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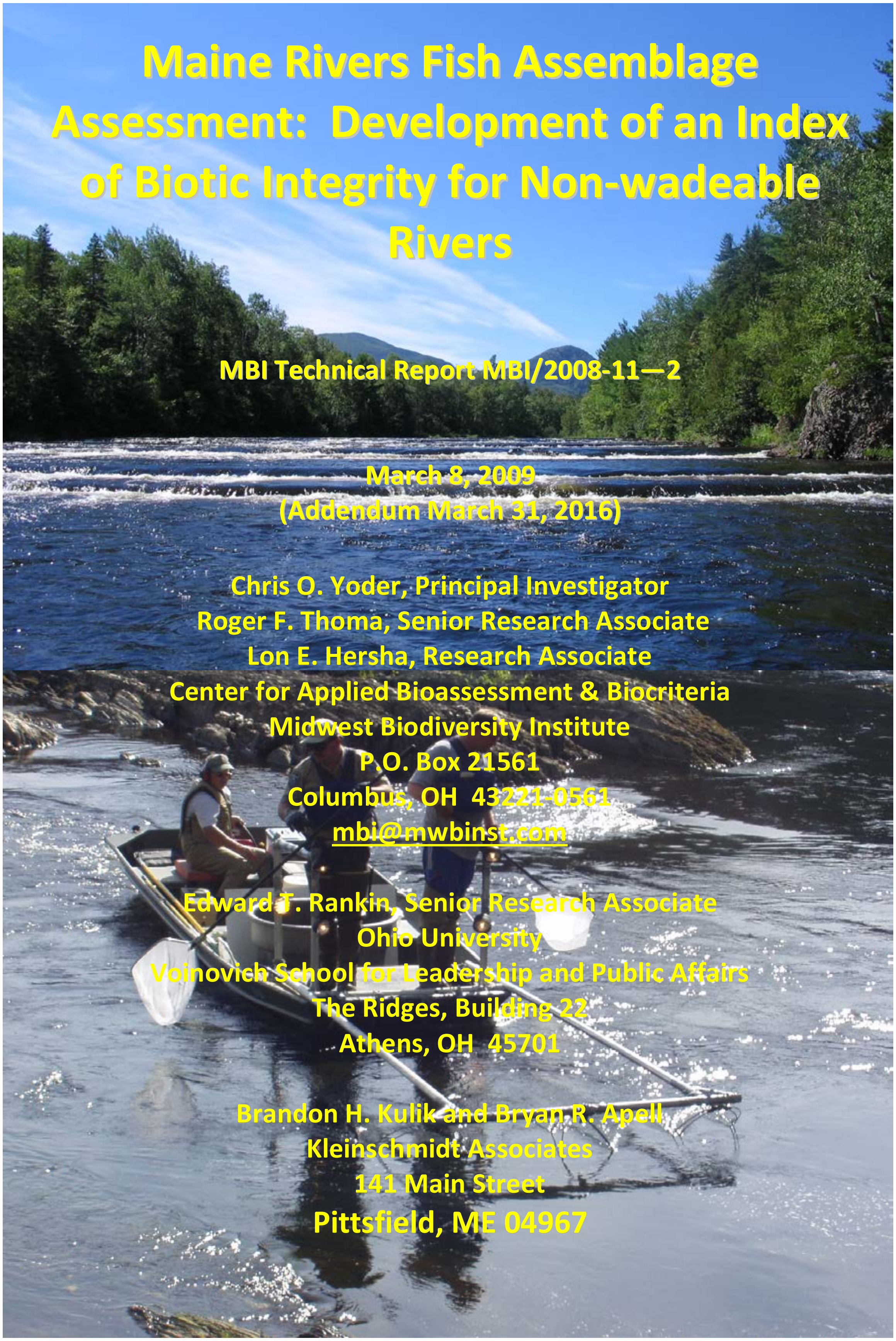

Maine Rivers Fish Assemblage Assessment: Development of an Index of Biotic Integrity for Non-wadeable Rivers

MBI Technical Report MBI/2008-11—2

March 8, 2009
(Addendum March 31, 2016)

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Dedicated to the memory of David Boucher, IF&W
(March 19, 1959-March 24, 2016)
Good Friend and Fellow Biologist

Maine Rivers Fish Assemblage Assessment: Development of an Index of Biotic Integrity for Non-wadeable Rivers

Final Project Report to:

U.S. EPA, Region I
1 Congress Street, Suite 1100
Boston MA 02114-2023
Steve Winnett, Work Assignment Manager

March 8, 2009
(Addendum March 31, 2016)

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SUMMARY AND CONCLUSIONS

This project involved the systematic sampling of non-wadeable rivers in Maine with the goal of developing a fish assemblage assessment tool that is useful to multiple water quality and natural resource management programs and objectives. The conceptual framework of the U.S. EPA Biological Condition Gradient (BCG: Davies and Jackson 2006) was used to guide the development and derivation of an Index of Biotic Integrity (IBI) applicable to a cool-coldwater, moderate-high gradient ecotype. This is the most widely occurring ecotype in Maine's non-wadeable rivers. However, it is not the only ecotype with low gradient and tidal freshwater habitats also present in lesser numbers.

