A BIOLOGICAL CONDITION GRADIENT (BCG) ASSESSMENT MODEL FOR STREAM FISH COMMUNITIES OF CONNECTICUT

FINAL REPORT


Beaver Brook in Barkhamsted CT

***Prepared for*:**

U.S. EPA Office of Science and Technology
Susan K. Jackson, Work Assignment Manager

USEPA Region 1
David McDonald, Work Assignment Manager

and

Prepared for CT DEEP Bureau of Water Protection and Land Reuse
Michael Beauchene* and Chris Bellucci

***Prepared by*:**

Jennifer Stamp
Jeroen Gerritsen

Tetra Tech, Inc.
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117

March 31, 2013

*at the initiation of this project affiliated with WPLR Monitoring and Assessment and is currently in the Inland Fisheries Division

EXECUTIVE SUMMARY

Since 2007, Connecticut Department of Energy and Environmental Protection (CT DEEP) Bureau of Water Protection and Land Reuse (WPLR) has been using a macroinvertebrate multi-metric index (MMI) and a Biological Condition Gradient (BCG) assessment model for determination of aquatic life use support (ALUS) assessments in high gradient streams (Gerritsen and Jessup 2007). The BCG supports development of biological criteria in a state's water quality standards that can protect the best quality waters, that can be used as a tool to prevent or remediate cumulative, incremental degradation, and that can help to establish realistic management goals for impaired waters. The basis of the framework is recognition that biological condition of water bodies responds to human-caused disturbance and stress, and that the biological condition can be measured reliably.

The BCG is a universal measurement system or yardstick that is calibrated on a common scale for all states and regions. It is divided into biologically recognizable categories of condition. The BCG is not a management system, nor does it describe management goals. However, biological information as measured by the BCG can tell us if criteria are being met.

WPLR has long recognized the need to obtain a broader perspective of biological integrity through incorporation of fish community assessment data into the biological monitoring process. This document describes the development of BCG assessment models for fish assemblages in freshwater small-cold and medium-large wadeable streams of Connecticut. The BCG model incorporates multiple attribute decision criteria to assign streams to levels of the BCG, and it can be directly applied to designation of multiple aquatic life uses in Connecticut's Criteria and Standards. These fish BCG models will complement Connecticut's existing macroinvertebrate assessment tools (MMI and BCG) along with the recently developed cold and mixed water fish MMIs, and could potentially serve as a starting point for a regional fish BCG model for New England.

ACKNOWLEDGEMENTS

The participants in this effort invested significant time and commitment in the process. We are grateful for their hard work and enthusiasm.

Organization	Name
Connecticut Department of Energy and Environmental Protection (CT DEEP), Bureau of Water Protection and Land Reuse (WPLR)	Chris Bellucci
	Guy Hoffman
CT DEEP, Bureau of Bureau of Natural Resources (BNR) Inland Fisheries Division	Mike Beauchene
	Neal Hagstrom
	Brian Murphy
	Mike Humphreys
Silvio O. Conte Anadromous Fish Research Center, U.S. Geological Survey	Yoichiro Kanno
Vermont Department of Environmental Conservation (VT DEC)	Rich Langdon
	Aaron Moore
Maine Department of Environmental Protection (Maine DEP)	Dave Halliwell
U.S. EPA Region 1	Hilary Snook
Midwest Biodiversity Institute (MBI)	Chris Yoder

ACRONYMS

ALUS	Aquatic Life Use Support
BCG	Biological Condition Gradient
CT	Connecticut
CT DEEP	Connecticut Department of Energy and Environmental Protection
EPA	United States Environmental Protection Agency
MBI	Midwest Biodiversity Institute
ME DEP	Maine Department of Environmental Protection
MMI	Multi-metric Index
NEIWPCC	New England Interstate Water Pollution Control Commission
OTU	Operational Taxonomic Unit
SOP	Standard Operating Procedure
TALU	Tiered Aquatic Life Use
TNC	The Nature Conservancy
VT DEC	Vermont Department of Environmental Conservation
WPLR	Bureau of Water Protection and Land Reuse

TABLE OF CONTENTS

APPENDIXES

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The Connecticut Department of Energy and Environmental Protection (CT DEEP) Bureau of Water Protection and Land Reuse (WPLR) routinely samples macroinvertebrates and fish as part of its comprehensive ambient water quality monitoring strategy (CT DEP 2005). Since 2007, WPLR has been using a macroinvertebrate multi-metric index (MMI) and a Biological Condition Gradient (BCG) assessment model for determination of aquatic life use support (ALUS) assessments in high gradient streams (Gerritsen and Jessup 2007). WPLR has long recognized the need to obtain a broader perspective of biological integrity through incorporation of fish community assessment data into the biological monitoring process. The fish assessments would complement the existing macroinvertebrate tools to ultimately produce the most accurate and appropriate aquatic life use support assessments.

There have been recent advancements in fish community assessments in Connecticut. Since 2009, CT DEEP has collected continuous water temperature data from hundreds of sites in Connecticut’s inland flowing waters. From these data, CT DEEP has defined 3 major thermal habitat types (cold, cool, warm) and has conducted analyses to identify which fish species are most strongly associated with each habitat type (Beauchene et al. 2012). Patterns of fish distributions in Connecticut’s wadeable streams were documented in a publication by Kanno and Vokoun (2008). WPLR fish community data were used to develop cold and mixed water MMIs specific to Connecticut streams (Kanno et al. 2010a) as well as to examine the effects of water withdrawals and impoundments on fish assemblages in southern New England streams (Kanno and Vokoun 2010b). The MMIs are currently being incorporated into WPLR’s ALUS. In developing the methods and indexes, WPLR has incorporated the regional New England context, as well as general knowledge on coldwater fish community assessments (e.g., Vermont’s Index of Biological Integrity (IBI) (VT DEC 2004); Halliwell et al. 1999; Lyons et al. 2009).

This document describes the development of BCG assessment models for small, cold and medium –large cool wadeable streams of Connecticut. The BCG model incorporates multiple attribute decision criteria to assign streams to levels of the BCG, and it can be directly applied to designation of multiple aquatic life uses in Connecticut’s Criteria and Standards, to improve the precision of aquatic life use criteria and assessments. The fish BCG models are intended to support development of fish community structure metrics that will provide a more quantitative approach to WPLR’s assessment process. The fish BCG models and MMIs will also supplement Connecticut’s macroinvertebrate MMI and BCG model.

2 METHODS

2.1 Study Design

The WPLR fish dataset consisted of 967 samples from 676 unique stations, with sample dates ranging from 1999-2010. The data used passed WLPR’s quality assurance procedures. WPLR also provided attribute data for 68 species of fish, along with data on fish size class, water chemistry and land use. Distribution maps for 62 of the fish species are shown in Appendix A.

Samples were initially grouped into temperature subclasses (cold, transitional cool, transitional warm) based on The Nature Conservancy's (TNC) Northeast Aquatic Habitat Classification (Olivero and Anderson 2008). The TNC designations are based on stream size, air temperature, gradient, and groundwater inputs, and are intended to represent natural flowing-water aquatic habitat types across the region. However, the TNC designations were found to be a poor predictor of actual temperature regime in small streams (Mike Beauchene, unpublished data).

Watershed size was deemed to be a more consistent and accurate indicator of temperature class than TNC designations. Stream size exerts a major influence on the longitudinal shift in fish assemblages (Vannote et al., 1980; Kanno and Vokoun, 2008). CT DEEP's continuous temperature sensor data supports the assertion that most of Connecticut's small streams are coldwater, while medium to large-sized streams provide mixed water habitats.

Accordingly, we changed the stream temperature classification to agree with the above findings. We used 6 square miles (=15 km^2) as the threshold for separating small from medium-large streams (Kanno et al. 2010a). This threshold also corresponds with a fairly distinct drop in percent sensitive individuals such as brook trout and slimy sculpin (Figure 2-1). There are obviously exceptions to our broad groupings (e.g., naturally occurring small cool, small warm and medium-large coldwater streams in Connecticut), but these occur in low numbers. While not applicable to all streams, the models we have developed should cover the majority of Connecticut streams.

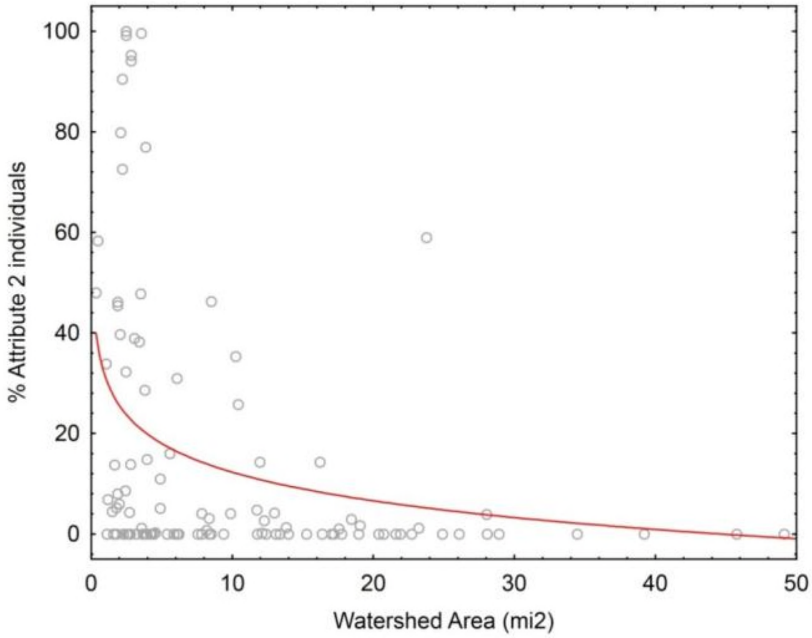


Figure 2-1. Relationship between watershed size (mi2) and % most sensitive (attribute 2) individuals, fit with a logarithmic trend line. In this figure, the scale of the x-axis has been limited to a maximum value of 50.

2.2 Sampling Methods

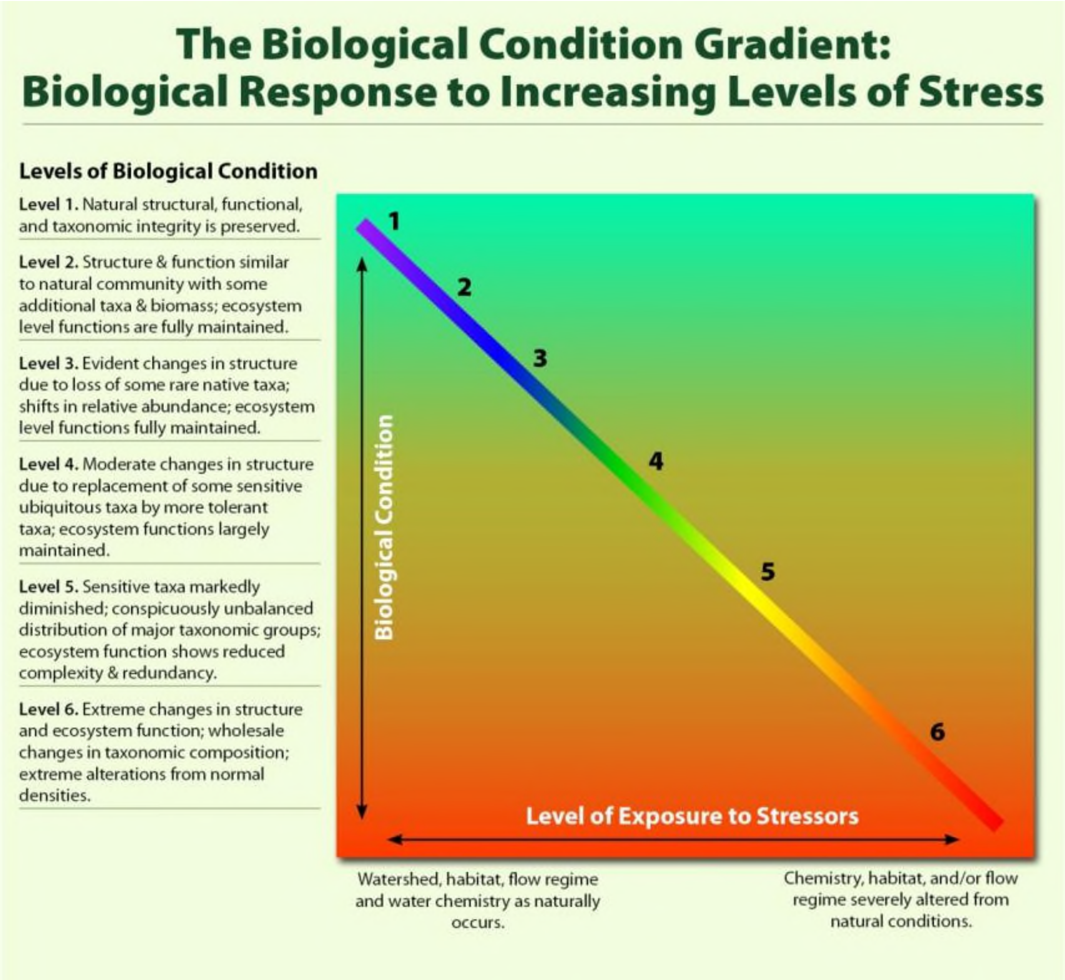
Samples in the WPLR fish dataset were collected using comparable single pass methods (CT DEEP 2013). Crews sample approximately 100-150 meter reaches or 10-20 mean stream widths. In larger streams, they may sample 200-300 meters. The larger the river, the fewer mean stream widths are typically sampled. The type of gear that a crew uses depends on the stream width. In small streams, crews typically sample with one backpack shocker. In medium-sized streams, they use 2 backpack shockers or 1 tote barge, and in large streams, crews sample with multi-tote barges. All captured individuals are measured to the nearest centimeter and are identified to the species level. Samples are collected during a June-September index period (Kanno et al. 2010a; M. Beauchene and Y Kanno unpublished data).

2.3 BCG Exercise

Biological condition levels and associated attributes are narrative statements on presence, absence, abundance, and relative abundance of several groups of taxa that have been empirically observed to have differing responses to stressors caused by human disturbance, as well as statements on system connectivity and ecosystem attributes (e.g., production, material cycling). The USEPA Tiered Aquatic Life Uses (TALU) national workgroup developed the statements out of consensus best professional judgments (Davies and Jackson 2006). The attributes and transitions between the levels that are described in the BCG model are based on years of biologists' field experience in a given region and reflect accumulated biological knowledge. The current generalized BCG model evolved from a prototype model that was adjusted following a series of exercises, conducted in several different regions of the United States, in which biologists attempted to place actual biomonitoring data into BCG levels (Figure 2-2). Greater detail about the BCG conceptual model may be found in Davies and Jackson (2006)).

The BCG is presented as a 6 by 10 matrix of levels and attributes that describe differences in the relative condition of the levels (Appendix B). The attributes are:

I. Historically documented, sensitive, long-lived or regionally endemic taxa
II. Highly sensitive taxa, often at low abundance
III. Sensitive but ubiquitous taxa
IV. Taxa of intermediate tolerance
V. Tolerant taxa
VI. Non-native taxa
VII. Organism condition
VIII. Ecosystem functions
IX. Spatial and temporal extent of detrimental effects
X. Ecosystem connectivity



Level 1. Natural structural, functional, and taxonomic integrity is preserved.

Level 2. Structure & function similar to natural community with some additional taxa & biomass; ecosystem level functions are fully maintained.

Level 3. Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained.

Level 4. Moderate changes in structure due to replacement of some sensitive ubiquitous taxa by more tolerant taxa; ecosystem functions largely maintained.

Level 5. Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy.

Level 6. Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities.

Watershed, habitat, flow regime and water chemistry as naturally occurs.

Chemistry, habitat, and/or flow regime severely altered from natural conditions.

Figure 2-2. The Biological Condition Gradient (BCG) (modified from Davies and Jackson 2006). The BCG was developed to serve as a scientific framework to synthesize expert knowledge with empirical observations and develop testable hypotheses on the response of aquatic biota to increasing levels of stress. It is intended to help support more consistent interpretations of the response of aquatic biota to stressors and to clearly communicate this information to the public, and it is being evaluated and piloted in several regions and states.

The ten attributes presented in the BCG describe multiple aspects of ecological condition, including taxonomic and structural information at the site scale (Attributes I-VI), organism and system performance at the site scale (Attributes VII and VIII), and physical-biotic interactions at broader temporal and spatial scales (Attributes IX and X). Some of the attributes in the BCG represent core data elements that are commonly measured in most state/tribal biological monitoring programs (e.g., Attributes II, III, IV, V, VI,VII) while others, though recognized as very important (e.g., Attributes I, VIII, IX and X), are not commonly measured due to resource limitations and technical complexity.

Development of the BCG is a collective exercise among regional biologists to develop consensus assessments of sites, and then to elicit the rules that the biologists use to assess the sites (Davies and Jackson 2006, US EPA 2007). The goal of this project was to develop a set of decision criteria rules for assigning sites to the BCG levels for small-cold and medium-large wadeable streams based on fish assemblages.

As part of this process, panelists first assigned BCG attributes to fish taxa (attribute assignments can be found in Appendix C). Attribute assignments were initially made during a November 8-9, 2010 workshop in Hartford, CT, and some were later revised following further examination of data and assessments. To help inform the attribute assignments, capture probability was plotted against disturbance gradient (plots can be found in Appendix D).

The panel created new sub-attributes from attribute 6, non-native taxa, to distinguish sensitive intermediate and tolerant non-native taxa (brown trout) and also to identify species that are technically native but have been locally extirpated and exist in some streams only through annual stocking of fry (Atlantic salmon). The sensitive nonnative category included naturalized nonnative salmonids and fry-stocked brown trout and Atlantic salmon. This distinction allowed the assessments to take into account that naturalized nonnative salmonids are highly valued, and are indicators of good water quality, good habitat, and naturally cold or cool temperature.

Table 2-1. Descriptions of the BCG attributes assigned to fish taxa for this exercise.

BCG	Description
1	Historically documented, sensitive, long-lived or regionally endemic taxa
2	Highly sensitive taxa, often occur in low abundance
3	Intermediate sensitive taxa
4	Taxa of intermediate tolerance
5	Tolerant native taxa
6	Non-native taxa of intermediate tolerance
6a	Highly tolerant non-native taxa
6b	Sensitive non-native salmonids (=highly valued recreational taxa)
10	Catadromous fish, indicating ecosystem connectivity
x	No attribute assignment (insufficient information)

Next the panelists examined biological data from individual sites and assigned those samples to levels 1 to 6 of the BCG. The intent was to achieve consensus and to identify rules that panelists were using to make their assignments. Sometimes questions arose regarding the classification of samples (e.g., if an obvious coldwater assemblage was being assessed with the group of coolwater samples). In these situations, we asked CTDEEP personnel to verify (or nullify) the classification based on their knowledge. When there was not an obvious error and when we could not verify or nullify a classification based on site knowledge, panelists made BCG level assignments under the assumption that the site classification was correct.

The panel met in person and per teleconference several times in the period November 2010 to October 2012. During the work, the panelists’ thinking evolved on attribute assignments and some of the rules. Accordingly, updates were made to some of the species attribute assignments (as described above), a revised classification scheme was put into place (small-cold and medium-large vs. the original size-TNC temperature subclasses, as described in Section 2.1) and changes were made to the BCG rules table.

In October 2012, the panelists made BCG level assignments on 50 additional samples (25 small-cold and 25 medium-large samples). Some of these were repeat samples, meaning that they had also been assessed during a previous calibration round. If there were discrepancies in the BCG level consensus calls for the repeat samples (e.g., in the first round a sample was assigned to BCG level 3 but in the second round, it was assigned to BCG level 4) we used the consensus call from the second round, since this captured the panelists' most recent thinking, and reflected the evolution in classification scheme, attribute assignments and BCG rules that occurred over the course of the exercise. The repeat samples were included in the calibration dataset. Samples that had not been assessed before were placed in a validation dataset and were used to confirm the models. A total of 124 samples were assessed, of which 94 were included in the calibration dataset, and 30 were placed in a validation dataset and were used to confirm the models.

The data that the experts examined when making BCG level assignments were provided in worksheets. The worksheets contained lists of taxa, taxa abundances, BCG attribute levels assigned to the taxa, BCG attribute metrics and limited site information, such as watershed area, TNC temperature/geology/gradient classifications, average July temperature (if available), and % forest. Participants were not allowed to view StationIDs or waterbody names when making BCG level assignments, as this might bias their assignments. A sample worksheet can be found in Appendix E. Other information that was gathered but not included in the worksheets was latitude and longitude, chemical water quality data and land use information. Site information data were not gathered with the intent of developing causal relationships; rather the intent was to define a stress gradient (mainly from land use data) and to learn more about the full range of anthropogenic disturbances that may be occurring in these streams.

2.4 Quantitative Description

Level descriptions in the conceptual model tend to be rather general (e.g., "reduced richness"). To allow for consistent assignments of sites to levels, it is necessary to formalize the expert knowledge by codifying level descriptions into a set of rules (e.g., Droesen 1996). If formalized properly, any person (with data) can follow the rules to obtain the same level assignments as the group of experts. This makes the actual decision criteria transparent to stakeholders.

Rules are logic statements that experts use to make their decisions; for example, "If taxon richness is high, then biological condition is high." Rules on attributes can be combined, for example: "If the number of highly sensitive taxa (Attribute II) is high, and the number of tolerant individuals (Attribute V) is low, then assignment is Level 2." In questioning individuals on how decisions are made in assigning sites to levels, people generally do not use inflexible, "crisp" rules, for example, the following rule is unlikely to be adopted:

"Level 2 always has 10 or more Attribute II taxa; 9 Attribute II taxa is always Level 3."

Rather, people use strength of evidence in allowing some deviation from their ideal for any individual attributes, as long as most attributes are in or near the desired range. Clearly, the definitions of "high," "moderate," "low," etc., are fuzzy. These rules preserve the collective professional judgment of the expert group and set the stage for the development of models that reliably assign sites to levels without having to reconvene the same group. In essence, the rules and the models capture the panel’s collective decision criteria.

Rule development requires discussion and documentation of BCG level assignment decisions and the reasoning behind the decisions. During our discussions, facilitators recorded:

- Each participant’s decision (“vote”) for the site
- The critical or most important information for the decision—for example, the number of taxa of a certain attribute, the abundance of an attribute, the presence of indicator taxa, etc.
- Any confounding or conflicting information and how this was resolved for the eventual decision

The criteria that panelists use to make their decisions are captured in preliminary, narrative rules. For example, “For BCG Level 2, sensitive taxa must make up half or more of all taxa in a sample.” The decision rule for a single level of the BCG does not always rest on a single attribute (e.g., highly sensitive taxa) but may include other attributes as well (intermediate sensitive taxa, tolerant taxa, indicator species), so these are termed “Multiple Attribute Decision Rules.” With data from the sites, the rules can be checked and quantified. Quantification of rules will allow the agency to consistently assess sites according to the same rules used by the expert panel, and will allow a computer algorithm, or other persons, to obtain the same level assignments as the panel.

Following the initial site assignment and rule development, we developed descriptive statistics of the attributes and other biological indicators for each BCG level determined by the panel. These descriptions assisted in review of the rules and their iteration for testing and refinement.

2.5 Develop Decision Criteria Model

Consensus professional judgment used to describe the BCG levels can take into account nonlinear responses, uncommon stressors, masking of responses, and unequal weighting of attributes. This is in contrast to the commonly used biological indexes, which are typically unweighted sums of attributes (e.g., multimetric indexes; Barbour et al. 1999; Karr and Chu 1999), or a single attribute, such as observed to expected taxa (e.g., Simpson and Norris 2000; Wright 2000). Consensus assessments built from the professional judgment of many experts result in a high degree of confidence in the assessments, but the assessments are labor-intensive (several experts must rate each site). It is also not practical to reconvene the same group of experts for every site that is monitored in the long term. Since experts may be replaced on a panel over time, assessments may in turn “drift” due to individual differences of new panelists. Management and regulation, however, require clear and consistent methods and rules for assessment, which do not change unless deliberately reset.

2.6 Development of a BCG Model Using a Decision Criteria Approach

A BCG-based index for use in routine monitoring and assessment thus requires a way to automate the consensus expert judgment so that the assessments are consistent. We incorporated the decision criteria into a decision model, which has the advantage that the criteria are visible and transparent. The model replicates the decision criteria of the expert panel by assembling the decision rules using logic and set theory, in the same way the experts used the rules.

Instead of a statistical prediction of expert judgment, this approach directly and transparently converts the expert consensus to automated site assessment. The method uses modern mathematical set theory and logic (called “fuzzy set theory”) applied to rules developed by the group of experts. Fuzzy set theory is directly applicable to environmental assessment, and has been used extensively in engineering applications worldwide (e.g., Demicco and Klir 2004) and environmental applications have been explored in Europe and Asia (e.g., Castella and Speight 1996; Ibelings et al. 2003).

Mathematical fuzzy set theory allows degrees of membership in sets, and degrees of truth in logic, compared to all-or-nothing in classical set theory and logic. Membership of an object in a set is defined by its membership function, a function that varies between 0 and 1. As an example, we compare how classical set theory and fuzzy set theory treat the common classification of sediment, where sand is defined as particles less than or equal to 2.0 mm diameter, and gravel is greater than 2.0 mm (Demicco and Klir 2004). In classical “crisp” set theory, a particle with diameter of 1.999 mm is classified as “sand”, and one with 2.001 mm diameter is classified as “gravel.” In fuzzy set theory, both particles have nearly equal membership in both classes (Demicco 2004). Measurement error of 0.005 mm in particle diameter greatly increases the uncertainty of classification in classical set theory, but not in fuzzy set theory (Demicco and Klir 2004). Demicco and Klir (2004) proposed four reasons why fuzzy sets and fuzzy logic enhance scientific methodology:

- Fuzzy set theory has greater capability to deal with “irreducible measurement uncertainty,” as in the sand/gravel example above.
- Fuzzy set theory captures vagueness of linguistic terms, such as “many,” “large” or “few.”
- Fuzzy set theory and logic can be used to manage complexity and computational costs of control and decision systems.
- Fuzzy set theory enhances the ability to model human reasoning and decision-making, which is critically important for defining thresholds and decision levels for environmental management.

In order to develop the decision criteria inference model, each attribute variable (e.g., “high taxon richness”) was defined quantitatively as a fuzzy set (e.g., Klir, 2004). A fuzzy set has a membership function. An example of membership functions of different classes of taxon richness are shown in Figure 2-3. We used piecewise linear functions to assign membership of a sample to the fuzzy sets. Numbers below a lower threshold have membership of 0, and numbers above an upper threshold have membership of one, and membership is a straight line between the lower and upper thresholds. For example, in Figure 2-3, a sample with 20 taxa would have a membership of 0.50 in the set “Low-moderate Taxa” and a membership of 0.50 in the set “Moderate Taxa.”

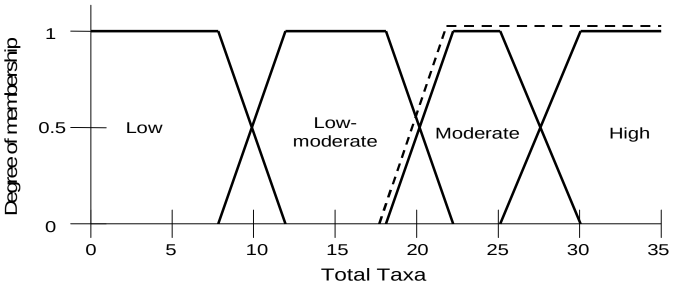


Figure 2-3. Fuzzy set membership functions assigning linguistic values of Total Taxa to defined quantitative ranges. Heavy dashed line shows membership of fuzzy set defined by "Total taxa are moderate to high."

Inference uses the logic statements developed by expert consensus. In "crisp" logic, an AND statement is the same as "Intersection" in crisp set theory, and logical OR is equivalent to set theory "Union". These are the same in fuzzy logic, however, a fuzzy AND uses the minimum membership of the two sets, and a fuzzy OR uses the maximum (Klir, 2004). For example, suppose a sample has membership of 0.25 in the set "Highly Sensitive taxa are Moderate" and membership of 0.75 in "Sensitive Taxa are High." If the rule is a fuzzy AND statement (e.g., Highly Sensitive taxa are Moderate AND Sensitive Taxa are High), then its membership in level 2 is min(0.75, 0.25) = 0.25. If the rule is a fuzzy OR statement, then its membership in level 2 equals max(0.75, 0.25) = 0.75. Output of the inference model may include membership of a sample in a single level only, ties between levels, and varying memberships among two or more levels. The level with the highest membership value is taken as the nominal level.

3 COMPREHENSIVE DECISION RULES AND BCG MODEL – SMALL-COLD

3.1. Site Assignments and BCG Level Descriptions

During the calibration exercise, participants made BCG level assignments on 40 small-cold calibration samples and 14 validation samples. Locations of the assessed small-cold sites are shown in Figure 3-1. These samples were assigned to 5 BCG levels (BCG levels 1-5)[1]. Five samples were assigned to BCG level 1, which consists of nearly pristine sites (Davies and Jackson 2006). Designating BCG level 1 samples is challenging because we lack sufficient information to know what the historical undisturbed assemblage in this region looked like.

---

[1] There was one majority opinion for a BCG Level 6 assignment, which is the most disturbed condition, but this was a questionable sample (Gulf Brook, StationID 5923 – it contained 1 American eel) so we did not include it in our calibration dataset.

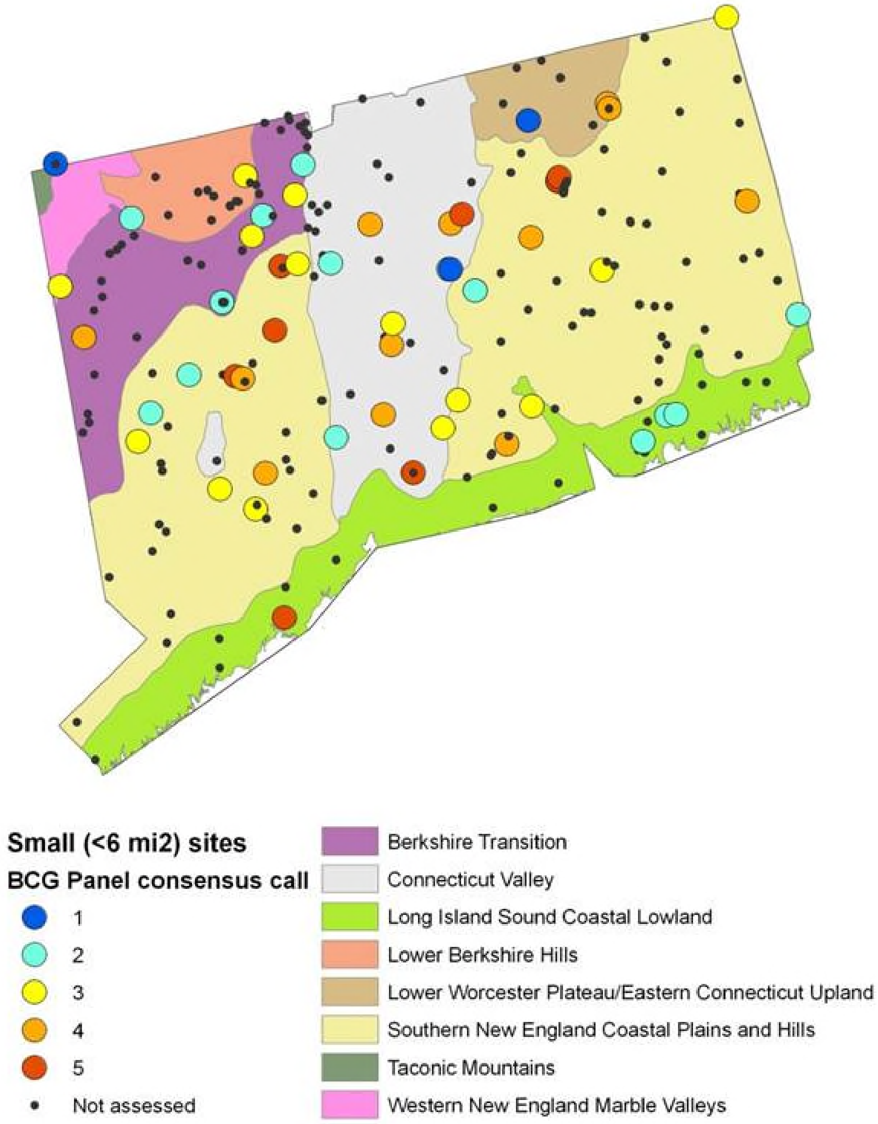


Figure 3-1. Locations of assessed small-cold samples (sites with drainage areas <6 mi2), coded by panelist BCG level assignment. This map also shows U.S. EPA Level 4 ecoregions. Ecoregions are delineated based on similarities in characteristics such as geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Omernik 1987, Omernik 1995).

3.2 BCG Attribute Metrics

We considered over 90 different metrics when calibrating the BCG model. Examinations of taxonomic attributes among the BCG levels determined by the panel showed that several of the attributes are useful in distinguishing levels, and indeed, were used by the panelists for decision criteria. The most important considerations were number of total taxa, percent native brook trout individuals and percent individuals and percent taxa metrics for sensitive (Attribute II+III), tolerant (Attribute V+VIa), non-native-non-salmonid (VI+VIa) and Attribute I-IV+VIb taxa.

Total richness showed a distinctly modal pattern, increasing as the assigned BCG level went from 1 to 4 (Figure 3-2), and then sharply fewer taxa in BCG Level 5. Watershed size was significantly and positively correlated with the total number of taxa ($r=0.53$, $p<0.01$) (Figure 3-3). Expectations of the panelists were in keeping with this relationship. In small, high quality coldwater streams (BCG levels 1-3), panelists expected the assemblage to be comprised of 6 or fewer species (the threshold of 6 is based on best professional judgment). As the streams increase in size, panelists expected more species to naturally be present. In BCG level 1 and 2 samples, the panelists expected to see high densities of native brook trout. If slimy sculpin and/or American Brook lamprey were also present, the panelists viewed this favorably, but since these species have limited spatial distributions, their presence was not required.

For the BCG attribute metrics, the percent individuals and percent taxa metrics were generally more effective at discriminating between BCG levels than absolute richness metrics. The Attribute II, II+III and IV metrics show relatively monotonic patterns, with Attribute IV metrics increasing and Attribute II+III metrics decreasing as the assigned BCG level goes from 1 to 5. The total taxa, Attribute II, II+III, percent wild brook individuals, percent tolerant (Attribute V+VIa) and percent non-native (Attribute VI+VIa+VIb) metrics were most effective at discriminating between BCG levels 1 and 2. All but one of these metrics (the percent non-native (Attribute VI+VIa+VIb) metric) also effectively captured the transition from BCG level 2 to 3. The percent non-native individuals (Attribute VI+VIa) was effective at distinguishing between BCG level 2 and 3 when nonnative salmonids were excluded (Attribute VIb). The transition from BCG level 3 to 4 was best captured by the Attribute II, Attribute II+III, Attribute II+III+non-native salmonid (VIb), Attribute II+III+IV+non-native salmonid (VIb) and tolerant (Attribute V+VIa) percent individuals and taxa metrics. BCG level 5 was discriminated from other BCG levels by the complete loss of Attribute II taxa, a decrease in Attribute II+III taxa and the concomitant increase in Attribute IV and percent tolerant (Attribute V + VIa) individuals. Distributions of various percent individuals and percent taxa metrics across BCG levels are shown graphically in Figures 3-4 through 3-6. Box plots for additional metrics can be found in Appendix F.

Presence and relative abundance of non-native taxa, in particular non-native trout, was another important consideration when panelists made BCG level assignments. Non-native trout were regarded as indicators of good water quality and coldwater habitat, but they also represent an altered fish assemblage. Panelists had different opinions on whether non-native trout could be present in BCG level 1 samples. In the end, a rule was established that requires all non-native taxa (including sensitive trout species) to be absent from BCG level 1 samples. In the original BCG level descriptions (Davies and Jackson 2006; Appendix B), the definition of BCG Level 1 does not explicitly state that non-natives cannot be present; however it does state that native structure must be preserved, so if non-natives are present, they cannot be displacing natives. The difference between BCG level 1 and 2 is subtle and comprises small changes in taxonomic composition versus functional degradation.

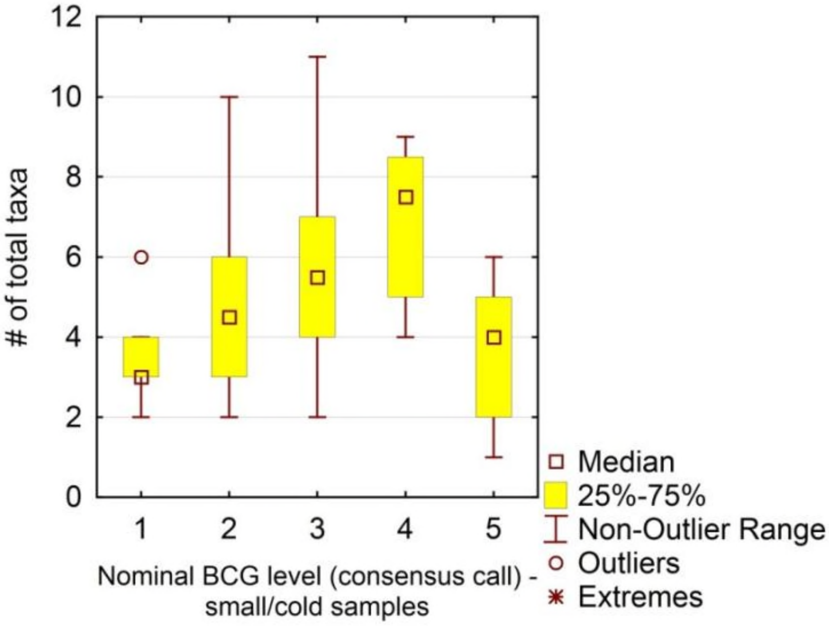


Figure 3-2. Box plots of total taxa metric values for small-cold samples, grouped by nominal BCG level (group majority choice). Sample size (which includes both calibration and validation samples) for BCG level 1 = 5, level 2 = 14, level 3 = 14, level 4 = 12, and level 5 = 9. The total taxa metric counts *all* taxa (even singletons), and counts native and non-native brook trout as separate species.

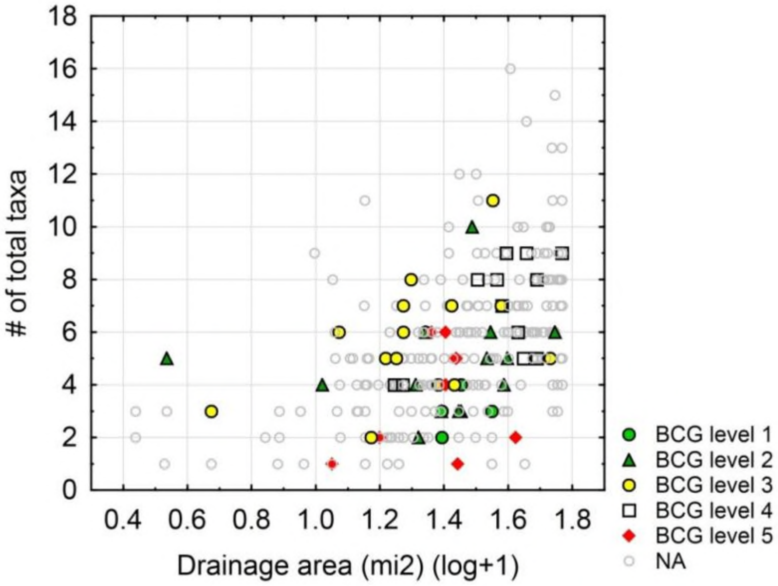


Figure 3-3. Relationship between total taxa metric values and watershed area for small-cold samples (r=0.53, p<0.01). Samples are coded by nominal BCG level (group majority choice).

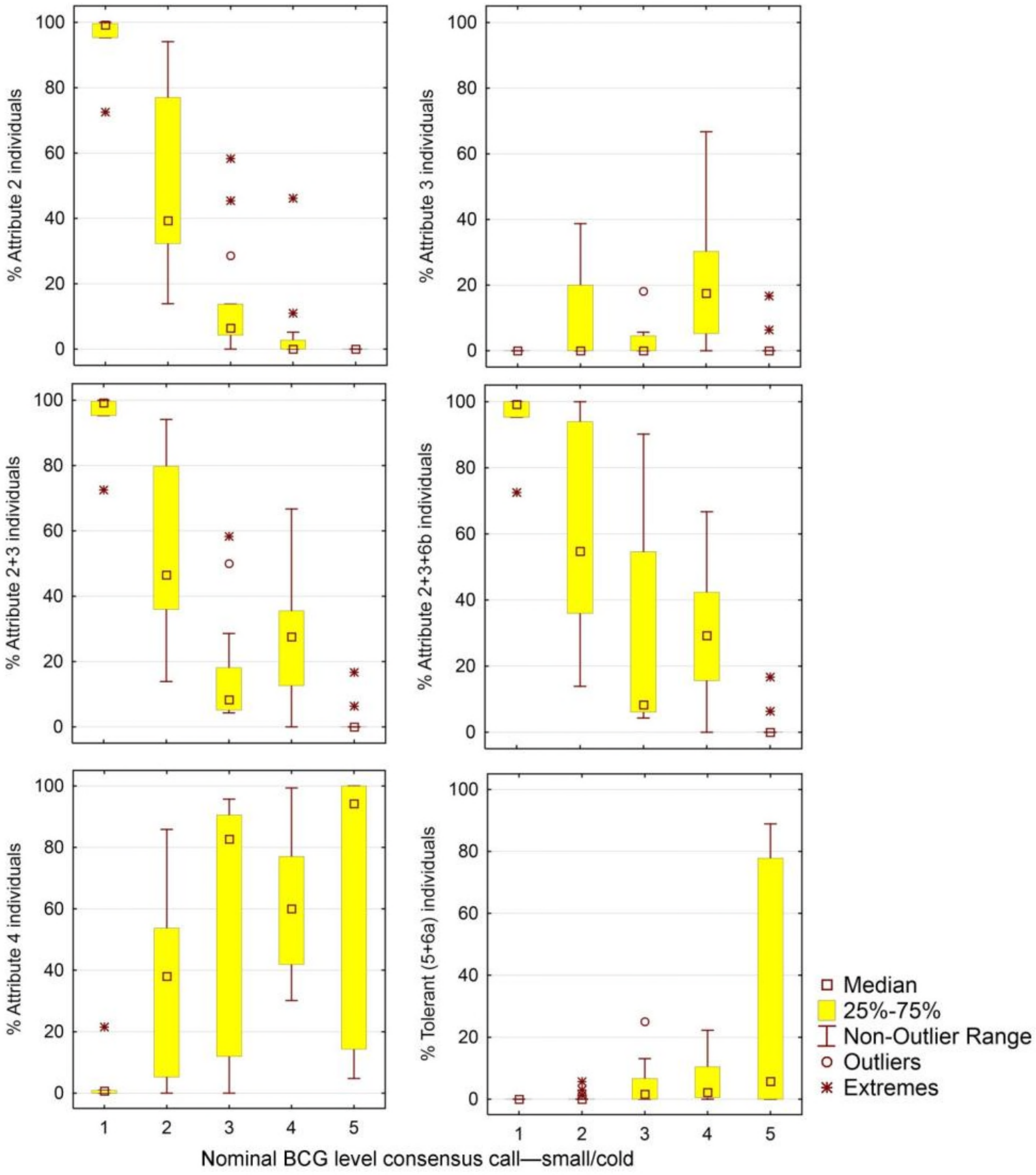


Figure 3-4. Box plots for a subset of BCG attribute percent individual metrics for the 54 small-cold samples that were assessed (this includes both calibration and validation samples), grouped by nominal BCG level (group majority choice). Sample size for BCG level 1 = 5, level 2 = 14, level 3 = 14, level 4 = 12, and level 5 = 9.

