134 |
| Trichoptera | Polycentropodidae | *Neureclipsis* | > | 1,424 | 711−1,620 | 32 |
| Trichoptera | Glossosomatidae | *Glossosoma* | > | 1,426 | 845−2,257 | 226 |
| Veneroida | Pisidiidae | *Pisidium* | > | 1,445 | 1,289−1,795 | 69 |
| Diptera | Simuliidae | *Prosimulium* | ~ | 1,451 | 478−2,439 | 271 |
| Ephemeroptera | Baetidae | *Baetis* | > | 1,460 | 1,171−1,859 | 2,493 |
| Plecoptera | Capniidae | *Allocapnia* | ~ | 1,478 | 230−1,540 | 34 |
| Coleoptera | Psephenidae | *Ectopria* | > | 1,505 | 1,016−2,768 | 501 |
| Trichoptera | Rhyacophilidae | *Rhyacophila* | > | 1,569 | 679−3,794 | 710 |
| Diptera | Chironomidae | *Paracladopelma* | > | 1,613 | 1,371−1,613 | 32 |
| Diptera | Chironomidae | *Psilometriocnemus* | > | 1,632 | 1,373−1,665 | 27 |
| Diptera | Chironomidae | *Potthastia* | > | 1,633 | 1,068−1,896 | 89 |
| Diptera | Chironomidae | *Brillia* | > | 1,676 | 1,065−2,768 | 152 |
| Diptera | Chironomidae | *Parakiefferiella* | > | 1,689 | 1,445−1,896 | 91 |
| Diptera | Chironomidae | *Pagastia* | > | 1,800 | 1,403−1,970 | 74 |
| Diptera | Tipulidae | *Limnophila* | ~ | 1,814 | 274−2,768 | 70 |
| Diptera | Chironomidae | *Eukiefferiella* | > | 1,858 | 1,585−2,020 | 796 |
| Diptera | Tipulidae | *Ormosia* | > | 1,959 | 1,263−1,977 | 42 |
| Diptera | Chironomidae | *Heleniella* | > | 2,016 | 916−2,768 | 74 |
| Hemiptera | Veliidae | *Rhagovelia* | > | 2,030 | 991−2,030 | 52 |
| Odonata | Gomphidae | *Lanthus* | > | 2,087 | 922−2,087 | 74 |
| Plecoptera | Leuctridae | *Leuctra* | > | 2,087 | 1,374−2,791 | 1,936 |
| Plecoptera | Perlidae | *Paragnetina* | = | 2,087 | 245−2,087 | 77 |
| Diptera | Chironomidae | *Sublettea* | > | 2,087 | 1,642−2,440 | 308 |
| Coleoptera | Elmidae | *Macronychus* | > | 2,160 | 1,489−2,160 | 99 |
| Amphipoda | Crangonyctidae | *Crangonyx* | > | 2,169 | 952−2,169 | 154 |
| Diptera | Tipulidae | *Molophilus* | ~ | 2,169 | 333−2,169 | 31 |
| Diptera | Ceratopogonidae | *Atrichopogon* | > | 2,257 | 1,120−2,257 | 60 |
| Diptera | Chironomidae | *Chaetocladius* | > | 2,320 | 1,700−5,057 | 270 |
| Diptera | Chironomidae | *Krenopelopia* | > | 2,320 | 1,700−2,320 | 63 |
| Diptera | Chironomidae | *Phaenopsectra* | > | 2,332 | 1,543−2,332 | 116 |
| Odonata | Cordulegastridae | *Cordulegaster* | > | 2,344 | 840−2,344 | 52 |
| Diptera | Chironomidae | *Natarsia* | > | 2,344 | 1,678−2,344 | 61 |
| Diptera | Chironomidae | *Nilotanypus* | > | 2,360 | 1,484−2,630 | 149 |
| Trichoptera | Polycentropodidae | *Polycentropus* | > | 2,445 | 1,381−4,713 | 641 |
| Diptera | Chironomidae | *Cardiocladius* | > | 2,485 | 1,573−3,174 | 374 |
| Hemiptera | Veliidae | *Microvelia* | > | 2,523 | 977−2,523 | 47 |
| Diptera | Culicidae | *Anopheles* | > | 2,768 | 823−2,768 | 28 |
| Diptera | Chironomidae | *Zavrelimyia* | > | 2,768 | 1,647−4,884 | 319 |
| Trichoptera | Hydroptilidae | *Ochrotrichia* | > | 2,791 | 1,210−2,791 | 54 |
| Coleoptera | Elmidae | *Oulimnius* | > | 2,791 | 1,327−5,000 | 409 |
| Diptera | Chironomidae | *Tvetenia* | > | 2,791 | 1,978−3,174 | 1,176 |
| Diptera | Tipulidae | *Tipula* | > | 3,140 | 2,020−6,492 | 967 |
| Decapoda | Cambaridae | *Orconectes* | > | 3,162 | 1,609−3,162 | 290 |
| Diptera | Empididae | *Chelifera* | > | 3,341 | 1,831−3,341 | 199 |
| Diptera | Ceratopogonidae | *Dasyhelea* | > | 3,341 | 1,608−3,341 | 109 |
| Trichoptera | Hydropsychidae | *Diplectrona* | > | 3,341 | 1,964−6,492 | 966 |
| Coleoptera | Elmidae | *Microcylloepus* | > | 3,341 | 1,796−3,341 | 231 |
| Diptera | Chironomidae | *Orthocladius* | > | 3,341 | 1,037−3,794 | 341 |
| Diptera | Chironomidae | *Microtendipes* | > | 3,489 | 1,694−7,053 | 823 |
| Diptera | Chironomidae | *Paratanytarsus* | > | 3,489 | 3,162−5,258 | 180 |
| Ephemeroptera | Caenidae | *Caenis* | > | 3,972 | 2,641−4,052 | 985 |
| Diptera | Chironomidae | *Polypedilum* | > | 4,400 | 3,162−7,093 | 2,749 |