We followed prior examples for IBI development adhering generally to the original guidance of Karr et al. (1986) and the later refinements of Hughes et al. (1998). Specifically, we followed the calibration methodology of Mebane et al. (2003) that was used to derive an IBI for a similar riverine ecotype (non-wadeable, cold water rivers) in the Pacific Northwest. These rivers have many generic similarities to the geographically isolated coastal drainage that comprises cool-cold water riverine ecotype of Maine.

The resulting riverine or Maine IBI consists of 12 metrics and a 0-100 scale. It produced an observed range of 13-92 among 20 major non-tidal river segments. We assigned boundaries to the numerical scale that approximate the six levels of the BCG based on best professional judgment using our knowledge of major stressors (Yoder et al. 2006a,b) and observations made at more than 350 sampling sites during the project period, 2002-7. The initial results suggest that the riverine IBI is the most applicable to the core fish assemblages expected for the cool-cold water, moderate-high gradient ecotype. It is especially responsive to major biological stressors in the form of invasive and non-indigenous species in addition to major physical stressors such as habitat and flow alterations. Chemical pollution gradients are not particularly strong due to the success of point source pollution controls in the 1980s and 1990s, but localized impacts were discernable with the riverine IBI.

The highest Maine IBI scores occurred in rivers with an absence of introduced species (especially blackbasses) and with the least degree of modification to natural habitat, flow regime, and water quality. These included the Allagash, Aroostook, and upper Branches of the Penobscot Rivers. Maine IBI scores were generally the lowest in the lower reaches of coastal draining rivers that have been impacted by extensive habitat and flow alterations by dams and their attendant impoundments. All of these rivers that have experienced intensive hydrological and physical alterations and also had the highest proportions of non-indigenous species and these are likely interrelated. However, questions about the role of diadromous species in the expected fish assemblage raised concerns about deficiencies in the ability of the Maine IBI to properly reflect this important component of the Maine Rivers BCG. As a result of this concern four supplemental diadromous metrics were derived and calibrated to provide a diadromous IBI (DIBI). Composed of four supplemental metrics, the DIBI directly represents the contribution of the diadromous fish assemblage attributes in the Maine Rivers BCG.

The DIBI applies only where diadromous species are expected to occur and where they have had historical access in Maine Rivers. The current scoring procedure is to add the DIBI to the Maine IBI based on the diadromous assemblage components present in a sample and without an adjustment to the total score. We considered pro-rating the total IBI that results from the addition of the riverine and diadromous IBIs, but this would have obscured the condition of the core freshwater assemblage and made it less comparable to rivers without diadromous species. Thus it was decided to initially keep the DIBI both separate and additive pending further exploratory analysis about how to better standardize combining the two IBIs. Taking this approach preserves the assessment of the “core” freshwater assemblage expectations accomplished by the Maine IBI and it simultaneously revealed the contribution of the “pulse” species in the diadromous assemblage. This approach does not penalize rivers that naturally lack diadromous species due to impassable barriers and it represents a more equitable and ecologically meaningful treatment of coastal rivers.

RECOMMENDATIONS

The following recommendations are made based on the results of the development and further testing of the riverine and diadromous IBI applicable to the non-wadeable rivers of Maine.

1. A systematic reassessment of the major rivers sampled by this study in 2002-7 should be undertaken to ascertain the impact of any changes due to long term stressors such as temperature and flow associated with climate change. Particularly vulnerable rivers such as the Allagash, Aroostook, and upper branches of the Penobscot should receive priority as these are already showing signs of being threatened by direct and indirect effects of climate change.

2. Selected rivers where aggressive diadromous fish restoration is taking place are being monitored on an annual basis (e.g., lower Kennebec, Sebasticook, and Penobscot Rivers), thus additional rivers where similar efforts are occurring will need similar levels of follow-up assessment. Sampling for certain diadromous species offers the additional challenge of the timing of sampling events especially for Clupeid species that are highly transitory in their occurrence and abundance.

3. The riverine and diadromous IBIs represent additional assemblage assessment tools that could fit within the existing Maine DEP designated use tiers and biological criteria framework.