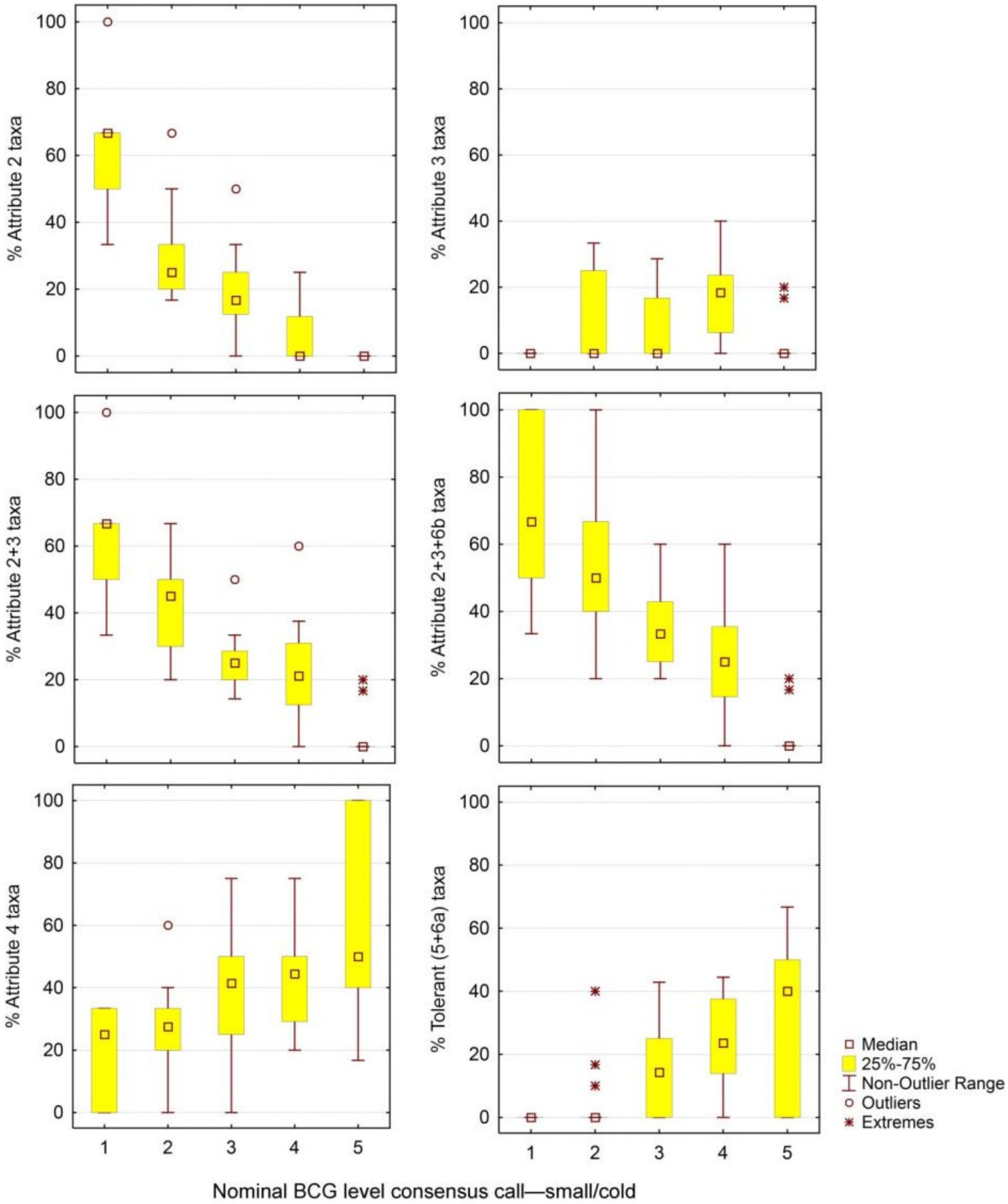


Figure 3-5. Box plots for a subset of BCG attribute percent taxa metrics for the 54 small-cold samples that were assessed (this includes both calibration and validation samples), grouped by nominal BCG level (group majority choice). Sample size for BCG level 1 = 5, level 2 = 14, level 3 = 14, level 4 = 12, and level 5 = 9.

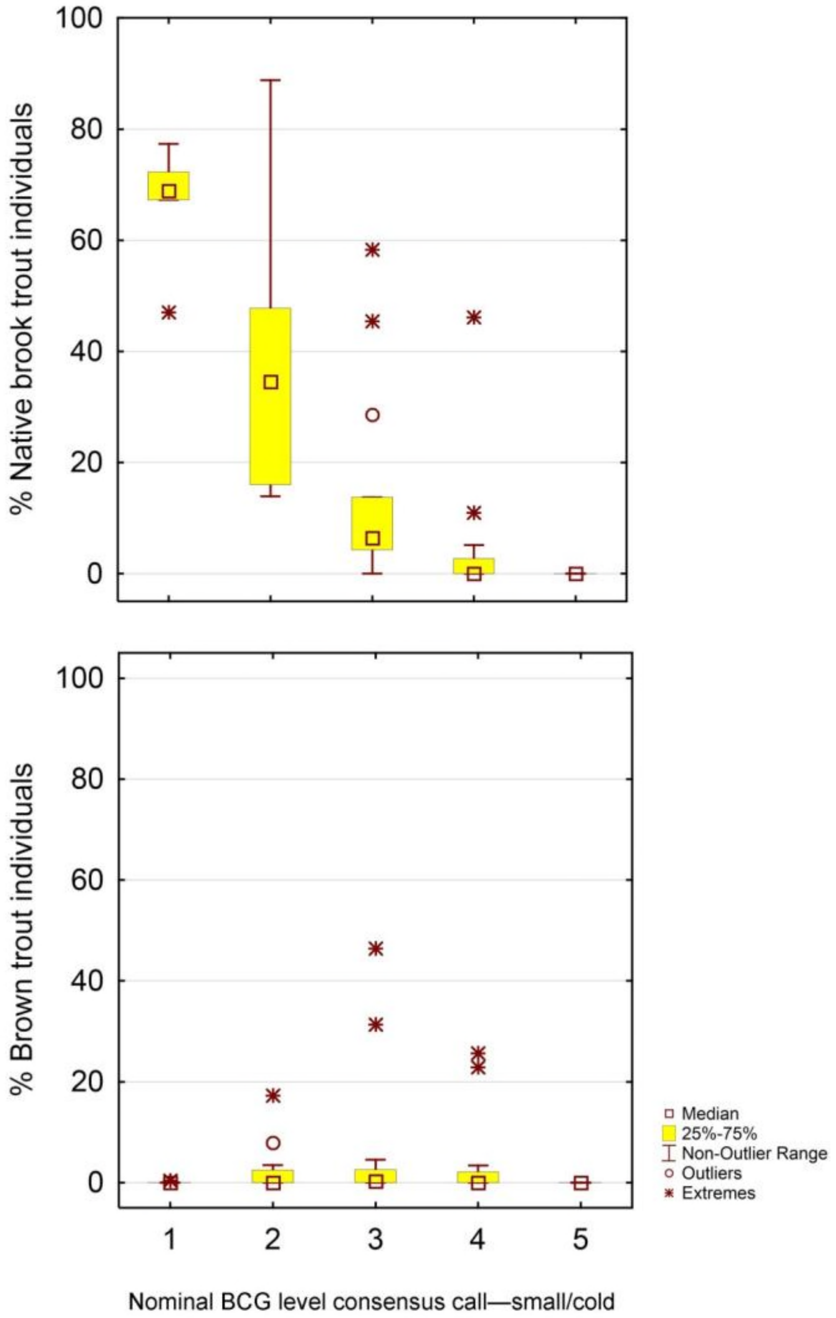


Figure 3-6. Box plots of native brook trout and brown trout percent individual metrics for the 54 small-cold samples that were assessed (this includes both calibration and validation samples), grouped by nominal BCG level (group majority choice). Sample size for BCG level 1 = 5, level 2 = 14, level 3 = 14, level 4 = 12, and level 5 = 9.

3.3 BCG Rule Development

The small-cold rules, which are shown in Table 3-1, were derived from discussions with the panelists on why individual sites were assessed at a certain level. They follow the observations shown in Figures 3-2 through 3-6. The rules were calibrated with 40 small-cold fish samples rated by the group, and were adjusted so that the model would replicate the panel's decisions as closely as possible. Inevitably, there were some places where the panel may have used different, unstated rules, or where rules were inconsistently applied. Panelist and model BCG level assignments for these 40 samples, along with site information, are summarized in Appendix G. Appendix G also contains panelist and model BCG level assignments for the 14 samples that were assessed during the validation round.

In the model, rules work as a logical cascade from BCG Level 1 to Level 6. A sample is first tested against the Level 1 rules; if a single rule fails, then the Level fails, and the assessment moves down to Level 2, and so on. All required rules must be true for a site to be assigned to a level. As described in Section 2.6, membership functions had to be defined for the richness and percent individual metrics.

The rules shown in Table 3-1 have been developed for distinguishing BCG levels for small-cold fish samples. They follow a general pattern of decreasing richness of sensitive taxa and increasing relative abundance of tolerant individuals as biological condition degrades. Small-cold BCG Level 1 rules require that fewer than 6 total taxa be present, that at least 70% of the assemblage be comprised of sensitive (Attribute I + II + III) individuals (at least 60% of which must be native brook trout), and that non-native (Attribute VI+VIa+VIb) taxa are absent.

In BCG Level 2 samples, fewer than 7 total taxa must be present. At least 30% of a BCG level 2 sample must be comprised of sensitive (Attribute I + II + III) individuals, at least 10% of the individuals must be native brook trout, and there must be less than 6 and 12% percent tolerant (Attribute V + VIa) and non-native, non-salmonid (Attribute VI + VIa) individuals, respectively.

BCG level 3 samples must have fewer than 9 total taxa. In addition, the percent Attribute II and percent sensitive (Attribute I + II + III) taxa metrics must exceed thresholds of 5 and 15%, respectively, there must be more than 5% percent sensitive (Attribute I + II + III) individuals, the most dominant Attribute V, VI or VIa taxon must comprise less than 50% of the assemblage and percent non-native, non-salmonid (Attribute VI + VIa) individuals must be less than 20%.

BCG Level 4 is characterized by decreased richness and abundance of sensitive (Attribute I + II + III) taxa. More than 3 total taxa must be present, or, alternately, if fewer than 3 are present, at least 1 of the taxa must be an Attribute II taxa. Sensitive taxa (Attribute II+III) must be present, and the assemblage must be comprised of more than 40% Attribute I + II + III + IV + non-native salmonid (VIb) individuals and taxa. There also must be less than 20% tolerant (Attribute V + VIa) individuals. BCG Level 5 rules require that Attribute I + II + III + IV + non-native salmonid (VIb) individuals comprise at least 30% of the taxa and at least 10% of the individuals

Table 3-1. BCG decision rules for fish assemblages in small-cold (<6 m^{i2}) and medium-large (≥6 m^{i2}) streams. Samples are flagged for professional assessment (outside experience of model) if < 20 total individuals are present (per Kanno et al. 2010a), if > 400 total individuals are present in streams < 6 mi2 or if > 500 total individuals are present in streams ≥ 6 mi2.

BCG Level 1	**Small-Cold (n=5)**			**Medium-Large (n=1)**		
Metrics	**data**	**rule**	**alt rule**	**data**	**rule**	**alt rule**
# Total taxa	2-6	≤ 5		7	≥ 6	
# Attribute I + II taxa	--	--		1	present	
% Native brook trout individuals	47-77%	> 60%		--	--	
% Attribute I + II + III taxa	33-100%			28%	> 25%	
% Attribute I + II + III individuals	72-100%	> 70%		79%	> 25%	
% Tolerant (V + VI a) individuals	--	--		0%	< 5%	
% Non-native (VI + VI a + VIb) individuals	0-0.4%	absent		0.4%	absent	
BCG Level 2	**Small-Cold (n=14)**			**Medium-Large (n=6)**		
Metrics	**data**	**rule**	**alt rule**	**data**	**rule**	**alt rule**
# Total taxa	2-10	≤ 6		4-12	area <20 mi^2, taxa ≥ 2; area >20 mi^2, taxa ≥ 8	
% Native brook trout individuals	14-89%	> 10%		--	--	
% Attribute I + II + III taxa	--	--		9-44%	> 20%	
% Attribute I + II + III individuals	14-94%	> 30%		1-64%	> 20%	
% Tolerant (V + VIa) individuals	0-6%	< 6%		--	--	
% Non-native, non-salmonid (VI + VIa) individuals	0-5%	< 12%		--	--	
% Most dominant intermediate tolerant (Att IV) taxon	--	--		14-52%	< 40%	
# Salmonidae taxa	--	--		1-4	present	
% Centrarchidae individuals	--	--		0-14%	< 2 % OR	
% Attribute II individuals	--	--		0-59%		> 5% OR

Continued…

BCG Level 3	**Small-Cold (n=14)**			**Medium-Large (n=24)**		
Metrics	**data**	**rule**	**alt rule**	**data**	**rule**	**alt rule**
# Total taxa	2-11	≤ 8		4-14	area <20 mi^2, taxa ≥ 2; area >20 mi^2, taxa ≥ 8	
% Attribute I + II taxa	0-50%	> 5%		--	--	
% Attribute I + II + III taxa	14-50%	> 10%		11-67%	> 10%	
% Attribute I + II + III individuals	4-58%	> 5%		3-64%	> 3%	
% Attribute I + II + III + non-native salmonid (VIb) taxa	--	--		14-67%	> 20%	
% Attribute I + II + III + non-native salmonid (VIb) individuals	--	--		11-65%	> 10%	
% Most dominant tolerant (Att V, VI or VIa) taxon	0-25%	< 50%		--	--	
% Most dominant tolerant (Att V) taxon	--	--		0-4%	< 5%	
% Centrarchidae individuals	--	--		0-25%	< 10%	
% Non-native, non-salmonid (VI + VIa) individuals	0-14%	< 20%		--	--	
% Cyprinid taxa	0-67%	--		22-67%	> 10%	
BCG Level 4	**Small-Cold (n=12)**			**Medium-Large (n=27)**		
Metrics	**data**	**rule**	**alt rule**	**data**	**rule**	**alt rule**
# Total taxa	4-9	> 3	≥ 1	--	--	
# Attribute I + II taxa	0-1	--	present	--	--	
# Attribute I + II + III taxa	0-3	present		--	--	
% Attribute I + II + III + IV + non-native salmonid (VIb) taxa	50-89%	> 40%		50-91%	> 40%	
% Attribute I + II + III + IV + non-native salmonid (VIb) individuals	74-100%	> 40%		49-99%	> 40%	
% Centrarchidae individuals	--	--		0-53%	< 40%	
% Tolerant (V + VIa) individuals	0-22%	< 20%		--	--	
% Cyprinid taxa	--	--		9-50%	present	
% Non-native, non-salmonid (VI + VIa) individuals	--	--			< 50%	

Continued…

BCG Level 5	**Small-Cold (n=9)**			**Medium-Large (n=12)**		
Metrics	**data**	**rule**	**alt rule**	**data**	**rule**	**alt rule**
# Total taxa	--	--		5-16	> 3	
% Attribute I + II + III + IV + non-native salmonid (VIb) taxa	33-100%	> 30%		38-86%	> 20%	
% Attribute I + II + III + IV + non-native salmonid (VIb) individuals	11-100%	> 10%		14-100%	> 10%	

As mentioned in Section 3.2, a rule was also developed for all BCG levels to flag samples with low and high densities. These rules are as follows: low density < 20 total individuals; high density >400 individuals in small (<6 mi^2) streams and >500 individuals in medium-large (≥ 6 mi^2) streams. Failure of the density rule causes the sample to be flagged for professional assessment. It should be noted that the model still makes BCG level assignments for samples that are flagged, and that density is not a consideration in these BCG level assignments.

3.4 Model Performance

To evaluate the performance of the 41-sample small-cold calibration dataset and the 14-sample validation dataset, we considered two matches in BCG Level choice: an exact match, where the BCG decision model's nominal level matched the panel's majority choice; and a "near match", where the model predicted a BCG level within one level of the majority expert opinion. When model performance was evaluated, the small-cold fish model matched exactly with the regional biologists' BCG level assignments on 68% of the calibration samples (Table 3-2). Eleven (27%) of the model assignments were within one level of the majority expert opinion, and two (5%) were off by two BCG levels. Where there were differences, the tendency was for the model to rate samples worse than the panel; the model assigned 9 samples to a BCG level that was 1 level worse than the panelists, 1 sample to a BCG level that was 2 levels worse, 2 samples to a BCG level that was 1 level better than the panelists' assignment and 1 sample to a BCG level that was 2 levels better than the panelists' assignment. These results should be interpreted with caution because some of the calibration consensus calls were made early on in the process (e.g. at the November 2010 workshop) and may not reflect changes that occurred in the group's thinking.

In order to confirm the model, panelists made BCG level assignments on 14 additional small-cold samples. When nominal level assignments from the BCG decision model were compared to the panelists' nominal level assignments[2], the small-cold fish model matched exactly with the regional biologists' BCG level assignments on 100% of the confirmation samples (Table 3-2). We believe the model performance is better in the validation dataset than in the calibration dataset because the calibration dataset reflects the twists and turns that occurred in the group's thinking during the model development process; the results from the validation dataset suggest that the group has indeed converged on this latest set of rules, and that these rules appear to have been successfully captured in the model.

It is possible that model performance in the calibration dataset could improve if the group reassesses some of the original calibration samples. In addition to potentially revising some of the consensus calls, closer examination of the anomalous samples may reveal issues that make some samples fall outside the realm of experience for the BCG model. For example, in this case, the two samples that differed the most from BCG model assignments both had such issues: one (Menunketesuck River, StationID 1976) was flagged for low density; and the other (East Mountain Brook , StationID 2714) was located near a large river, which likely resulted in an

---

[2] For most small-cold validation samples, panelists worked independently to rate the samples and did not discuss these ratings as a group.

inflated species count (which caused the sample to exceed the total taxa richness threshold for small streams).

Table 3-2. Summary of differences between model and panelist BCG level assignments for small-cold water samples**.**

Difference (model minus panel consensus call)*	**Calibration**		**Confirmation**
	# samples	**notes**	**# samples**
2 better**	1	this sample was flagged for low density	0
1 better	2		0
same	28		14
1 worse	9	2 of these samples were flagged for high density; 5 of these had differences between BCG levels 3 & 4	0
2 worse	1	site located near large river, likely resulting in inflated species count	0
Total # Samples	**41**		**14**
% Correct	**70%**		**100%**

* In some instances, the model output was a tie between two BCG levels. We considered these to be matches if the range of model assignments matched with the range of panelist calls. For example, if the model output was a tie between BCG levels 1 and 2 and the panelist calls ranged from 1 to 2, we called this a match. If the model output was a tie between BCG levels 1 and 2 and the panelist calls ranged from 2 to 3, we considered this to be a difference of 1 BCG level. If there were ties between panelist calls, we used the lower score (e.g., BCG level 2 vs. 3) as the consensus call.

** this means that the model score was 2 levels better than the panelist score; for example, the model assigned it to BCG level 2 and the panel assigned it to BCG level 4.

4 COMPREHENSIVE DECISION RULES AND BCG MODEL – MEDIUM-LARGE

4.1 Site Assignments and BCG Level Descriptions

Participants made BCG level assignments on 54 medium-large calibration samples and 16 validation samples. Locations of the assessed medium-large sites are shown in Figure 4-1. These samples were assigned to BCG levels 1-5. One sample (Green Fall River, StationID 606) was assigned to BCG level 1. Designating BCG level 1 samples was challenging because there is not enough information to know what the historical undisturbed fish assemblage in medium-large streams in this region looked like. Most panelists said that they had greater difficulty making BCG level assignments on samples from medium-large streams versus small-cold streams.

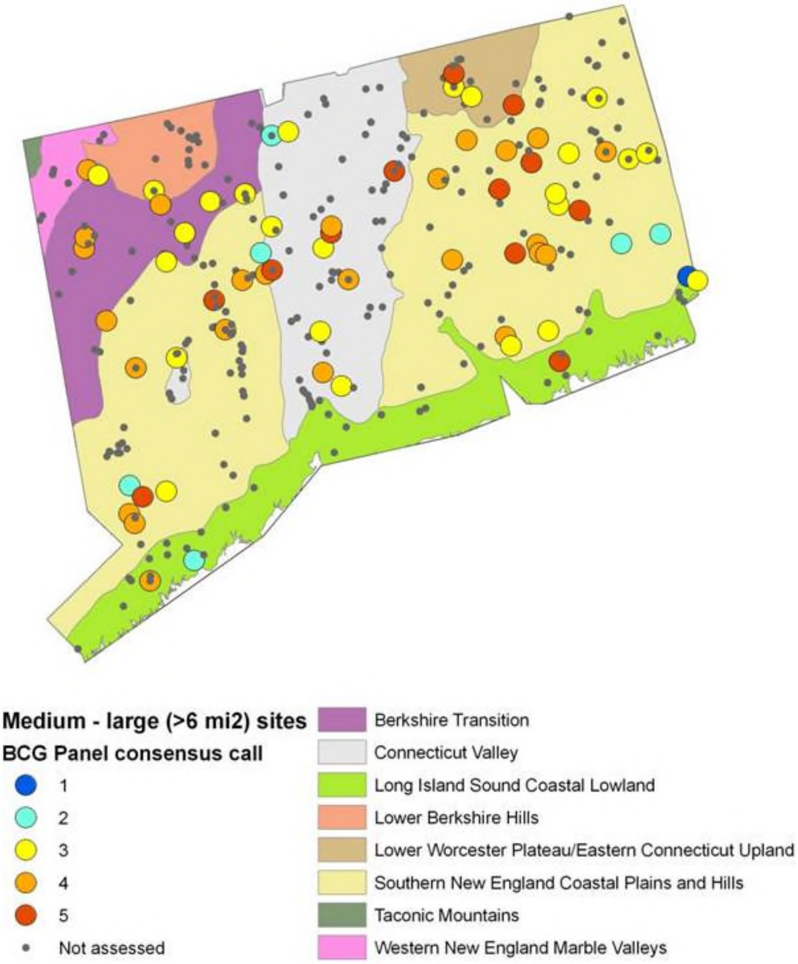


Figure 4-1. Locations of assessed medium-large (drainage areas ≥6 mi2) sites, coded by panelist BCG level assignment. This map also shows U.S. EPA Level 4 ecoregions. Ecoregions are delineated based on similarities in characteristics such as geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Omernik 1987, Omernik 1995).

4.2 BCG Attribute Metrics

The same metrics that were evaluated for coldwater samples (Section 3.2) were evaluated for samples from medium-large streams. Panelists considered an assortment of metrics when distinguishing between BCG levels for these samples. The most important considerations were number of total taxa, percent individuals and percent taxa metrics for sensitive (Attribute II+III), tolerant (Attribute V+VIa), non-native-non-salmonid (VI+VIa) taxa, Attribute I-IV+non-native salmonid (VIb) taxa, number of salmonid taxa, percent Cyprinid taxa and percent Centrarchidae individuals.

Total taxa richness did not show a clear pattern across BCG levels (Figure 4-2). As expected, watershed size was significantly and positively correlated with total fish species richness (r=037, p<0.01) (Figure 4-2). In high quality medium-large streams (BCG levels 1-3), panelists expected the assemblage to be comprised of at least 2 species. As the streams increase in size (>20 mi^2), they expected more species (≥8) to naturally be present. In high quality, medium-large streams, panelists expected to see a balanced assemblage of cool water species, with at least 2 species of sensitive (Attribute II + III) taxa like longnose dace, common shiner and fallfish, and no hyperabundance of blacknose dace and/or white suckers. Panelists said they would consider samples with high proportions of native coldwater species to be BCG Level 1.

Overall, patterns in the medium-large BCG attribute metrics were less evident than those in the small-cold plots. However, the sensitive (Attribute II+III & Attribute II+III+VIb) and tolerant (Attribute VI + VIa) metrics did show fairly clear monotonic patterns, with sensitive metrics decreasing and tolerant metrics generally increasing as the assigned BCG level increased from 1 to 5 (Figures 4-3 & 4-4). Percent Cyprinid taxa and percent Centrarchidae individuals also show relatively monotonic patterns, with percent Cyprinid taxa decreasing and percent Centrarchidae individuals increasing with BCG level 1 to 5.

The total taxa, Attribute II+III and percent tolerant (Attribute V+VIa) are most effective at discriminating between BCG levels 1 and 2, and Attribute II taxa must be present and non-native taxa (Attribute VI+VIa+VIb) must be absent in BCG level 1 samples. Salmonids must be present in BCG level 2 samples, and the transition from BCG level 2 to 3 is captured by total taxa, Attribute II+III metrics, percent most dominant Attribute IV taxon and an alternate rule related to percent Centrarchidae individuals and percent Attribute II individuals. Metrics effective at discriminating between BCG levels 3 and 4 include Attribute II+III, Attribute II+III+ VIb and Attribute II+III+ IV+VIb metrics, as well as metrics related to Centrarchids and Cyprinids. The transition from BCG level 4 to 5 is captured by decreases in Attribute II+III+ IV+VIb metrics and increases in percent tolerant (Attribute V+VIa) individuals. Distributions of percent individuals and percent taxa metrics across BCG levels are shown graphically in Figures 4-2 through 4-6. Box plots for additional metrics can be found in Appendix H.

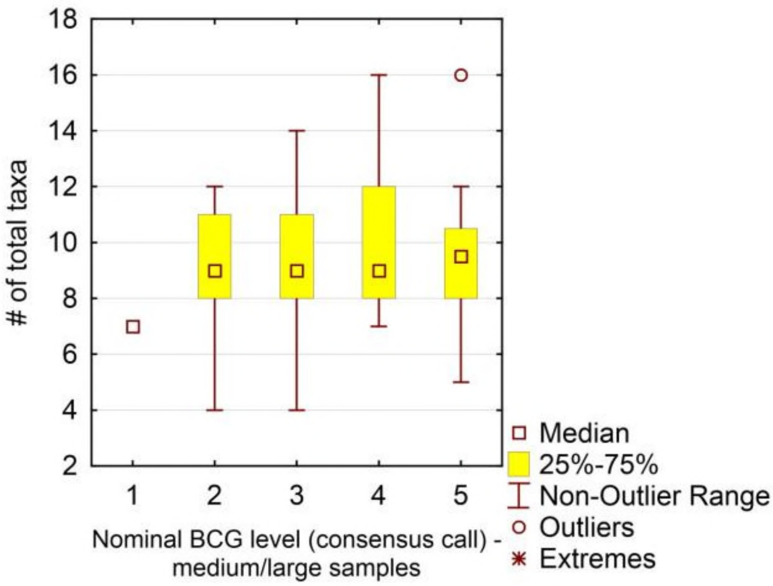


Figure 4-2. Box plots of total taxa metric values for medium-large samples, grouped by nominal BCG level (group majority choice). Sample size (which includes both calibration and validation samples) for BCG level 1 = 5, level 2 = 6, level 3 = 24, level 4 = 27, and level 5 = 12. The total taxa metric counts *all* taxa (even singletons), and counts native and non-native brook trout as separate species.

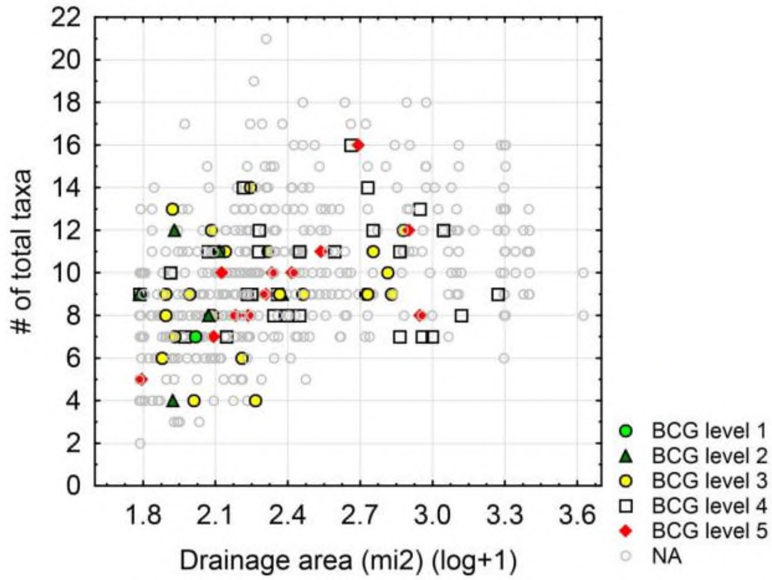


Figure 4-3. Relationship between total taxa metric values and watershed area for medium-large samples (r=0.37, p<0.01). Samples are coded by nominal BCG level (group majority choice).

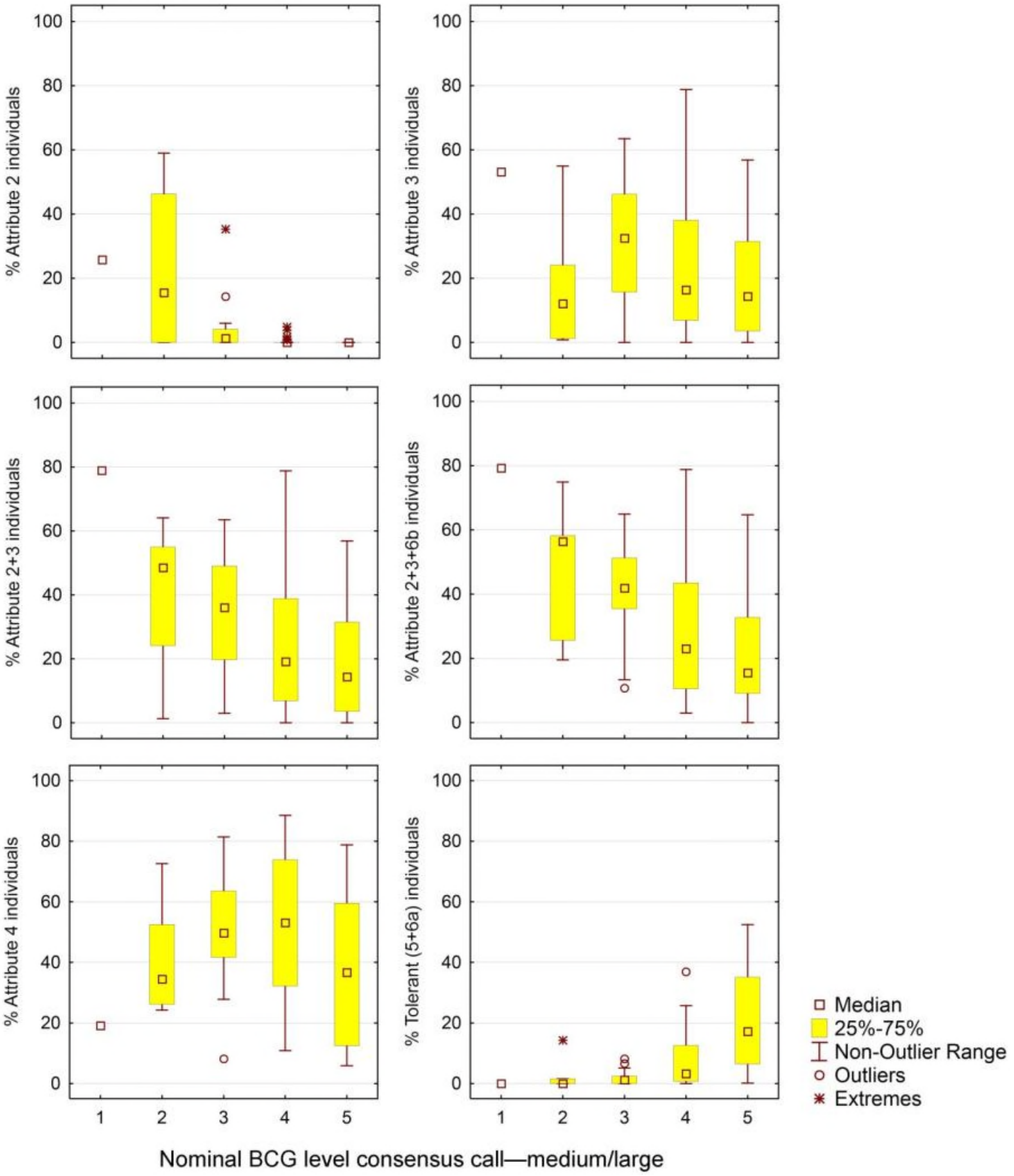


Figure 4-4. Box plots for a subset of BCG attribute percent taxa metrics for 70 medium-large samples that were assessed (this includes both calibration and validation samples), grouped by nominal BCG level (group majority choice). Sample size (which includes both calibration and validation samples) for BCG level 1 = 5, level 2 = 6, level 3 = 24, level 4 = 27, and level 5 = 12.

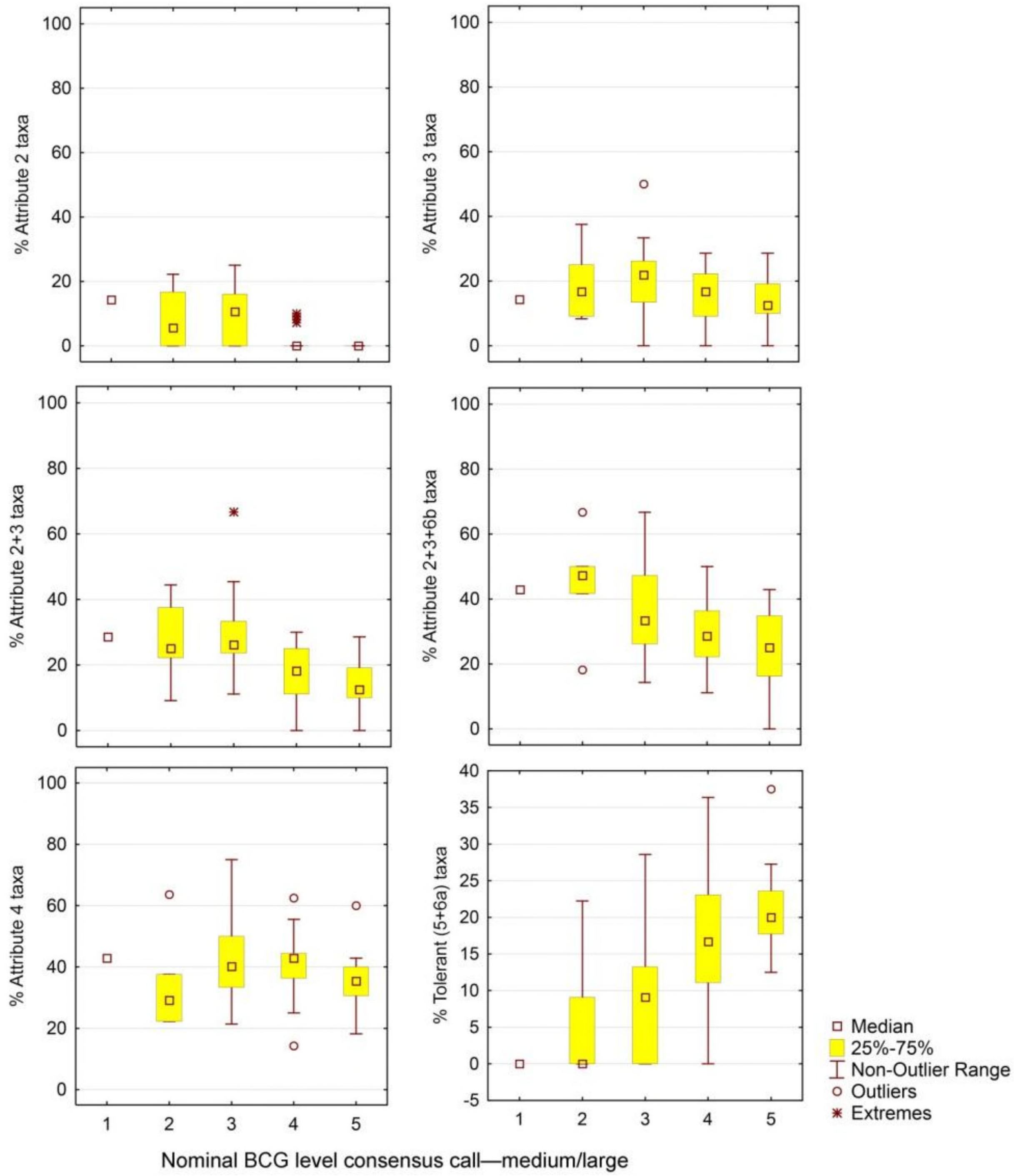


Figure 4-5. Box plots for a subset of BCG attribute percent taxa metrics for 70 medium-large samples that were assessed (this includes both calibration and validation samples), grouped by nominal BCG level (group majority choice). Sample size (which includes both calibration and validation samples) for BCG level 1 = 5, level 2 = 6, level 3 = 24, level 4 = 27, and level 5 = 12.

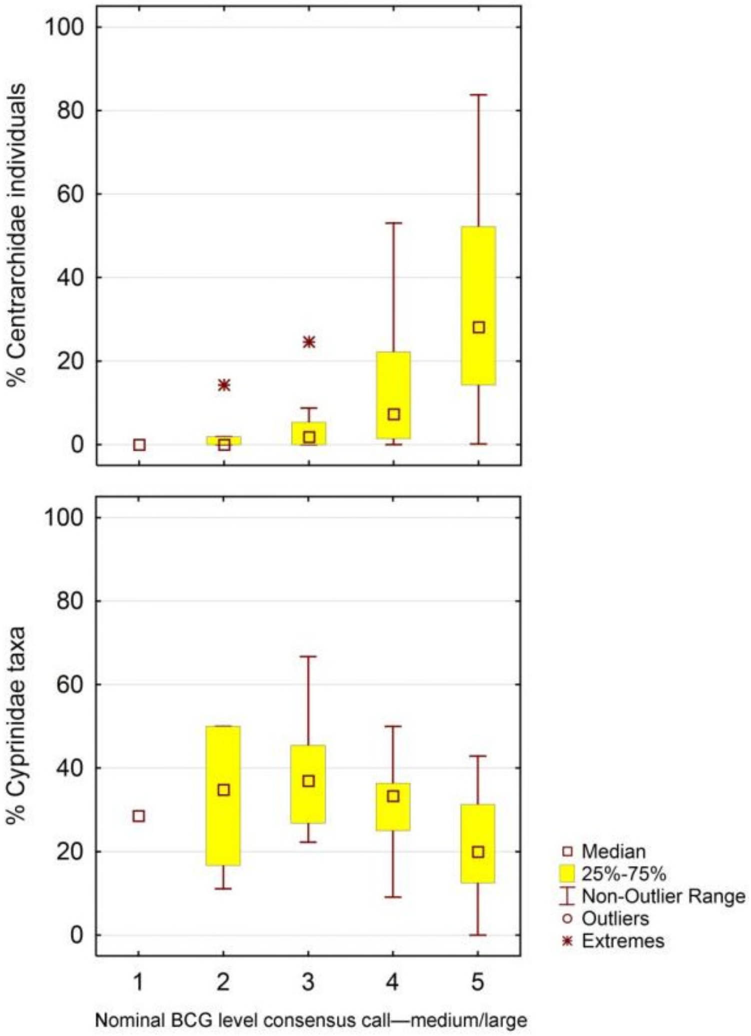


Figure 4-6. Box plots of the percent Centrarchidae individuals and percent Cyprinid taxa metrics for 70 medium-large samples that were assessed (this includes both calibration and validation samples), grouped by nominal BCG level (group majority choice). Sample size (which includes both calibration and validation samples) for BCG level 1 = 5, level 2 = 6, level 3 = 24, level 4 = 27, and level 5 = 12.

4.3 BCG Rule Development

Rules for medium-large (≥ 6 mi^2) streams, which are shown in Table 3-1, were derived from discussions with the panelists on why individual sites were assessed at a certain level. They follow the observations shown in Figures 4-2 through 4-6. The rules were calibrated with the 54 medium-large samples rated by the group, and were adjusted so that the model would replicate the panel's decisions as closely as possible. Panelist and model BCG level assignments for these 54 samples, along with site information, are summarized in Appendix I. Appendix I also contains panelist and model BCG level assignments for the 16 samples that were assessed during the validation round.

The rules for medium-large streams are shown in Table 3-1. They follow a general pattern of decreasing richness of sensitive taxa and increasing relative abundance of tolerant individuals as biological condition degrades. BCG Level 1 rules for medium-large streams require that at least 6 total taxa must be present, that at least 25% of the assemblage be comprised of sensitive (Attribute I + II + III) taxa and individuals, that less than 5% of the assemblage be comprised of tolerant (Attribute V+VIa) individuals and that non-native (Attribute VI+VIa+VIb) taxa be absent.

In BCG Level 2 samples, at least 2 total taxa must be present in streams less than 20 mi^2, and 8 or more taxa must be present in streams greater than 20 mi^2. At least 20% of a BCG level 2 sample must be comprised of sensitive (Attribute I + II + III) taxa and individuals and at least one species of salmonid must be present. The most dominant Attribute IV taxon must comprise less than 40% of the assemblage and there is an alternate rule in which percent Centrarchidae individuals must comprise less than 2% of the assemblage or percent Attribute II individuals must make up more than 5% of the assemblage.

The same total taxa richness rule holds true for BCG level 3 samples, with thresholds of 2 in smaller (<20 mi^2) streams and 8 in larger (>20 mi^2) streams. In addition, the percent sensitive (Attribute I + II + III) taxa and individuals metrics must exceed thresholds of 10 and 3%, respectively, the percent Attribute I + II + III + IV + non-native salmonid (VIb) taxa and individuals metrics must exceed 20 and 10%, respectively, the most dominant Attribute V taxon must not comprise more than 5% of the assemblage, percent Centrarchidae individuals must be less than 10% and percent Cyprinid taxa must be greater than 10%.

BCG Level 4 is characterized by decreased richness and abundance of sensitive (Attribute I + II + III) taxa. There is no rule for total taxa richness. Cyprinid taxa must be present, and percent Attribute I + II + III + IV + non-native salmonid (VIb) taxa and individuals must both exceed 40%. Percent Centrarchidae individuals must comprise less than 40% of the assemblage and non-native, non-salmonid (Attribute VI+VIa) must be less than 50%. BCG Level 5 rules require that more than 3 taxa be present, and that the percent Attribute I + II + III + IV + non-native salmonid (VIb) taxa and individuals metrics must exceed thresholds of 20 and 10%, respectively.