| Diptera | Chironomidae | *Rheotanytarsus* | > | 4,400 | 2,573−4,636 | 1,558 |
| Diptera | Chironomidae | *Corynoneura* | > | 4,636 | 1,481−4,636 | 211 |
| Diptera | Chironomidae | *Diamesa* | > | 4,636 | 2,160−4,713 | 766 |
| Diptera | Chironomidae | *Parametriocnemus* | > | 4,636 | 2,572−4,969 | 2,277 |
| Diptera | Chironomidae | *Rheocricotopus* | > | 4,636 | 2,485−4,884 | 908 |
| Isopoda | Asellidae | *Caecidotea* | > | 4,713 | 1,970−4,713 | 246 |
| Diptera | Empididae | *Clinocera* | > | 4,713 | 1,418−4,713 | 83 |
| Diptera | Tipulidae | *Antocha* | > | 4,953 | 3,748−6,468 | 924 |
| Diptera | Tipulidae | *Limonia* | > | 5,057 | 2,160−5,057 | 68 |
| Diptera | Chironomidae | *Limnophyes* | > | 5,120 | 1,597−5,120 | 124 |
| Diptera | Simuliidae | *Simulium* | > | 5,120 | 2,874−7,053 | 1,965 |
| Diptera | Chironomidae | *Cryptochironomus* | > | 5,258 | 2,641−7,093 | 432 |
| Diptera | Chironomidae | *Larsia* | > | 5,258 | 1,408−5,258 | 121 |
| Diptera | Chironomidae | *Tribelos* | > | 5,258 | 1,309−5,258 | 79 |
| Megaloptera | Corydalidae | *Nigronia* | > | 5,720 | 3,162−9,790 | 1,172 |
| Trichoptera | Hydropsychidae | *Ceratopsyche* | > | 6,468 | 4,052−7,010 | 1,598 |
| Diptera | Chironomidae | *Micropsectra* | > | 6,468 | 1,870−6,468 | 390 |
| Diptera | Chironomidae | *Paraphaenocladius* | > | 6,468 | 1,461−6,468 | 77 |
| Odonata | Gomphidae | *Stylogomphus* | > | 6,468 | 2,344−6,468 | 161 |
| Plecoptera | Perlidae | *Acroneuria* | > | 6,492 | 1,793−11,646 | 802 |
| Trichoptera | Philopotamidae | *Chimarra* | > | 6,492 | 3,174−7,053 | 1,040 |
| Plecoptera | Perlidae | *Perlesta* | > | 6,492 | 1,468−6,492 | 518 |
| Coleoptera | Psephenidae | *Psephenus* | > | 6,492 | 5,068−9,790 | 1,503 |
| Diptera | Tipulidae | *Pseudolimnophila* | > | 6,492 | 1,331−6,492 | 221 |
| Plecoptera | Chloroperlidae | *Sweltsa* | > | 6,492 | 709−6,492 | 480 |
| Diptera | Chironomidae | *Thienemannimyia* | > | 6,492 | 4,400−7,053 | 2,326 |
| Diptera | Tipulidae | *Dicranota* | > | 7,010 | 1,914−7,370 | 529 |
| Coleoptera | Elmidae | *Optioservus* | > | 7,010 | 4,636−9,790 | 2,365 |
| Coleoptera | Elmidae | *Stenelmis* | > | 7,010 | 4,052−9,790 | 2,224 |
| Odonata | Aeshnidae | *Boyeria* | > | 7,340 | 2,445−7,340 | 272 |
| Coleoptera | Elmidae | *Dubiraphia* | > | 7,340 | 3,162−7,370 | 272 |
| Diptera | Tipulidae | *Hexatoma* | > | 7,340 | 4,884−9,790 | 1,251 |
| Trichoptera | Hydropsychidae | *Hydropsyche* | > | 7,370 | 4,713−10,140 | 1,628 |
| Trichoptera | Hydropsychidae | *Cheumatopsyche* | > | 9,180 | 5,258−9,180 | 2,816 |
| Diptera | Chironomidae | *Tanytarsus* | > | 9,180 | 4,884−9,790 | 1,920 |
| Basommatophora | Physidae | *Physella* | > | 9,790 | 6,468−9,790 | 231 |
| Diptera | Tabanidae | *Tabanus* | > | 9,790 | 2,291−9,790 | 83 |
| Diptera | Chironomidae | *Thienemanniella* | > | 9,790 | 6,468−11,227 | 580 |
| Diptera | Empididae | *Hemerodromia* | > | 10,235 | 7,010−11,646 | 865 |
| Amphipoda | Gammaridae | *Gammarus* | > | 10,350 | 2,316−10,350 | 317 |
| Megaloptera | Corydalidae | *Corydalus* | > | 11,227 | 7,010−11,646 | 599 |
| Diptera | Chironomidae | *Cricotopus* | > | 11,227 | 6,468−11,646 | 761 |
| Trichoptera | Hydroptilidae | *Hydroptila* | > | 11,227 | 5,319−11,646 | 615 |
| Diptera | Chironomidae | *Procladius* | > | 11,227 | 2,630−11,227 | 46 |
| Megaloptera | Sialidae | *Sialis* | > | 11,227 | 3,725−11,227 | 365 |
| Diptera | Chironomidae | *Dicrotendipes* | > | 11,310 | 9,790−11,646 | 377 |
| Diptera | Chironomidae | *Ablabesmyia* | > | 11,646 | 7,679−11,646 | 253 |
| Diptera | Athericidae | *Atherix* | > | 11,646 | 7,340−11,646 | 278 |
| Diptera | Tabanidae | *Chrysops* | > | 11,646 | 7,053−11,646 | 92 |
| Diptera | Chironomidae | *Cladotanytarsus* | > | 11,646 | 5,266−11,646 | 178 |
| Coleoptera | Dryopidae | *Helichus* | > | 11,646 | 1,528−11,646 | 553 |
| Diptera | Chironomidae | *Pseudochironomus* | > | 11,646 | 4,400−11,646 | 74 |