ACKNOWLEDGEMENTS

Numerous individuals and organizations contributed conceptual, technical, and material support to this project. David Halliwell, Maine DEP (project quality assurance/control coordinator), provided extensive assistance with all aspects of the project including expertise in freshwater fish identifications, their status, distribution, and abundance in Maine and New England, shared laboratory space for reviewing voucher specimens, assisted in the field, and, gave helpful advice and report reviews. The following persons and organizations contributed as members of an ad hoc working group in the development of the project QAPP, the study design, BCG development, and/or with assistance for field logistics: David Courtemanch, Susan Davies, Barry Mower, John Reynolds, and Joe Sowa, Maine Department of Environmental Protection; Merry Gallagher, Steve Timpano, Gordon Cramer, Dave Basley, and Dave Boucher, Maine Department of Inland Fisheries & Wildlife; Gail Wippelhauser, Maine Department of Marine Resources; Joan Trial, Kevin Dunham, Dan McCaw, and Paul Christman, Maine Atlantic Salmon Commission; Larry Miller, U.S. Fish and Wildlife Service; Jennie Bridge, Ralph Abele, and Hilary Snook, U.S. Environmental Protection Agency; Jeff Reardon, Trout Unlimited; Clem Fay and John Banks, Penobscot Indian Nation; Dusti Faucher, Friends of the Presumpscot River; Karen Young, Beverly Bayley-Smith, and Matthew Craig, University of Southern Maine; Marilyn Tourtelotte, Maine DOC - Allagash Wilderness Waterway. The Maine DOC provided remote overnight accommodations in 2006 and Florida Power & Light provided remote overnight accommodations in 2006 and 2007. The Maine North Woods, Inc. graciously provided free access to rivers on their properties. Assistance with the identification of immature Clupeids was provided by Nathan Gray and John Perry, Maine DMR. Karsten Hartel, Harvard University Museum of Comparative Zoology, graciously received the voucher specimens and provided final verifications of our field and laboratory identifications. Assistance with field sampling and laboratory resources was additionally provided by Dave Potter, Unity College. The following staff of Kleinschmidt Associates volunteered field time and other logistical support: Peter Bastien, Torrey Sheafe, Allison Murray, Alan Haberstock, Matt Bernier, Andy Qua, Jon Christensen, and Jennifer Dow. We also thank the numerous private land owners who granted river access via their properties.

This project was made possible by grants and contracts to MBI from the U.S. EPA, Region I under Section 104[b][3] of the Clean Water Act and additional funds from the U.S. EPA National Biocriteria program. We thank Jennie Bridge, Steve Winnett (EPA, Region I), and Susan Jackson (EPA, HQ) for their support of this project. The Sebasticook River data were collected under a grant from the Gulf of Maine Council on the Environment (GOMCE) to the Sebasticook River Watershed Association (SRWA) and the Presumpscot River data were collected under a grant from the Casco Bay Estuary Partnership to the University of Southern Maine.

INTRODUCTION

A project to develop a systematic approach to the assessment of fish assemblages in the non-wadeable rivers of Maine was initiated in 2002 by the Midwest Biodiversity Institute and Kleinschmidt Associates with funding support from U.S. EPA. Sampling was initially conducted in the Kennebec River mainstem in 2002 and included the development and refinement of a boat mounted electrofishing protocol that is described in a Quality Assurance Project Plan (MBI 2002). Surveys of the Androscoggin and Sebasticook Rivers followed in 2003 and along with the 2002-3 Kennebec survey are described in the first project report (Yoder et al. 2006a). The Penobscot River and its major branches and tributaries were sampled in 2004, selected northern and Downeast Maine rivers (Allagash, Aroostook, St. Croix, St. John) were sampled in 2005, the Saco and Presumpscot Rivers were sampled in 2006, and selected rivers in western and northern Maine were sampled in 2007. Annual surveys of the lower Kennebec and Sebasticook Rivers have been conducted through 2015 and led to the development of the supplemental diadromous metrics. The combined aggregate effort has produced an intensive, statewide coverage of non-wadeable rivers in Maine (Figure 1).

The principal objective of this project has been and remains the development and demonstration of a fish assemblage assessment tool that can be used to systematically assess the status of the non-wadeable rivers and streams of Maine and New England. Such a tool should be useful for assessing multiple resource management objectives that include the existing status and quality of rivers at the site, reach, and basin level and for measuring the effectiveness of management efforts aimed at restoring native fish assemblages including diadromous species. An ongoing purpose of the project is the development and testing of the U.S. EPA Biological Condition Gradient (BCG; Davies and Jackson 2006), which is a product of the U.S. EPA Tiered Aquatic Life Uses working group (U.S. EPA 2005). The first project report (Yoder et al. 2006a) addressed the essential methodological issues and initiated the description of species autecological information that is essential to the eventual development of bioassessment tools and biocriteria. The second project report (Yoder et al. 2006b) accomplished pre-index developmental tasks such as the distributional status of all species encountered, relating their occurrence to large scale gradients, and further refining autecological guild and metric assignments. The primary goal of this project report is to describe the derivation of an IBI based on the EPA Biological Condition Gradient (Davies and Jackson 2006) as a conceptual framework.

METHODS

Field Sampling Protocols

Boat mounted electrofishing is the method of choice based on its successful application as a single gear methodology to non-wadeable rivers in other parts of the U.S. and Canada (Yoder and Kulik 2003), its successful trial application in selected Maine rivers by Kleinschmidt in 2000-1, and by MBI and Kleinschmidt in 2002-3 (Yoder et al. 2006a).