The rules for flagging high and low density samples (see Section 3.2) also apply to samples from medium-large streams.

4.4 Model Performance

To evaluate the performance of the 54-sample medium-large calibration dataset and the 16-sample validation dataset, we considered two matches in BCG Level choice: an exact match, where the BCG decision model's nominal level matched the panel's majority choice; and a "near match", where the model predicted a BCG level within one level of the majority expert opinion. When model performance was evaluated, the medium-large fish model matched exactly with the regional biologists' BCG level assignments on 61% of the calibration samples (Table 4-1). Eighteen of the model assignments were within one level of the majority expert opinion, one was off by two BCG levels and two were off by a half level (these were ties). Where there were differences, there wasn't a clear tendency for the model to rate samples better or worse than the panel; the model assigned 10 samples to a BCG level that was 1 level better than the panelists, 8 were assigned to a BCG level that was 1 level worse, and 1 was assigned to a BCG level that was 2 levels worse than the panelists' assignment. The results from the calibration dataset should be interpreted with caution because some of these BCG level assignments were made early in the process (e.g. at the November 2010 workshop) and may not reflect changes that have occurred in the group's thinking since that time.

In order to confirm the model, panelists made BCG level assignments on 16 additional medium-large samples. When nominal level assignments from the BCG decision model were compared to the panelists' nominal level assignments[3], the model performed better on the validation dataset than on the calibration dataset. The medium-large fish model matched exactly with the regional biologists' BCG level assignments on 75% of the confirmation samples (Table 4-1). Where there were differences, there was a tendency for the model to rate samples worse than the panel; the model assigned 1 samples to a BCG level that was 1 level better than the panelists, 2 were assigned to a BCG level that was 1 level worse (one of these samples was flagged for high density), and 1 was assigned to a BCG level that was 2 levels worse than the panelists' assignment.

As with the small-cold samples, we believe the model performance is better in the validation dataset than in the calibration dataset because the calibration dataset reflects evolution that occurred in the group's thinking during the model development process; the improved results in the validation dataset suggest that the group has converged more on this latest set of rules, and the model appears to have captured this.

It is possible that model performance in the calibration dataset could improve if the group reassesses some of the original calibration samples. In addition to potentially revising some of the consensus calls, closer examination of the anomalous samples may reveal issues that make some samples fall outside the realm of experience for the BCG model. For example, of the 4 anomalous samples in the validation dataset, two (Pease Brook, StationID 1482 and Mount Hope River, StationID 1671) were flagged for high density.

---

[3] For the medium/large validation samples, panelists first assessed samples independently but then discussed them as a group to reach a consensus call.

Table 4-1. Summary of differences between model and panelist BCG level assignments for medium-large samples.

Difference (model minus panel consensus call)	**Calibration**		**Confirmation**
	# samples	**notes**	**# samples**
1 better	10	5 of these had differences between BCG levels 4 & 5	1
0.5 better*	2		0
same	33		12
1 worse	8	1 sample was flagged for high density; 4 had differences between BCG levels 3 & 4	2 (one flagged for high density)
2 worse	1		1
Total # Samples	**54**		**16**
% Correct	**61%**		**75%**

* the model assignments were ties between BCG levels 3 & 4, and panelist scores were solid 4s; we considered this to be a difference of 0.5.

5 MMI PERFORMANCE

We examined how the panelist BCG level assignments compared to Connecticut MMI scores (Kanno et al. 2010a) for samples for which MMI scores were available. Figure 5-1 shows box plots of cold water MMI scores grouped by nominal BCG level (panelist consensus) for small-cold samples and mixed water MMI scores grouped by nominal BCG level for medium-large samples. Overall, there is good agreement between the two. In both plots, the MMI scores do not discriminate well between BCG levels 4 and 5, and for the small-cold streams, MMI does not discriminate well between BCG levels 3 and 4.

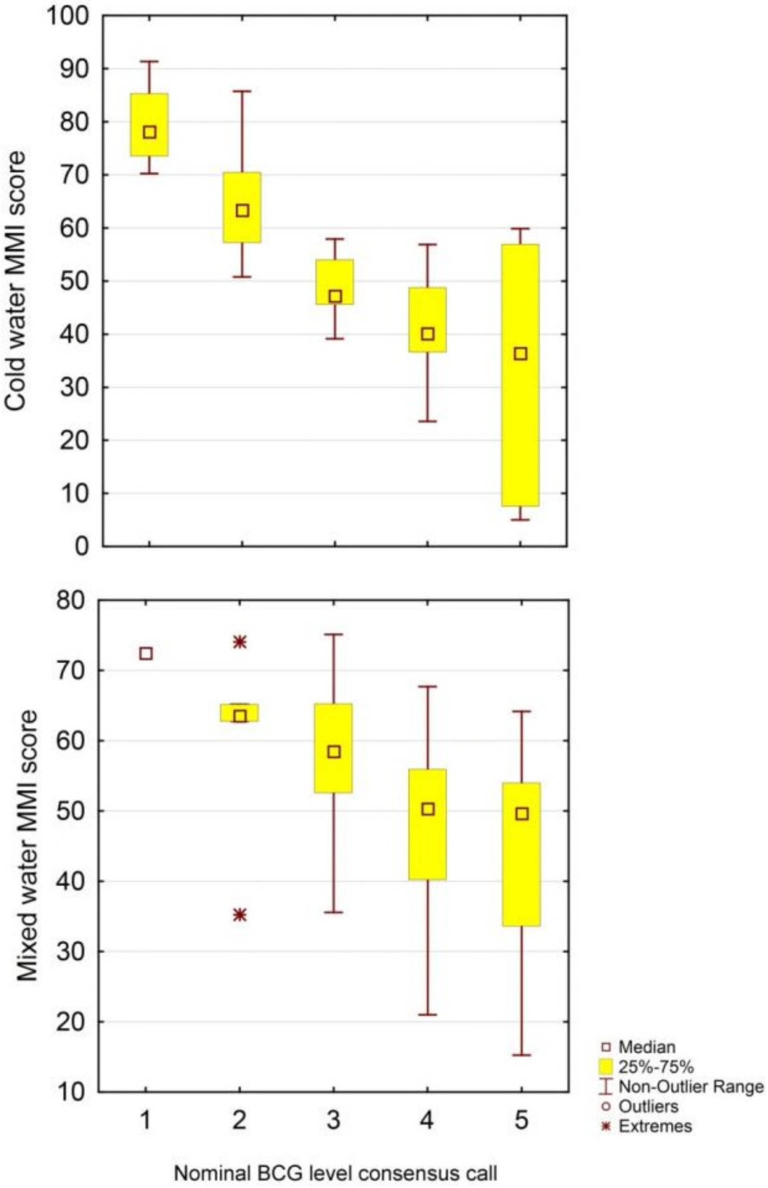


Figure 5-1. Comparison of panelist BCG level consensus assignments for small-cold samples with cold water MMI scores (top), and BCG level calls on medium-large samples with mixed water MMI scores (bottom).

6 DISCUSSION

The development of fish BCG models for small-cold and medium-large freshwater streams in Connecticut marks an important step towards the development of fish community structure metrics that will provide a more quantitative approach to WPLR's assessment process. This was a collective exercise among biologists to develop consensus on assessments of samples. We elicited the rules that the biologists used to assess the samples, and developed a set of quantitative decision criteria rules for assigning fish samples to BCG levels. The regional biologists were able to establish and quantify their differing expectations for small-cold and medium-large streams. These fish BCG models will complement Connecticut's existing macroinvertebrate assessment tools (MMI and BCG) along with the recently developed cold and mixed water fish MMIs, and could potentially serve as a starting point for a regional fish BCG model for New England (e.g., similar to the regional model that was developed for benthic macroinvertebrates (Stamp and Gerritsen 2009). The calibration exercise suggests that the BCG discriminates fair and poor levels of condition (BCG levels 4 and 5) more consistently than a fish MMI (Figure 5-1).

During this process, biologists were faced with a number of challenging questions, including:

- **What is the best classification scheme?** Samples were initially grouped into temperature subclasses (cold, transitional cool, transitional warm) based on TNC's Northeast Aquatic Habitat Classification (Olivero and Anderson 2008). During phase 2 of our work, watershed size was deemed to be a more consistent indicator of temperature class than the TNC designations, and we used 6 square miles as the threshold for separating small-cold from medium-large streams.

- **Do BCG level 1 communities exist in Connecticut streams?** There is not enough information to know what the historical undisturbed assemblage in this region looked like. The biologists felt that additional information, particularly on genetics (stocked vs. native) and age/size class, could help further refine the models (e.g., with active stocking of trout, and without reliable data on genetics and size/class, it is difficult to differentiate between a fish community in BCG level 2 versus 3).

- **How should samples with native vs. non-native trout be assessed?** Non-native trout are regarded as indicators of good water quality and coldwater habitat, but they also represent an altered fish assemblage. For purposes of this exercise, we developed the models in keeping with the traditional BCG levels. The consensus was that BCG level 1 required absence of non-native trout, and that non-native trout could not outnumber natives in BCG Level 2 (this is also consistent with cold and coolwater fish BCG models that have been developed in the Midwest (Gerritsen and Stamp 2012)). During these discussions, differences sometimes arose between those managing for recreational purposes and those managing for native assemblages. Recreational management of highly valued species such as brook, brown, and rainbow trout has a long history in Connecticut. CT DEEP Inland Fisheries Division has a trout management plan with a diverse set of management objectives and actively stocks these fish into many waters of the state (Hyatt et al. 2000). Stocking occurs for a variety of reasons including: natural reproduction is not adequate to support harvest pressure; streams are capable of supporting trout seasonally but not year round; proximity of the waterbody to population centers; to increase the size and probability of capture; and to supplement populations in streams with marginal habitat.

There were also some lessons learned and blind alleys that we went down, including:

- **Not excluding singletons and doubletons**. We explored using richness metrics in which certain species were excluded if they occurred as singletons (only 1 individual of a species occurs in a sample) or doubletons (2 individuals of a species occurs in a sample). We did this because participants were consciously (or subconsciously) screening samples to exclude what they thought were transient taxa (versus residents). After exploratory analyses and much deliberation, we decided not to use the exclusion metrics because:

  - We lacked the data necessary to draw a clear line between transient vs. resident taxa
  - If rules were being applied, it was not being done in a way that was consistent across participants.
  - The exclusion metrics did not clearly show better performance/discriminatory ability across BCG levels than the original metrics.

- **Not establishing a rule based on an abundance threshold**. We initially tried to make a rule based on total number of individuals. However, we decided against this because it was difficult to set an abundance threshold, especially since expectations were influenced by factors such as watershed size and productivity. Also, panelists did not consistently apply rules related to abundance and sometimes placed more emphasis on the presence of particular species, such as brook trout. In the end, we flagged samples with high and low numbers of individuals since they are considered to be unusual samples that are outside the realm of the BCG model. We also considered including a rule for situations in which there is a hyperabundance of blacknose dace, creek chub, cutlips minnow and/or white suckers (60% was proposed as a threshold). However, this metric did not have enough discriminatory power to include in the final models.

While we were able to accomplish a great deal through this exercise, further work could be done. We conclude by making the following recommendations:

- **Work towards developing models for additional stream types.** There are exceptions to the broad groupings (small-cold and medium-large) that we used for this exercise. Examples include naturally occurring small cool, small warm and medium-large coldwater streams. In the future, if CT DEEP is able to identify, describe and classify these ‘exceptions’ and has sufficient samples to assess them, models could be developed for these additional stream types. CT DEEP could also explore developing a warm-water model, although the scarcity of high quality warm-water streams in Connecticut would make this challenging.

- **Gather additional information on genetics (stocked vs. native) and age/size class.** The biologists felt that this type of information could help further refine the models (e.g., with active stocking of trout, and without reliable data on genetics and size/class, it is difficult to differentiate between a fish community in BCG level 2 versus 3). If resources permit, we recommend that CT DEEP start to consistently gather information on genetics (stocked vs. native) and age/size class to help inform future assessments.

7 LITERATURE CITED

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA/841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Beauchene, M., Becker, M., Belluci, C., Hagstrom, N. and Y. Kanno. 2012. Defining Water Temperature Habitat Types; Connecticut Inland Streams and Rivers – Draft. Connecticut Department of Energy and Environmental Protection.

Castella, E. and M.C.D. Speight. 1996. Knowledge representation using fuzzy coded variables: an example based on the use of Syrphidae (Insecta, Diptera) in the assessment of riverine wetlands. Ecological Modelling 85:13-25.

Connecticut DEP. 2005. Connecticut Comprehensive Ambient Water Quality Monitoring Strategy. Connecticut Department of Environmental Protection, Bureau of Water Management, Hartford, CT.

Connecticut DEEP. 2013. Standard Operating Procedures For the Collection of Fish Community Data From Wadeable Streams For Aquatic Life Assessment. Connecticut Department of Energy and Environmental Protection, Bureau of Water Protection and Land Resuse, Hartford, CT.

Davies, S.B., and S. K. Jackson. 2006. The Biological Condition Gradient: A descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16(4):1251–1266.

Demicco, R.V. 2004. Fuzzy Logic and Earth Science: An Overview. In Fuzzy Logic in Geology, R.V. Demicco and G.J. Klir (eds.), pp. 11-61. Elsevier Academic Press, San Diego, CA.

Demicco, R.V. and G.J. Klir. 2004. Introduction. In Fuzzy Logic in Geology, R.V. Demicco and G.J. Klir (eds.), pp. 1-10. Elsevier Academic Press, San Diego, CA.

Droesen, W.J. 1996. Formalisation of ecohydrological expert knowledge applying fuzzy techniques. Ecological Modelling 85:75-81.

Gerritsen, J. and B. Jessup. 2007. Calibration of the Biological Condition Gradient for High Gradient Streams of Connecticut. Prepared for the U.S. EPA Office of Science and Technology and Connecticut Department of Environmental Protection. Prepared by Tetra Tech, Inc., Owings Mills, MD. 86 pp.

Gerritsen, J. and J. Stamp. 2012. Calibration of the Biological Condition Gradient (BCG) in Cold and Cool Waters of the Upper Midwest: Fish and Benthic Macroinvertebrate Assemblages. Prepared for U.S. EPA Office of Science and Technology and U.S. EPA Region 5; prepared by Tetra Tech, Inc. 400 Red Brook Blvd., Suite 200, Owings Mills, MD 21117.

Halliwell, D.B., Langdon, R.W., Daniels, R.A., Kurtenbach, J.P. and R.A. Jacobson. 1999. Classification of freshwater fish species of the Northeastern United States for use in the development of indices of biological integrity, with regional applications .In Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, LLC. Pp. 301-337.

Hyatt, W., M. Humphreys, and N. T. Hagstrom, 2000. A Trout Management Plan for Connecticut Rivers and Streams. Conn. D.E.P. Bureau of Natural Resources, Inland Fisheries Division, Hartford, CT. 50p.

Ibelings, B.W., M Vonk, H.F.J. Los, D.T. Van Der Molen, and W.M. Mooij. 2003. Fuzzy modeling of Cyanobacterial surface waterblooms: validation with NOAA-AVHRR satellite images. Ecological Applications 13:1456-1472.

Kanno, Y., Vokoun, J.C. and M. Beauchene. 2010a. Development of dual fish multi-metric indices of biological condition for streams with characteristic thermal gradients and low species richness. Ecological Indicators 10(3): 565-571.

Kanno, Y., and J.C. Vokoun. 2010b. Evaluating effects of water withdrawals and impoundments on fish assemblages in southern New England streams, USA. Fisheries Management and Ecology 17: 272–283.

Kanno, Y., and J.C. Vokoun. 2008. Biogeography of Stream Fishes in Connecticut: Defining Faunal Regions and Assemblage Types. Northeastern Naturalist 15(4):557–576.

Karr, J.R. and E.W. Chu. 1999. Restoring Life. In Running Waters: Better Biological Monitoring. Island Press, Washington, DC.

Klir, G.J. 2004. Fuzzy Logic: A Specialized Tutorial. In Fuzzy Logic in Geology, R.V. Demicco and G.J. Klir (eds.), pp. 11-61. Elsevier Academic Press, San Diego, CA.

Lyons, J., Zorn, T., Stewart, J., Seelbach, P., Wehrly, K. and L. Wang. 2009. Defining and Characterizing Coolwater Streams and Their Fish Assemblages in Michigan and Wisconsin, USA. North American Journal of Fisheries Management 29:1130–1151

Olivero, A.P. and Anderson, M.G. 2008. Northeast Aquatic Habitat Classification. The Nature Conservancy in Collaboration with the Northeast Association of Fish and Wildlife Agencies. 86 pp.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers 77(1):118-125.

Omernik, J.M. 1995. Ecoregions: A spatial framework for environmental management. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and T.P. Simon (eds.), Lewis Publishers, Boca Raton, FL. p. 49-62.

Simpson, J.C and R.H. Norris. 2000. Biological assessment of river quality: development of AusRivAS models and outputs. In Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques. J.F. Wright, D.W. Sutcliffe and M.T. Furse (eds.), pp. 125-142. Freshwater Biological Association, Ambleside, UK.

Stamp, J. and J. Gerritsen 2009. Methods and Assessment Comparability Among State and Federal Biological Monitoring Protocols. Prepared for New England Interstate Water Pollution Control Commission (NEIWPCC), Boott Mills South, 100 Foot of John Street, Lowell, MA 01852.

U.S. EPA. 2005. Use of biological information to tier designated aquatic life uses in state and tribal water quality standards. EPA-822-R-05-001.

U.S. EPA. 2007. The New England Wadeable Stream Survey (NEWS): Development of Common Assessments in the Framework of the Biological Condition Gradient. Prepared for the US EPA Office of Science and Technology and the US EPA Office of Watersheds.

Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J.R., and Cushing,C. E. 1980. The River Continuum Concept.Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

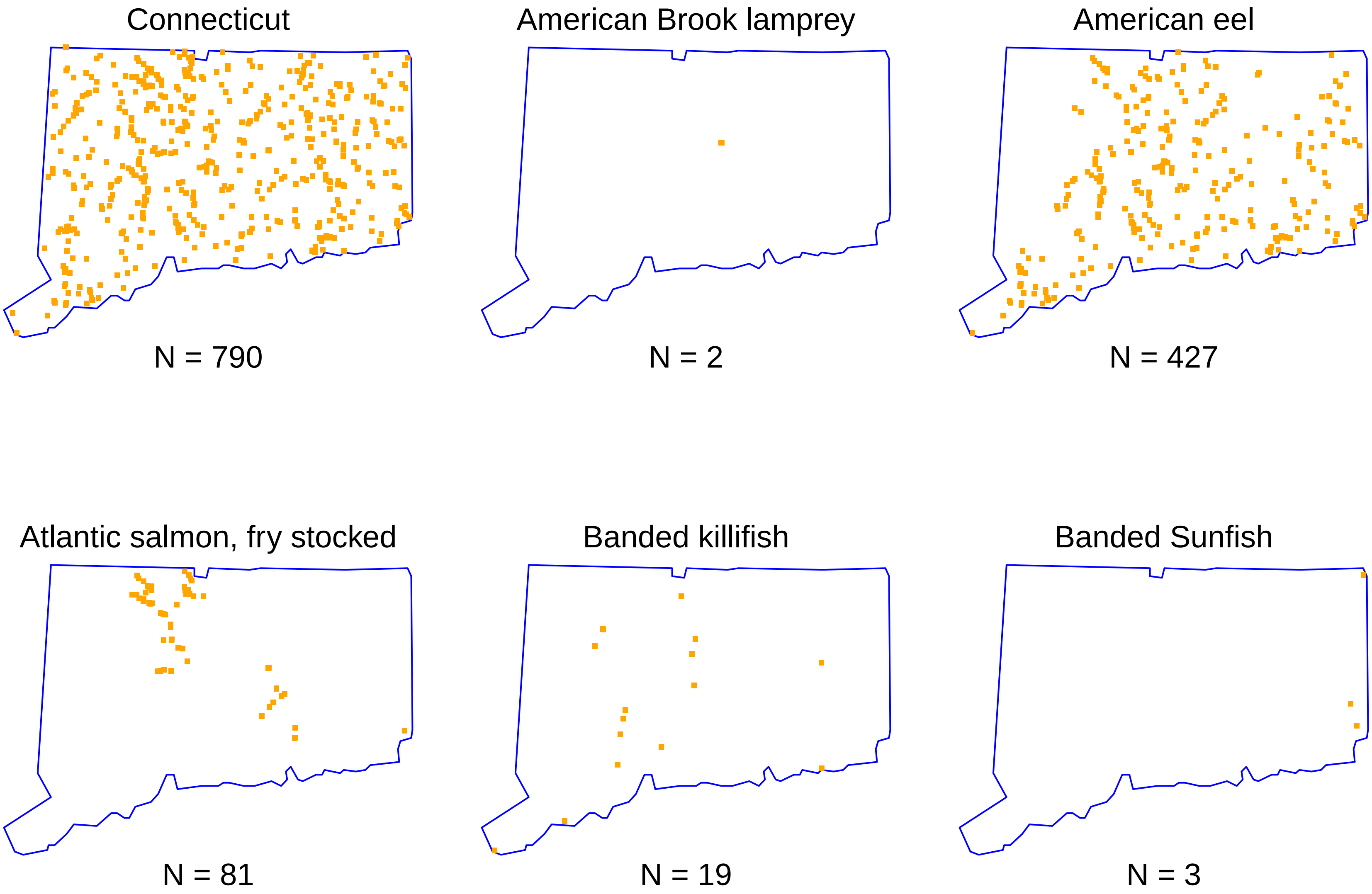
Vermont DEC. 2004. Wadeable Stream Biocriteria Development and Implementation Methods for Fish and Macroinvertebrate Assemblages in Vermont Wadeable Streams and Rivers. Water Quality Division, Biomonitoring and Aquatic Studies Section. 83 pp.

Whittier, T.R., Hughes, R.M., Stoddard, J.L., Lomnicky, G.A., Peck, D.V., Herlihy, A.T., 2007. A structured approach for developing indices of biotic integrity: three examples from streams and rivers in the western USA. Trans. Am. Fish. Soc. 136, 718–735.

Wright, J.F. 2000. An introduction to RIVPACS. In Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques. J.F. Wright, D.W. Sutcliffe and M.T. Furse (eds.), pp. 1-24. Freshwater Biological Association, Ambleside, UK.

APPENDIX A

Distribution maps



Connecticut

American Brook lamprey

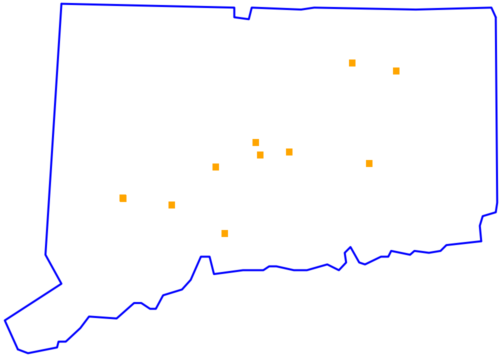
American eel

Atlantic salmon, fry stocked

Banded killifish

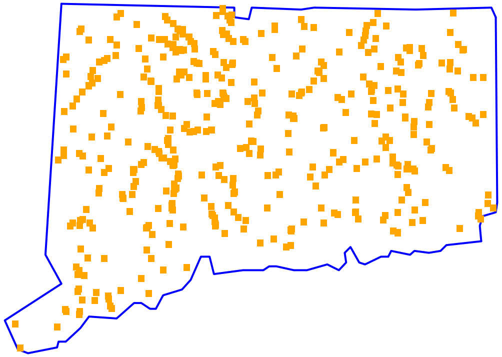
Banded Sunfish

Black Crappie



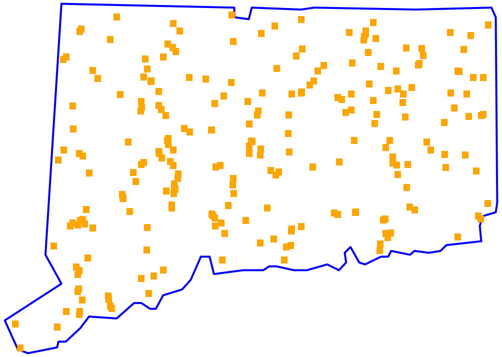
N = 12

Blacknose dace



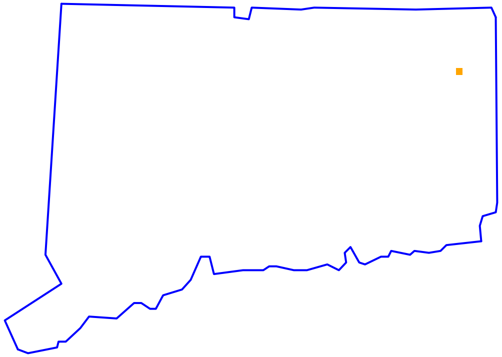
N = 648

Bluegill sunfish



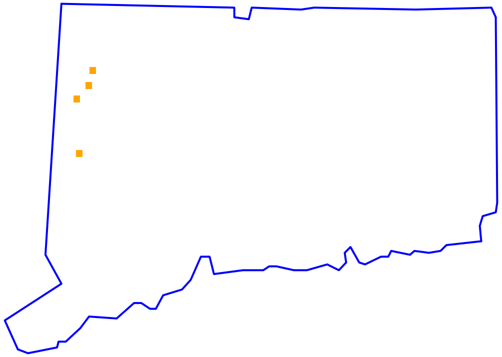
N = 320

Bluegill X Pumpkinseed



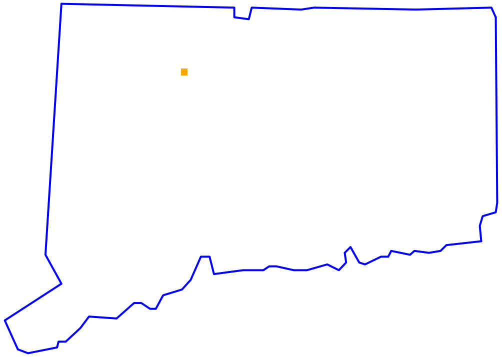
N = 1

Bluntnose minnow

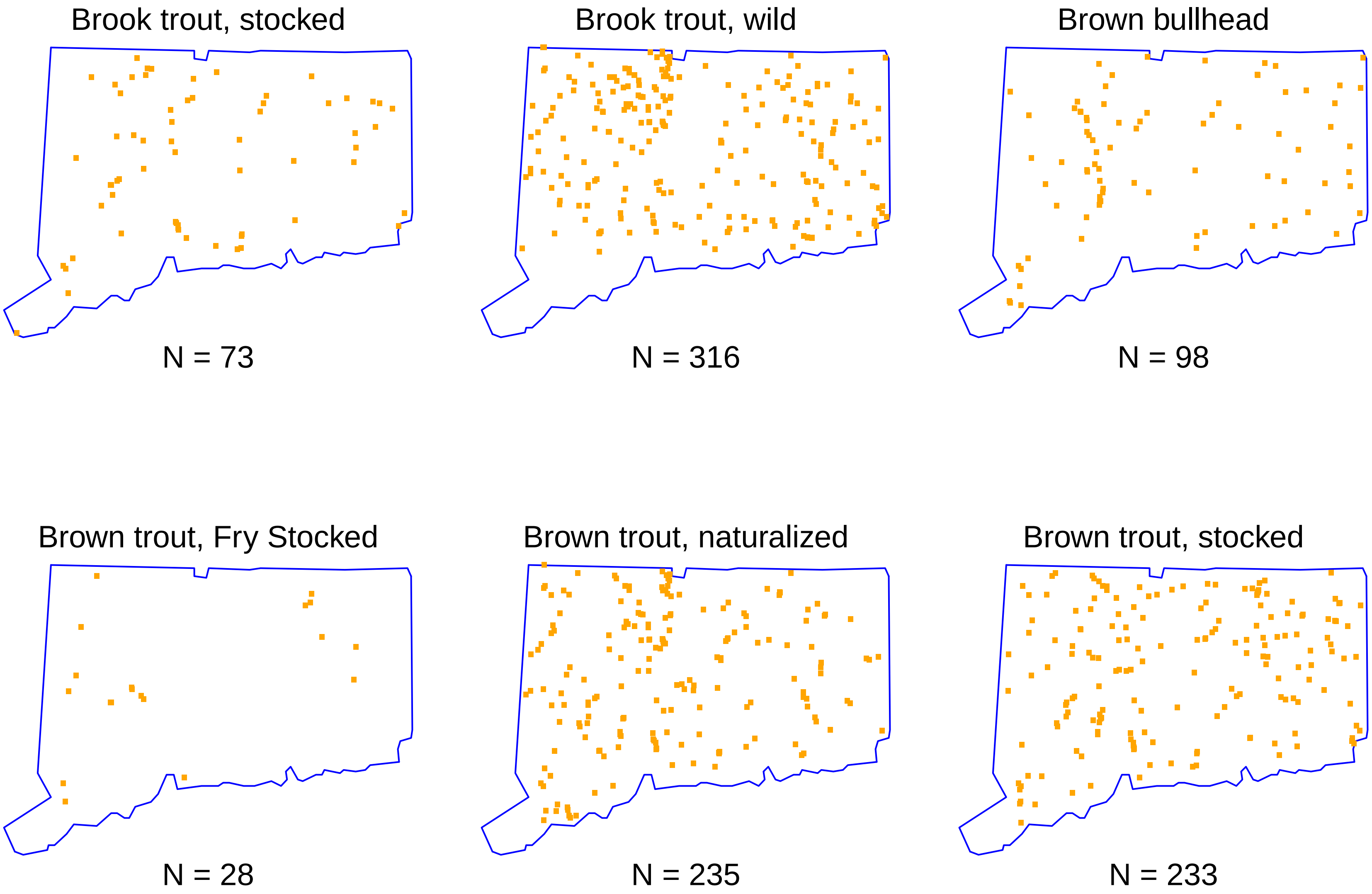


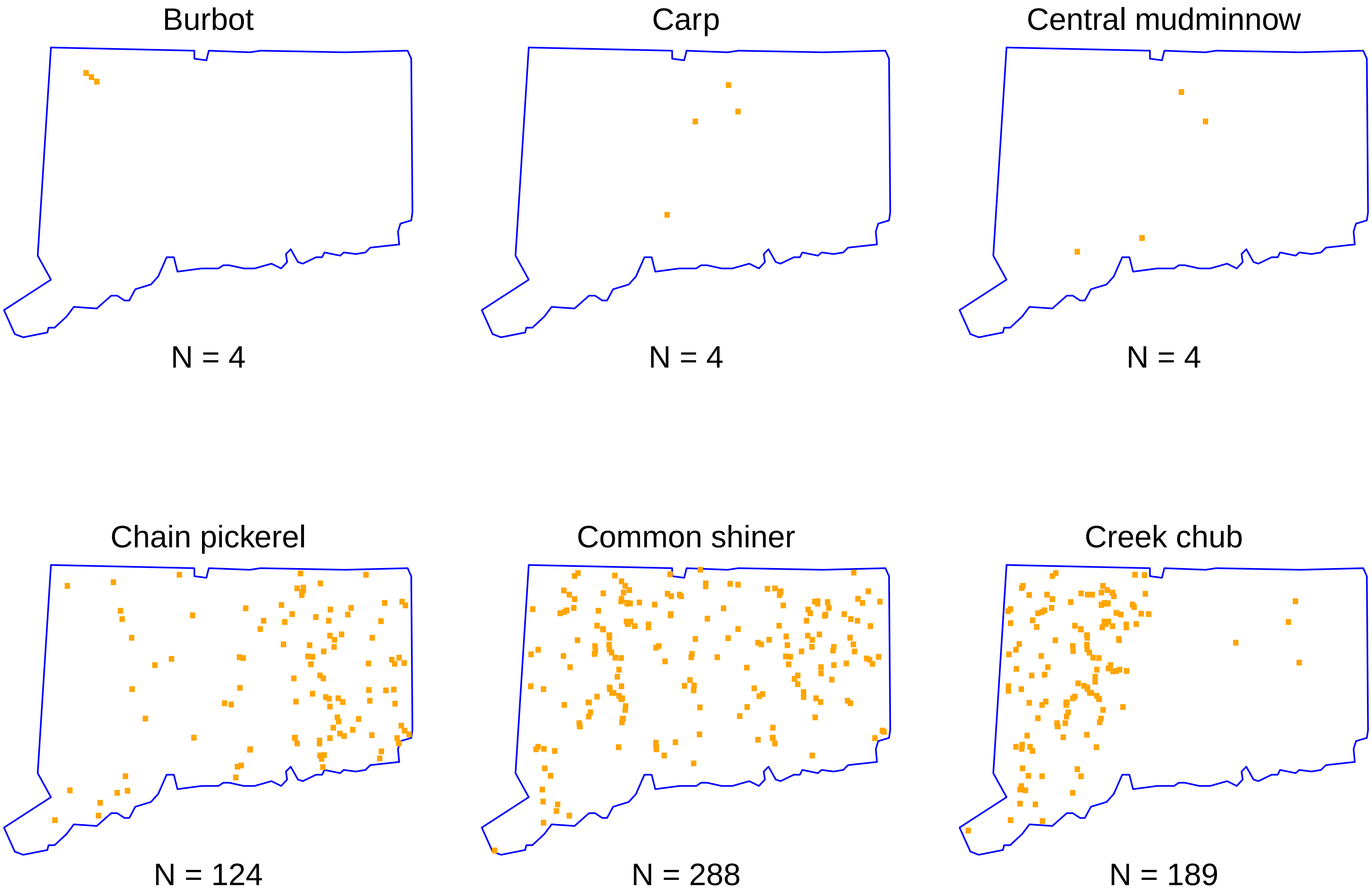
N = 4

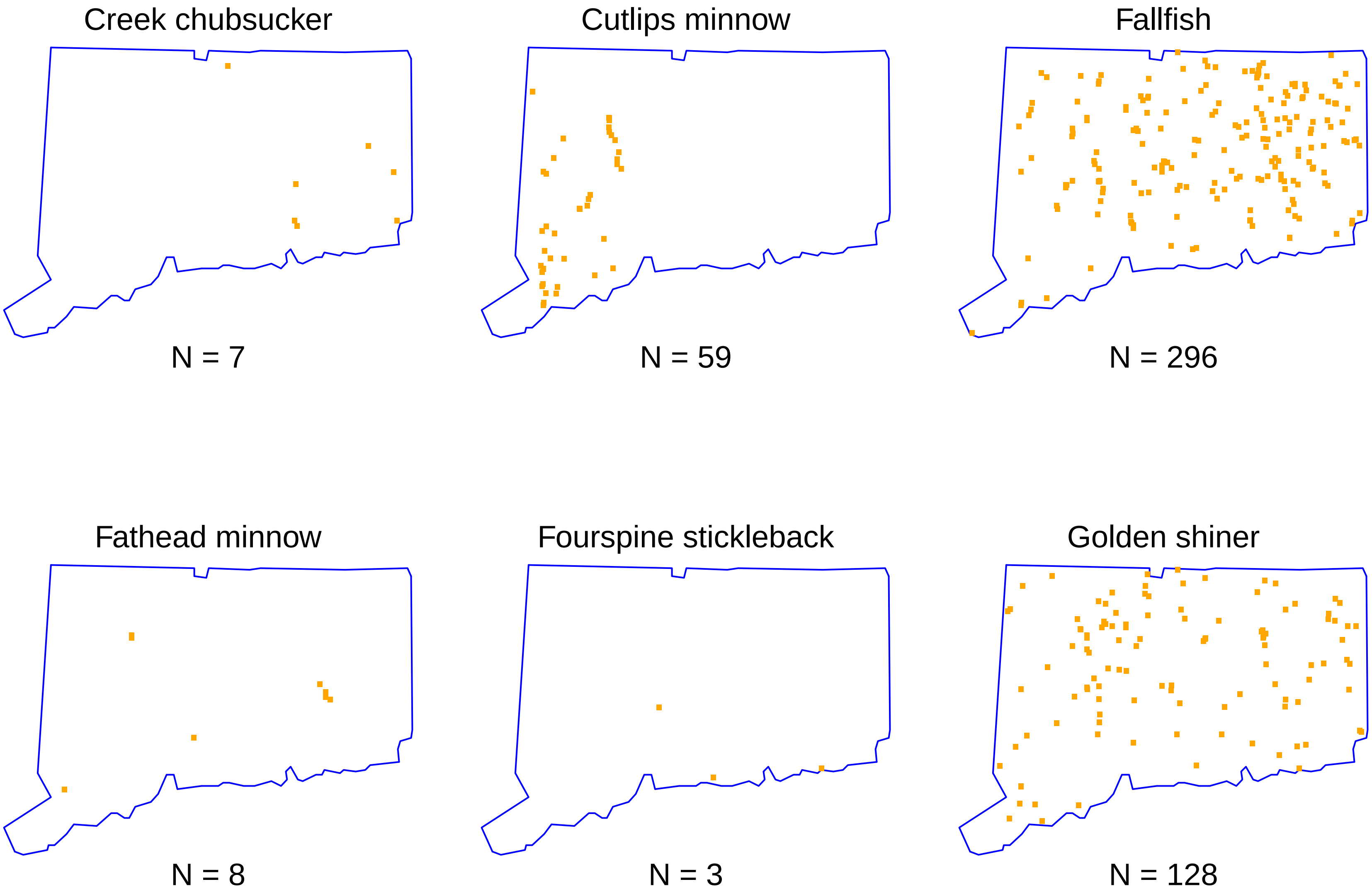
Bridled shiner

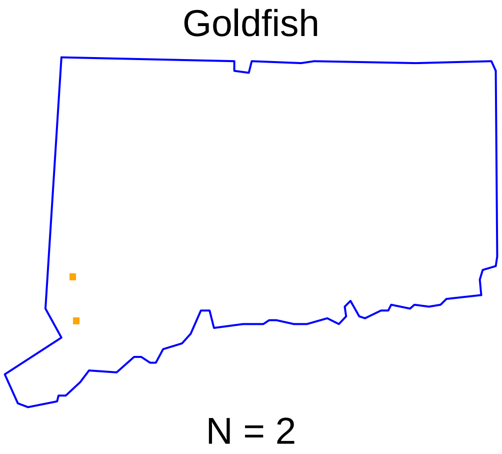


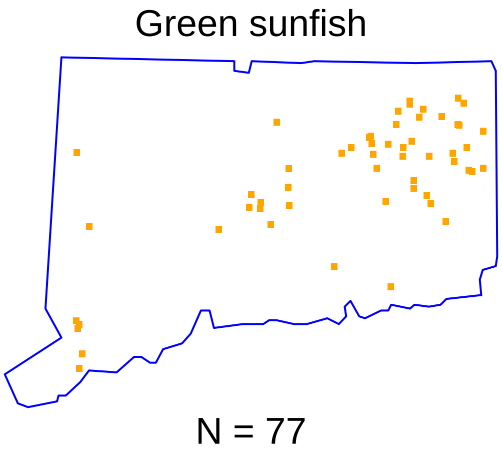
N = 1

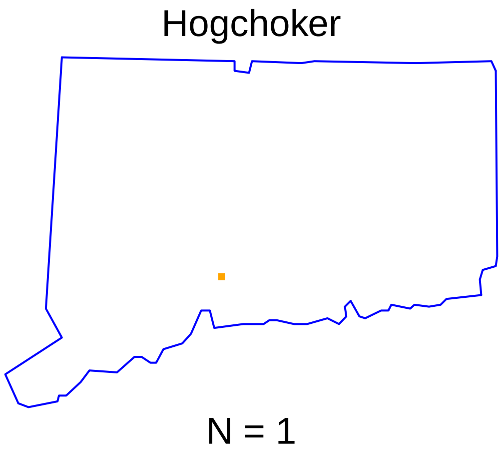

Brook trout, stocked
N = 73
Brook trout, wild
N = 316
Brown bullhead
N = 98
Brown trout, Fry Stocked
N = 28
Brown trout, naturalized
N = 235
Brown trout, stocked
N = 233

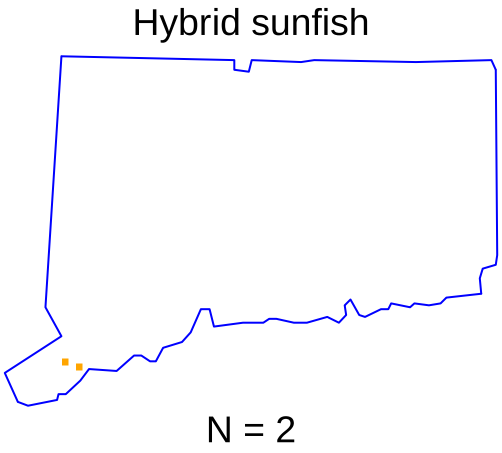

Burbot
N = 4
Carp
N = 4
Central mudminnow
N = 4
Chain pickerel
N = 124
Common shiner
N = 288
Creek chub
N = 189

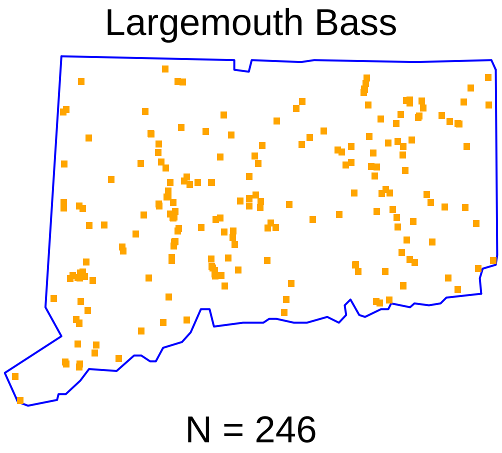

Creek chubsucker
N = 7
Cutlips minnow
N = 59
Fallfish
N = 296
Fathead minnow
N = 8
Fourspine stickleback
N = 3
Golden shiner
N = 128