# REFERENCES

Coffey, DB, Cormier, SM, Harwood, J. 2013. Using field-based species sensitivity distributions to infer multiple causes. HERA 20(2): 402–432. Available online at <http://dx.doi.org/10.1080/10807039.2013.767071>.

Cormier, S; Coffey, DB; Griffith, M. 2012. Letter to the Editor in Chief concerning the article "Status of fish and macroinvertebrate communities in a watershed experiencing high rates of fossil fuel extraction: Tenmile Creek, a major Monongahela River tributary" by Kimmel and Argent, 2012. Water Air Soil Pollut 223: 4659-4662.

Cormier, SM; Zheng, L; Leppo, EW; and Hamilton, A. (a) Step-by-step calculation and spreadsheet tools for predicting stressor levels that extirpate genera and species. Integrated Environmental Assessment and Management.

Omernik JM. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geogr. 77:118-125.

USEPA (U.S. Environmental Protection Agency). 2011. A field-based aquatic life benchmark for conductivity in central Appalachian streams. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington, DC. EPA/600/R-10/023F.

USEPA (U.S. Environmental Protection Agency). 2016. Public review draft: field-based methods for developing aquatic life criteria for specific conductivity. Washington (DC), USA: U.S. Environmental Protection Agency, Office of Water. EPA-822-R-07-010.