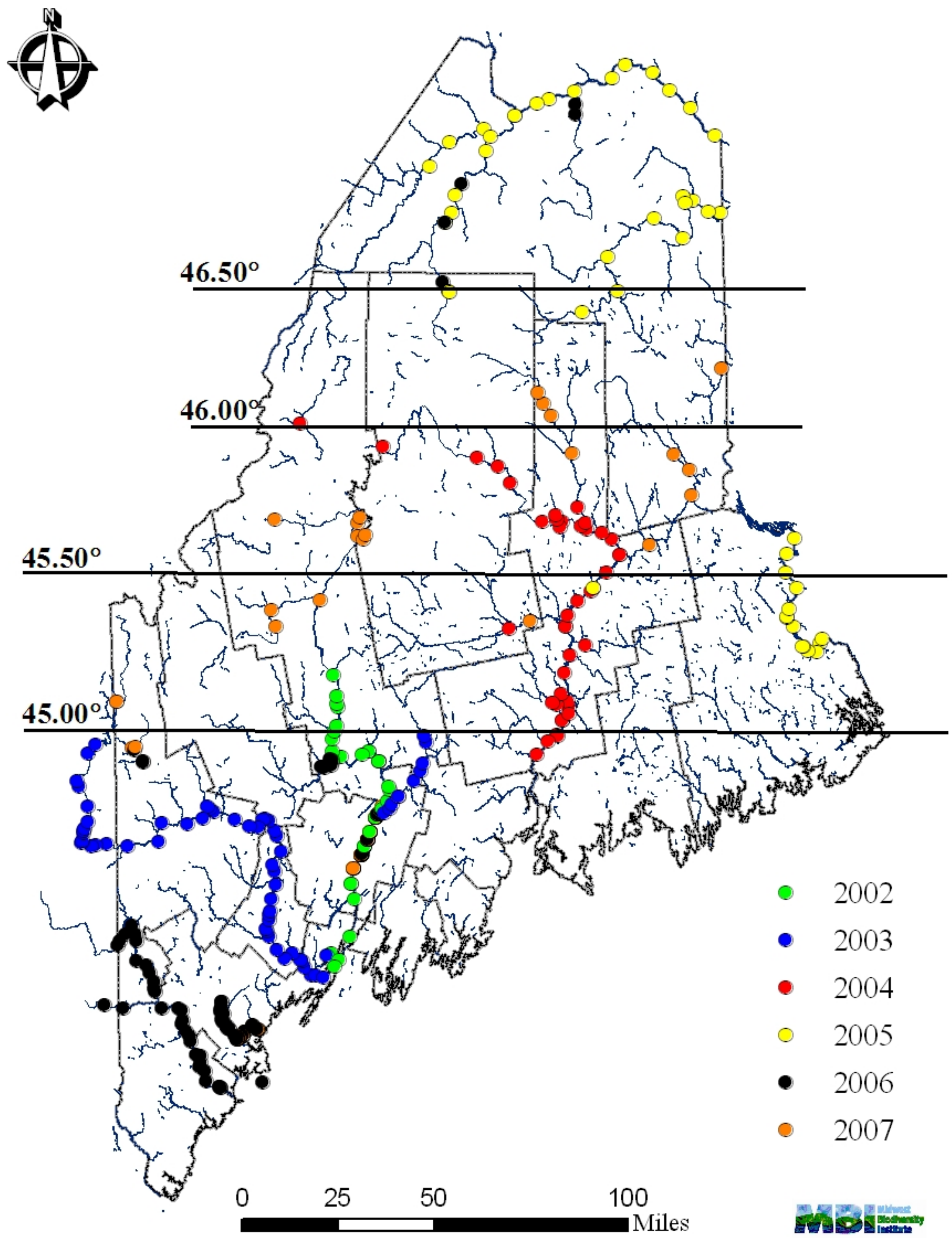

***Figure 1**. Locations of electrofishing sites in non-wadeable rivers during 2002-7. All samples were collected within a July 1 – September 30 seasonal index period following methods in Yoder et al. (2006a).*

Rivers that offered sufficient width and depth were sampled using a 16' john boat rigged for daytime and nighttime electrofishing. In 2005, a 14' raft platform was introduced and used to sample smaller, moderate-high gradient non-wadeable rivers that were not accessible by the 16' john boat. The design and operation of the electrofishing equipment is described in more detail by Yoder et al. (2006 a,b). Other details about field data recording and sample processing procedures are described in the project QAPP (MBI 2002), which has been updated annually through 2007.

Data Management

Data were managed and analyzed using routines available in the Maine ECOS data management system that was adapted for use by MBI in this project. Standardized data reports on fish species relative abundance and condition, assemblage attributes such as numbers, biomass, functional and tolerance guilds, condition metrics, and compositional expressions are included. The outputs can be exported as Excel files and Adobe Acrobat reports. Relative abundance data is reported as numbers and biomass per kilometer. Taxonomic nomenclature follows Nelson et al. (2004).

Data Analysis

The analyses conducted for this report were done in support of the development of a multimetric index for Maine's riverine fish assemblages. The initial exploration of this development was accomplished by the second project report (Yoder et al. 2006b). While several types of data expressions, indices, and models are possible, we focused primarily on the development of an Index of Biotic Integrity (IBI) following the seminal guidance of Karr et al. (1986), later refinements by Hughes et al. (1998), and a specific application to cool-cold, non-wadeable rivers by Mebane et al. (2003). We also incorporated the concepts of the target fish community approach (Bain and Meixler 2000, 2008) that was first considered in the 2002-3 report (Yoder et al. 2006a) and the 2005 pre-IBI development and analyses (Yoder et al. 2006b).