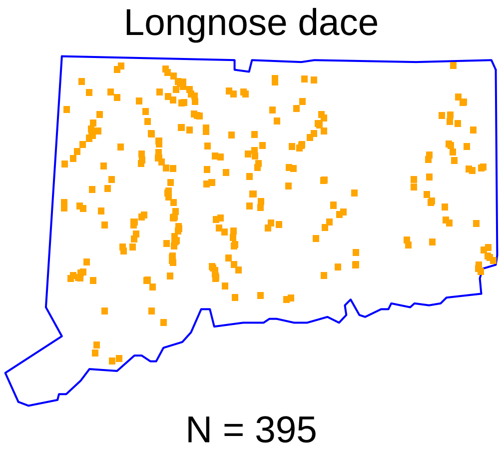

Goldfish
N = 2


Green sunfish
N = 77

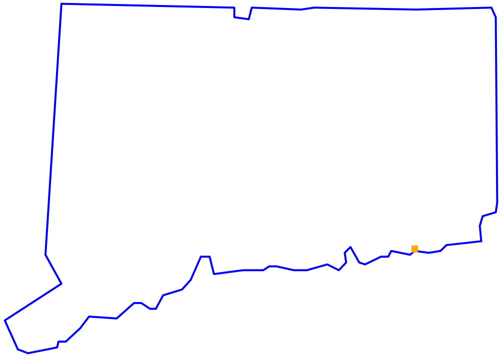

Hogchoker
N = 1


Hybrid sunfish
N = 2


Largemouth Bass
N = 246

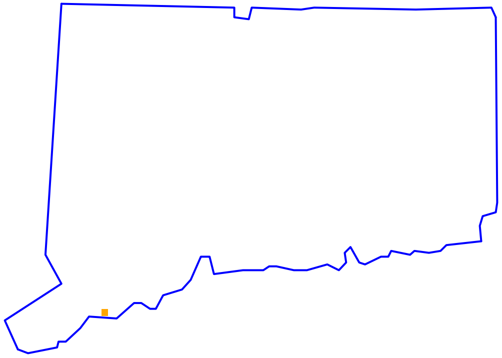

Longnose dace
N = 395

Mummichog



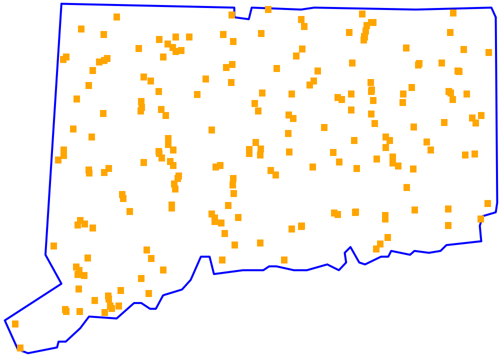
N = 2

Ninespine stickleback



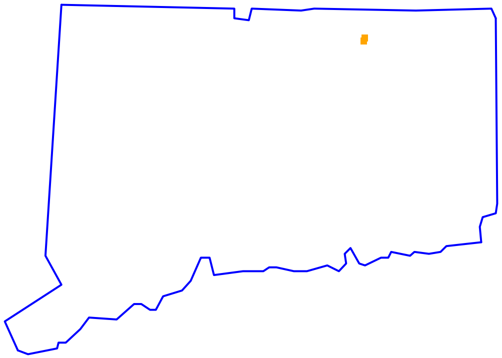
N = 1

Pumpkinseed



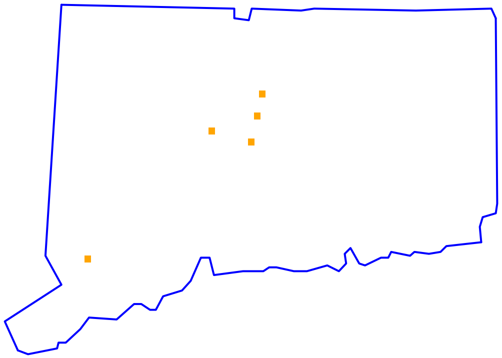
N = 266

Pumpkinseed Hybrid



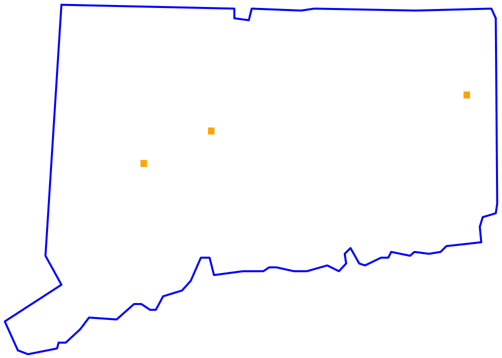
N = 2

Pumpkinseed X Red breast



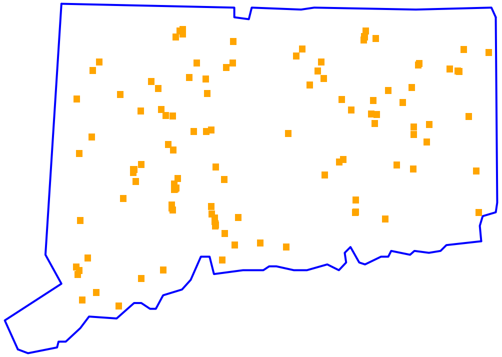
N = 5

Rainbow trout, feral



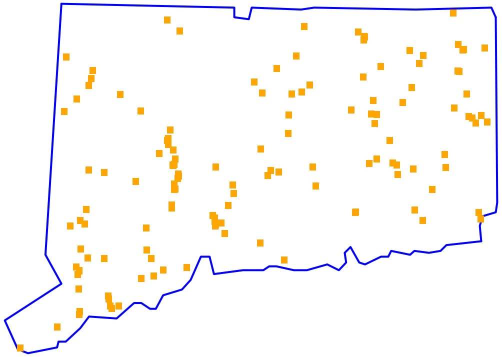
N = 3

Rainbow trout, Stocked



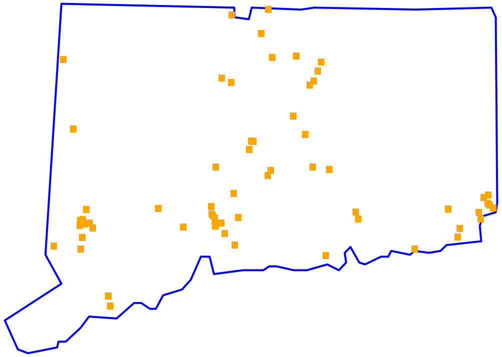
N = 136

Redbreast sunfish



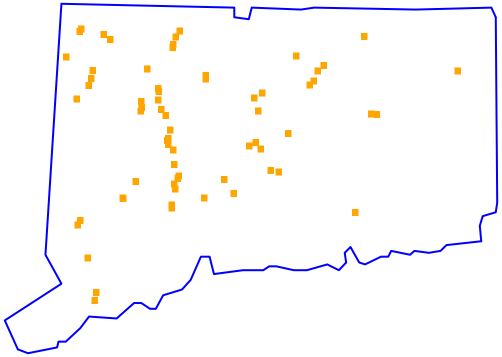
N = 210

Redfin pickerel



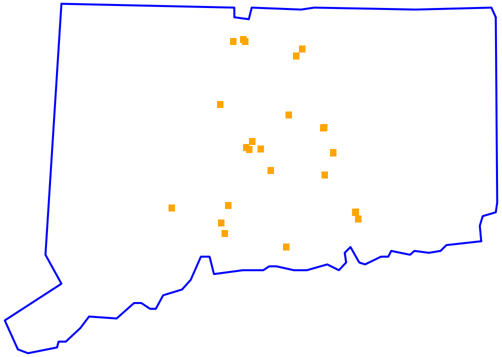
N = 75

Rock Bass



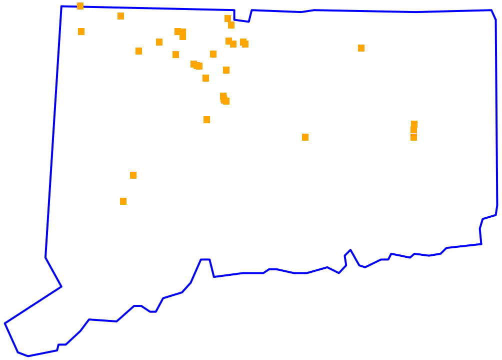
N = 98

Sea lamprey

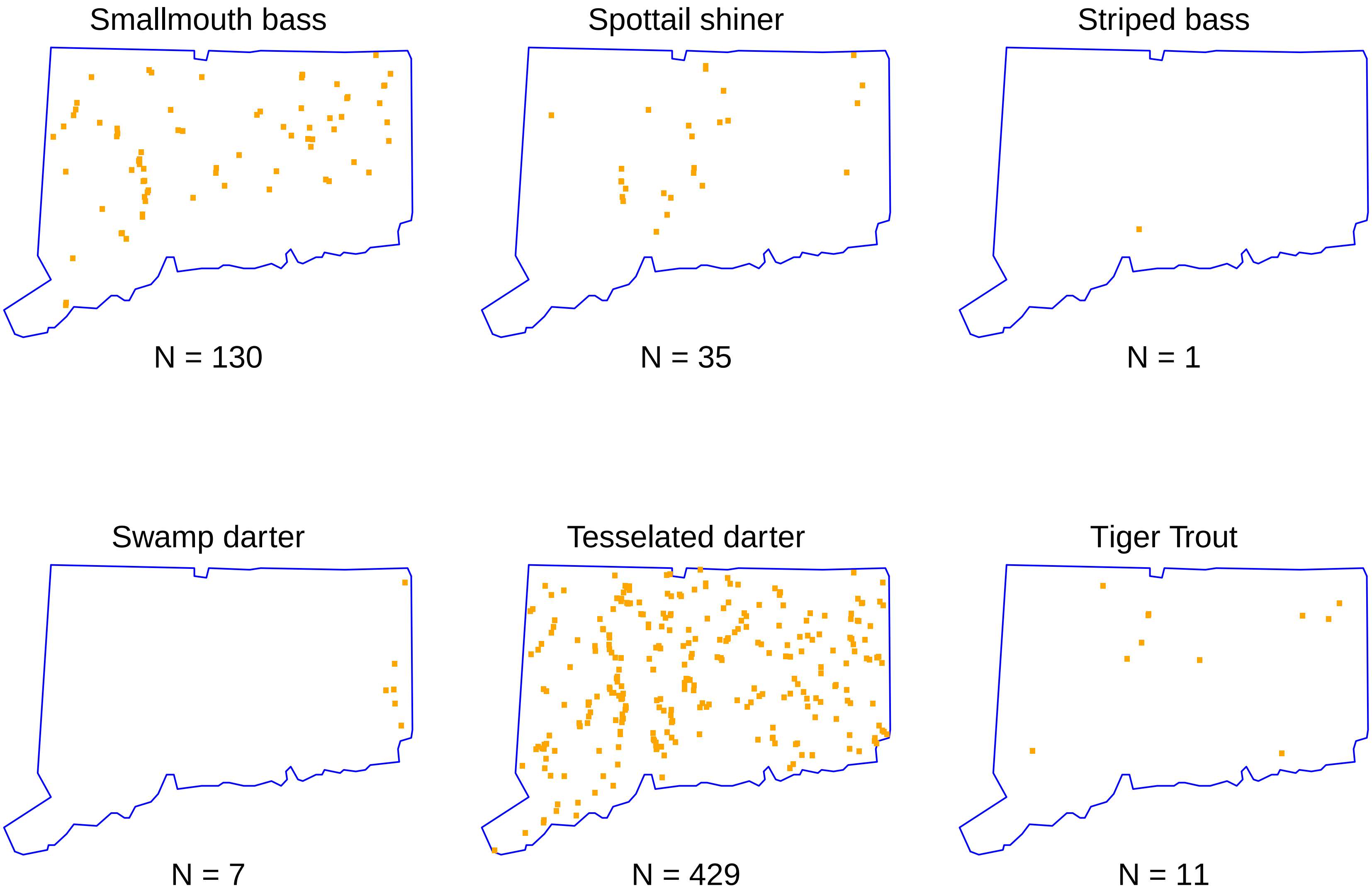


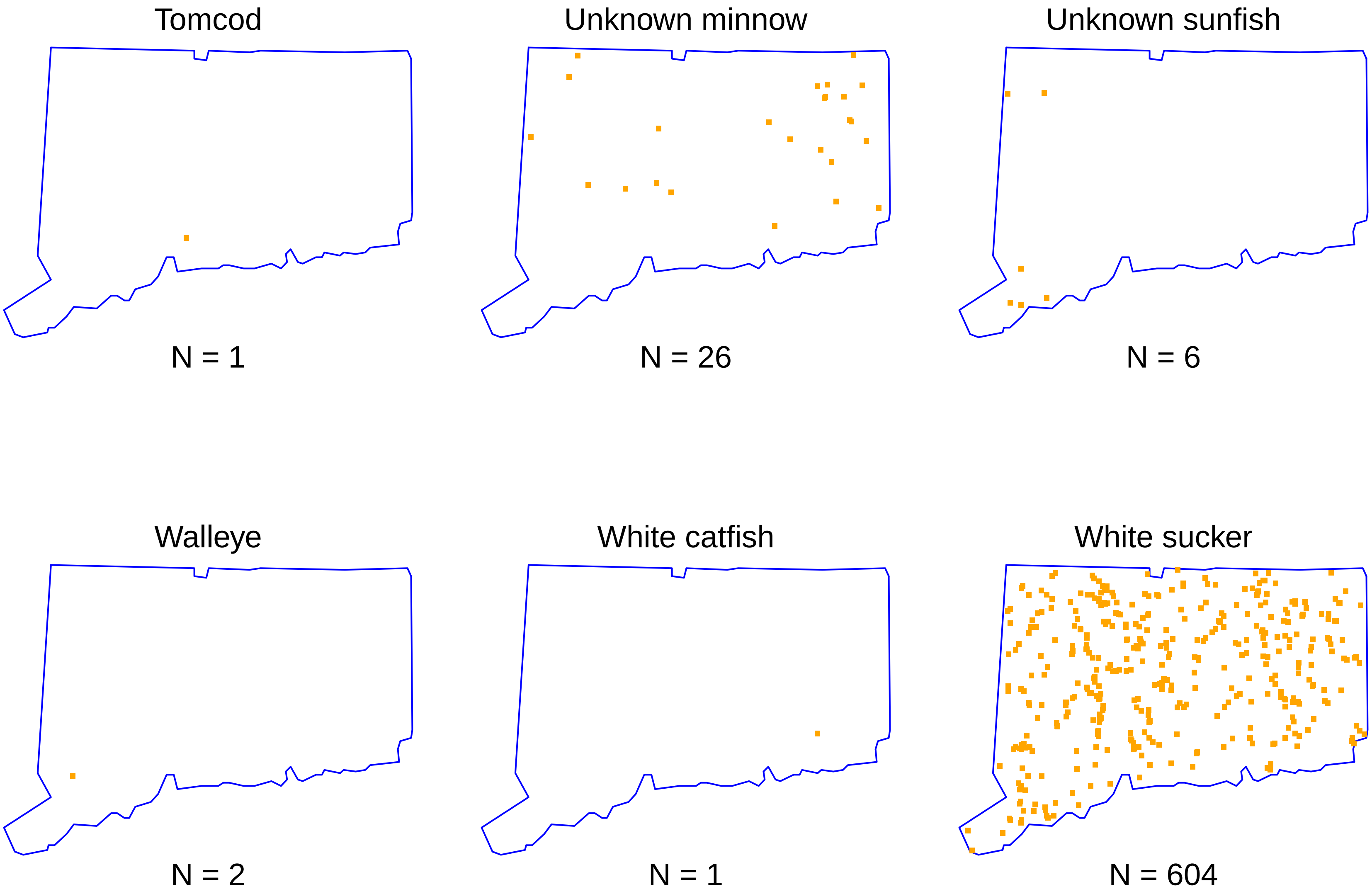
N = 29

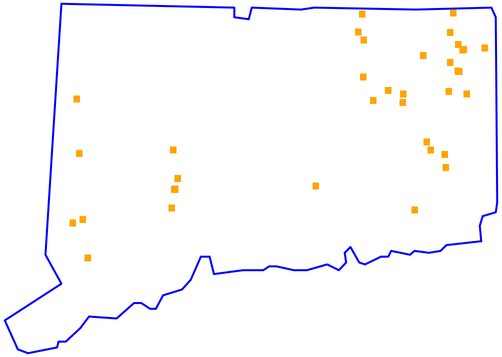
Slimy sculpin



N = 51

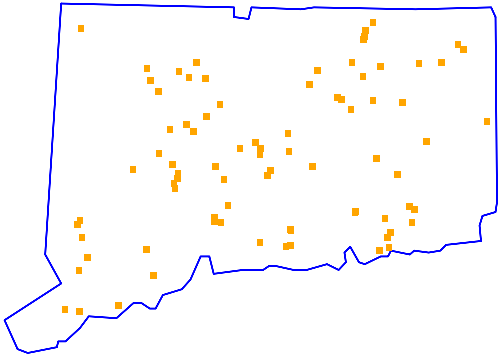

Smallmouth bass
N = 130
Spottail shiner
N = 35
Striped bass
N = 1
Swamp darter
N = 7
Tesselated darter
N = 429
Tiger Trout
N = 11


Tomcod
N = 1
Unknown minnow
N = 26
Unknown sunfish
N = 6
Walleye
N = 2
White catfish
N = 1
White sucker
N = 604



Yellow bullhead

N = 51



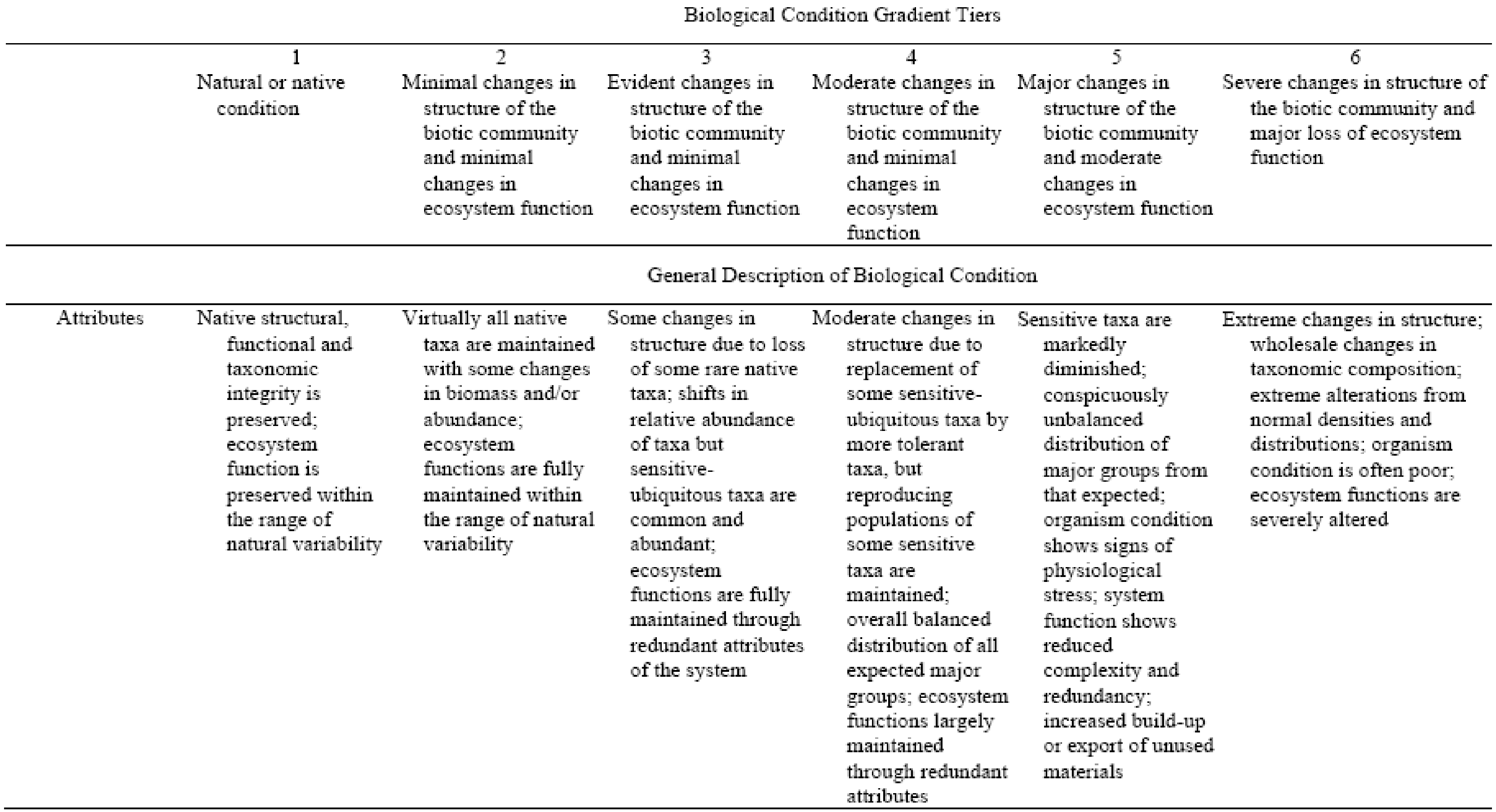
Yellow perch

N = 100

APPENDIX B

Additional BCG Background Information

Table B1. Narrative descriptions of the 10 attributes that distinguish the six tiers of the Biological Condition Gradient (Davies and Jackson 2006).



	Biological Condition Gradient Tiers					
	1 Natural or native condition	2 Minimal changes in structure of the biotic community and minimal changes in ecosystem function	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function	5 Major changes in structure of the biotic community and moderate changes in ecosystem function	6 Severe changes in structure of the biotic community and major loss of ecosystem function
	General Description of Biological Condition					
Attributes	Native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability	Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability	Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but sensitive-ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system	Moderate changes in structure due to replacement of some sensitive-ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes	Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials	Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered

Table B1. Continued…

	1 Natural or native condition	2 Minimal changes in structure of the biotic community and minimal changes in ecosystem function	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function	5 Major changes in structure of the biotic community and moderate changes in ecosystem function	6 Severe changes in structure of the biotic community and major loss of ecosystem function
I Historically documented, sensitive, long-lived or regionally endemic taxa	As predicted for natural occurrence except for global extinctions	As predicted for natural occurrence except for global extinctions	Some may be absent due to global extinction or local extirpation	Some may be absent due to global, regional or local extirpation	Usually absent	Absent
II Sensitive-rare taxa	As predicted for natural occurrence, with at most minor changes from natural densities	Virtually all are maintained with some changes in densities	Some loss, with replacement by functionally equivalent sensitive-ubiquitous taxa	May be markedly diminished	Absent	Absent
III Sensitive-ubiquitous taxa	As predicted for natural occurrence, with at most minor changes from natural densities	Present and may be increasingly abundant	Common and abundant; relative abundance greater than sensitive-rare taxa	Present with reproducing populations maintained; some replacement by functionally equivalent taxa of intermediate tolerance	Frequently absent or markedly diminished	Absent

Table B1. Continued…

	1 Natural or native condition	2 Minimal changes in structure of the biotic community and minimal changes in ecosystem function	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function	5 Major changes in structure of the biotic community and moderate changes in ecosystem function	6 Severe changes in structure of the biotic community and major loss of ecosystem function
IV Taxa of intermediate tolerance	As predicted for natural occurrence, with at most minor changes from natural densities	As naturally present with slight increases in abundance	Often evident increases in abundance	Common and often abundant; relative abundance may be greater than sensitive-ubiquitous taxa	Often exhibit excessive dominance	May occur in extremely high or extremely low densities; richness of all taxa is low
V Tolerant taxa	As predicted for natural occurrence, at most minor changes from natural densities	As naturally present with slight increases in abundance	May be increases in abundance of functionally diverse tolerant taxa	May be common but do not exhibit significant dominance	Often occur in high densities and may be dominant	Usually comprise the majority of the assemblage; often extreme departures from normal densities (high or low)
VI Non-native or intentionally introduced taxa	Non-native taxa, if present, do not displace native taxa or alter native structural or functional integrity	Non-native taxa may be present, but occurrence has a non-detrimental effect on native taxa	Sensitive or intentionally introduced non-native taxa may dominate some assemblages (e.g., fish or macrophytes)	Some replacement of sensitive non-native taxa with functionally diverse assemblage of non-native taxa of intermediate tolerance	Some assemblages (e.g., fish or macrophytes) are dominated by tolerant non-native taxa	Often dominant; may be the only representative of some assemblages (e.g., plants, fish, bivalves)

Table B1. Continued…

	1 Natural or native condition	2 Minimal changes in structure of the biotic community and minimal changes in ecosystem function	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function	5 Major changes in structure of the biotic community and moderate changes in ecosystem function	6 Severe changes in structure of the biotic community and major loss of ecosystem function
VII Organism condition (especially of long-lived organisms)	Any anomalies are consistent with naturally occurring incidence and characteristics	Any anomalies are consistent with naturally occurring incidence and characteristics	Anomalies are infrequent	Incidence of anomalies may be slightly higher than expected	Biomass may be reduced; anomalies increasingly common	Long-lived taxa may be absent; biomass reduced; anomalies common and serious; minimal reproduction except for extremely tolerant groups
VIII Ecosystem functions	All are maintained within the range of natural variability	All are maintained within the range of natural variability	Virtually all are maintained through functionally redundant system attributes; minimal increase in export except at high storm flows	Virtually all are maintained through functionally redundant system attributes though there is evidence of loss of efficiency (e.g., increased export or decreased import)	Apparent loss of some ecosystem functions manifested as increased export or decreased import of some resources, and changes in energy exchange rates (e.g., P/R, decomposition)	Most functions show extensive and persistent disruption
IX Spatial and temporal extent of detrimental effects	N/A A natural disturbance regime is maintained	Limited to small pockets and short duration	Limited to the reach scale and/or limited to within a season	Mild detrimental effects may be detectable beyond the reach scale and may include more than one season	Detrimental effects extend far beyond the reach scale leaving only a few islands of adequate conditions; effect extends across multiple seasons	Detrimental effects may eliminate all refugia and colonization sources within the catchment and affect multiple seasons

Table B1. Continued…

	1 Natural or native condition	2 Minimal changes in structure of the biotic community and minimal changes in ecosystem function	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function	5 Major changes in structure of the biotic community and moderate changes in ecosystem function	6 Severe changes in structure of the biotic community and major loss of ecosystem function
X Ecosystem connectance	System is highly connected in space and time, at least annually	Ecosystem connectance is unimpaired	Slight loss of connectance but there are adequate local recolonization sources	Some loss of connectance but colonization sources and refugia exist within the catchment	Significant loss of ecosystem connectance is evident; recolonization sources do not exist for some taxa	Complete loss of ecosystem connectance in at least one dimension (i.e., longitudinal, lateral, vertical, or temporal) lowers reproductive success of most groups; frequent failures in reproduction and recruitment

Table B2. Ecological attributes used to develop the BCG.

Attribute	**Description**
I	Historically documented, sensitive, long-lived or regionally endemic taxa *"Historically documented" refers to taxa known to have been supported in a waterbody or region prior to enactment of the 1972 Clean Water Act, according to historical records compiled by State or federal agencies or published scientific literature.*
II	Highly Sensitive Taxa (note: this was identified as "Sensitive-Rare taxa" in Davies and Jackson 2006) *These are taxa that naturally occur in low numbers relative to total population density but may make up a large relative proportion of richness. In high quality sites, they may be ubiquitous in occurrence or may be restricted to certain micro-habitats. Many of these species commonly occur at low densities, thus their 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). They may have specialized food resource needs or feeding strategies, and are generally intolerant to significant alteration of the physical or chemical environment. They are often the first taxa observed to be lost from a community following moderate disturbance or pollution (Figure 3-1).*
III	Intermediate Sensitive Taxa (or Sensitive and Common Taxa) *These taxa are ordinarily common and abundant in natural communities when conventional sampling methods are used (Figure 3-1). They often have a broader range of tolerances than highly sensitive taxa, and usually occur in reduced abundance and reduced frequencies at disturbed or polluted sites. These are taxa that comprise a substantial portion of natural communities, and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.*
IV	Taxa of Intermediate Tolerance *Taxa that comprise a substantial portion of natural communities; may be r-strategists (early colonizers with rapid turn-over times; e.g.," boom/bust population characteristics or they may be eurythermal (having a broad thermal tolerance range). Many have generalist or facultative feeding strategies enabling utilization of diverse food types. They are readily collected with conventional sample methods. These species have little or no detectable response to a stress gradient (Figure 3-1), and are often equally abundant in both reference and stressed sites. Some intermediate taxa may show an "intermediate disturbance" response, where densities and frequency of occurrence are highest at intermediate levels of stress but are intolerant of excessive pollution loads or habitat alteration. These taxa are readily collected with conventional sample methods.*

V	Tolerant Taxa *Taxa that comprise a low proportion of natural communities. Taxa often are tolerant of a greater degree of disturbance and stress than other organisms and are thus resistant to a variety of pollution or habitat induced stress. They may increase in number (sometimes greatly) under severely altered or stressed conditions, and may possess adaptations for highly enriched conditions, hypoxia, or toxic substances (Figure 3-1). Commonly r-strategists (early colonizers with rapid turn-over times: e.g., "boom/bust" population characteristics), these are the last survivors in severely disturbed systems.*
VI	Non-native taxa *With respect to a particular ecosystem, any species not native to that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal range are non-native or non-indigenous, as are species introduced from other continents.* VIa – Highly tolerant non-native taxa
X	Catadromous fish, indicating ecosystem connectivity *Access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation; necessary for metapopulation maintenance and natural flows of energy and nutrients across ecosystem boundaries.*

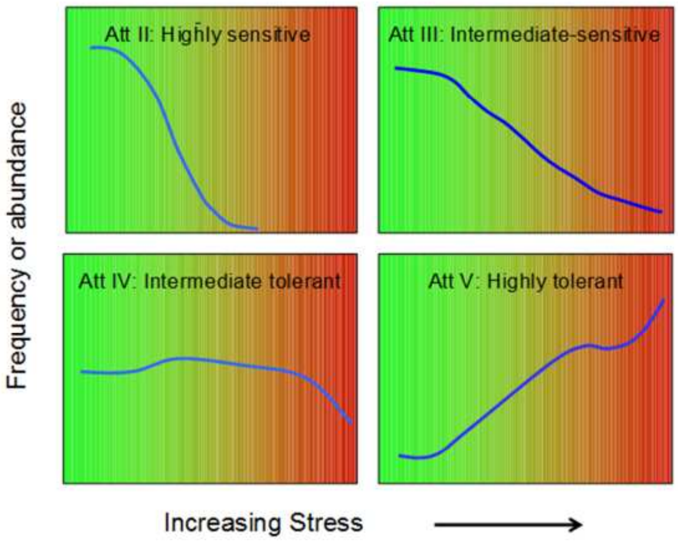


Figure B1. Diagram showing responses of attributes to a stress gradient.

APPENDIX C

Fish BCG Attribute Assignments

Appendix C. Table C -1. BCG attribute assignments for fish. Assignments are the same for both small-cold and medium-large subclasses. This list is sorted first by family, then by common name.

BCG Attribute	Order	Family	Scientific Name	Common Name	Total # individuals
x	Pleuronectiformes	Achiridae	Trinectes maculatus	Hogchoker	4
10	Anguilliformes	Anguillidae	Anguilla rostrata	American eel	10397
2	Cypriniformes	Catostomidae	Erimyzon oblongus	Creek chubsucker	15
4	Cypriniformes	Catostomidae	Catostomus commersoni	White sucker	23426
x	Perciformes	Centrachidae	Centrachidae	Unknown sunfish	11
x	Perciformes	Centrarchidae	Enneacanthus obesus	Banded Sunfish	5
6	Perciformes	Centrarchidae	Pomoxis nigromaculatus	Black Crappie	19
6a	Perciformes	Centrarchidae	Lepomis macrochirus	Bluegill sunfish	2784
x	Perciformes	Centrarchidae		Bluegill X Pumpkinseed	2
6a	Perciformes	Centrarchidae	Lepomis cyanellus	Green sunfish	364
x	Perciformes	Centrarchidae		Hybrid sunfish	4
6a	Perciformes	Centrarchidae	Micropterus salmoides	Largemouth Bass	1648
4	Perciformes	Centrarchidae	Lepomis gibbosus	Pumpkinseed	1764
x	Perciformes	Centrarchidae		Pumpkinseed Hybrid	7
x	Perciformes	Centrarchidae		Pumpkinseed X Red breast	20
4	Perciformes	Centrarchidae	Lepomis auritus	Redbreast sunfish	4485
6	Perciformes	Centrarchidae	Ambloplites rupestris	Rock Bass	801
6	Perciformes	Centrarchidae	Micropterus dolomieu	Smallmouth bass	2285
2	Scorpaeniformes	Cottidae	Cottus cognatus	Slimy sculpin	2194
4	Cypriniformes	Cyprinidae	Rhinichthys atratulus	Blacknose dace	55137
6a	Cypriniformes	Cyprinidae	Pimephales notatus	Bluntnose minnow	11

Table C -1 continued…

BCG Attribute	Order	Family	Scientific Name	Common Name	Total # individuals
x	Cypriniformes	Cyprinidae	Notropis bifrenatus	Bridled shiner	3
6a	Cypriniformes	Cyprinidae	Cyprinus carpio	Carp	13
3	Cypriniformes	Cyprinidae	Luxilus cornutus	Common shiner	9046
4	Cypriniformes	Cyprinidae	Semotilus atromaculatus	Creek chub	4974
4	Cypriniformes	Cyprinidae	Exoglossum maxillingua	Cutlips minnow	2552
3	Cypriniformes	Cyprinidae	Semotilus corporalis	Fallfish	10020
6a	Cypriniformes	Cyprinidae	Pimephales promelas	Fathead minnow	45
5	Cypriniformes	Cyprinidae	Notemigonus crysoleucas	Golden shiner	595
6a	Cypriniformes	Cyprinidae	Carassius auratus	Goldfish	3
3	Cypriniformes	Cyprinidae	Rhinichthys cataractae	Longnose dace	15499
4	Cypriniformes	Cyprinidae	Notropis hudsonius	Spottail shiner	1344
x	Cypriniformes	Cyprinidae	Cyprinidae	Unknown minnow	383
4	Esociformes	Esocidae	Esox niger	Chain pickerel	521
4	Esociformes	Esocidae	Esox americanus	Redfin pickerel	612
5	Cyprinodontiformes	Fundulidae	Fundulus diaphanus	Banded killifish	259
x	Cyprinodontiformes	Fundulidae	Fundulus heteroclitus	Mummichog	18
x	Gadiformes	Gadidae	Lota lota	Burbot	29
x	Gadiformes	Gadidae	Microgadus tomcod	Tomcod	2
4	Gasterosteiformes	Gasterosteidae	Apeltes quadracus	Fourspine stickleback	118
x	Gasterosteiformes	Gasterosteidae	Pungitius pungitius	Ninespine stickleback	1
5	Siluriformes	Ictaluridae	Ameiurus nebulosus	Brown bullhead	479
x	Siluriformes	Ictaluridae	Ameiurus catus	White catfish	1
6a	Siluriformes	Ictaluridae	Ameiurus natalis	Yellow bullhead	187
10	Perciformes	Moronidae	Morone saxatilis	Striped bass	1

Table C -1 continued…

BCG Attribute	Order	Family	Scientific Name	Common Name	Total # individuals
4	Perciformes	Moronidae	Morone americana	White perch	2
x	Perciformes	Percidae	Etheostoma fusiforme	Swamp darter	21
4	Perciformes	Percidae	Etheostoma olmstedi	Tesselated darter	8832
x	Perciformes	Percidae	Stizostedion vitreum	Walleye	5
x	Perciformes	Percidae	Perca flavescens	Yellow perch	744
2	Petromyzontiformes	Petromyzontidae	Lampetra appendix	American Brook lamprey	19
10	Petromyzontiformes	Petromyzontidae	Petromyzon marinus	Sea lamprey	174
6b	Salmoniformes	Salmonidae	Salmo salar (stocked)	Atlantic salmon	3237
6b	Salmoniformes	Salmonidae	Salvelinus fontinalis (stocked)	Brook trout (stocked)	246
2	Salmoniformes	Salmonidae	Salvelinus fontinalis (wild)	Brook trout (wild)	8221
6b	Salmoniformes	Salmonidae	Salmo trutta	Brown trout	5321
6b	Salmoniformes	Salmonidae	Oncorhynchus mykiss	Rainbow trout	475
x	Salmoniformes	Salmonidae	Sibericus sabertoohii	Tiger Trout	13
6a	Esociformes	Umbridae	Umbra limi	Central mudminnow	32

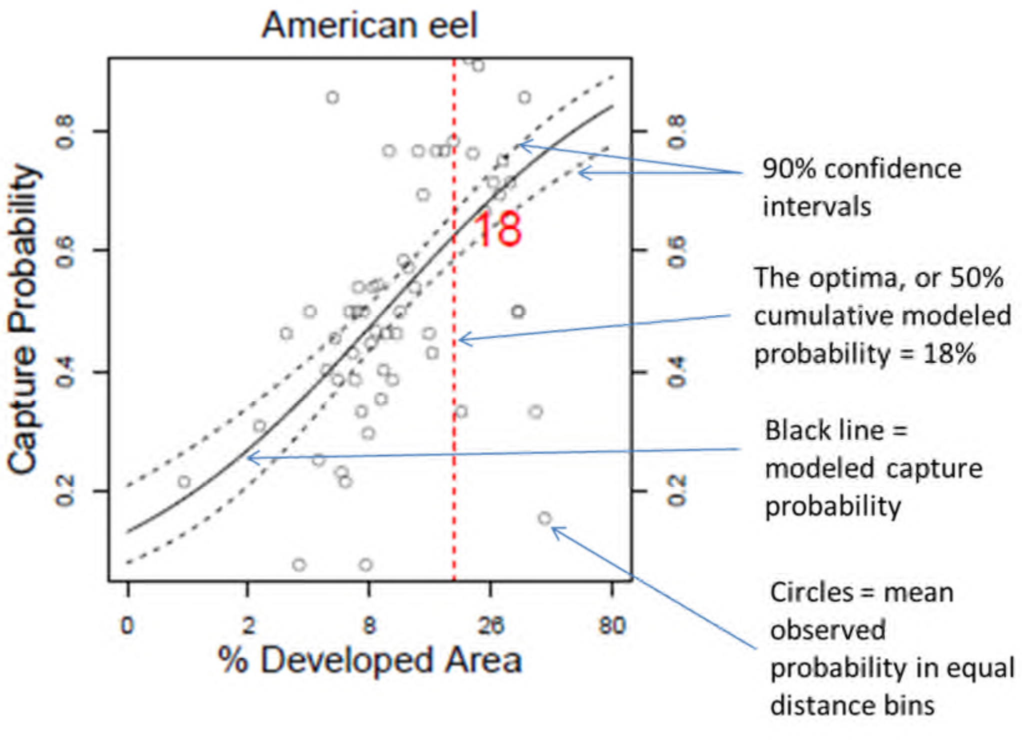
APPENDIX D

Capture probability modeled vs. disturbance gradient

Generalized additive models (GAM) were used to characterize the relationships between species presence/absence and the percent of the watershed comprised of developed land[1]. Capture probability plots were generated for species that occurred at 20 or more sites. Capture probability refers to the likelihood of occurrence along the gradient of interest.

Curve shapes generally fall into three categories: increasing, decreasing, or unimodal. In the example in Figure D-1, the American eel has an increasing curve shape; this means that the probability of capturing the American eel increases as % developed area increases.

The black solid line in the plots is the modeled capture probability (based on the GAM model) and the circles are the mean observed probability in equal distance bins. For example, if you divide the stressor gradient into 50 equal distance bins, the mean of any data points (1 or 0) within that bin are taken as the probability of capture and plotted against the mean stressor value in the bin. The black dashed lines represent the 90% confidence interval, and the vertical red dashed line and number associated with it represent the optima, which in these plots equals the 50% area under the modeled curve. In the example in Figure D-1, the American eel has a 50% chance of occurring at sites with 18% developed area.



90% confidence intervals

The optima, or 50% cumulative modeled probability = 18%

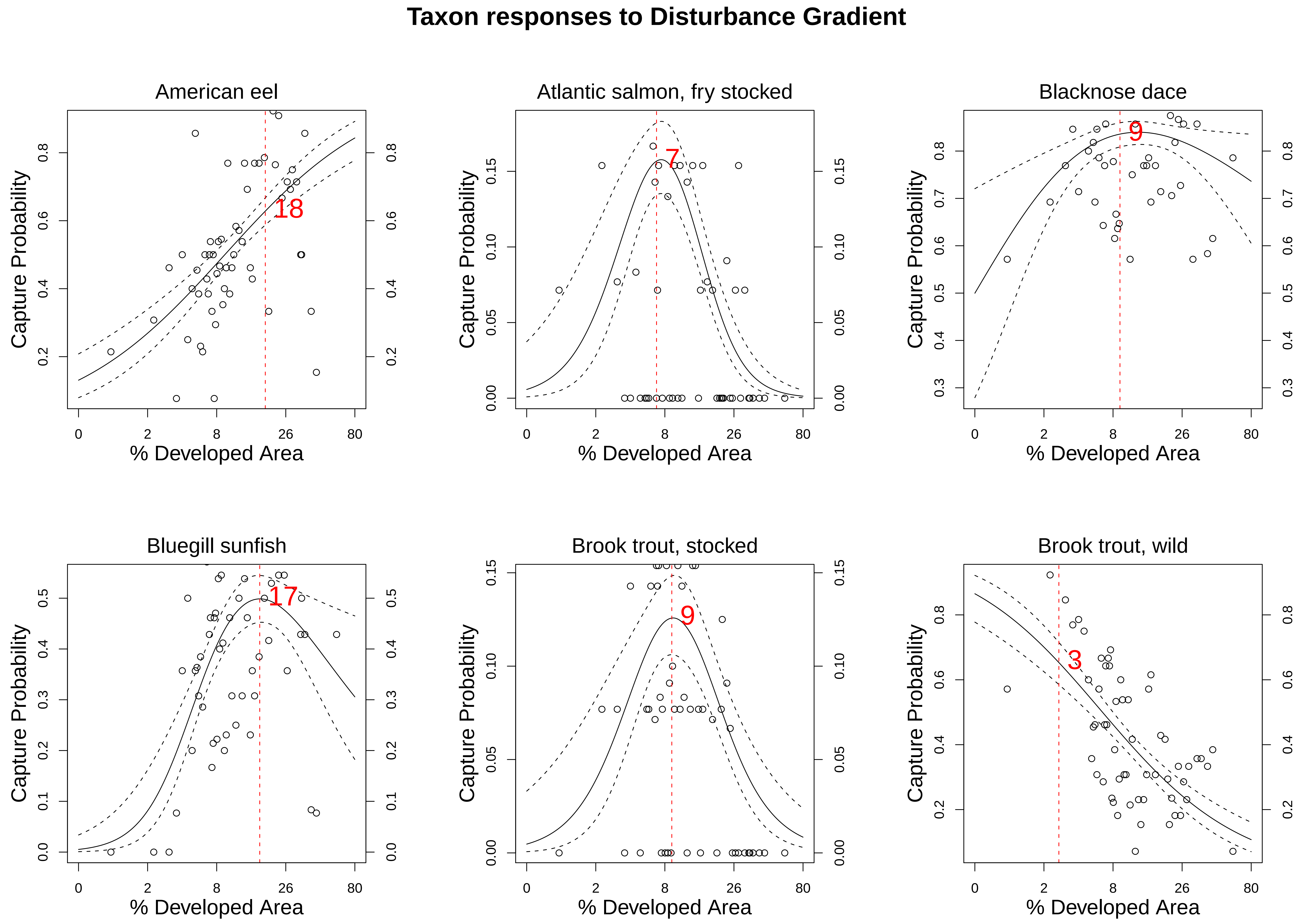
Black line = modeled capture probability

Circles = mean observed probability in equal distance bins

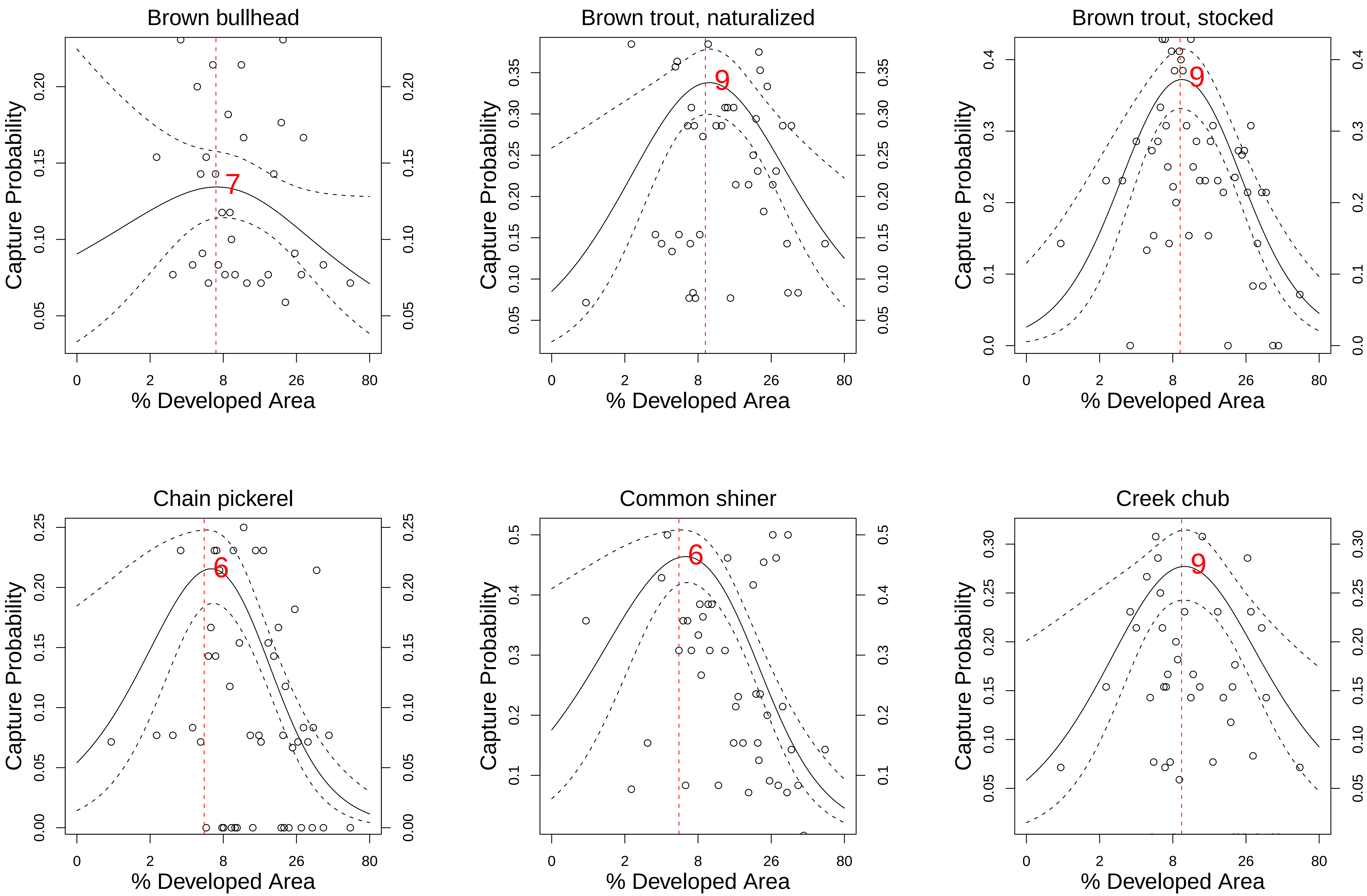
Figure D-1. Percent developed tolerance plot for the American eel. The probability of capturing this species at a site increases as % developed area increases.