Maine Rivers IBI Development – Summary of Tasks

In order to achieve the goal of developing an IBI, specific tasks are prerequisite. These include:

1) Development of an effective and systematically employed sampling methodology;
2) Establishment of a sufficient spatial and temporal database using the sampling methodology;
3) Describing the autecology of the extant fish fauna and formulate and test candidate metrics;
4) Differentiating obvious lotic ecotypes;
5) Describe expected fish assemblage attributes along the Biological Condition Gradient (BCG);
6) Establish reference and test sites;

7) Derive indices by applicable ecotype; and,
8) Test the indices with data representing a range of stressors common to Maine.

This process follows that described by Hughes et al. (1998) and it has been followed by other leading examples in North America and elsewhere (see summary by Yoder and Kulik 2003). Tasks 1 through 6 were accomplished in the first two project reports. Task 1 is detailed in Yoder et al. (2006a) and tasks 2-5 were described by Yoder et al. (2006b). Tasks 3-5 are updated with tasks 6-7 completed herein.

Autecology (Task 3)

The autecology of the extant fish fauna includes information that is essential to the development and testing of candidate IBI metrics. This includes compiling information about environmental tolerance, native status, habitat and flow preferences, thermal regime, foraging habitats, and reproductive habits, all of which comprise the breadth of the type of information that Karr et al. (1986) included in their seminal guidance for developing fish IBIs. In addition to several newer guilds that have appeared in contemporary IBIs of the past 10-15 years, we included a guild that has not been included in prior fish IBIs, a fluvial classification scheme based on the target fish community of Bain and Meixler (2000, 2008). Table 1 is updated from Yoder et al. (2006b) and provides the classifications for 60 species known or suspected to occur in the non-wadeable rivers of Maine. These classifications were compiled from a number of sources about native status, target fish classification, common riverine habitats where each species occurred, spatial occurrence in the state, thermal classification, foraging habits, reproductive habits, and predominant habitat residence. We used the most recent and geographically relevant sources to make these assignments combined with our own judgments based on six years of field observations.

Differentiating Riverine Ecotypes (Task 4)

It is essential to recognize and include naturally occurring and distinctive strata early in the index development process. Ecotypes are used here to differentiate the fundamental characteristics that determine the make-up of a fish assemblage and, as such, provide the context within which “as naturally occurs” can be described. Obvious distinctions such as cold and warmwater assemblages represent such strata, but there are others that can be less obvious. We noted at least 3 distinctive riverine ecotypes across Maine both in terms of baseline habitat characteristics and fish assemblage composition. Some of these are included in the common habitats column in Table 1 and include high-moderate gradient riverine, low gradient riverine, and freshwater-brackish water tidal habitats. Impounded habitats are also included in Table 1, but these are viewed as a human induced modification of moderate-high gradient riverine habitats thus they are not considered to be a naturally occurring ecotype. Data from these modified habitats will play an important role in testing the responsiveness of candidate metrics and IBIs to human-made modifications of natural riverine habitat. The emphasis of the IBI development analyses is on the moderate-high gradient riverine ecotype.

Table 1. *Native, tolerance, habitat, foraging, and reproductive guild designations and other notes on the distribution and occurrence of 60 fish species documented or suspected to occur in Maine's non-wadeable rivers. Sources for guild and metric assignments appear in the footnotes (scientific nomenclature adheres to Page et al. 2013).*

Species	Native Status[1]	Environmental Tolerance[2]	Target Fish Classification[3]	Common Habitat(s)[4]	Spatial Occurrence[5]	Thermal Guild[6]	Foraging Guild[7]	Reproductive Guild[8]	Habitat Guild[9]	Notes
Petromyzondidae										
Sea lamprey *(Petromyzon marinus)*	N	M	A	T1,R1	C	M	D	LN	B	Occurred primarily as ammocoetes.
Acipenseridae										
Shortnose sturgeon *(Acipenser brevirostrum)*	N	I	A	T1	C	M	I	NGL	W	Observed in Presumpscot R. 2006.
Atlantic sturgeon *(Acipenser oxyrinchus)*	N	I	A	R1	C	M	I	NGL	W	Observed in Kennebec R. 2005 and. Presumpscot R. 2006.
Anguillidae										
American eel *(Anguilla rostrata)*	N	T	C	All	All	M	C	na	W,B	
Clupeidae										
Blueback herring *(Alosa aestivalis)*	N	M	A	T1,T2	C	M	P	NGL	W	All y-o-y, no adults collected.
Alewife *(Alosa pseudoharengus)*	N	M	A	T1-R2	C	M	P	PS	W	Mostly y-o-y, few adults collected.
American shad *(Alosa sapidissima)*	N	M	A	R1,T1-2	C	M	P	PS	W	Mostly y-o-y, few adults collected.
Gizzard shad *(Dorosoma cepedianum)*	IC	T	[MG]	na	na	E	D	L	W	Collected in Kennebec R. in 2000.
Cyprinidae										
Lake chub *(Couesius plumbeus)*	N	I	[FD]	R1	N	S	BI	NGL	B	
Common carp *(Cyprinus carpio)*	E	T	MG	T1-2	C	E	O	V	W	Merrymeeting Bay and lower Kennebec R.
Common shiner *(Luxilis cornutus)*	N	M	FD	R1-T1	All	E	I	NGL	W	
Golden shiner *(Notemigonus crysoleucas)*	N,IS	T	MG	R2,I1	All	E	G	L	W	

[1] After Halliwell (2005): N – native; E – exotic of inter-continental origin; IC – introduced of intracontinental origin; IS – introduced of interstate origin; IM – introduced and managed; U – undetermined origin.
[2] I – highly intolerant; S – sensitive (moderately intolerant); M – intermediate; P – moderately tolerant; T – highly tolerant.; sources used include Ohio EPA (1987), Whittier and Hughes (1998), Halliwell et al. (1999), Langdon (2001)
[3] After Bain and Meixler (2000) : FS – fluvial specialist; FD – fluvial dependent; MG – macrohabitat generalist; A – anadromous; C – catadromous; [ ] - designations in brackets were not classified by Bain and Meixler (2000).
[4] R1 – high gradient riverine; R2 – low gradient riverine; I1 – impounded riverine; T1 – tidal riverine freshwater; T2 – tidal embayment brackish
[5] Spatial distribution within the state: C – primarily coastal rivers; S – primarily south of 46.000° latitude; N – primarily north of 45.500° latitude; U – ubiquitous statewide occurrence.
[6] After Hokanson (1977); S – temperate stenotherm; M – temperate mesotherm; E – temperate eurytherm.
[7] After Goldstein and Simon (1999); H – herbivore, D – detritivore, I – invertivore, BI – benthic insectivore, C – top carnivore, P – piscivore, G – generalist, O – omnivore, P – planktivore.
[8] After Ohio EPA (1987) and Hughes et al. (1998),; NGL – non-guarding lithophil [simple lithophil], LN – lithophilic nester, L – lithophil, V – vegetation, P – psammophil [sand-fine gravel], CN – cavity nester, VN – vegetation nester, PN – psammophil nester.
[9] After Hughes et al. (1998); W – water column, B – benthic, E – edge, H – hider, G – generalist.

***Table 1**. continued.*

Species	Native Status[1]	Environmental Tolerance[2]	Target Fish Classification[3]	Common Habitat(s)[4]	Spatial Occurrence[5]	Thermal Guild[6]	Foraging Guild[7]	Reproductive Guild[8]	Habitat Guild[9]	Notes
Bridle shiner *(Notropis bifrenatus)*	N	I	MG	R2	S	E	I	L	W	Presumpscot R. – one location only.
Spottail shiner *(Notropis hudsonius)*	U	M	MG	T1,I1	C	E	I	L	W	
E. Blacknose dace *(Rhinichthys atratulus)*	N	S	FS	R1	N	M	BI	NGL	B	
Longnose dace *(Rhinichthys cataractae)*	N	M	FS	R1	S	M	BI	NGL	B	Collected only in upper Androscoggin R.
Rudd *(Scardinius erythrophthalmus)*	E	T	[MG]	na	na	E	G	L	W	Possible single specimen – not confirmed.
Creek chub *(Semotilus atromaculatus)*	N	M	MG	R1	N	E	G	LN	W	
Fallfish *(Semotilus corporalis)*	N	M	FS	R1-I1	U	E	G	LN	W	
Blacknose shiner *(Notropis heterolepis)*	N	M	MG	R1-2	N	E	I	L	W	
Fathead minnow *(Pimephales promelas)*	N,IS	I	MG	R1	N	E	G	CN	W	
N. Redbelly dace *(Phoxinus eos)*	N	I	MG	R1-2	N	M	G	NGL	W	
Finescale dace *(Phoxinus neogaeus)*	N	I	[FD]	R1	N	M	G	NGL	W	
Pearl dace *(Margariscus margarita)*	N	S	[FD]	R1-2	N	S	G	NGL	W	
Catostomidae										
Longnose sucker *(Catostomus catostomus)*	N	I	[FD]	R1	N	S	BI	NGL	B	Adults prefer riverine run habitat.
White sucker *(Catostomus commersonii)*	N	P	FD	R1-T2	U	M	I,D	NGL	W	Adults prefer riverine run habitat.
Creek chubsucker *(Erimyzon oblongus)*	N	I	[FD]	R2	S	W	G	NGL	W	Saco R. (Old Course) only.
Ictaluridae										
White catfish *(Ameiurus catus)*	IC	T	MG	R1,T1-2	C	E	I,C	P	W	
Brown bullhead *(Ameirus nebulosus)*	N	T	MG	R2,I1	U	E	G	P,CN	W	

[1] After Halliwell (2005): N – native; E – exotic of inter-continental origin; IC – introduced of intracontinental origin; IS – introduced of interstate origin; IM – introduced and managed; U – undetermined origin.
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[9] After Hughes et al. (1998); W – water column, B – benthic, E – edge, H – hider, G – generalist.