---

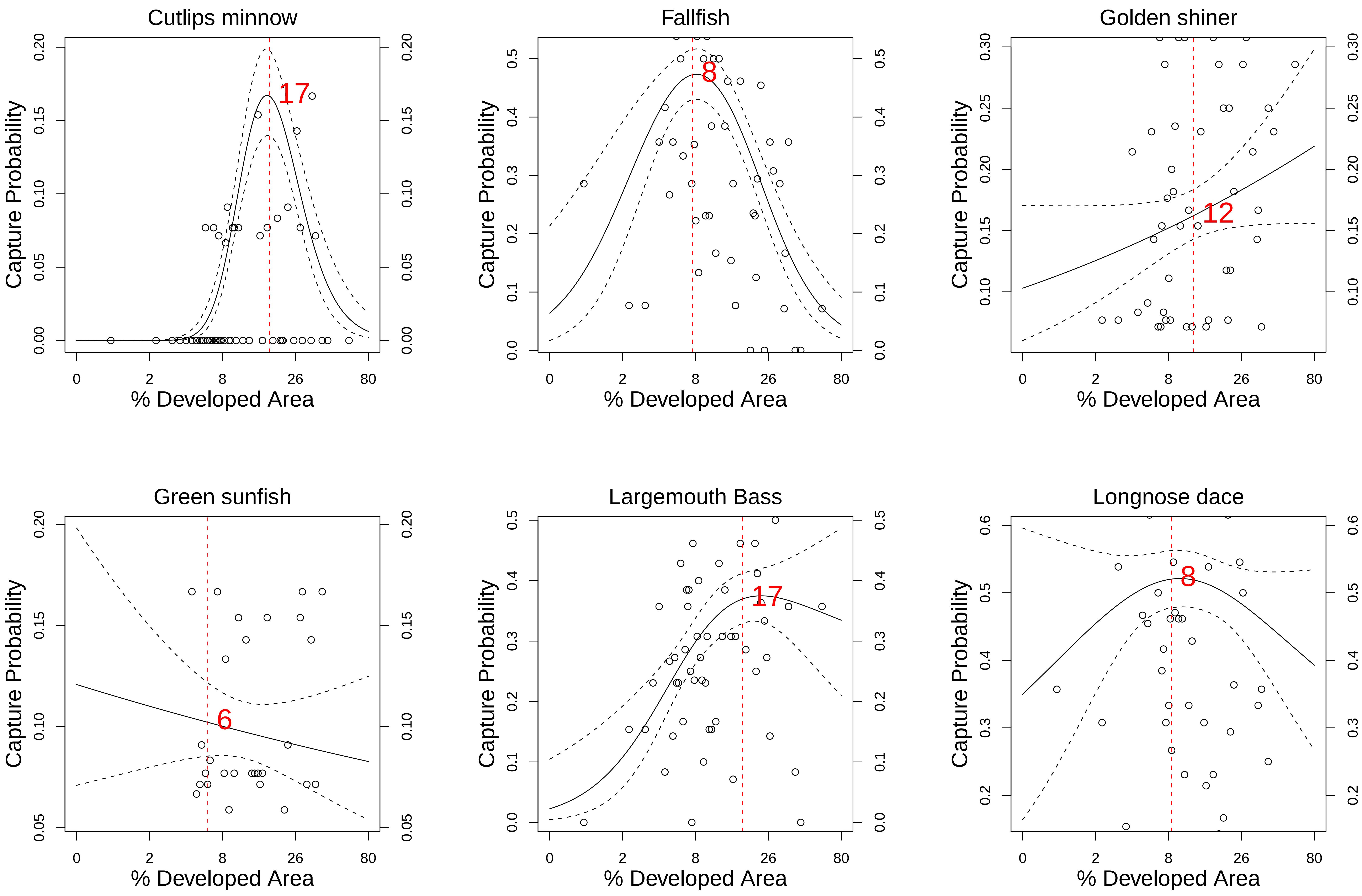
[1] The developed land data were provided by CT DEEP.

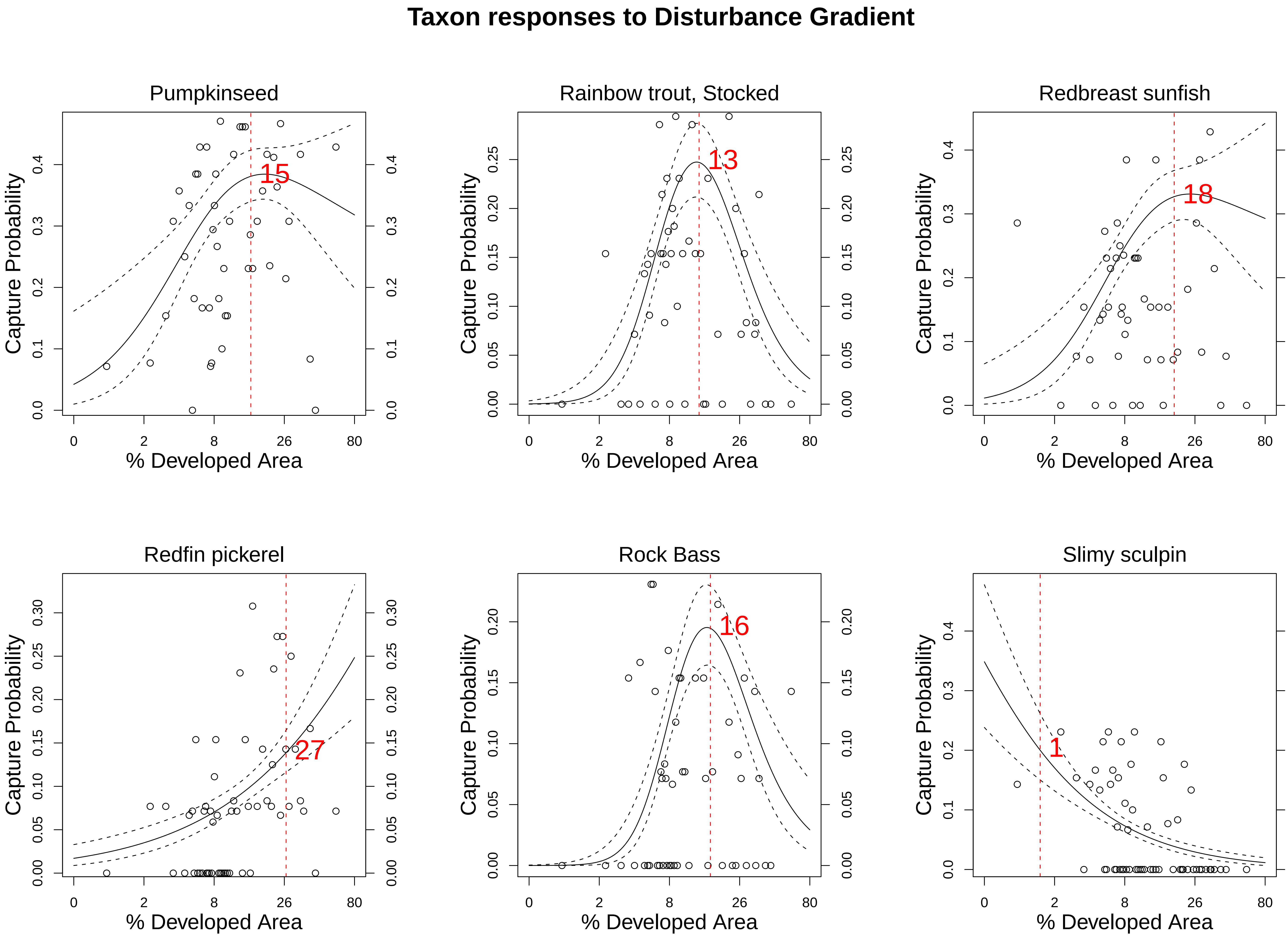

Taxon responses to Disturbance Gradient
American eel
Atlantic salmon, fry stocked
Blacknose dace
Bluegill sunfish
Brook trout, stocked
Brook trout, wild
Capture Probability
% Developed Area
0
2
8
26
80
18
7
9
17
9
3
0.2
0.4
0.6
0.8
0.00
0.05
0.10
0.15
0.3
0.5
0.7
0.0
0.1

Taxon responses to Disturbance Gradient

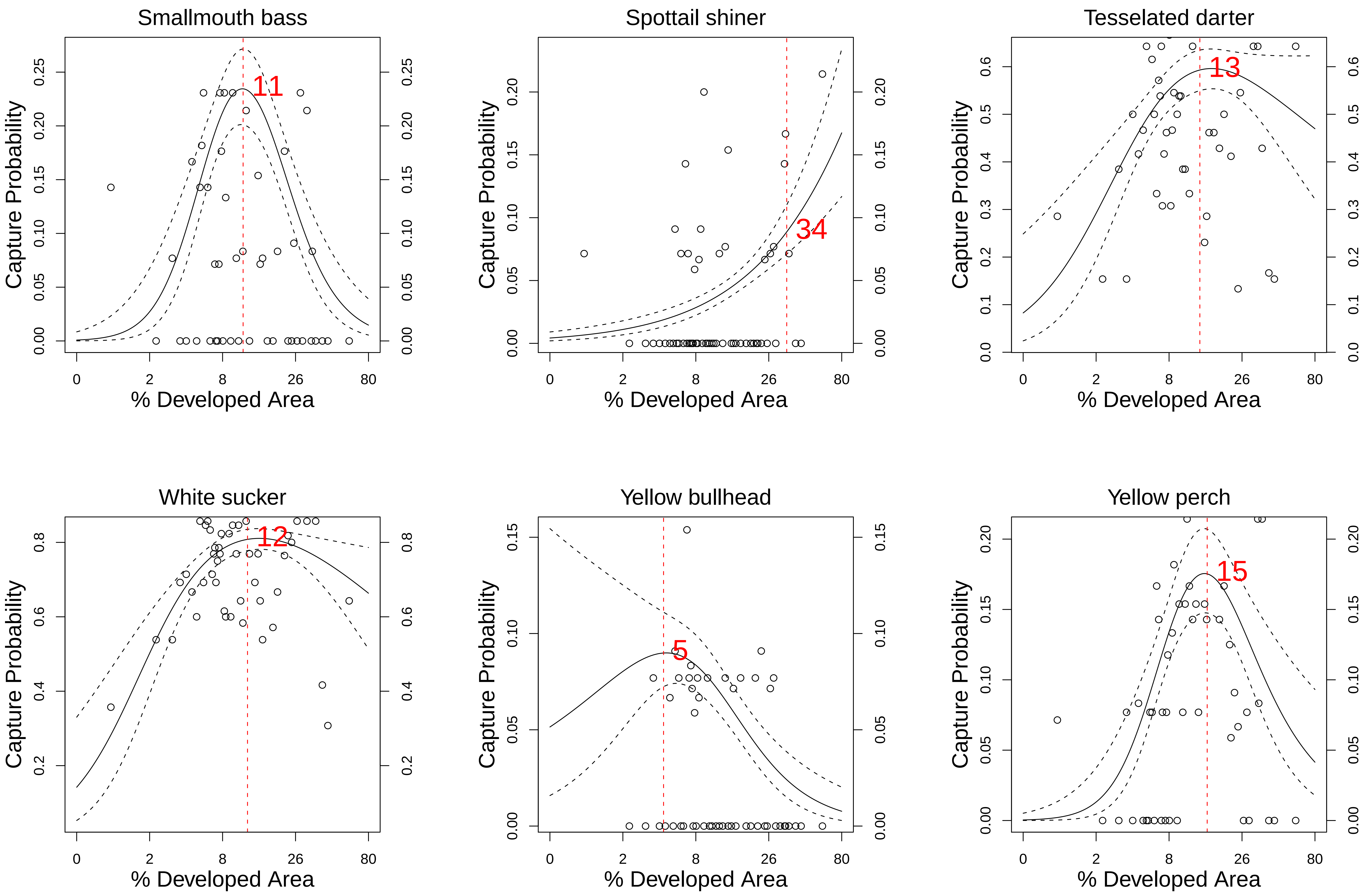


Taxon responses to Disturbance Gradien




Taxon responses to Disturbance Gradient
Pumpkinseed
Rainbow trout, Stocked
Redbreast sunfish
Redfin pickerel
Rock Bass
Slimy sculpin
Capture Probability
% Developed Area
0
2
8
26
80
0.0
0.1
0.2
0.3
0.4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
15
13
18
27
16
1

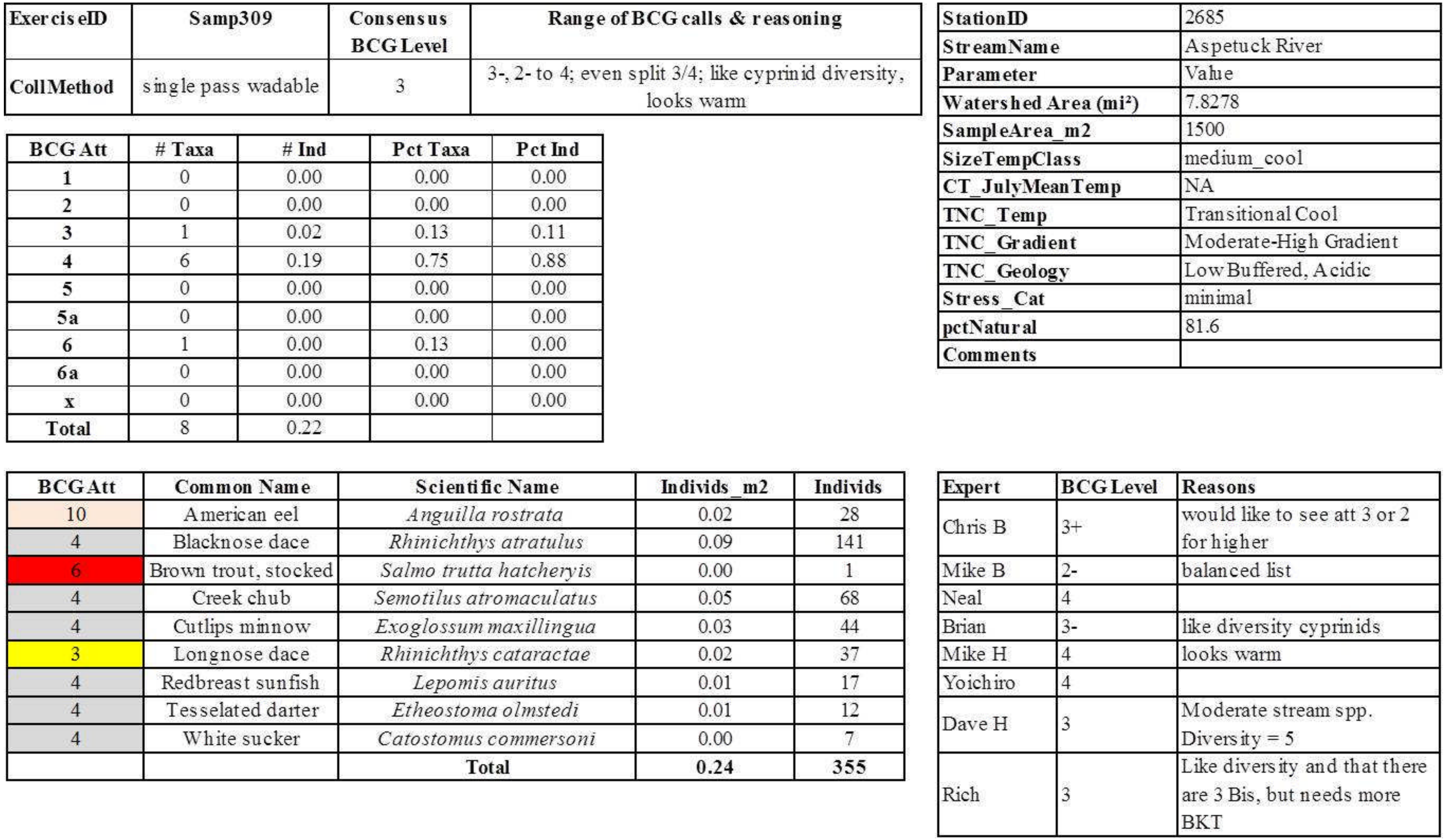
Taxon responses to Disturbance Gradient



APPENDIX E

Sample worksheet

Figure E1. Example of a worksheet that was used when making BCG level assignments.



ExerciseID	Samp309	Consensus BCG Level	Range of BCG calls & reasoning
CollMethod	single pass wadable	3	3-, 2- to 4; even split 3/4; like cyprinid diversity, looks warm

BCG Att	# Taxa	# Ind	Pct Taxa	Pct Ind
1	0	0.00	0.00	0.00
2	0	0.00	0.00	0.00
3	1	0.02	0.13	0.11
4	6	0.19	0.75	0.88
5	0	0.00	0.00	0.00
5a	0	0.00	0.00	0.00
6	1	0.00	0.13	0.00
6a	0	0.00	0.00	0.00
x	0	0.00	0.00	0.00
Total	8	0.22		

StationID	2685
StreamName	Aspetuck River
Parameter	Value
Watershed Area (mi²)	7.8278
SampleArea_m2	1500
SizeTempClass	medium_cool
CT_JulyMeanTemp	NA
TNC_Temp	Transitional Cool
TNC_Gradient	Moderate-High Gradient
TNC_Geology	Low Buffered, Acidic
Stress_Cat	minimal
pctNatural	81.6
Comments	

BCG Att	Common Name	Scientific Name	Individs_m2	Individs
10	American eel	*Anguilla rostrata*	0.02	28
4	Blacknose dace	*Rhinichthys atratulus*	0.09	141
6	Brown trout, stocked	*Salmo trutta hatcheryis*	0.00	1
4	Creek chub	*Semotilus atromaculatus*	0.05	68
4	Cutlips minnow	*Exoglossum maxillingua*	0.03	44
3	Longnose dace	*Rhinichthys cataractae*	0.02	37
4	Redbreast sunfish	*Lepomis auritus*	0.01	17
4	Tesselated darter	*Etheostoma olmstedi*	0.01	12
4	White sucker	*Catostomus commersoni*	0.00	7
		Total	**0.24**	**355**

Expert	BCG Level	Reasons
Chris B	3+	would like to see att 3 or 2 for higher
Mike B	2-	balanced list
Neal	4	
Brian	3-	like diversity cyprinids
Mike H	4	looks warm
Yoichiro	4	
Dave H	3	Moderate stream spp. Diversity = 5
Rich	3	Like diversity and that there are 3 Bis, but needs more BKT

APPENDIX F

Box plots of metrics for small-cold samples that were assessed

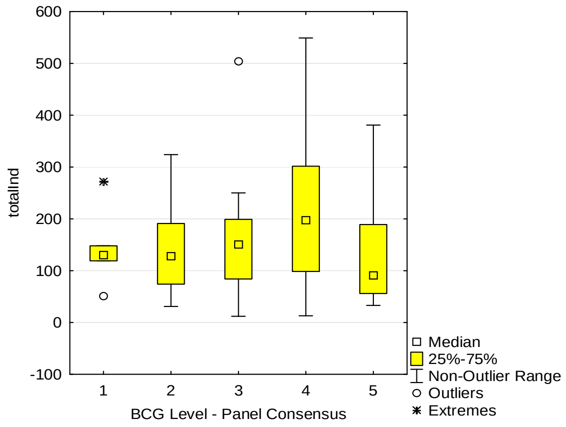
Box plots were generated to examine the distributions of metric values across BCG levels. Table F1 contains descriptions of the metric codes that are on the y-axes of the plots.

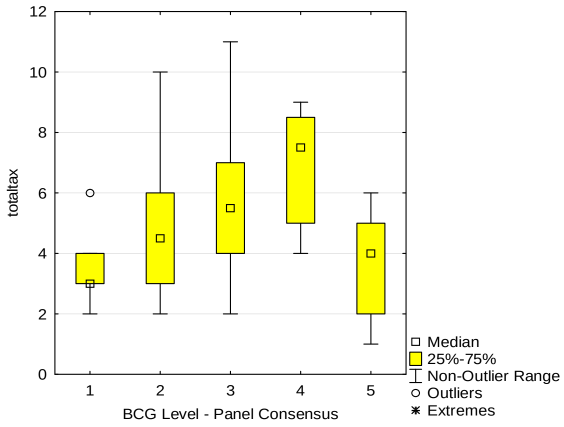
Table F1. Descriptions of the metric codes that are on the y-axes of the box plots.

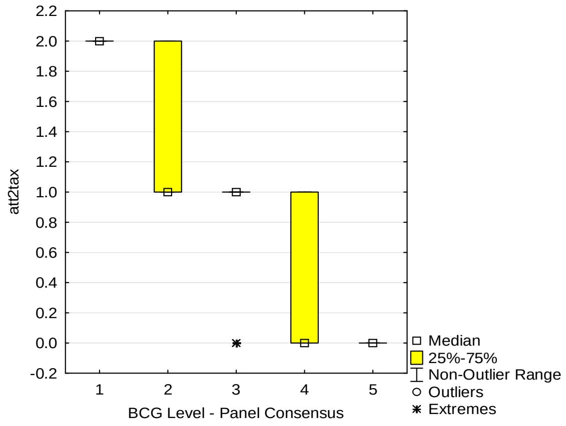
Metric Code	Description
totalInd	Number of total individuals
totaltax	Number of total taxa
att2tax	Number of Attribute II taxa
att23tax	Number of Attribute II + III taxa
att3tax	Number of Attribute III taxa
att4tax	Number of Attribute IV taxa
att5tax	Number of Attribute V taxa
att6tax	Number of Attribute VI taxa
att56tax	Number of Attribute V + VI taxa
att6atax	Number of Attribute VIa taxa
att10tax	Number of Attribute X taxa
att2PCInd	% Attribute II individuals
att23PCInd	% Attribute II + III individuals
att3PCInd	% Attribute III individuals
att23_6bPCInd	% Attribute II + III + VIb individuals
att4PCInd	% Attribute IV individuals
att1234PCInd	% Attribute I + II + III + IV individuals
att5PCInd	% Attribute V individuals
att6PCInd	% Attribute VI individuals
att5_6PCInd	% Attribute V + VI individuals
att5_6aPCInd	% Attribute V + VIa individuals
att6_6aPCInd	% Attribute VI + VIa individuals
att6b_PCInd	% Attribute VIb individuals
att6ab_PCInd	% Attribute VIa + VIb individuals
att10PCInd	% Attribute X individuals
att2PCtax	% Attribute II taxa
att3PCtax	% Attribute III taxa
att23PCtax	% Attribute II + III taxa
att23_6bPctax	% Attribute II + III + VIb taxa
att4Pctax	% Attribute IV taxa
att234_6bPctax	% Attribute I + II + III + IV + VIb taxa
att5Pctax	% Attribute V taxa
att6Pctax	% Attribute VI taxa
att6aPctax	% Attribute VIa taxa
att6bPctax	% Attribute VIb taxa
att10Pctax	% Attribute X taxa
att4Dom	% Most dominant Attribute IV taxon

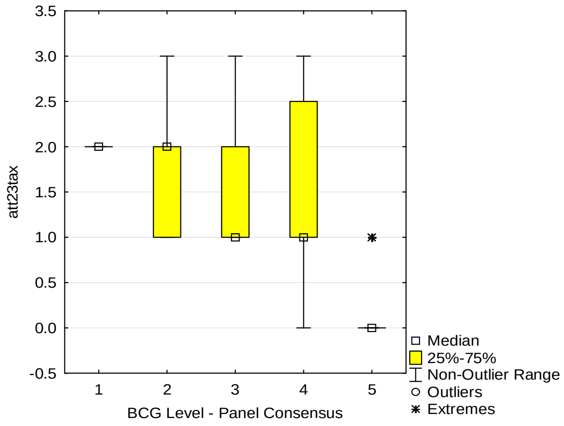
Table F1 continued…

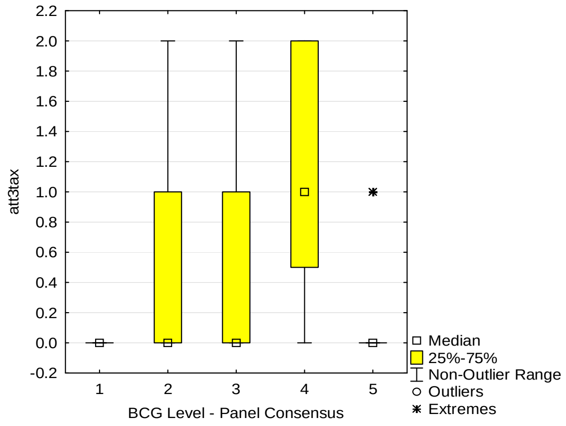
Metric Code	**Description**
att5Dom	% Most dominant Attribute V taxon
att6Dom	% Most dominant Attribute VI taxon
att6aDom	% Most dominant Attribute VIa taxon
att566aDom	% Most dominant Attribute V + VI + VIa taxon
BrookTroutPCInd	% Wild brook trout individuals
BrownTroutPCInd	% Brown trout individuals
BKT_TotalSalm_PCind	(# Wild brook trout individuals/# total salmonid individuals)*100
att6bSalm_TotalSalm_PCIid	(# Attribute 6b salmonid individuals/# total salmonid individuals)*100
Centrarchid_tax	Number of Centrarchidae taxa
Centrarchid_PCtax	Percent Centrarchidae taxa
Centrarchid_PCind	Percent Centrarchidae individuals
Salmonid_tax	Number of Salmonidae taxa
Salmonid_PCtax	Percent Salmonidae taxa
Salmonid_PCind	Percent Salmonidae individuals
Cyprin_tax	Number of Cyprinidae taxa
Cyprin_PCtax	Percent Cyprinidae taxa
Cyprin_PCind	Percent Cyprinidae individuals
BNDCCCMWS_PCind	% Black nose dace + % creek chub + % cutlips minnow + % white sucker individuals
totaltax5Plus	Number of total taxa, counting only taxa with 5 or more individuals
Shan_base_2	Shannon-wiener diversity index (base 2)
Evenness	Evenness
totalDens_m2	Total density/meter^2
totalDens_100m2	Total density/100 meter^2
totaltaxNoStocked	Total number of taxa, not counting stocked taxa

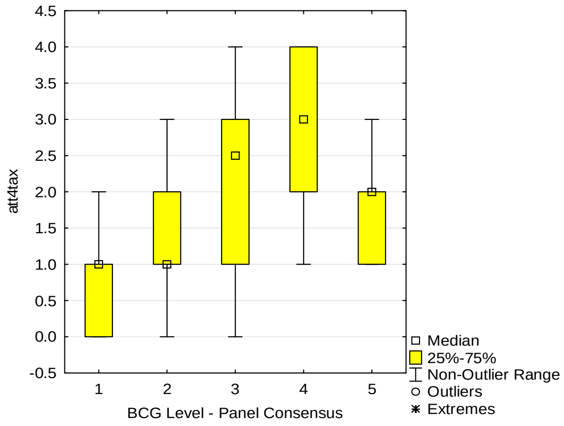

600
500
400
300
200
100
0
-100
totalInd
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

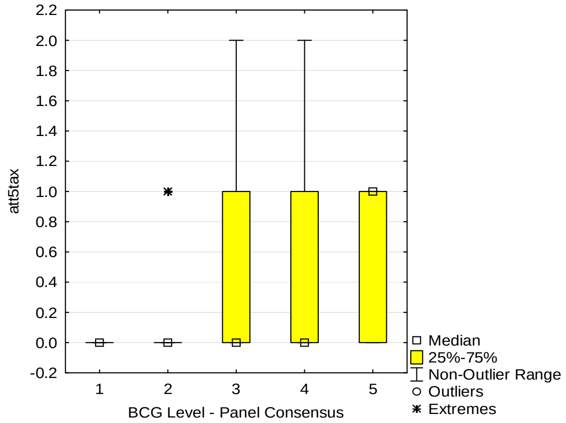

12
10
8
6
4
2
0
totaltax
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

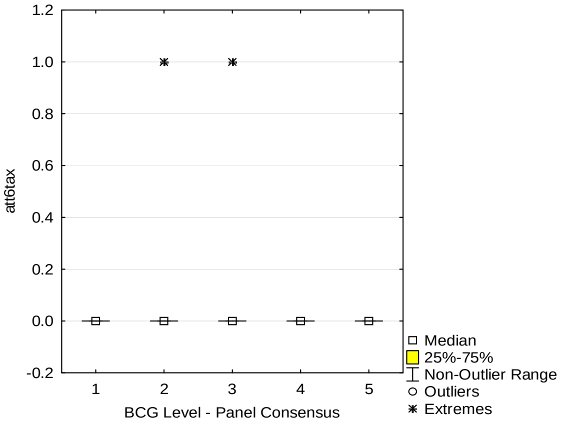

2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
att2tax
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

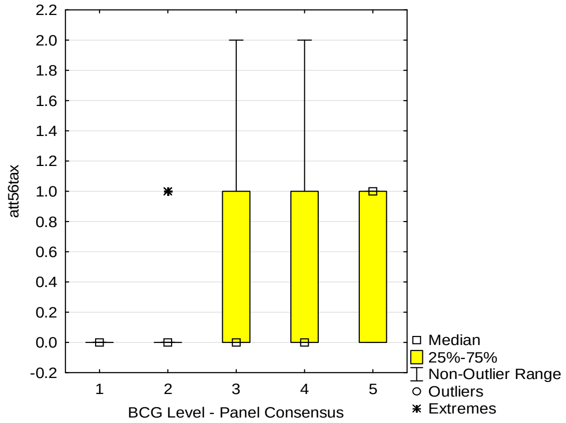

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
att23tax
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

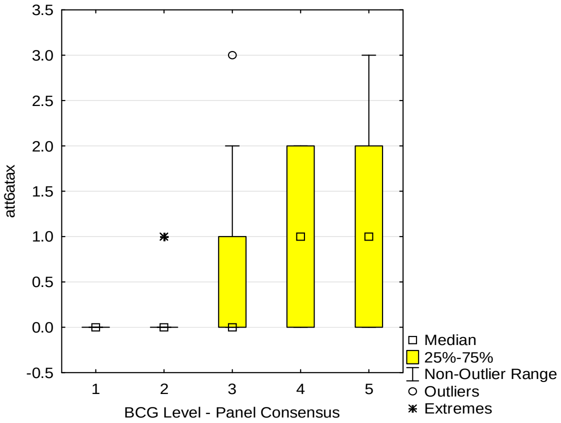

2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
att3tax
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

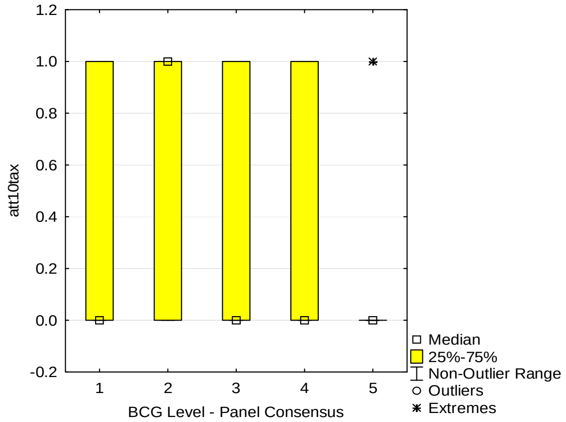

4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
att4tax
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

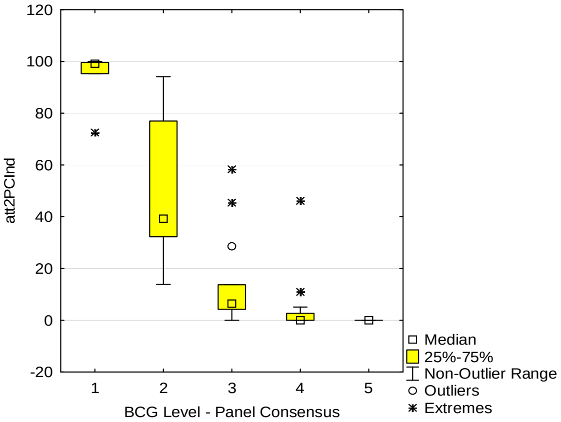

att5tax
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

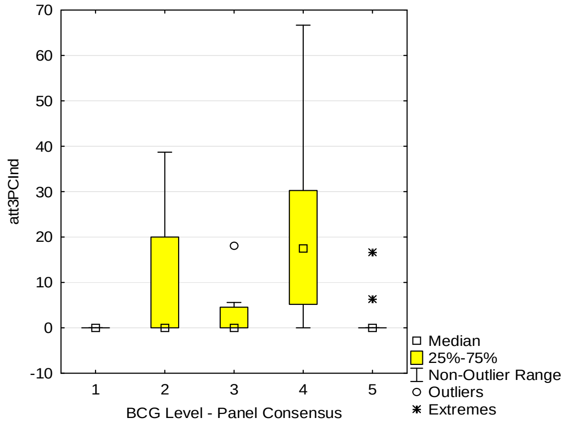

att6tax
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

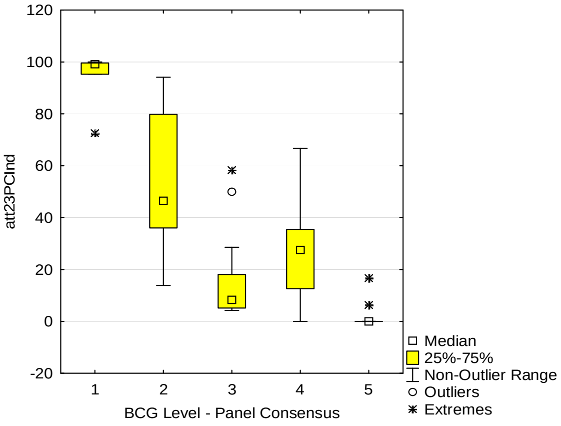

att56tax
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

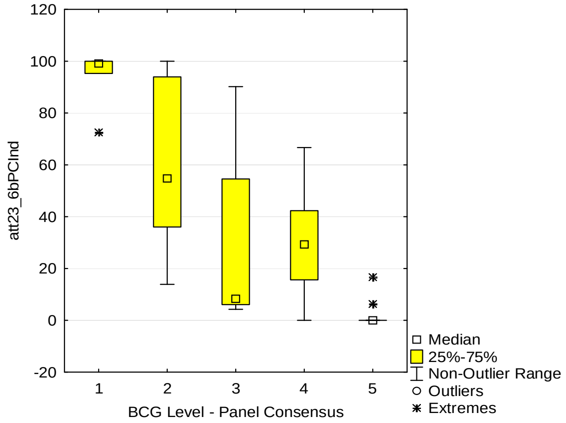

att6atax
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

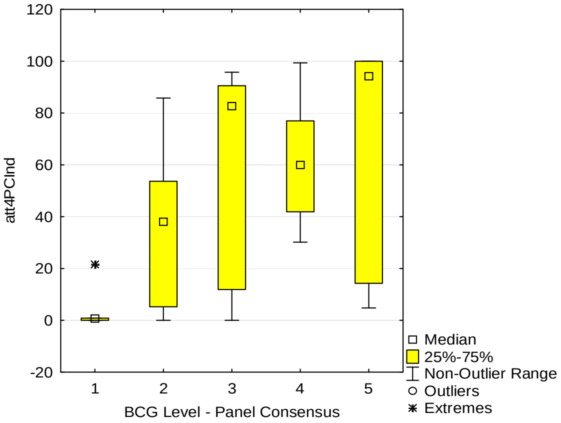

att10tax
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

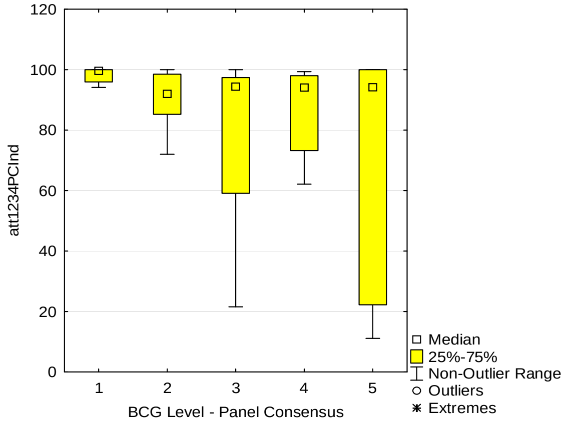

att2PCInd
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

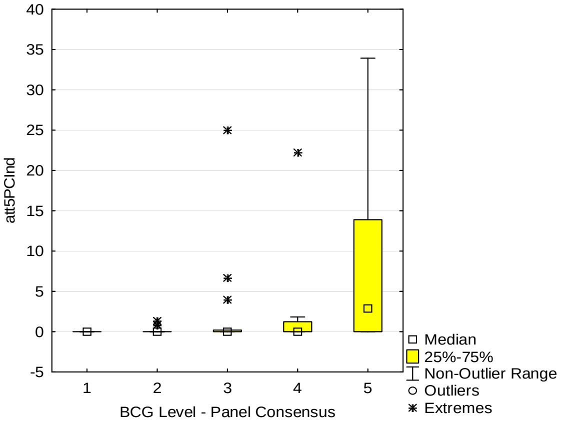

att3PCInd
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

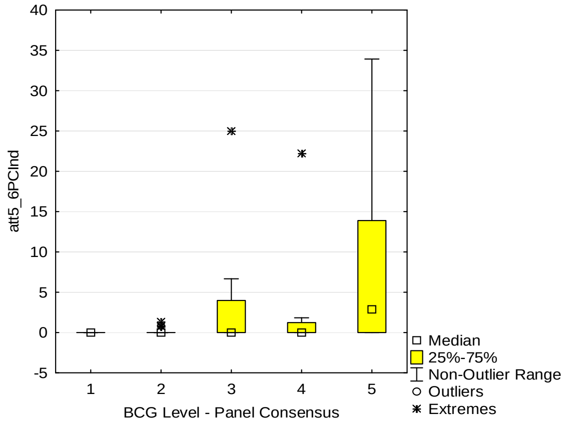

att23PCInd
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

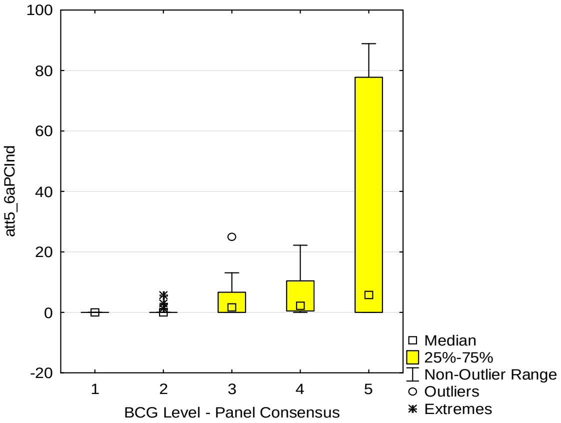

att23_6bPCInd
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

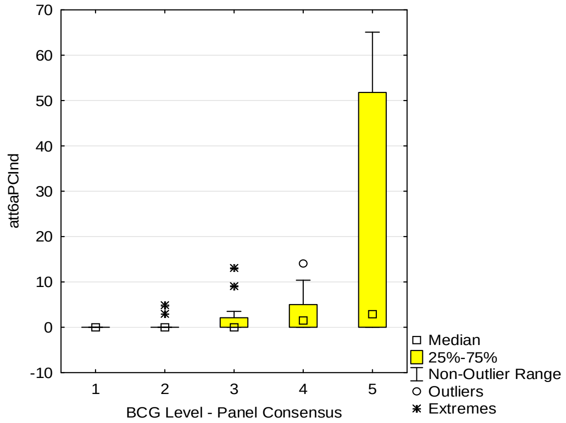

att4PCInd
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

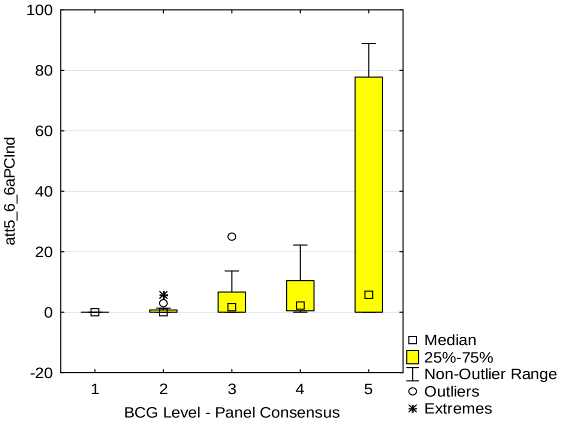

att1234PCInd
120
100
80
60
40
20
0
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