***Table 1**. continued.*

Species	Native Status[1]	Environmental Tolerance[2]	Target Fish Classification[3]	Common Habitat(s)[4]	Spatial Occurrence[5]	Thermal Guild[6]	Foraging Guild[7]	Reproductive Guild[8]	Habitat Guild[9]	Notes
Esocidae										
Muskellunge *(Esox masquinongy)*	IC	I	MG	R1-2	N	M	P	L	H	St. John R. mainstem only.
Northern pike *(Esox lucius)*	IC	M	MG	I1	S	M	P	L	H	Sabattus R., Kennebec R. (single specimen)
Chain pickerel *(Esox niger)*	N,IS	P	MG	I1,R2	S	M	P	L	H	
Umbridae										
Central mudminnow *(Umbra limi)*	IC	T	[MG]	R1	N	E	I	VN	H	St. John R. (single specimen)
Osmeridae										
Rainbow smelt *(Osmerus mordax)*	N	M	A	T2	C	M	I,C	L	W	Rare in all study areas.
Salmonidae										
Rainbow trout (Oncorhynchus mykiss)	IC	I	FD	R1	S	S	C	LN	W	
Atlantic salmon – sea run *(Salmo salar)*	N	I	A	R1	C	S	C	LN	W	Sea run fish only
Atlantic salmon – landlocked *(Salmo salar)*	N,IS	I	[FD]	[FD]	R1	S	C	LN	W	Hatchery origin - stocked
Brown trout *(Salmo trutta)*	E	I	FD	[FS}	R1	S	C	LN	W	
Brook trout *(Salvelinus fontinalis)*	N	I	FS	FS	R1	S	C	LN	W	
Round whitefish *(Prosopium cylindraceum)*	N	I	[FD]	R1	N	S	C	L	W	
Gadidae										
Burbot *(Lota lota)*	N	S	[FD]	R1	N	S	C	NGL	B	

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[6] After Hokanson (1977); S – temperate stenotherm; M – temperate mesotherm; E – temperate eurytherm.
[7] After Goldstein and Simon (1999); H – herbivore, D – detritivore, I – invertivore, BI – benthic insectivore, C – top carnivore, P – piscivore, G – generalist, O – omnivore, P – planktivore.
[8] After Ohio EPA (1987) and Hughes et al. (1998); NGL – non-guarding lithophil [simple lithophil], LN – lithophilic nester, L – lithophil, V – vegetation, P – psammophil [sand-fine gravel], CN – cavity nester, VN – vegetation nester, PN – psammophil nester.
[9] After Hughes et al. (1998); W – water column, B – benthic, E – edge, H – hider, G – generalist.

Table 1. *continued.*

Species	Native Status[1]	Environmental Tolerance[2]	Target Fish Classification[3]	Common Habitat(s)[4]	Spatial Occurrence[5]	Thermal Guild[6]	Foraging Guild[7]	Reproductive Guild[8]	Habitat Guild[9]	Notes
Fundulidae										
Banded killifish *(Fundulus diaphanus)*	N	M	MG	R1-T2	S	E	I	VN	E	
Mummichog *(Fundulus heteroclitus)*	N	T	[TS]	T1-2	C	E	D	VN	E	Tidal habitats only.
Atherinopsidae										
Inland silverside *(Menidia beryllina)*	N	M	[TS]	T2	C	E	P	V	E	Rare in all study rivers.
Gasterosteidae										
Brook stickleback *(Culea inconstans)*	N	I	[MG]	I1	N	M	P,I	VCN	H	Rare in all study rivers.
Fourspine stickleback *(Apeltes quadracus)*	N	M	[TS]	T1-2	C	M	P	VCN	E	Rare in all study rivers.
Threespine stickleback *(Gasterosteus aculeatus)*	N	M	[MG]	R1	N	M	I	PN	E	
Ninespine stickleback *(Pungitius pungitius)*	N	M	[MG]	R1,T2	N,C	M	P	VCN	E	
Cottidae										
Slimy sculpin *(Cottus cognatus)*	N	I	FS	R1	N	S	BI	NGL	B	
Moronidae										
White perch *(Morone americana)*	N,IS	M	MG	I1,T1-2	S	M	C	L	W	
Striped bass *(Morone saxatilis)*	N	I	A	R1,T1-2	C	M	P	L	W	
Centrarchidae										
Rock bass *(Ambloplites rupestris)*	IC	M	MG	I1	S	E	C	LN	W	Androscoggin R. (New Hampshire only).