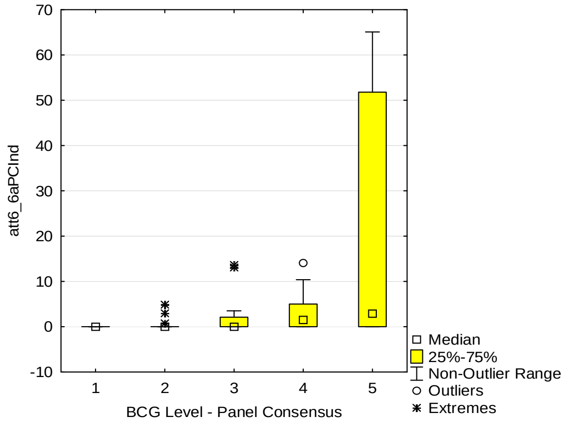

att5PCInd
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

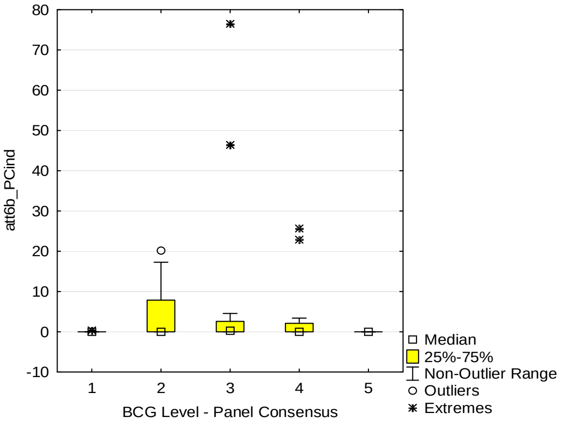

att5_6PCInd
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

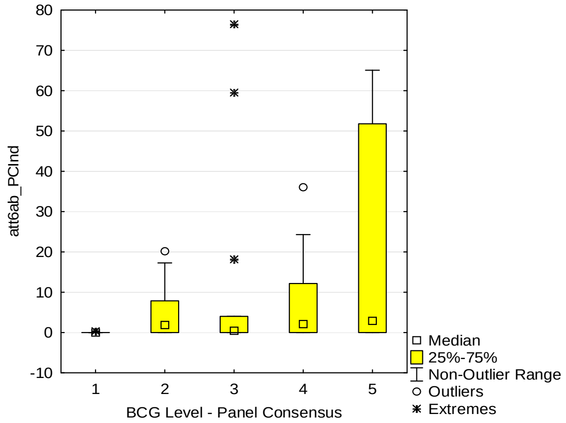

att5_6aPCInd
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

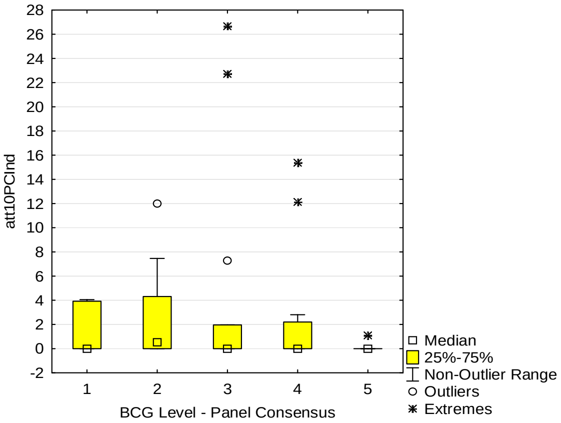

att6aPCInd
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

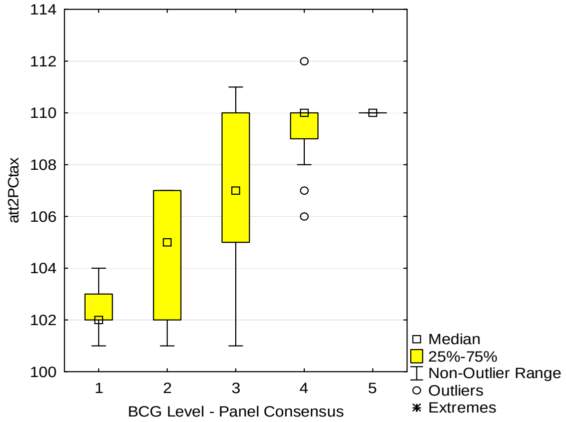

att5_6_6aPCInd
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

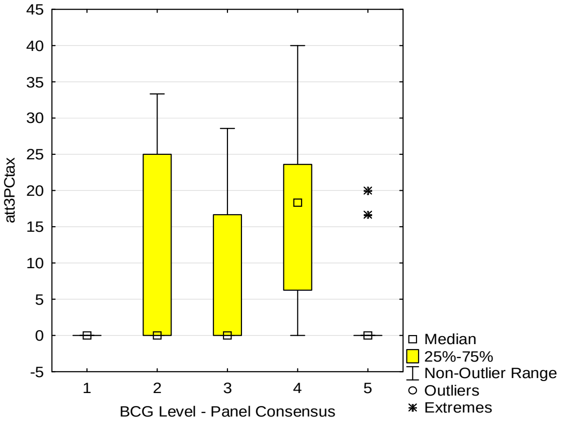

att6_6aPCInd
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

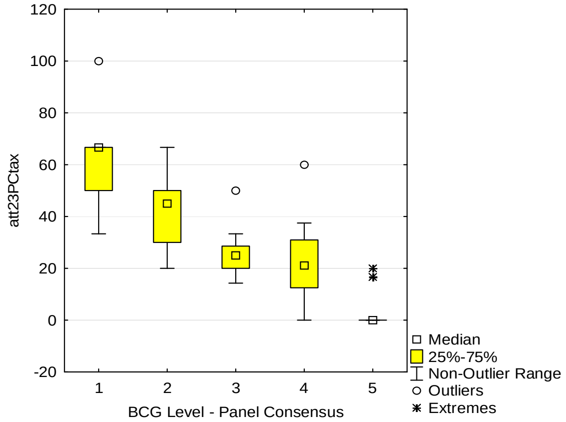

att6b_PCind
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

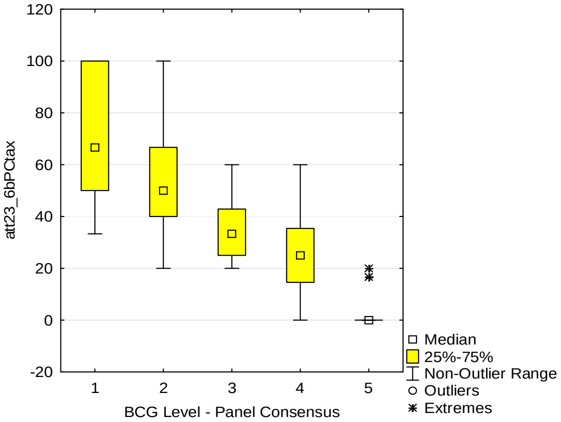

att6ab_PCInd
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

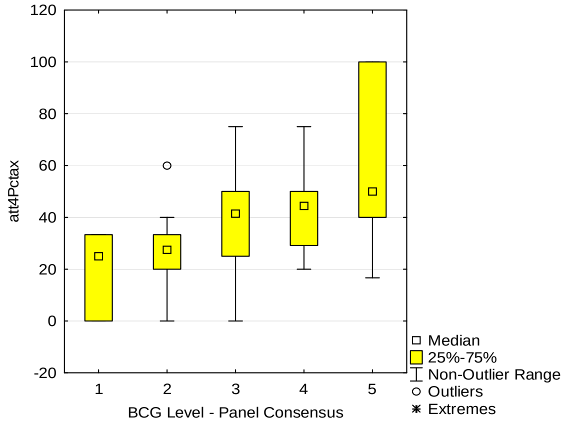

att10PCInd
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

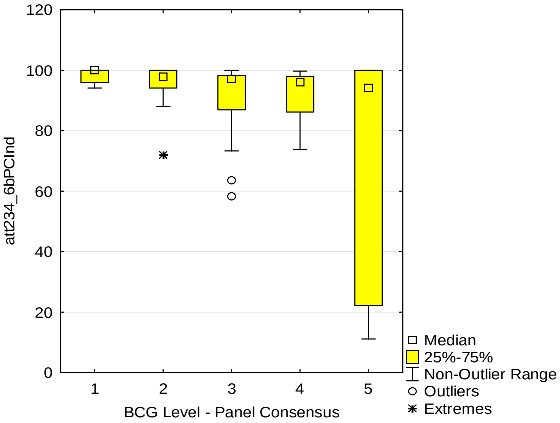

att2PCtax
114
112
110
108
106
104
102
100
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

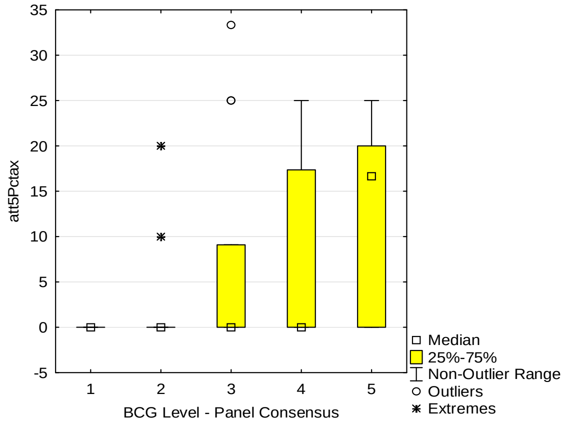

att3PCtax
45
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

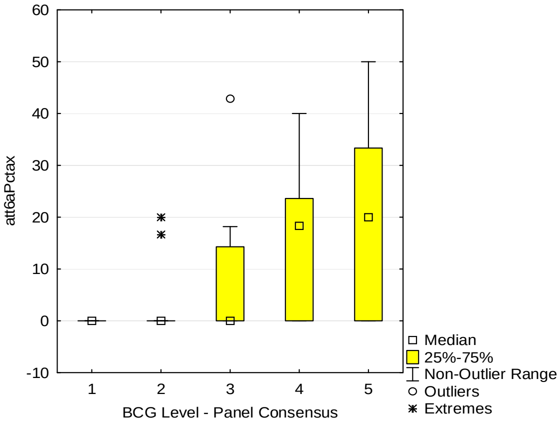

att23PCtax
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

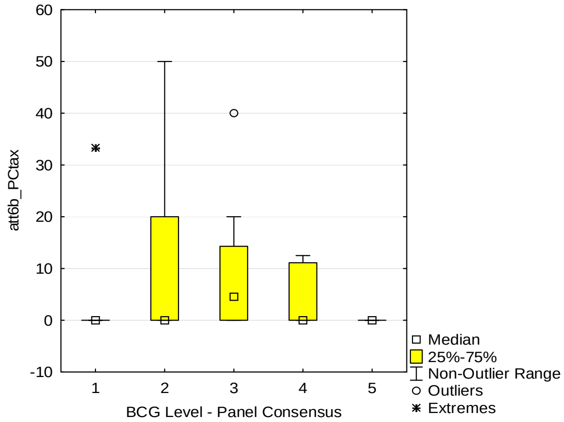

att23_6bPCtax
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

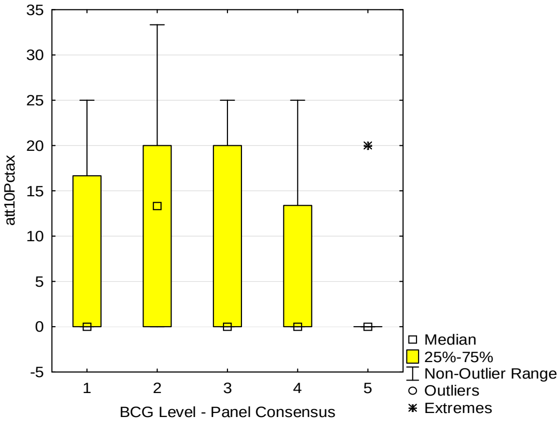

120
100
80
60
40
20
0
-20
att4Pctax
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

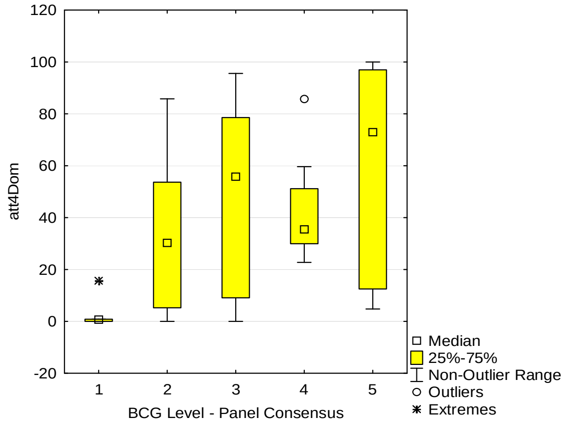

120
100
80
60
40
20
0
att234_6bPCInd
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

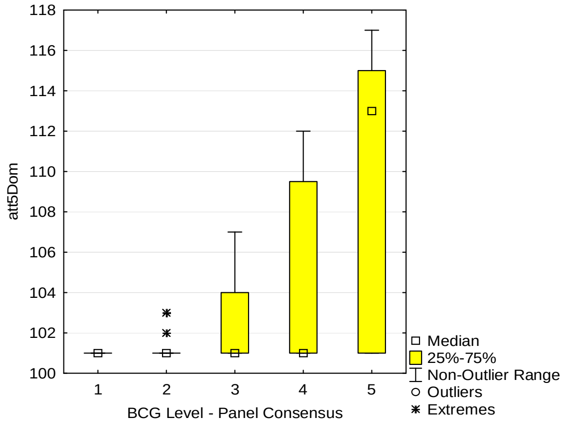

35
30
25
20
15
10
5
0
-5
att5Pctax
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

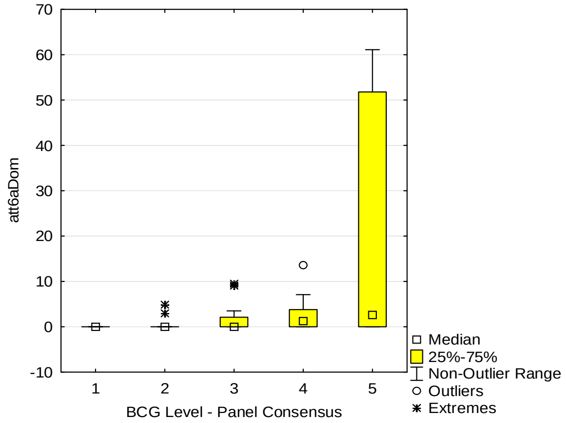

60
50
40
30
20
10
0
-10
att6aPctax
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

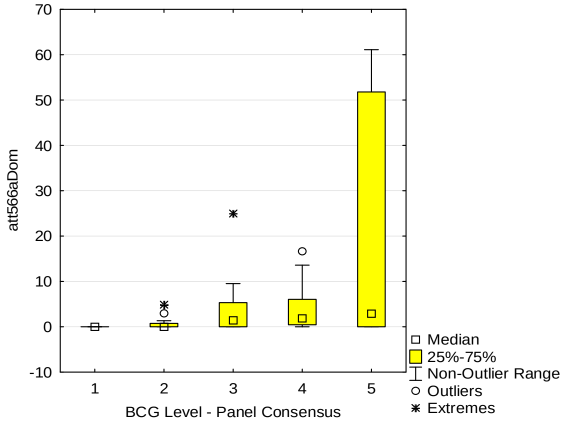

60
50
40
30
20
10
0
-10
att6b_PCtax
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

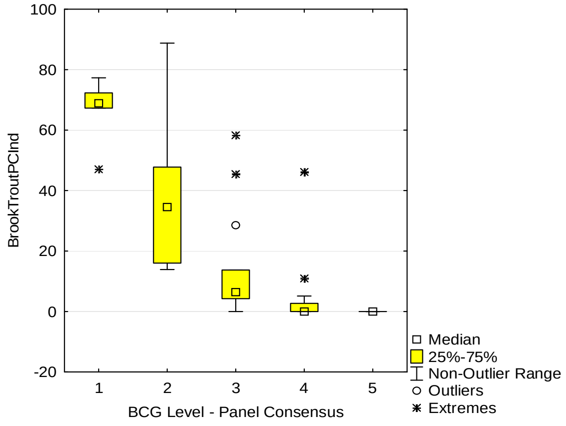

35
30
25
20
15
10
5
0
-5
att10Pctax
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

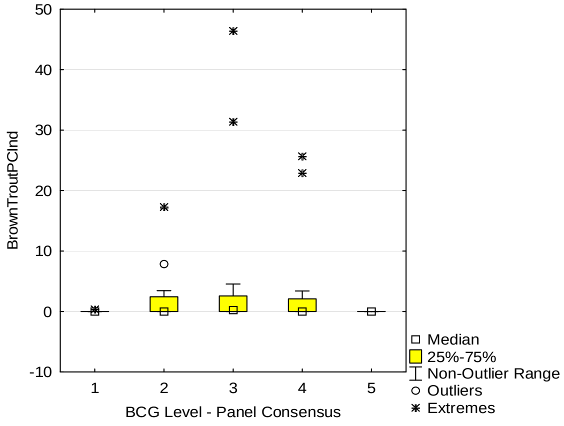

att4Dom
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

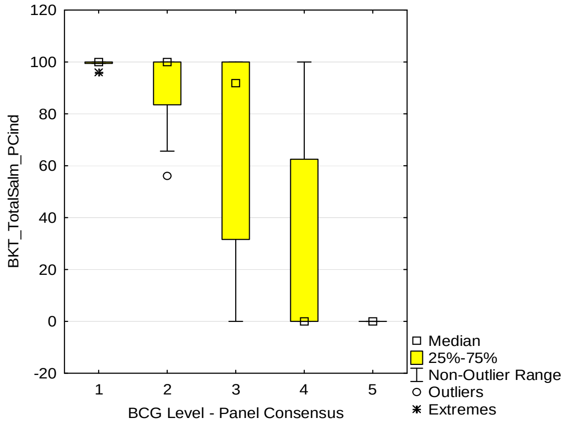

att5Dom
118
116
114
112
110
108
106
104
102
100
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

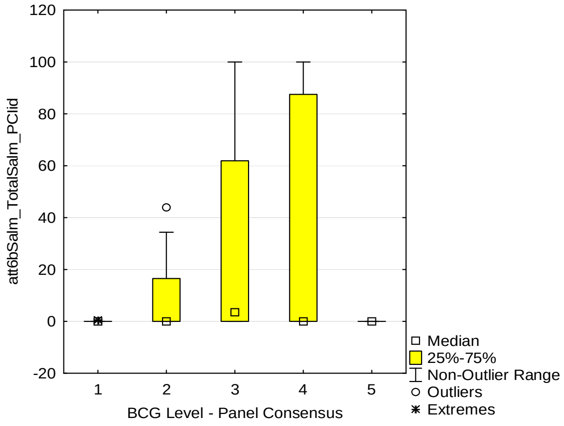

att6aDom
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

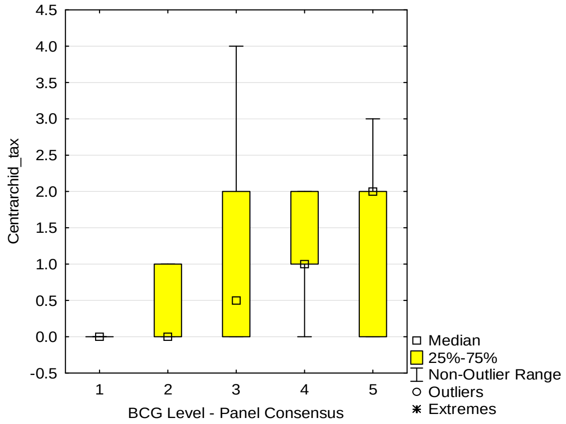

att566aDom
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

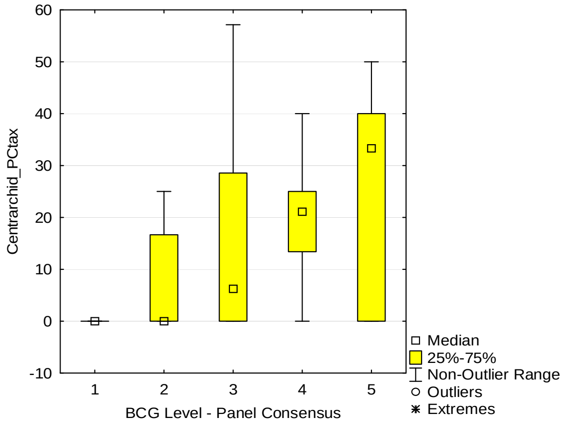

BrookTroutPCInd
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

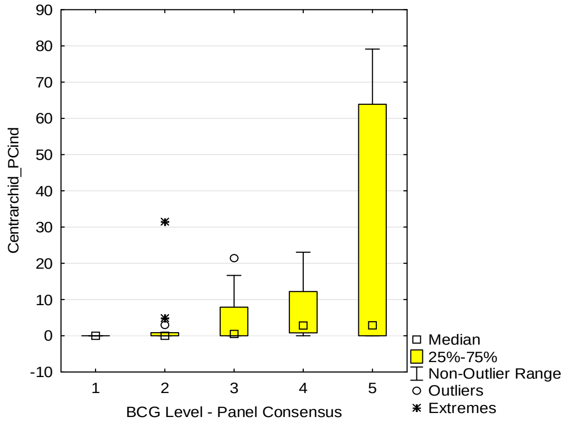

BrownTroutPCInd
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

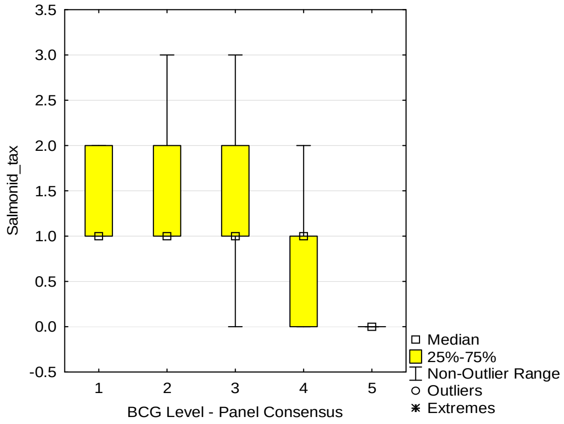

BKT_TotalSalm_PCind
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

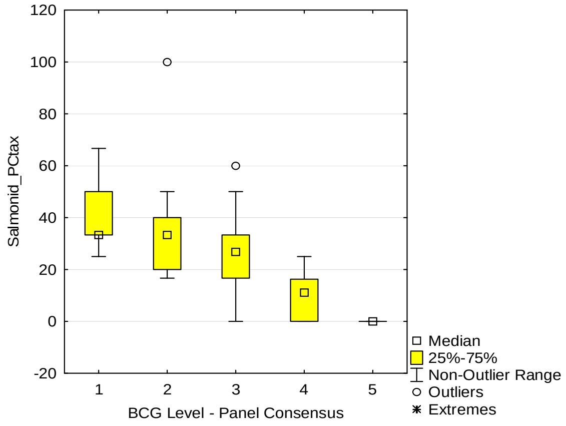

att6bSalm_TotalSalm_PCid
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

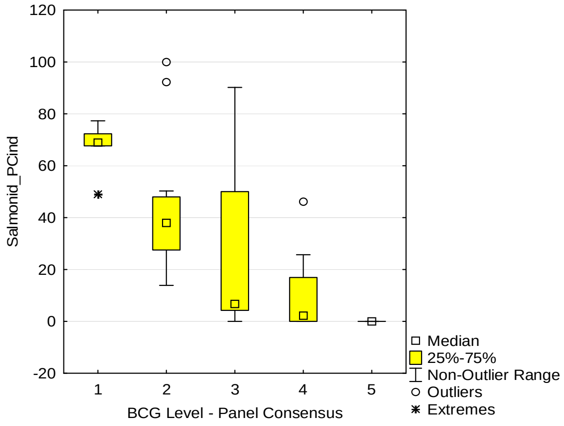

Centrarchid_tax
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

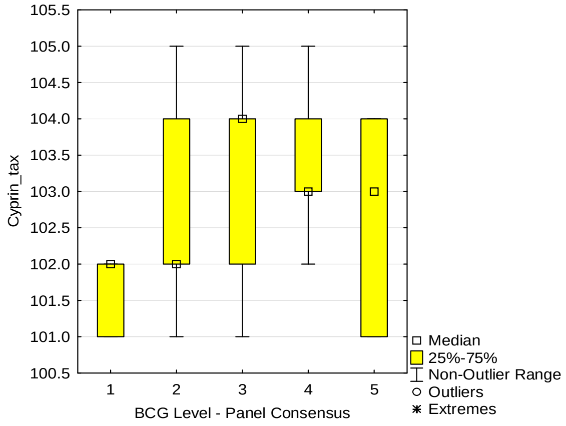

Centrarchid_PCtax
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

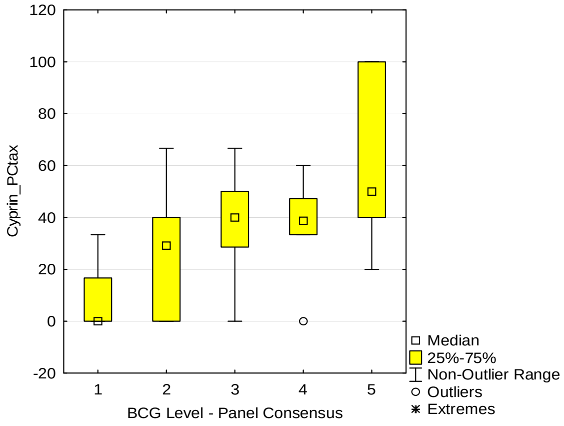

Centrarchid_PCind
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

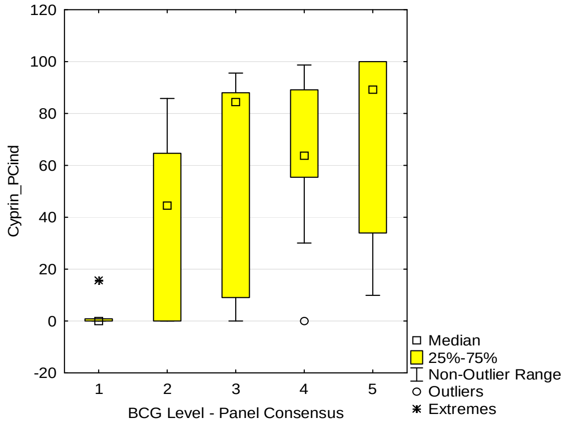

Salmonid_tax
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

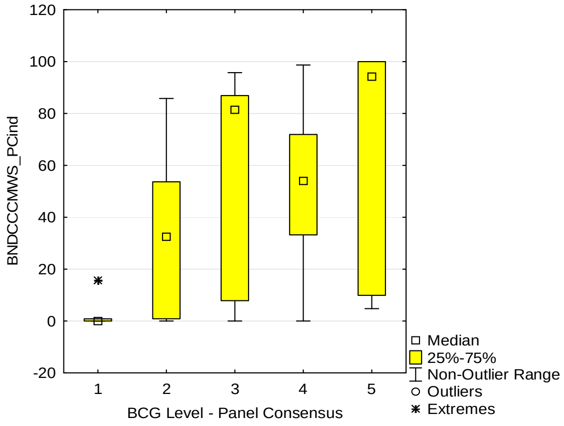

Salmonid_PCtax
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

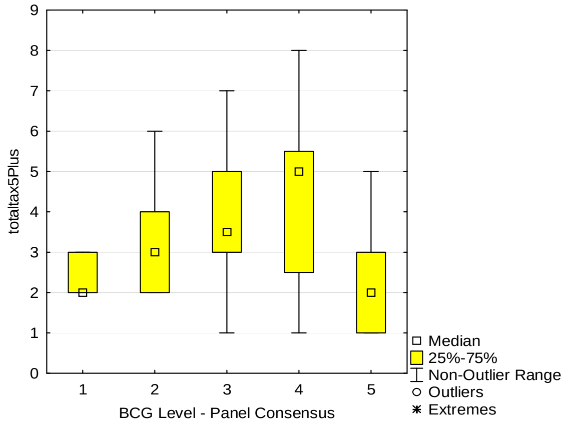

Salmonid_PCind
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes


Cyprin_tax
105.5
105.0
104.5
104.0
103.5
103.0
102.5
102.0
101.5
101.0
100.5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

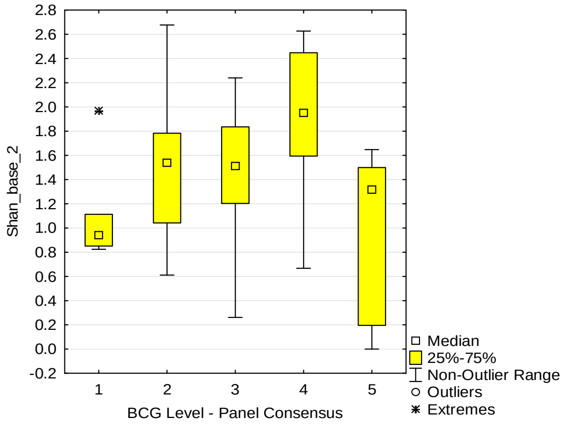

Cyprin_PCtax
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes


Cyprin_PCind
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

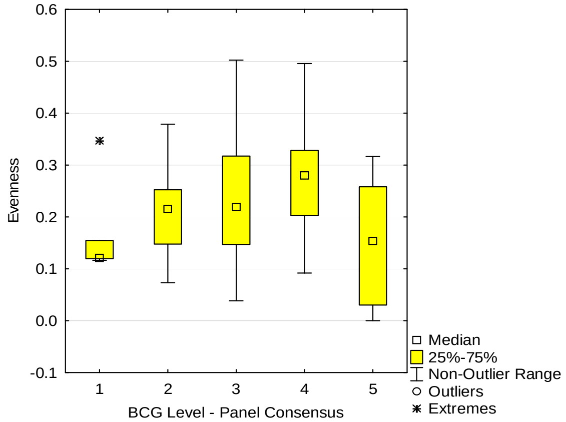

BNDCCCMWS_PCind
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes



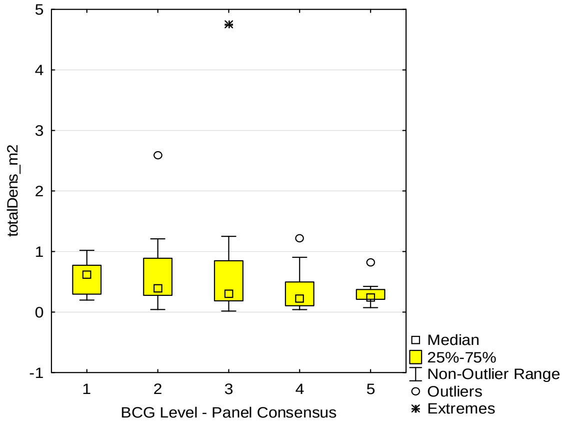
totaltax5Plus
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



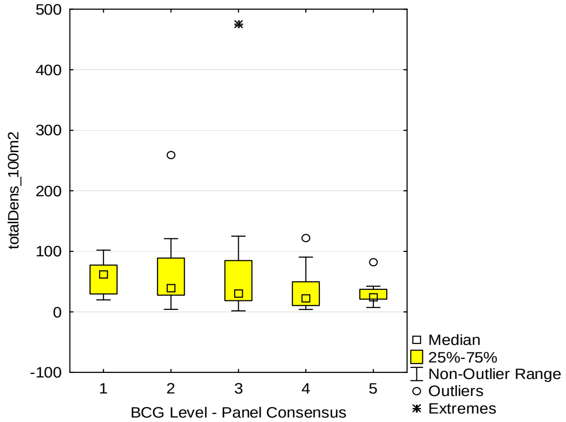
Shan_base_2
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



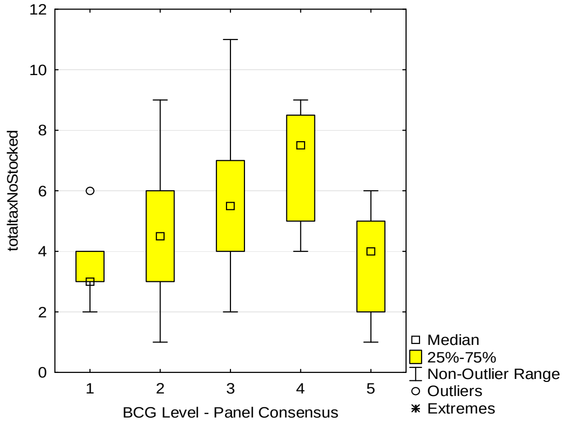
Evenness
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



totalDens_m2
5
4
3
2
1
0
-1
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



totalDens_100m2
500
400
300
200
100
0
-100
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



totaltaxNoStocked
12
10
8
6
4
2
0
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

APPENDIX G

Small-cold BCG Level Assignments

Appendix G. Participants made BCG level assignments on 40 small-cold samples for the calibration exercise and 14 samples for the validation exercise. Samples were assessed using the scoring scale shown in Table G1.

Table G1. Scoring scale that was used for making BCG level assignments.

best	1
	1-
	2+
	2
	2-
	3+
	3
	3-
	4+
	4
	4-
	5+
	5
	5-
	6+
	6
worst	6-

Table G-2. BCG level assignments and sample information for ***small-cold*** samples that were assessed during the ***calibration*** exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants), without the + or - (2+ and 2- were assigned to level 2, etc.); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table G1); Worst=the worst BCG level assignment given by a participant; Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model.

Fish SampID	Collection Date	Station ID	Waterbody Name	Phase 1 Class	Panelist consensus			Primary Model	Notes
					Final	Best	Worst		
13245	6/10/2008	23	Bunnell Brook	small_cold	5	4	5	5	
3045	7/9/2001	131	Hubbard Brook	small_cold	1	1	3+	2/3 (tie)	repeat sample (round1=2; round 2=1)
3044	7/9/2001	132	Hubbard Brook	small_cold	2	2+	3	2	
13313	8/1/2008	428	Coginchaug River	small_cool	3	2	4+	4	
21557	7/29/2010	670	Brides Brook	small_cool	2	1	2-	2	
22345	9/10/2010	697	Steele Brook	small_cool	4	3	5	5	
14439	6/4/2009	763	Rocky Brook	small_cold	3	1	3-	3	
4519	7/22/2003	911	Beach Brook	small_cold	2	1	3	1	
4468	7/2/2003	924	Clark Creek	small_cool	3	2	3-	3	
8647	7/19/2006	927	Fivemile Brook	small_cold	3	3	4	3	
4430	6/24/2003	933	Wood Creek	small_cold	2	2	3	2	
4514	7/17/2003	971	Jefferson Hill Brook	small_cold	2	2+	3-	2	
21547	7/28/2010	1035	Meetinghouse Brook	small_cool	4	3-	5	4	repeat sample (both rounds=4)
13159	7/17/2008	1257	Webster Brook	small_cool	3	2	3	4	
5249	6/28/2004	1440	Sages Ravine Brook	small_cold	1	1	2+	1	
21322	7/21/2010	1456	Bone Mill Brook	small_cold	1	1	2	1	
6557	7/12/2005	1659	Cedar Swamp Brook	small_cold	5	5	6	5	
6558	7/12/2005	1660	Cedar Swamp Brook	small_cold	5	5+	6+	5	
20495	6/11/2010	1916	Thompson Brook	small_cool	2	1	2	2	repeat sample (both rounds=2)
8561	7/11/2006	1939	Sanford Brook	small_cold	2	2+	3	2	

Table G-2. continued…

Fish SampID	Collection Date	Station ID	Waterbody Name	Phase 1 Class	Panelist consensus			Primary Model	Notes
					Final	Best	Worst		
8682	7/20/2006	1951	Town Farm Brook (Clatter Valley)	small_cold	3	2	4	3	repeat sample (both rounds=3)
8815	7/31/2006	1966	Ekonk Brook	small_cool	4	3	5+	4	
8919	8/4/2006	1976	Menunketesuck River	small_cool	4	3	4	2	
11067	7/19/2007	2295	Mott Hill Brook	small_cold	1	1	2	1	
20315	6/2/2010	2295	Mott Hill Brook	small_cold	2	1	2	2	
20630	6/17/2010	2342	Brown Brook	small_cold	2	2+	3+	2/3 (tie)	
12733	6/18/2008	2343	Bruce Brook	small_cool	5	4-	6	5	repeat sample (both rounds=5)
20256	6/1/2010	2532	Branch Brook	small_cold	4	2-	4-	3	
13038	7/7/2008	2533	Straddle Brook	small_cold	4	3-	5+	4	
21127	7/9/2010	2634	Green Fall River	small_cool	2	2+	3-	2	repeat sample (round1=2; round 2=2/3 tie)
14944	7/17/2009	2672	Sumner Brook	small_cold	3	2	4	4	repeat sample (round1=4; round 2=3)
12676	6/11/2008	2680	Jacks Brook	small_cool	4	4	5	5	
12595	6/9/2008	2693	Lydall Brook	small_cold	5	5	6	5	
12597	6/9/2008	2709	Bigelow Brook	small_cool	4	2+	4-	4	repeat sample (round1=2; round 2=4)
13244	6/10/2008	2710	Punch Brook	small_cold	3	2	4	3	
13105	7/11/2008	2714	East Mountain Brook	small_cold	2	2+	3-	4	
21307	7/16/2010	5845	Stony Brook	small_cool	2	1-	4+	3	repeat sample (both rounds=2)
15551	9/9/2009	5923	Gulf Brook	small_cold	5	3	5-	5	
20632	6/17/2010	6125	Beebe Brook	small_cool	3	2-	4	4	repeat sample (both rounds=3)
21440	7/22/2010	6163	Pease Brook	small_cool	3	3	4	4	

Table G-3. Site information for ***small-cold*** fish samples that were analyzed during the BCG ***calibration*** exercise. Area refers to the upstream watershed area. Land use (%Devl=% developed, % Imperv= % impervious, % Natl= % natural) is for the upstream catchment area. TNC fields are derived from The Nature Conservancy's Northeast Aquatic Habitat Classification (Olivero and Anderson 2008). TITAN thermal classes were based on Beauchene et al. 2012. Additional information (i.e. nutrient and habitat data) may available for some of the sites.

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
23	Bunnell Brook	-72.9657	41.7846	4.2	Southern New England Coastal Plains and Hills	11.7	4.4	67.3	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	
131	Hubbard Brook	-72.5803	41.7082	2.2	Connecticut Valley	27.5	10.5	50.3	High Gradient: >=2 < 5%	Low Buffered, Acidic	Cold	
132	Hubbard Brook	-72.5843	41.7089	2.2	Connecticut Valley	27.5	10.5	50.3	High Gradient: >=2 < 5%	Low Buffered, Acidic	Cold	
428	Coginchaug River	-72.6882	41.4435	3.6	Connecticut Valley	5.1	2.7	78.8	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
670	Brides Brook	-72.2419	41.3360	0.3	Long Island Sound Coastal Lowland	15.0	4.8	79.3	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
697	Steele Brook	-73.1153	41.6105	5.9	Southern New England Coastal Plains and Hills	19.3	8.1	40.7	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	1
763	Rocky Brook	-71.8020	42.0134	0.5	Southern New England Coastal Plains and Hills	2.2	4.2	14.8	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	
911	Beach Brook	-72.8575	41.9460	2.1	Berkshire Transition	1.3	1.6	95.5	Very High Gradient: >5%	Moderately Buffered, Neutral	Cold	
924	Clark Creek	-72.4735	41.4426	2.4	Long Island Sound Coastal Lowland	3.6	2.0	94.2	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	
927	Fivemile Brook	-73.1597	41.3846	1.9	Southern New England Coastal Plains and Hills	15.9	4.9	74.3	Very High Gradient: >5%	Moderately Buffered, Neutral	Cold	

Table G-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
933	Wood Creek	-73.2362	41.6387	3.4	Southern New England Coastal Plains and Hills	7.9	3.3	75.9	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
971	Jefferson Hill Brook	-73.1195	41.7477	2.5	Berkshire Transition	4.5	2.5	79.9	Very High Gradient: >5%	Moderately Buffered, Neutral	Cold	1
1035	Meetinghouse Brook	-72.8160	41.4913	4.3	Connecticut Valley	45.2	21.1	16.6	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	
1257	Webster Brook	-72.7421	41.6405	5.4	Connecticut Valley	57.1	27.8	15.1	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
1440	Sages Ravine Brook	-73.4245	42.0497	3.5		0.7	1.8	22.1	Very High Gradient: >5%	Moderately Buffered, Neutral	Cold	1
1456	Bone Mill Brook	-72.3162	41.9250	2.5	Lower Worcester Plateau/Eastern Connecticut Upland	5.3	2.6	88.6	High Gradient: >=2 < 5%	Low Buffered, Acidic	Cold	1
1659	Cedar Swamp Brook	-72.2790	41.8164	2.5	Southern New England Coastal Plains and Hills	16.4	5.2	70.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	3
1660	Cedar Swamp Brook	-72.2841	41.8110	2.5	Southern New England Coastal Plains and Hills	16.4	5.2	70.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
1916	Thompson Brook	-72.8497	41.7681	3.9	Connecticut Valley	22.3	9.7	53.6	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	1
1939	Sanford Brook	-72.9364	41.4723	1.0	Connecticut Valley	14.8	6.6	76.9	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	

Table G-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
1951	Town Farm Brook (Clatter Valley)	-73.3889	41.5477	3.8	Southern New England Coastal Plains and Hills	14.1	4.9	60.7	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
1966	Ekonk Brook	-71.8652	41.6952	3.7	Southern New England Coastal Plains and Hills	3.8	2.5	76.5	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
1976	Menunketesuck River	-72.5519	41.3898	1.9	Southern New England Coastal Plains and Hills	10.8	4.0	78.6	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
2295	Mott Hill Brook	-72.5365	41.6615	2.8	Southern New England Coastal Plains and Hills	3.1	2.2	90.1	High Gradient: >=2 < 5%	Low Buffered, Acidic	Cold	1
2342	Brown Brook	-73.2799	41.9267	5.6	Berkshire Transition	0.5	1.2	98.6	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	1.5
2343	Bruce Brook	-73.1551	41.1899	2.7	Long Island Sound Coastal Lowland	79.9	35.9	5.8	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	
2532	Branch Brook	-72.1256	41.9199	4.9	Lower Worcester Plateau/Eastern Connecticut Upland	3.8	2.0	90.4	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
2533	Straddle Brook	-72.3782	41.7270	4.4	Southern New England Coastal Plains and Hills	8.1	3.3	78.1	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	

Table G-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
2634	Green Fall River	-71.8159	41.4816	4.0	Southern New England Coastal Plains and Hills	2.8	2.0	93.5	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
2672	Sumner Brook	-72.6375	41.4835	1.5	Southern New England Coastal Plains and Hills	7.6	3.1	86.3	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
2680	Jacks Brook	-73.1170	41.4420	1.8	Southern New England Coastal Plains and Hills	7.9	3.3	78.5	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	
2693	Lydall Brook	-72.5215	41.7952	2.8	Connecticut Valley	39.0	29.8	45.8	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	2
2709	Bigelow Brook	-72.5530	41.7846	3.2	Connecticut Valley	73.8	32.5	14.1	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	1
2710	Punch Brook	-72.9259	41.7815	1.7	Southern New England Coastal Plains and Hills	8.2	3.4	84.7	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
2714	East Mountain Brook	-72.9778	41.8772	3.1	Berkshire Transition	9.6	3.5	80.2	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
5845	Stony Brook	-72.1730	41.3691	2.8	Long Island Sound Coastal Lowland	19.7	7.3	65.5	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
5923	Gulf Brook	-72.7807	41.3805	1.1	Connecticut Valley	0.0	1.3	100.0	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	

Table G-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
6125	Beebe Brook	-73.4807	41.8406	2.7	Western New England Marble Valleys	2.1	1.5	96.2	Very Low Gradient: <0.02%	Moderately Buffered, Neutral	Transitional Cool	
6163	Pease Brook	-72.2349	41.6418	2.7	Southern New England Coastal Plains and Hills	5.6	2.9	72.3	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	

Table G-4. BCG level assignments and sample information for ***small-cold*** samples that were assessed during the ***validation*** exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants), without the + or - (2+ and 2- were assigned to level 2, etc.); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table G1); Worst=the worst BCG level assignment given by a participant; Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model (model assignment 1=primary; 2=secondary; tie=tie between primary and secondary).

Fish SampID	Collection Date	Station ID	Waterbody Name	Phase 1 Class	Panelist consensus			Primary Model	Notes
					Final	Best	Worst		
12725	6/16/2008	260	Pequabuck River	small_cold	5	4+	5	5	
12686	6/13/2008	1004	Wash Brook	small_cool	4	3+	4-	4	
13155	7/17/2008	1338	Belcher Brook	small_cool	4	3-	4-	4	
5255	6/29/2004	1445	Cobble Brook	small_cold	4	3-	4-	4	
5324	7/7/2004	1454	Shepaug River, tributary to	small_cold	2	1-	2-	2	
5373	7/9/2004	1456	Bone Mill Brook	small_cold	1	1	1	1	
8678	7/20/2006	1518	Lee Brook	small_cold	3	2-	5+	3	
13279	7/25/2008	1625	Beaver Brook	small_cold	3/4 (tie)	3	4	3/4 (tie)	
6559	7/12/2005	1661	Nelson Brook	small_cool	5	4-	6	5	
14337	8/24/2007	2291	Branch Brook	small_cold	4	1-	4+	3/4 (tie)	
15533	9/10/2009	2407	Steele Brook	small_cold	5	4	6+	5	
13150	7/14/2008	2719	Cherry Brook, tributary to	small_cold	3	3	4+	3	model assignment is close to a 4
13203	7/18/2008	2724	North Brook	small_cold	3	3+	4+	3	
21473	7/27/2010	5346	Jordan Brook	small_cool	2	2+	3	2/3 (tie)	

Table G-5. Site information for ***small-cold*** fish samples that were analyzed during the BCG ***validation*** exercise. Area refers to the upstream watershed area. Land use (%Devl=% developed, % Imperv= % impervious, % Natl= % natural) is for the upstream catchment area. TNC fields are derived from The Nature Conservancy's Northeast Aquatic Habitat Classification (Olivero and Anderson 2008). Additional information (i.e. nutrient and habitat data) may available for some of the sites.

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class (median)
260	Pequabuck River	-73.01503	41.67887	2.3	Southern New England Coastal Plains and Hills	21.8	8.8	48.2	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	
1004	Wash Brook	-72.73766	41.81698	3.8	Connecticut Valley	26.1	9.2	34.4	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
1338	Belcher Brook	-72.75766	41.60498	3.9	Connecticut Valley	28.8	9.1	52.9	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	3
1445	Cobble Brook	-73.45424	41.74538	4.5	Berkshire Transition	5.9	2.9	78.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
1454	Shepaug River, tributary to	-73.34472	41.59025	2.1	Southern New England Coastal Plains and Hills	9.2	3.9	55.1	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
1456	Bone Mill Brook	-72.31624	41.92499	2.5	Lower Worcester Plateau/Eastern Connecticut Upland	5.3	2.6	88.6	High Gradient: >=2 < 5%	Low Buffered, Acidic	Cold	1

Table G-5. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class (median)
1518	Lee Brook	-73.22893	41.43336	1.2	Southern New England Coastal Plains and Hills	17.9	5.3	74.9	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
1625	Beaver Brook	-72.99575	41.95125	2.0	Lower Berkshire Hills	3.9	2.0	89.8	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
1661	Nelson Brook	-72.28434	41.81076	1.8	Southern New England Coastal Plains and Hills	14.9	4.8	74.4	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
2291	Branch Brook	-72.12450	41.91081	4.9	Lower Worcester Plateau/Eastern Connecticut Upland	3.8	2.0	90.4	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
2407	Steele Brook	-73.13100	41.61750	1.6	Southern New England Coastal Plains and Hills	14.5	7.1	30.1	High Gradient: >=2 < 5%	Low Buffered, Acidic	Cold	
2719	Cherry Brook, tributary to	-72.89249	41.89822	1.8	Berkshire Transition	4.8	2.4	91.6	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
2724	North Brook	-73.01374	41.84648	1.9	Berkshire Transition	10.3	3.6	80.1	High Gradient: >=2 < 5%	Moderately Buffered, Neutral	Cold	
5346	Jordan Brook	-72.15078	41.36723	3.5	Long Island Sound Coastal Lowland	18.7	6.1	64.9	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	

APPENDIX H

Box plots of metrics for medium-large samples that were assessed

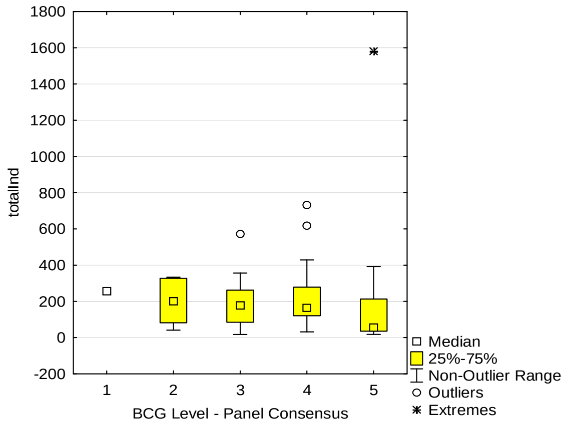
Box plots were generated to examine the distributions of metric values across BCG levels. Table F1 contains descriptions of the metric codes that are on the y-axes of the plots.

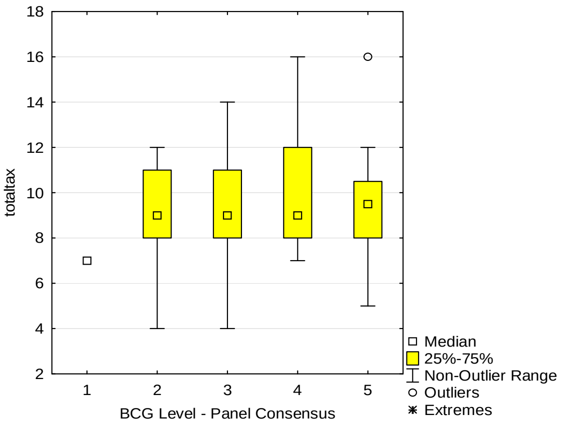
Table H1. Descriptions of the metric codes that are on the y-axes of the box plots.

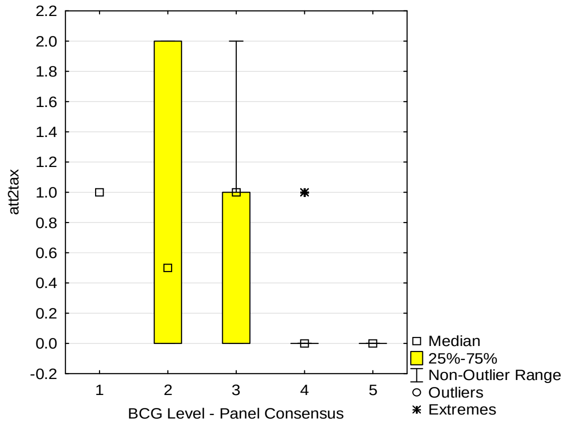
Metric Code	**Description**
totalInd	Number of total individuals
totaltax	Number of total taxa
att2tax	Number of Attribute II taxa
att23tax	Number of Attribute II + III taxa
att3tax	Number of Attribute III taxa
att4tax	Number of Attribute IV taxa
att5tax	Number of Attribute V taxa
att6tax	Number of Attribute VI taxa
att56tax	Number of Attribute V + VI taxa
att6atax	Number of Attribute VIa taxa
att10tax	Number of Attribute X taxa
att2PCInd	% Attribute II individuals
att23PCInd	% Attribute II + III individuals
att3PCInd	% Attribute III individuals
att23_6bPCInd	% Attribute II + III + VIb individuals
att4PCInd	% Attribute IV individuals
att1234PCInd	% Attribute I + II + III + IV individuals
att5PCInd	% Attribute V individuals
att6PCInd	% Attribute VI individuals
att5_6PCInd	% Attribute V + VI individuals
att5_6aPCInd	% Attribute V + VIa individuals
att6_6aPCInd	% Attribute VI + VIa individuals
att6b_PCInd	% Attribute VIb individuals
att6ab_PCInd	% Attribute VIa + VIb individuals
att10PCInd	% Attribute X individuals
att2PCtax	% Attribute II taxa
att3PCtax	% Attribute III taxa
att23PCtax	% Attribute II + III taxa
att23_6bPctax	% Attribute II + III + VIb taxa
att4Pctax	% Attribute IV taxa
att234_6bPctax	% Attribute I + II + III + IV + VIb taxa
att5Pctax	% Attribute V taxa
att6Pctax	% Attribute VI taxa
att6aPctax	% Attribute VIa taxa
att6bPctax	% Attribute VIb taxa
att10Pctax	% Attribute X taxa
att4Dom	% Most dominant Attribute IV taxon

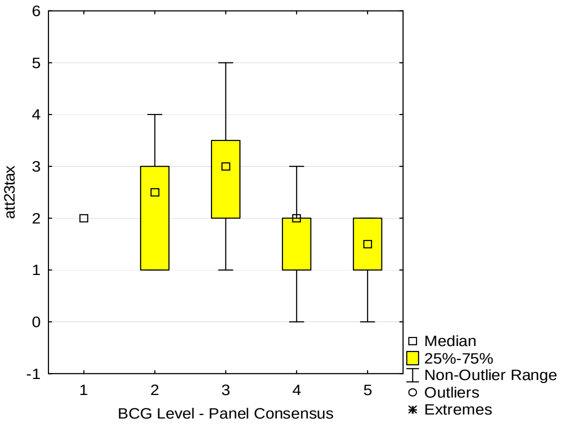
Table H1 continued…

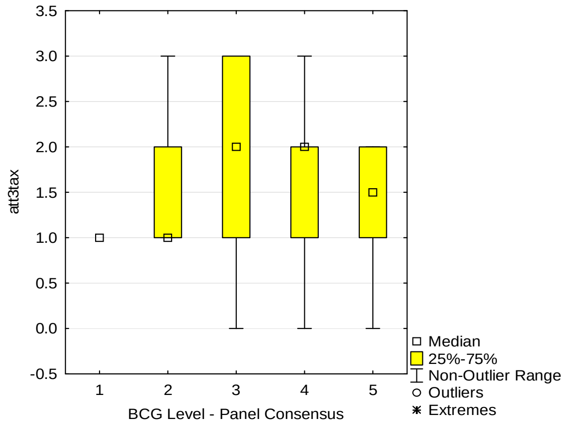
Metric Code	**Description**
att5Dom	% Most dominant Attribute V taxon
att6Dom	% Most dominant Attribute VI taxon
att6aDom	% Most dominant Attribute VIa taxon
att566aDom	% Most dominant Attribute V + VI + VIa taxon
BrookTroutPCInd	% Wild brook trout individuals
BrownTroutPCInd	% Brown trout individuals
BKT_TotalSalm_PCind	(# Wild brook trout individuals/# total salmonid individuals)*100
att6bSalm_TotalSalm_PCIid	(# Attribute 6b salmonid individuals/# total salmonid individuals)*100
Centrarchid_tax	Number of Centrarchidae taxa
Centrarchid_PCtax	Percent Centrarchidae taxa
Centrarchid_PCind	Percent Centrarchidae individuals
Salmonid_tax	Number of Salmonidae taxa
Salmonid_PCtax	Percent Salmonidae taxa
Salmonid_PCind	Percent Salmonidae individuals
Cyprin_tax	Number of Cyprinidae taxa
Cyprin_PCtax	Percent Cyprinidae taxa
Cyprin_PCind	Percent Cyprinidae individuals
BNDCCCMWS_PCind	% Black nose dace + % creek chub + % cutlips minnow + % white sucker individuals
totaltax5Plus	Number of total taxa, counting only taxa with 5 or more individuals
Shan_base_2	Shannon-wiener diversity index (base 2)
Evenness	Evenness
totalDens_m2	Total density/meter^2
totalDens_100m2	Total density/100 meter^2
totaltaxNoStocked	Total number of taxa, excluding stocked taxa

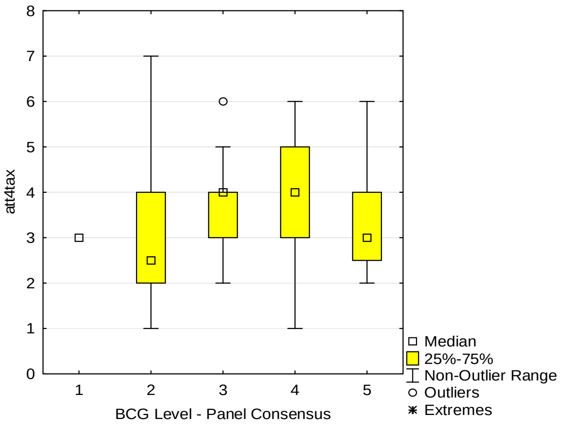

totalInd
1800
1600
1400
1200
1000
800
600
400
200
0
-200
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

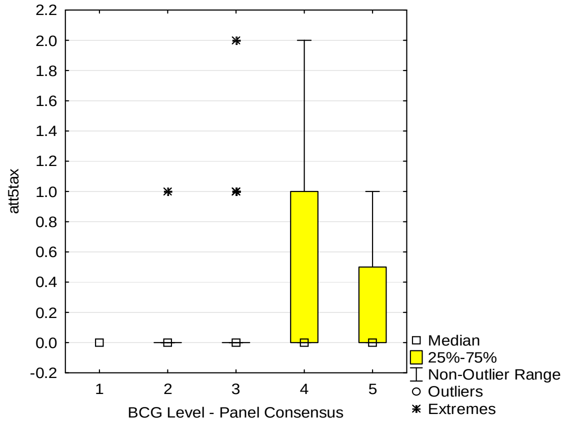

totaltax
18
16
14
12
10
8
6
4
2
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

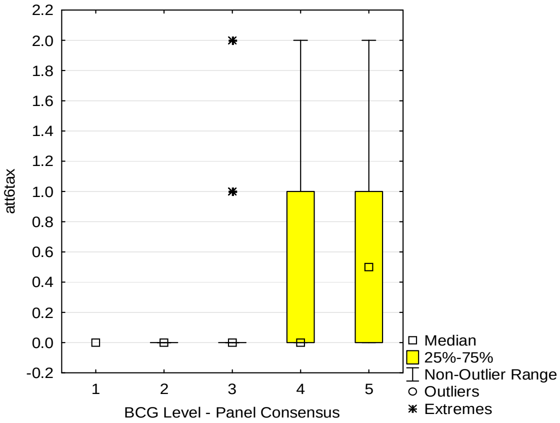

att2tax
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

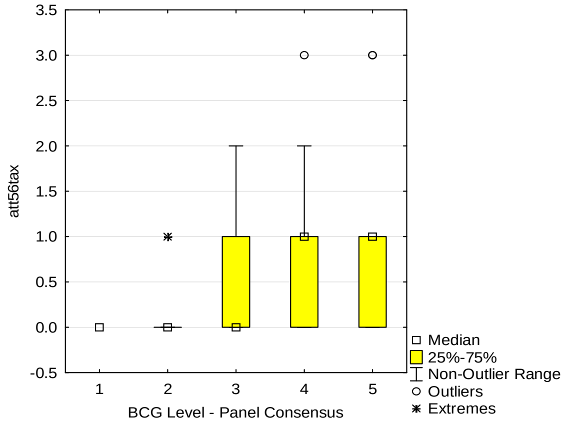

att23tax
6
5
4
3
2
1
0
-1
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

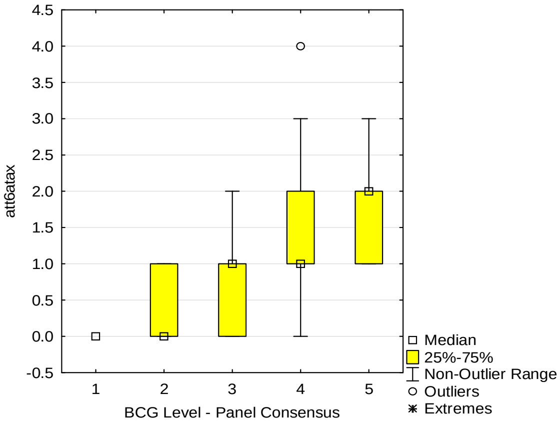

att3tax
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

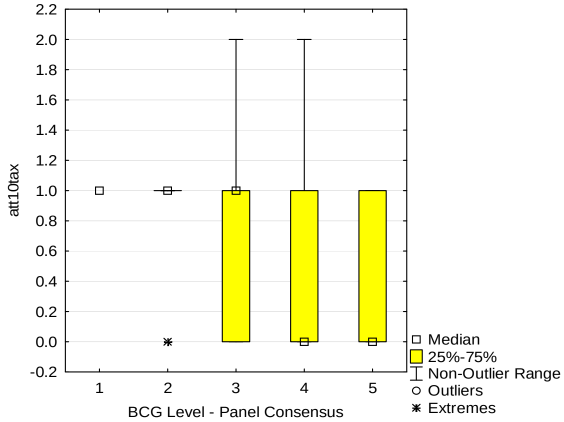

att4tax
8
7
6
5
4
3
2
1
0
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

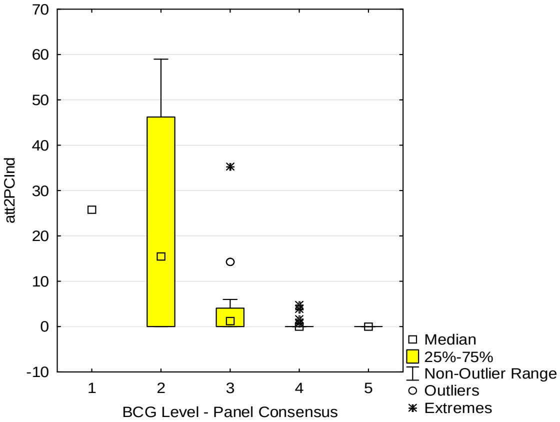

att5tax
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

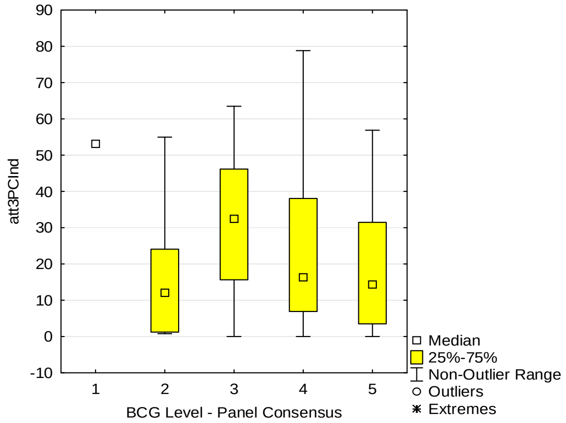

att6tax
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

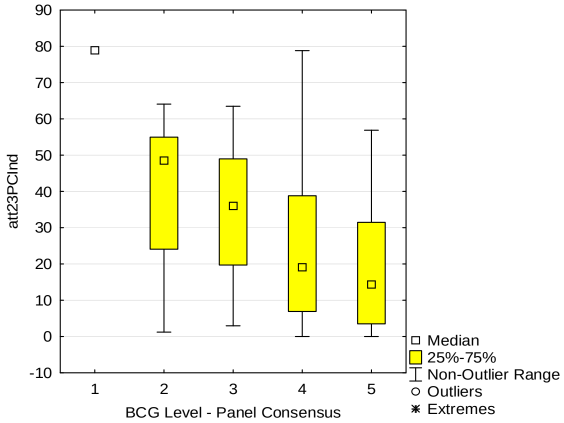

att56tax
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

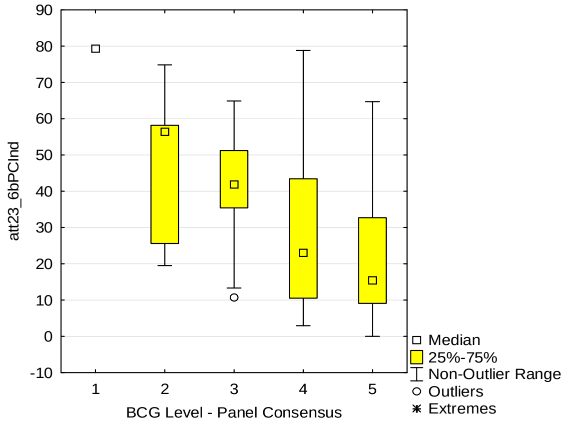

att6atax
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

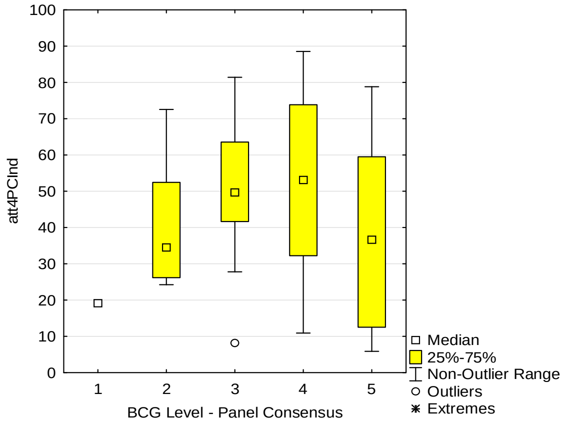

att10tax
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

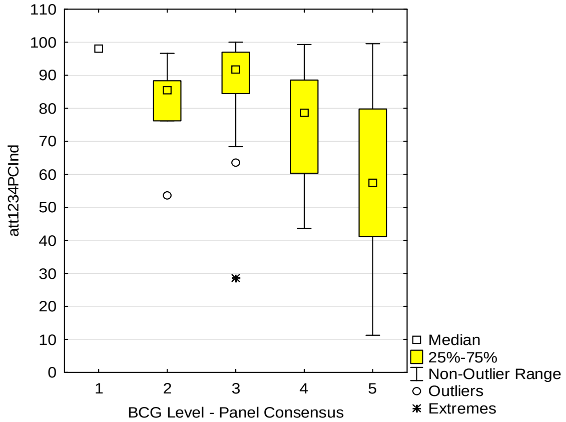

att2PCInd
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

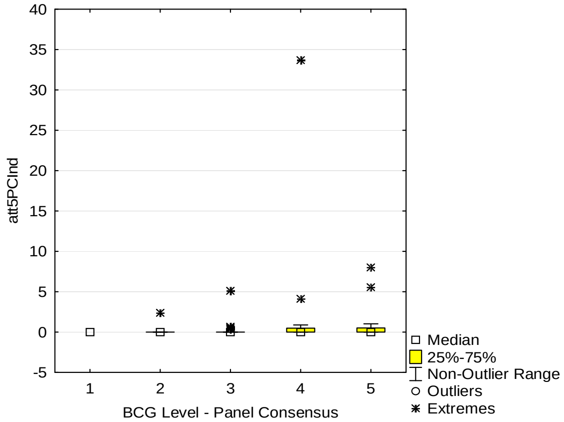

att3PCInd
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

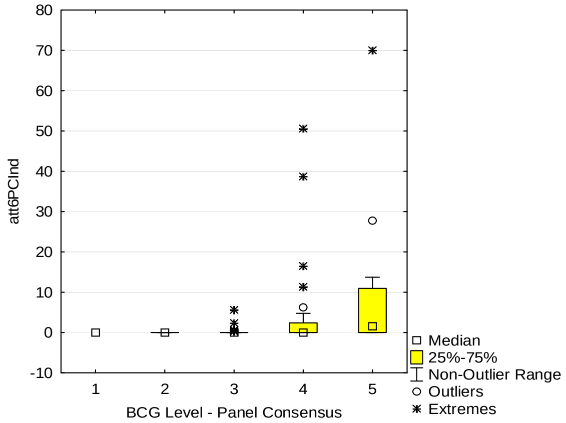

att23PCInd
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

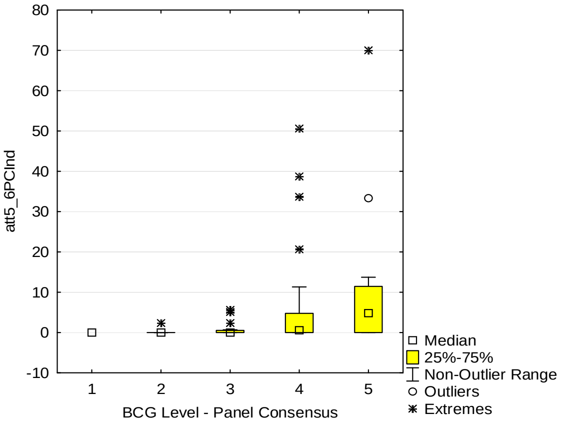

att23_6bPCInd
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

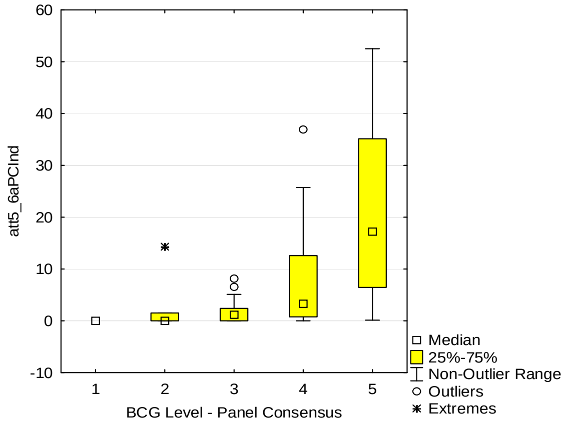

att4PCInd
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

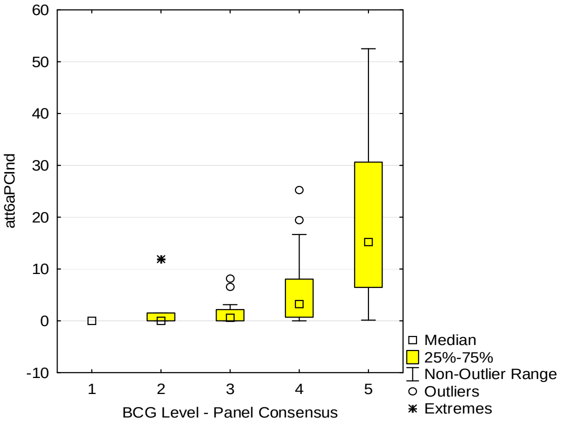

att1234PCInd
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

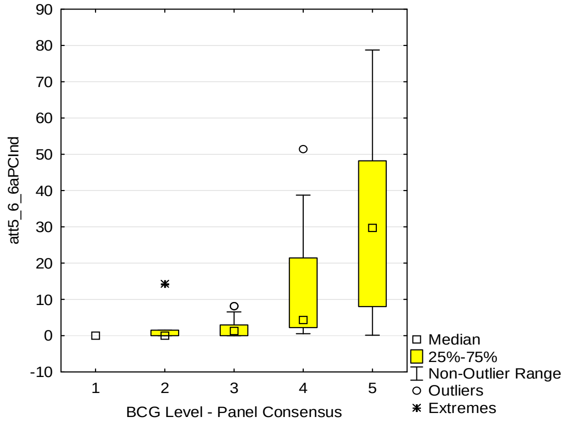

att5PCInd
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

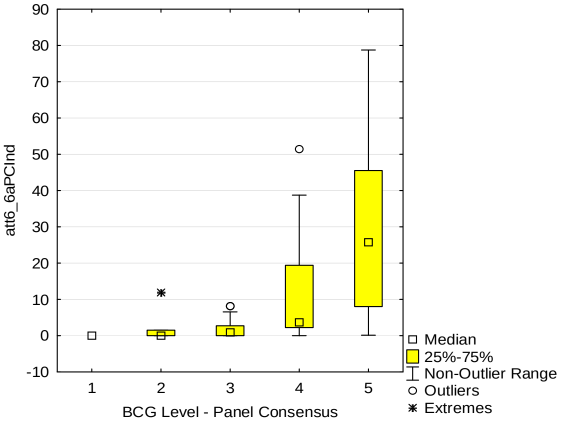

att6PCInd
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

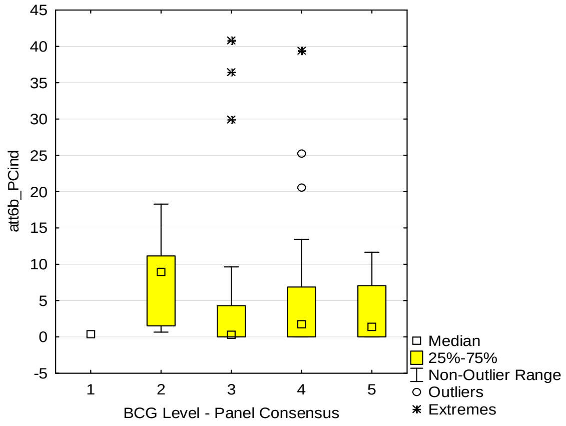

att5_6PCInd
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

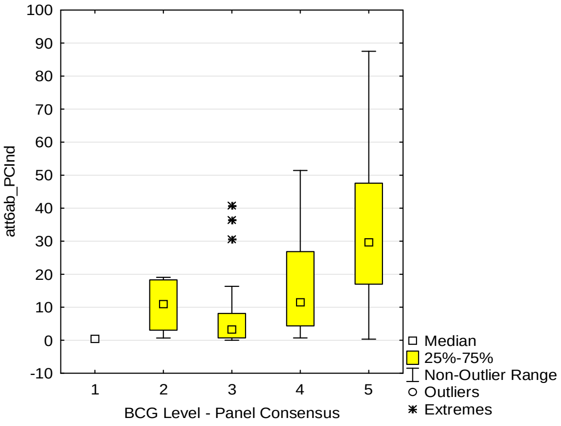

att5_6aPCInd
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

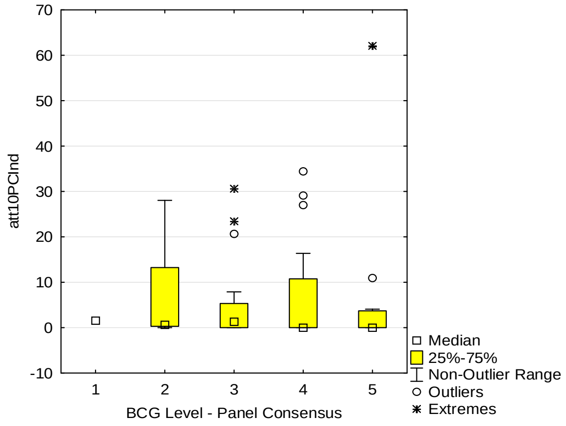

att6aPCInd
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

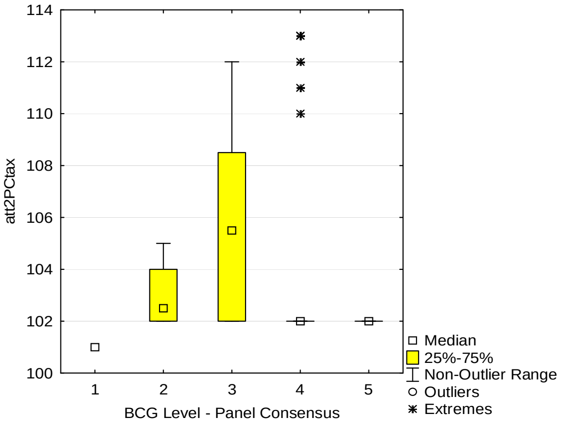

att5_6_6aPCInd
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

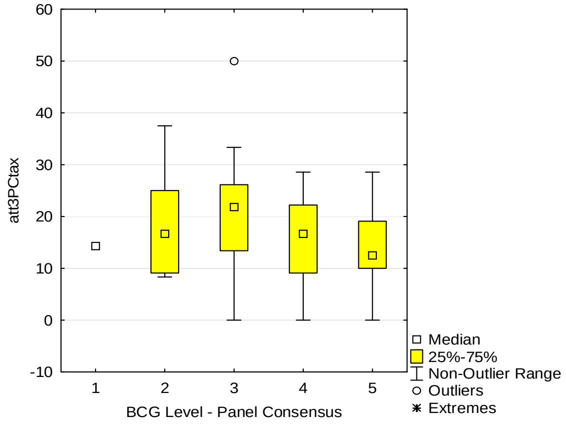

att6_6aPCInd
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

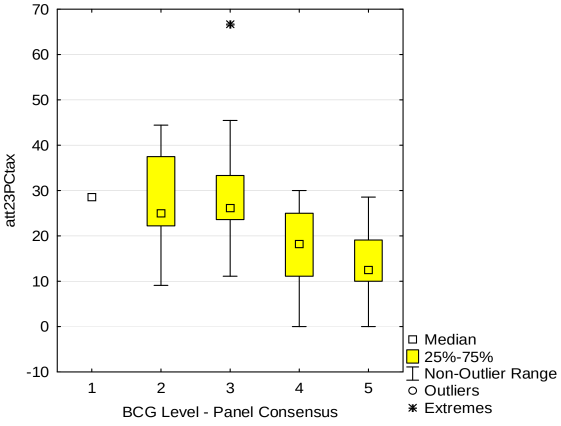

att6b_PCind
45
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

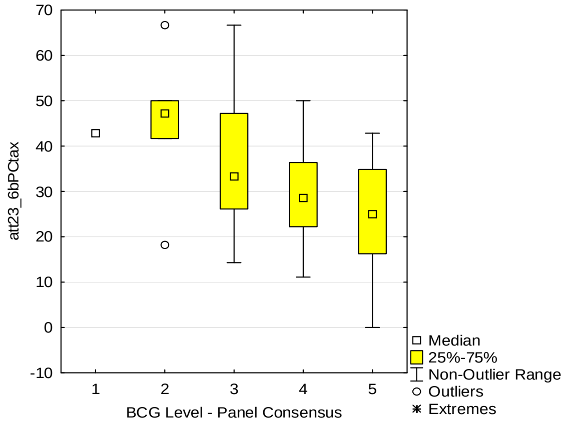

att6ab_PCInd
100
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

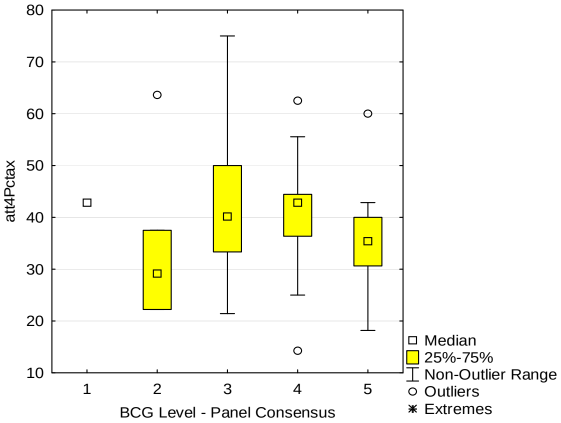

att10PCInd
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

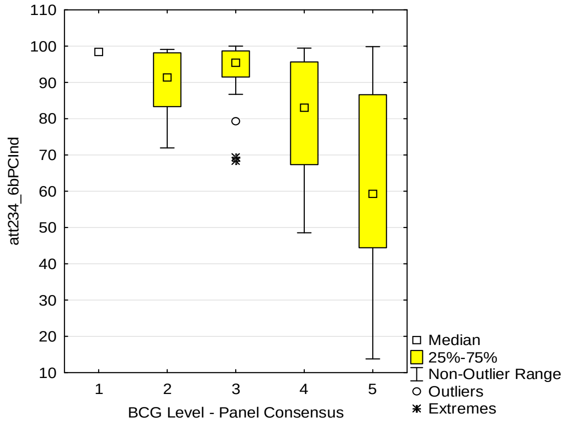

att2PCtax
114
112
110
108
106
104
102
100
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

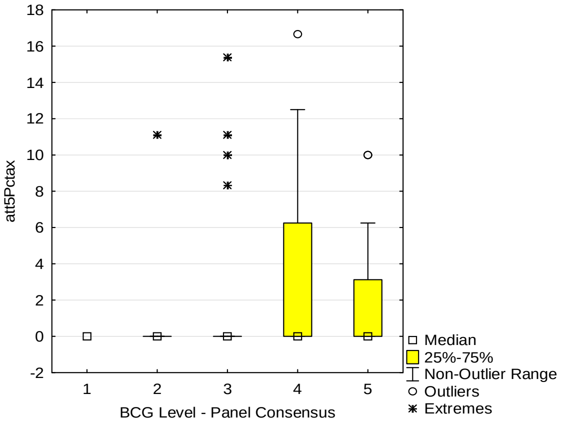

att3PCtax
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

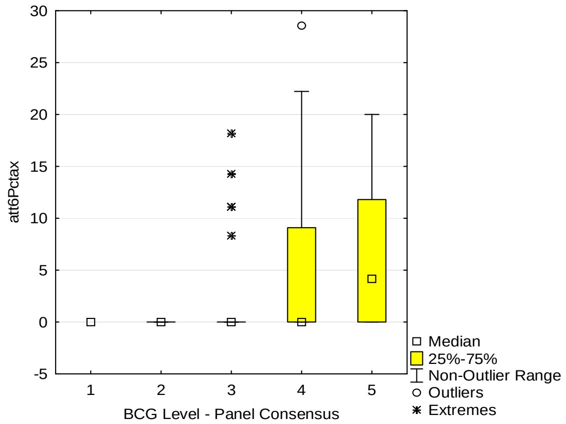

att23PCtax
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

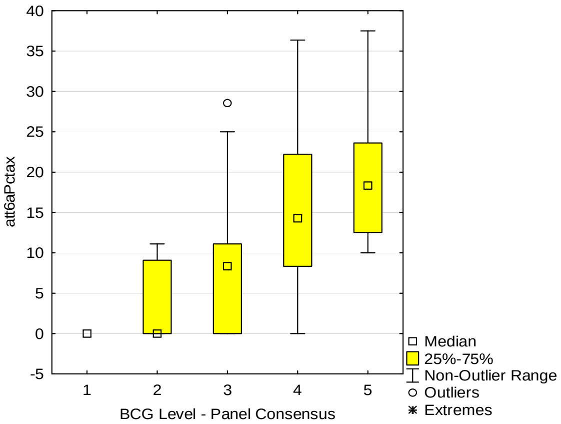

att23_6bPCtax
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

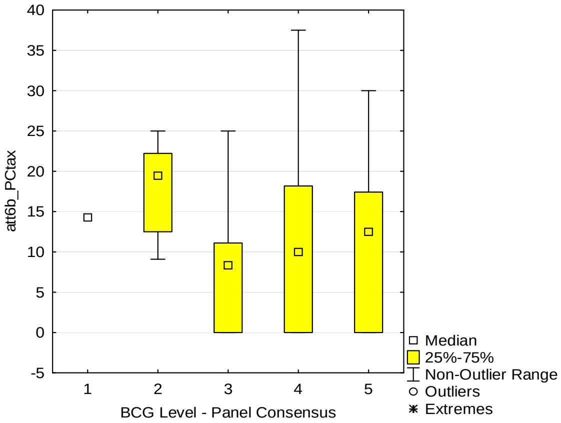

att4Pctax
80
70
60
50
40
30
20
10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

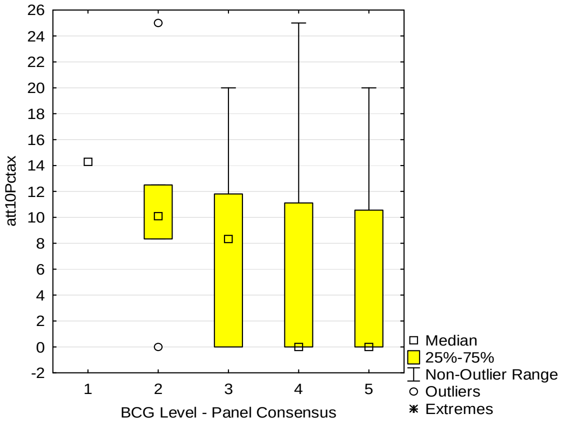

att234_6bPCInd
110
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

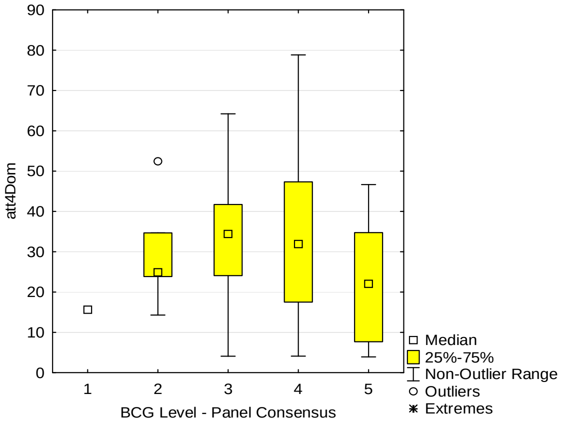

att5Pctax
18
16
14
12
10
8
6
4
2
0
-2
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

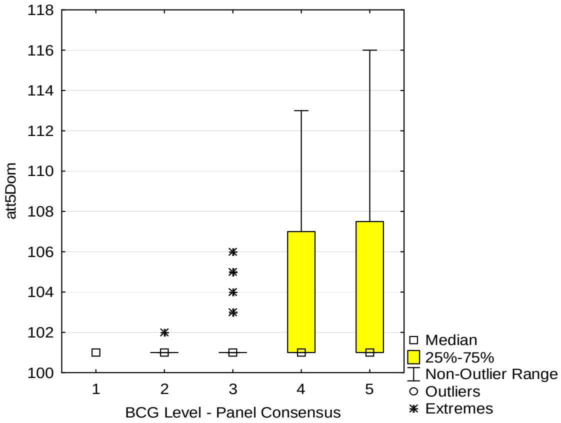

att6Pctax
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

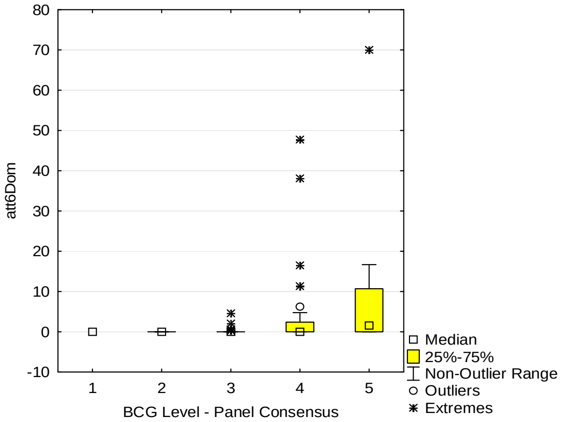

att6aPctax
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✳ Extremes

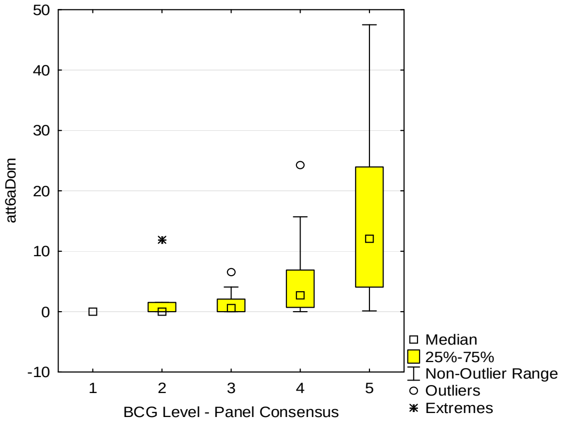

att6b_PCtax
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

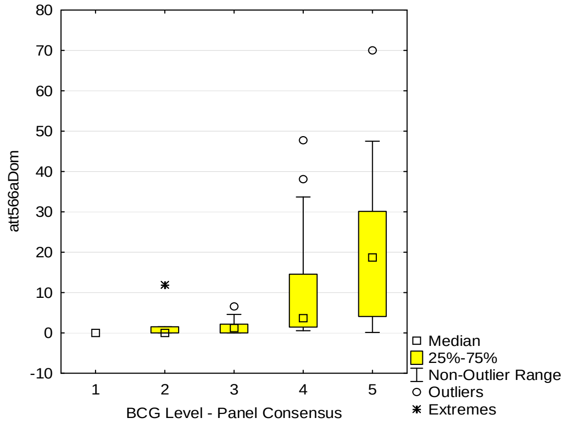

att10Pctax
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

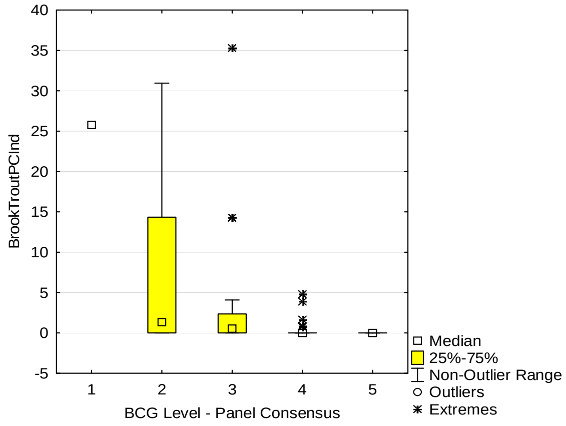

att4Dom
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

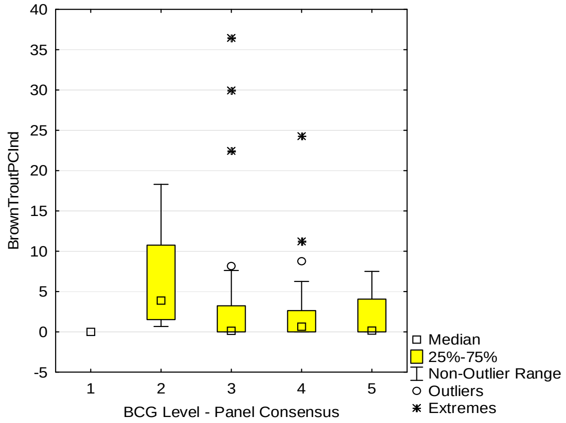

att5Dom
118
116
114
112
110
108
106
104
102
100
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

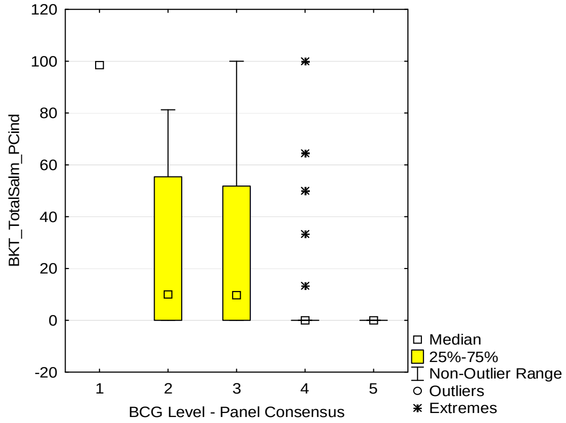

att6Dom
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

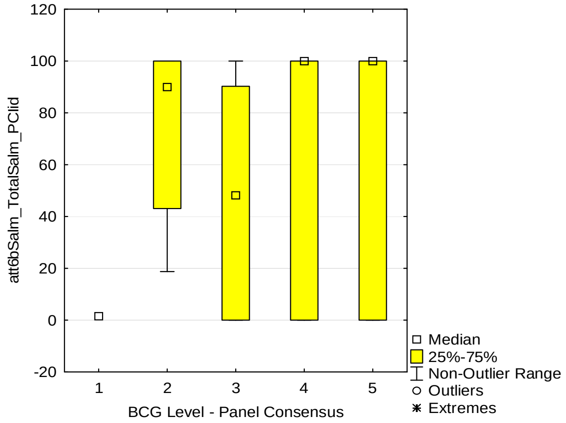

att6aDom
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

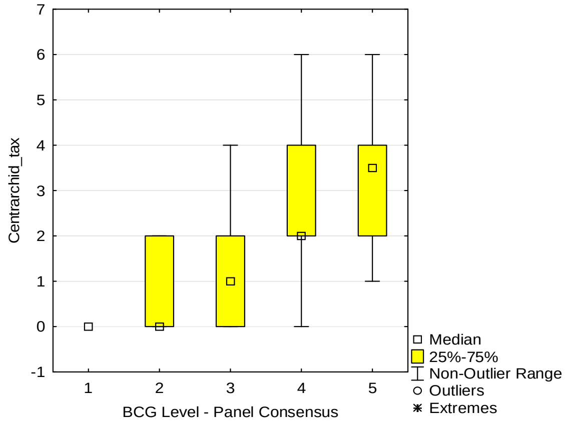

att566aDom
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

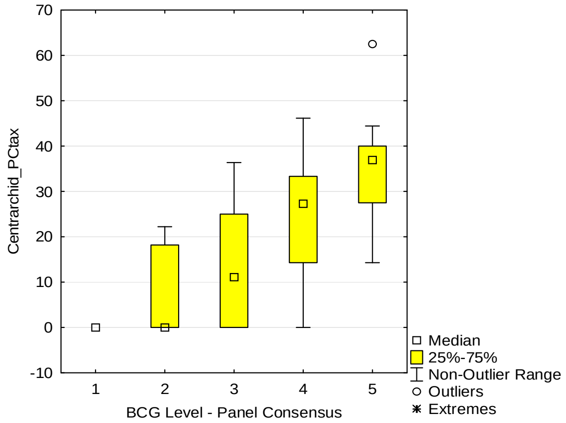

BrookTroutPCInd
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

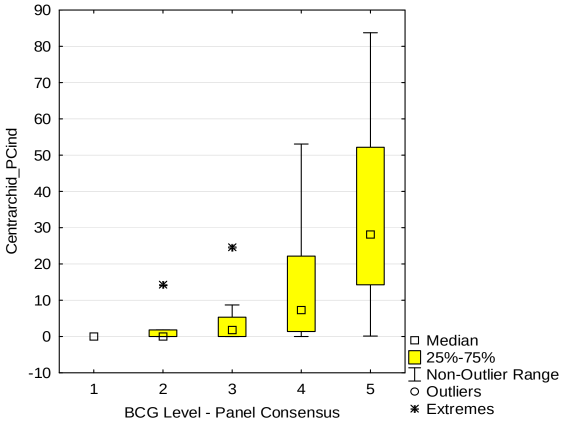

BrownTroutPCInd
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

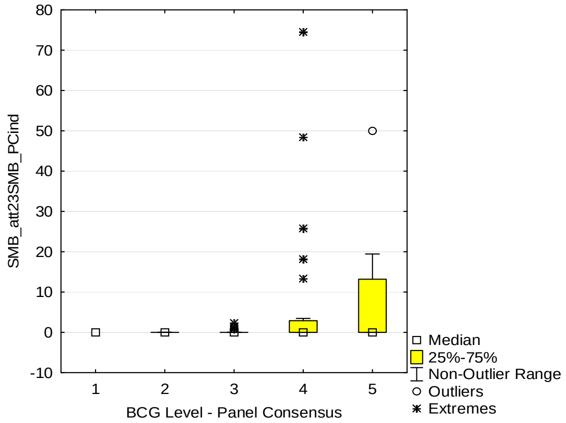

BKT_TotalSalm_PCInd
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

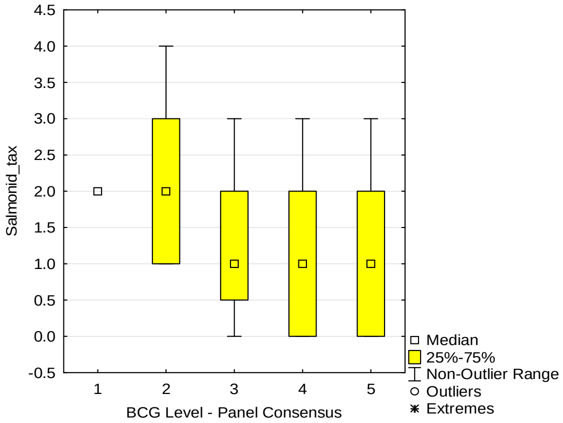

att6bSalm_TotalSalm_PCIid
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

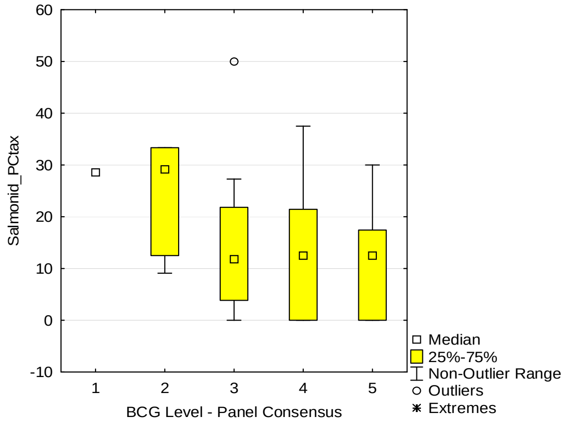

Centrarchid_tax
7
6
5
4
3
2
1
0
-1
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
▨ 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

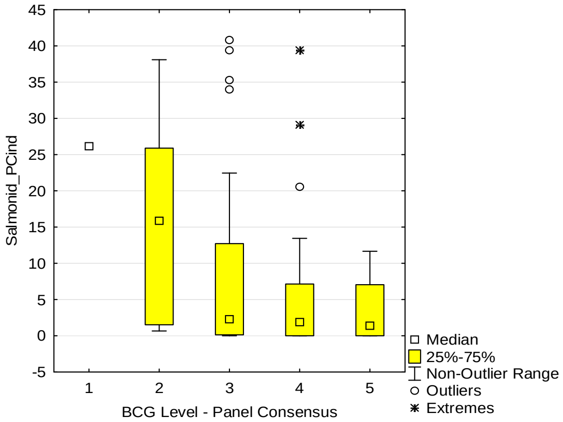

Centrarchid_PCtax
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

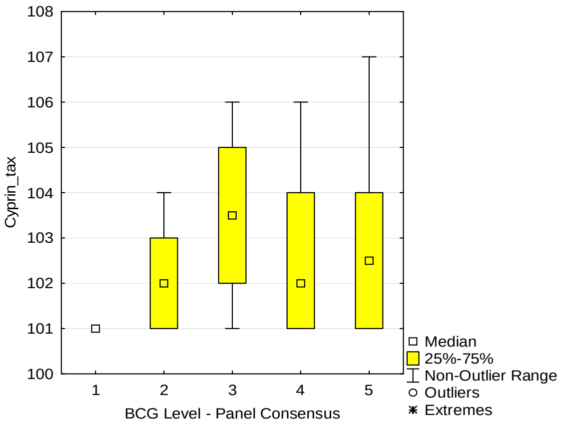

Centrarchid_PCind
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

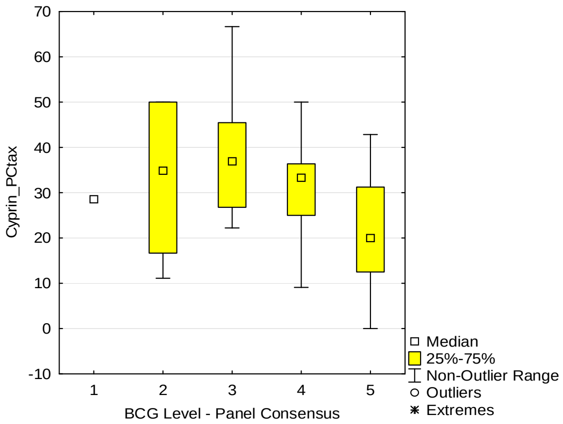

SMB_att23SMB_PCind
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

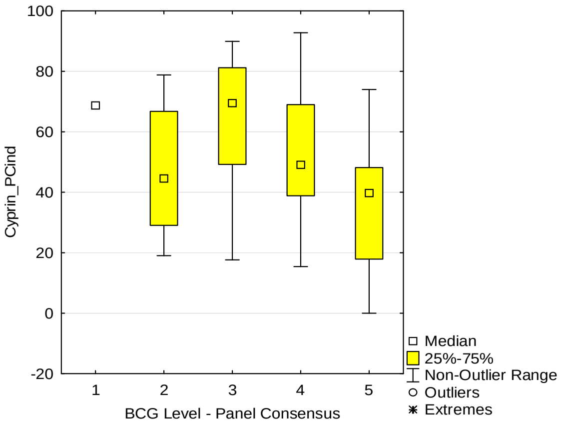

Salmonid_tax
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

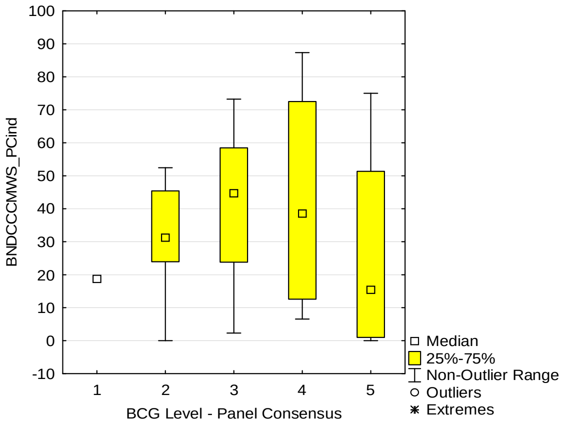

Salmonid_PCtax
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

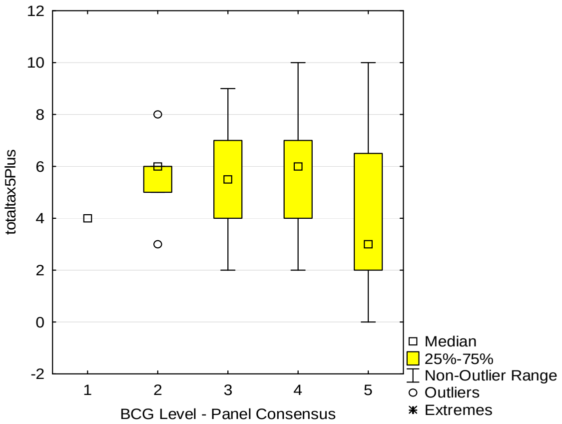

Salmonid_PCind
45
40
35
30
25
20
15
10
5
0
-5
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
🟨 25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

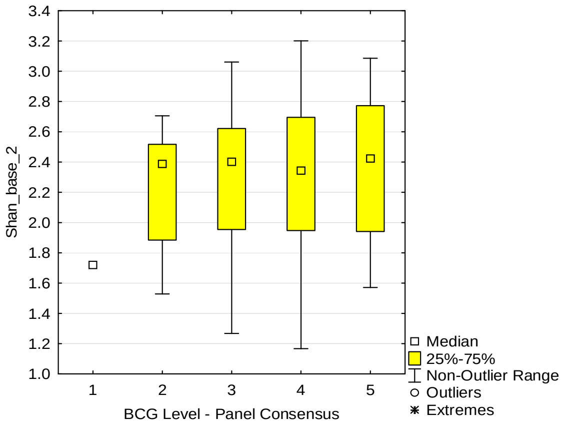

Cyprin_tax
108
107
106
105
104
103
102
101
100
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

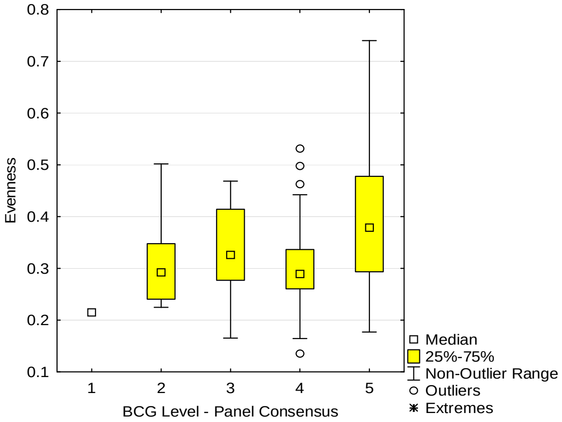

Cyprin_PCtax
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

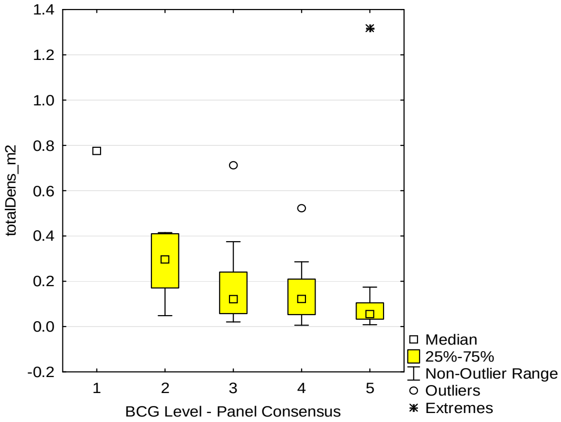

Cyprin_PCind
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

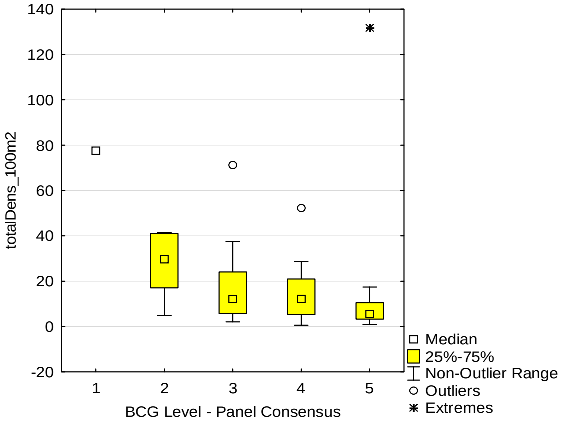

BNDCCMWS_PCind
100
90
80
70
60
50
40
30
20
10
0
-10
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes

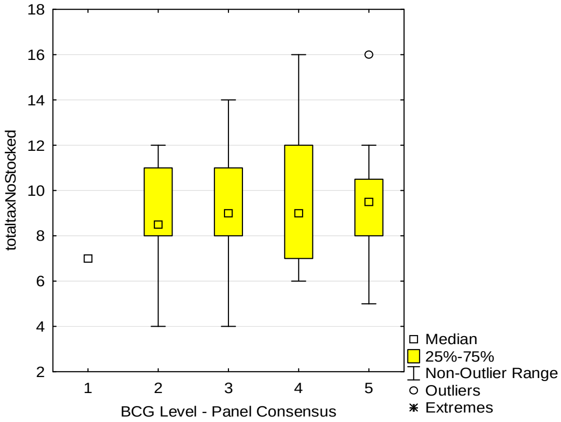

totaltax5Plus
12
10
8
6
4
2
0
-2
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes


Shan_base_2
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
1
2
3
4
5
BCG Level - Panel Consensus
□ Median
25%-75%
Non-Outlier Range
○ Outliers
✱ Extremes


Evenness
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


totalDens_m2
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


totalDens_100m2
140
120
100
80
60
40
20
0
-20
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


totaltaxNoStocked
18
16
14
12
10
8
6
4
2
1
2
3
4
5
BCG Level - Panel Consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

APPENDIX I

Medium-large BCG Level Assignments

Appendix I. Participants made BCG level assignments on 54 medium-large samples for the calibration exercise and 16 samples for the validation exercise. Samples were assessed using the scoring scale shown in Table I1.

Table I1. Scoring scale that was used for making BCG level assignments.

best	1
	1-
	2+
	2
	2-
	3+
	3
	3-
	4+
	4
	4-
	5+
	5
	5-
	6+
	6
worst	6-

Table I-2. BCG level assignments and sample information for ***medium-large*** samples that were assessed during the ***calibration*** exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants), without the + or - (2+ and 2- were assigned to level 2, etc.); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table G1); Worst=the worst BCG level assignment given by a participant; Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model.

Fish SampID	Collection Date	Station ID	Waterbody Name	Phase 1 Class	Panelist consensus			Primary Model	Notes
					Final	Best	Worst		
1922	6/19/2000	272	Piper Brook	medium_cool	5	4	5	4	
3692	7/3/2002	761	Latimer Brook	medium_cool	3	2-	4-	3	
4473	7/8/2003	910	Hollenbeck River	medium_cool	4	3	4	4	
4516	7/18/2003	918	Moosup River	large_cool	3	3	5	4	
5256	6/29/2004	1446	Bantam River	medium_cool	3	2	3	3	
5308	7/1/2004	1449	Yantic River	large_cool	4	3	5	4	
5311	7/1/2004	1450	Blackledge River	medium_cold	4	4+	4-	3/4 (tie)	
5433	7/16/2004	1088	Natchaug River	large_cool	4	3+	5	4	
6520	8/26/2004	1498	Roaring Brook	medium_cold	3	3	4	4	
6539	7/15/2005	472	Moosup River	large_cool	3	2-	3-	3	
8174	6/12/2006	20	Branch Brook	medium_cool	5	4-	6	5	
8510	7/10/2006	319	Saugatuck River	medium_cool	5	5	5-	5	
8788	7/28/2006	216	Naugatuck River	large_cool	3	3+	4-	3	repeat sample (round1=3; round 2=3/4)
9628	9/8/2006	331	Steele Brook	medium_cool	4	3+	5	4	repeat sample (round1=3; round 2=4)
10501	6/14/2007	101	Harbor Brook	medium_cool	3	3+	4	4	
10590	6/21/2007	1281	Sasco Brook	medium_cool	2	2+	3-	4	
10714	6/27/2007	241	Norwalk River	medium_cool	4	3-	4-	4	repeat sample (both rounds=4)
10717	6/28/2007	235	Norwalk River	medium_cool	4	4+	4-	4	
10802	7/5/2007	2311	Hall Meadow Brook	medium_cold	3	3	4-	3	
10979	7/11/2007	1806	Muddy River	medium_cool	3	1	3-	3	

Table I-2. continued…

Fish SampID	Collection Date	Station ID	Waterbody Name	Phase 1 Class	Panelist consensus			Primary Model	Notes
					Final	Best	Worst		
12540	6/4/2008	1088	Natchaug River	large_cool	5	4	5-	5	
12726	6/16/2008	264	Pequabuck River	medium_cold	4	4+	5	4	
12826	6/19/2008	2642	Pequabuck River	medium_cold	4	4	5	4	
12833	6/25/2008	2662	Bass Brook	medium_cool	3	3	4	4	
13202	7/18/2008	1644	Nepaug River	medium_cold	3	2	4	3 (close to 2)	repeat sample (both rounds=3); model assignment is close to a 2
13763	9/2/2008	127	Housatonic River	large_cool	4	2-	4	4 (close to 5)	model assignment is close to a 5
13764	9/2/2008	914	Housatonic River	large_cool	4	3	4-	5	
14242	7/21/2008	2658	Coppermine Brook	medium_cold	2	1	3	2	
14243	8/23/2008	1081	Roaring Brook	medium_cool	3	2	4	3	repeat sample (round1=3; round 2=3/4)
14246	8/30/2008	2641	Hop River	medium_cold	4	4+	4-	3 (close to 2)	model assignment is close to a 2
14248	8/31/2008	354	Trout Brook	medium_cool	4	3	4-	4	
14401	6/1/2009	90	Furnace Brook	medium_cool	5	4+	6	5	repeat sample (round1=5; round 2=4/5)
14618	6/25/2009	2659	Pequabuck River	medium_cold	5	5+	5-	4	
14688	6/26/2009	1701	Patagansett River	medium_cool	5	5	6+	5	
14717	6/29/2009	2679	West Branch Naugatuck River	medium_cold	4	3-	5+	4	
14719	6/29/2009	2673	East Aspetuck River	medium_cold	4	4+	5+	3/4 (tie)	
14970	7/22/2009	470	Fenton River	medium_cold	4	3+	5	4	
14986	7/23/2009	464	Hop River	large_cool	5	5+	5-	4	
15044	7/27/2009	1656	Little River	medium_cool	3	1-	3-	2	
15057	7/28/2009	1125	Beaver Brook	medium_cold	3	2-	3-	2/3 (tie)	
15461	9/1/2009	2685	Aspetuck River	medium_cool	3	2-	4	3	
15462	9/1/2009	2681	Saugatuck River	medium_cool	2	2	3-	3	

Table I-2. continued…

Fish SampID	Collection Date	Station ID	Waterbody Name	Phase 1 Class	Panelist consensus			Primary Model	Notes
					Final	Best	Worst		
15464	8/5/2009	477	Mashamoquet Brook	medium_cool	3	2	3-	3	
15740	8/13/2009	367	Willimantic River	large_cool	4	3	5	4	
15834	8/10/2009	189	Natchaug River	large_cool	4	4+	4-	5	
18772	9/2/2009	152	Little River	medium_cold	5	4	5	4	
20928	6/30/2010	606	Green Fall River	medium_cool	1	1	2-	2	repeat sample (round1=2; round 2=1)
21232	7/15/2010	49	East Branch Eightmile River	medium_cool	4	3	4-	3	
21233	7/15/2010	1236	Beaver Brook	medium_cool	3	2	4	2	
21300	7/16/2010	475	Myron Kinney Brook	medium_cool	2	2	3	2	
21302	7/16/2010	1841	Broad Brook	medium_cool	2	2	3	2	
21303	7/16/2010	650	Ashaway River	medium_cool	3	3	4+	2	
21438	7/22/2010	6161	Bartlett Brook	medium_cold	5	4+	5	4	
22114	8/30/2010	289	Quinnipiac River	large_cool	4	3	4-	4	repeat sample (both rounds=4)

Table I-3. Site information for ***medium-large*** fish samples that were analyzed during the BCG ***calibration*** exercise. Area refers to the upstream watershed area. Land use (%Devl=% developed, % Imperv= % impervious, % Natl= % natural) is for the upstream catchment area. TNC fields are derived from The Nature Conservancy's Northeast Aquatic Habitat Classification (Olivero and Anderson 2008). TITAN thermal classes were based on Beauchene et al. 2012. Additional information (i.e. nutrient and habitat data) may available for some of the sites.

Station ID	**Waterbody Name**	**Long**	**Lat**	**Area (mi2)**	**Level 4 Ecoregion**	**% Devl**	**% Imperv**	**% Natl**	**TNC Gradient**	**TNC Geology**	**TNC Thermal Class**	**TITAN thermal class**
20	Branch Brook	-73.0810	41.6434	21.6	Southern New England Coastal Plains and Hills	9.8	4.2	64.6	Low Gradient: >= 0.02 < 0.1%	Moderately Buffered, Neutral	Transitional Cool	
49	East Branch Eightmile River	-72.3375	41.4309	16.4	Southern New England Coastal Plains and Hills	8.2	3.4	77.6	Low Gradient: >= 0.02 < 0.1%	Moderately Buffered, Neutral	Transitional Cool	3
90	Furnace Brook	-72.2979	41.9679	15.3	Lower Worcester Plateau/Eastern Connecticut Upland	6.6	2.9	70.5	Very Low Gradient: <0.02%	Moderately Buffered, Neutral	Transitional Cool	2
101	Harbor Brook	-72.8218	41.5314	12.1	Connecticut Valley	48.2	19.1	27.5	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	2
127	Housatonic River	-73.3815	41.8280	90.5	Berkshire Transition	6.1	3.0	72.3	Low-Moderate Gradient: >= 0.1 < 0.5%	Assume Moderately Buffered (Size 3+ rivers)	Transitional Cool	

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
152	Little River	-72.0582	41.6393	34.5	Southern New England Coastal Plains and Hills	6.8	3.1	78.7	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
189	Natchaug River	-72.1182	41.8008	73.2	Southern New England Coastal Plains and Hills	6.8	2.8	83.0	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
216	Naugatuck River	-73.1145	41.7891	52.9	Berkshire Transition	13.9	6.4	75.1	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
235	Norwalk River	-73.4414	41.2675	6.1	Southern New England Coastal Plains and Hills	22.1	6.9	69.7	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
241	Norwalk River	-73.4341	41.2460	9.4	Southern New England Coastal Plains and Hills	24.0	7.8	66.3	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
264	Pequabuck River	-72.9936	41.6693	14.0	Southern New England Coastal Plains and Hills	15.6	7.2	69.2	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	
272	Piper Brook	-72.7274	41.7186	17.2	Connecticut Valley	52.9	28.2	28.1	Low Gradient: >= 0.02 < 0.1%	Moderately Buffered, Neutral	Transitional Cool	

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
289	Quinnipiac River	-72.8407	41.4501	111.0	Connecticut Valley	33.6	14.7	43.2	Very Low Gradient: <0.02%	Moderately Buffered, Neutral	Transitional Cool	2
319	Saugatuck River	-73.3948	41.2945	20.4	Southern New England Coastal Plains and Hills	10.7	4.3	79.3	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	3
331	Steele Brook	-73.0703	41.5805	17.0	Southern New England Coastal Plains and Hills	33.8	13.8	38.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	2
354	Trout Brook	-72.7231	41.7314	17.7	Connecticut Valley	46.5	22.8	32.4	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
367	Willimantic River	-72.3079	41.8326	99.6	Southern New England Coastal Plains and Hills	9.4	3.7	75.0	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
464	Hop River	-72.2548	41.7212	79.8	Southern New England Coastal Plains and Hills	11.0	4.0	72.9	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
470	Fenton River	-72.2100	41.7925	28.0	Southern New England Coastal Plains and Hills	9.7	4.0	79.1	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
472	Moosup River	-71.8931	41.7148	75.6	Southern New England Coastal Plains and Hills	5.4	3.7	42.8	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	3
475	Myron Kinney Brook	-71.8619	41.5533	6.1	Southern New England Coastal Plains and Hills	3.9	2.4	78.7	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
477	Mashamoquet Brook	-71.9359	41.8499	28.9	Southern New England Coastal Plains and Hills	7.0	3.2	71.9	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
606	Green Fall River	-71.8169	41.4568	10.4	Long Island Sound Coastal Lowland	3.4	2.3	80.8	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	1
650	Ashaway River	-71.7963	41.4433	23.2		4.4	2.5	78.8	Low-Moderate Gradient: >= 0.1 < 0.5%	Low Buffered, Acidic	Transitional Cool	
761	Latimer Brook	-72.2209	41.4209	10.2	Southern New England Coastal Plains and Hills	8.3	3.8	77.1	Low-Moderate Gradient: >= 0.1 < 0.5%	Low Buffered, Acidic	Transitional Cool	
910	Hollenbeck River	-73.3316	41.9581	28.1	Western New England Marble Valleys	3.8	2.2	85.8	Very Low Gradient: <0.02%	Moderately Buffered, Neutral	Transitional Cool	

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
914	Housatonic River	-73.3906	41.8072	186.4	Berkshire Transition	6.1	2.9	75.0	Low-Moderate Gradient: >= 0.1 < 0.5%	Assume Moderately Buffered (Size 3+ rivers)	Transitional Cool	
918	Moosup River	-71.8422	41.7172	67.4	Southern New England Coastal Plains and Hills	4.4	3.4	40.2	Low Gradient: >= 0.02 < 0.1%	Low Buffered, Acidic	Transitional Cool	
1081	Roaring Brook	-72.8808	41.7594	7.6	Connecticut Valley	23.9	8.3	63.1	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
1088	Natchaug River	-72.1523	41.7569	88.7	Southern New England Coastal Plains and Hills	6.9	2.9	82.7	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	2
1125	Beaver Brook	-72.1092	41.6841	7.8	Southern New England Coastal Plains and Hills	5.9	2.9	78.7	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
1236	Beaver Brook	-72.3289	41.4100	8.3	Southern New England Coastal Plains and Hills	4.5	2.4	86.5	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	3
1281	Sasco Brook	-73.3012	41.1457	8.4	Long Island Sound Coastal Lowland	25.2	8.8	43.6	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	2.5

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
1446	Bantam River	-73.1823	41.7417	20.7	Southern New England Coastal Plains and Hills	7.8	3.5	69.3	Low-Moderate Gradient: >= 0.1 < 0.5%	Low Buffered, Acidic	Transitional Cool	
1449	Yantic River	-72.1759	41.5702	53.8	Southern New England Coastal Plains and Hills	8.4	3.4	70.0	Low Gradient: >= 0.02 < 0.1%	Moderately Buffered, Neutral	Transitional Cool	2
1450	Blackledge River	-72.4261	41.6069	21.9	Southern New England Coastal Plains and Hills	13.7	4.7	70.8	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	2
1498	Roaring Brook	-72.2656	41.9152	18.4	Lower Worcester Plateau/Eastern Connecticut Upland	7.4	2.9	85.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
1644	Nepaug River	-73.0271	41.8382	9.9	Berkshire Transition	9.2	3.5	77.4	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
1656	Little River	-72.0473	41.7561	16.2	Southern New England Coastal Plains and Hills	7.4	3.2	76.3	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	1
1701	Patagansett River	-72.2124	41.3557	6.2	Long Island Sound Coastal Lowland	18.3	1.4	69.6	Low Gradient: >= 0.02 < 0.1%	Low Buffered, Acidic	Transitional Cool	

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
1806	Muddy River	-72.8012	41.4151	12.3	Connecticut Valley	15.8	5.9	48.8	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	3
1841	Broad Brook	-71.9703	41.5538	11.8	Southern New England Coastal Plains and Hills	4.8	2.7	80.8	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
2311	Hall Meadow Brook	-73.1689	41.8861	12.0	Lower Berkshire Hills	4.3	2.2	89.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	2
2641	Hop River	-72.4089	41.7712	8.2	Southern New England Coastal Plains and Hills	14.8	4.8	68.2	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
2642	Pequabuck River	-72.9272	41.6698	24.9	Southern New England Coastal Plains and Hills	27.8	12.1	53.1	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	
2658	Coppermine Brook	-72.9261	41.7137	8.5	Southern New England Coastal Plains and Hills	15.0	6.5	75.6	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
2659	Pequabuck River	-72.9082	41.6740	26.1	Connecticut Valley	29.2	12.8	52.0	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Cold	

Table I-3. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
2662	Bass Brook	-72.7587	41.6931	8.5	Connecticut Valley	40.6	26.4	41.0	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	
2673	East Aspetuck River	-73.3785	41.6546	19.0	Southern New England Coastal Plains and Hills	8.6	3.4	74.4	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
2679	West Branch Naugatuck River	-73.1602	41.8561	19.1	Berkshire Transition	3.7	2.2	90.8	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	
2681	Saugatuck River	-73.4229	41.3220	13.1	Southern New England Coastal Plains and Hills	10.8	4.4	81.8	Low-Moderate Gradient: >= 0.1 < 0.5%	Low Buffered, Acidic	Transitional Cool	
2685	Aspetuck River	-73.3303	41.2933	7.8	Southern New England Coastal Plains and Hills	8.1	3.4	81.6	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
6161	Bartlett Brook	-72.2563	41.5883	13.4	Southern New England Coastal Plains and Hills	6.7	3.0	73.3	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	

Table I-4. BCG level assignments and sample information for ***medium-large*** samples that were assessed during the ***validation*** exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants), without the + or - (2+ and 2- were assigned to level 2, etc.); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table G1); Worst=the worst BCG level assignment given by a participant; Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model.

Fish SampID	**Collection Date**	**Station ID**	**Waterbody Name**	**Phase 1 Class**	**Panelist consensus**			**Primary Model**	**Notes**
					Final	**Best**	**Worst**		
327	7/19/1999	163	Mattabesset River	medium_cool	4	3-	4-	4	
4228	7/26/1999	246	Norwalk River	large_cool	4	4	5+	4	
4537	7/29/2003	916	Hockanum River	medium_cool	5	4	5-	5	
5257	6/30/2004	359	West Branch Salmon Brook	medium_cold	2	1	2-	2	
5434	7/16/2004	189	Natchaug River	large_cool	4	3	5	4	
5548	7/27/2004	310	Salmon Brook	large_cool	3	2+	3-	3	
6606	7/25/2005	478	Blackwell Brook	medium_cool	4	3-	4-	4	
7263	7/29/2005	1671	Mount Hope River	medium_cool	5	3+	5-	3	has direct agricultural influence
8782	7/24/2006	122	Hollenbeck River	medium_cold	3	2+	3-	3	
12991	7/2/2008	325	Shepaug River	large_cool	4	3	5-	4	
14244	8/23/2008	1513	Cherry Brook	medium_cold	3	1-	3-	4	
14723	7/1/2009	458	Willimantic River	large_cool	3	3+	5+	3	
15058	7/28/2009	480	Merrick Brook	medium_cold	3	2	3-	2/3 (tie)	
15734	8/4/2009	1482	Pease Brook	medium_cool	4	3+	4+	3	panel call was very close to a 3
20873	6/29/2010	278	Pomperaug River	large_cool	3	2-	3	2	
21183	7/1/2010	621	Yantic River	medium_cool	4	3	4	4	

Table I-5. Site information for ***medium-large*** fish samples that were analyzed during the BCG ***validation*** exercise. Area refers to the upstream watershed area. Land use (%Devl=% developed, % Imperv= % impervious, % Natl= % natural) is for the upstream catchment area. TNC fields are derived from The Nature Conservancy's Northeast Aquatic Habitat Classification (Olivero and Anderson 2008). TITAN thermal classes were based on Beauchene et al. 2012. Additional information (i.e. nutrient and habitat data) may available for some of the sites.

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
122	Hollenbeck River	-73.3058	41.9431	17.6	Berkshire Transition	4.8	2.5	81.6	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
163	Mattabesset River	-72.7127	41.6189	45.8	Connecticut Valley	31.4	13.9	44.3	Very Low Gradient: <0.02%	Moderately Buffered, Neutral	Transitional Cool	3
189	Natchaug River	-72.1182	41.8008	73.2	Southern New England Coastal Plains and Hills	6.8	2.8	83.0	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
246	Norwalk River	-73.4295	41.1267	56.5	Long Island Sound Coastal Lowland	27.6	12.0	52.7	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	
278	Pomperaug River	-73.2165	41.5491	56.8	Connecticut Valley	9.1	3.8	64.9	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
310	Salmon Brook	-72.7749	41.9366	65.2	Connecticut Valley	8.1	3.7	69.7	Very Low Gradient: <0.02%	Moderately Buffered, Neutral	Transitional Cool	1

Table I-5. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
325	Shepaug River	-73.3308	41.5489	131.4	Southern New England Coastal Plains and Hills	7.9	3.4	72.6	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	3
359	West Branch Salmon Brook	-72.8215	41.9372	23.8	Connecticut Valley	7.1	3.0	84.6	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
458	Willimantic River	-72.3058	41.9423	53.8	Lower Worcester Plateau/Eastern Connecticut Upland	9.0	3.7	71.5	Low-Moderate Gradient: >= 0.1 < 0.5%	Low Buffered, Acidic	Transitional Cool	3
478	Blackwell Brook	-71.9488	41.7407	22.7	Southern New England Coastal Plains and Hills	7.8	3.4	73.7	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	
480	Merrick Brook	-72.1101	41.6610	13.0	Southern New England Coastal Plains and Hills	6.5	3.1	72.4	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
621	Yantic River	-72.1918	41.5766	39.2	Southern New England Coastal Plains and Hills	8.6	3.4	74.4	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Transitional Cool	
916	Hockanum River	-72.5204	41.8078	49.1	Connecticut Valley	25.0	10.4	49.9	Moderate-High Gradient: >=0.5 < 2%	Low Buffered, Acidic	Transitional Cool	2.5

Table I-5. continued…

Station ID	Waterbody Name	Long	Lat	Area (mi2)	Level 4 Ecoregion	% Devl	% Imperv	% Natl	TNC Gradient	TNC Geology	TNC Thermal Class	TITAN thermal class
1482	Pease Brook	-72.1923	41.5947	11.7	Southern New England Coastal Plains and Hills	7.0	3.5	55.0	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	1
1513	Cherry Brook	-72.9295	41.8365	13.8	Berkshire Transition	7.5	3.1	82.9	Moderate-High Gradient: >=0.5 < 2%	Moderately Buffered, Neutral	Cold	1
1671	Mount Hope River	-72.1603	41.8772	12.4	Lower Worcester Plateau/Eastern Connecticut Upland	8.0	3.1	83.2	Low-Moderate Gradient: >= 0.1 < 0.5%	Moderately Buffered, Neutral	Transitional Cool	2