[1] After Halliwell (2005): N – native; E – exotic of inter-continental origin; IC – introduced of intracontinental origin; IS – introduced of interstate origin; IM – introduced and managed; U – undetermined origin.
[2] I – highly intolerant; S – sensitive (moderately intolerant); M – intermediate; P – moderately tolerant; T – highly tolerant.; sources used include Ohio EPA (1987), Whittier and Hughes (1998), Halliwell et al. (1999), Langdon (2001)
[3] After Bain and Meixler (2000) : FS – fluvial specialist; FD – fluvial dependent; MG – macrohabitat generalist; A – anadromous; C – catadromous; [ ] - designations in brackets were not classified by Bain and Meixler (2000).
[4] R1 – high gradient riverine; R2 – low gradient riverine; I1 – impounded riverine; T1 – tidal riverine freshwater; T2 – tidal embayment brackish
[5] Spatial distribution within the state: C – primarily coastal rivers; S – primarily south of 46.000° latitude; N – primarily north of 45.500° latitude; U – ubiquitous statewide occurrence.
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[7] After Goldstein and Simon (1999); H – herbivore, D – detritivore, I – invertivore, BI – benthic insectivore, C – top carnivore, P – piscivore, G – generalist, O – omnivore, P – planktivore.
[8] After Ohio EPA (1987) and Hughes et al. (1998); NGL – non-guarding lithophil [simple lithophil], LN – lithophilic nester, L – lithophil, V – vegetation, P – psammophil [sand-fine gravel], CN – cavity nester, VN – vegetation nester, PN – psammophil nester.
[9] After Hughes et al. (1998); W – water column, B – benthic, E – edge, H – hider, G – generalist.

***Table 1**. continued.*

Species	Native Status[1]	Environmental Tolerance[2]	Target Fish Classification[3]	Common Habitat(s)[4]	Spatial Occurrence[5]	Thermal Guild[6]	Foraging Guild[7]	Reproductive Guild[8]	Habitat Guild[9]	Notes
Redbreast sunfish *(Lepomis auritus)*	N	M	MG	R1-T1	S	E	I	PN	W	
Green sunfish *(Lepomis cyanellus)*	IC	T	MG	na	S	E	I	PN	W	Collected in Sebasticook ust. study area.
Pumpkinseed *(Lepomis gibbosus)*	N	T	MG	R2-T1	U	E	I	VN	W	
Bluegill *(Lepomis macrochirus)*	IC	T	MG	R1-2,I1,T1	S	E	I	VN	W	Saco and Presumpscot R.
Smallmouth bass *(Micropterus dolomieu)*	IC	M	MG	R1-T1	S	E	C	LN	W	
Largemouth bass *(Micropterus salmoides)*	IC	T	MG	R2-T1	S	E	C	PN	W	
Black crappie *(Pomoxis nigromaculatus)*	IC	T	MG	R1,I1	S	E	I	VN	W	
Percidae										
Yellow perch *(Perca flavescens)*	N,IS	P	MG	I1,T1-2	U	M	C	V	W	

[1] After Halliwell (2005): N – native; E – exotic of inter-continental origin; IC – introduced of intracontinental origin; IS – introduced of interstate origin; IM – introduced and managed; U – undetermined origin.
[2] I – highly intolerant; S – sensitive (moderately intolerant); M – intermediate; P – moderately tolerant; T – highly tolerant.; sources used include Ohio EPA (1987), Whittier and Hughes (1998), Halliwell et al. (1999), Langdon (2001)
[3] After Bain and Meixler (2000) : FS – fluvial specialist; FD – fluvial dependent; MG – macrohabitat generalist; A – anadromous; C – catadromous; [ ] - designations in brackets were not classified by Bain and Meixler (2000).
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[9] After Hughes et al. (1998); W – water column, B – benthic, E – edge, H – hider, G – generalist.

Expected Fish Assemblages along the Biological Condition Gradient (Task 5)

Developing an understanding of the natural fish assemblages that historically occurred in Maine's non-wadeable rivers is critical to determining the current status of the fish assemblages and for judging their potential for restoration. We used the Biological Condition Gradient (BCG) concept developed by U.S. EPA (2005; Figure 2) and as detailed by Davies and Jackson (2006) for this task. This process required the characterization of the "as naturally occurs" assemblage as the ultimate potential for quality and restoration. While restoring all rivers to such a condition may be impractical given the economically dependent activities and ingrained species introductions that have substantially altered the Maine riverine fish assemblages, it is important to qualitatively visualize this penultimate condition. It serves as an essential anchor for the "upper end" of the BCG and for scaling an IBI. We accomplished this by visualizing the "as naturally occurs" fish fauna that was likely encountered by the first European settlers coupled with our knowledge about how such assemblages were most likely organized based on current knowledge of species autecology and distribution. The latter was partly derived from available sampling data (Yoder et al. 2006b).

This process allows us to visualize how the "as naturally occurs" fish fauna changed as the effect of large scale human disturbances such as land uses (forestry, agriculture, urbanization), water pollution (point source discharges, nonpoint source runoff), habitat modification (dams/impoundments, riparian encroachment, channel modification), hydrologic alterations (flow diversions, withdrawals), changes to energy processing (nutrient enrichment, climatic changes), and biotic changes (introductions of non-indigenous species) increased in magnitude and scope through time. Each of these stressor categories illustrates the fundamental concept of Karr's five factors that determine the integrity of a water resource (Karr et al. 1986). Many of these impacts are well documented in Maine and the biological consequences as currently reported in terms of the macroinvertebrate assemblage (Davies et al. 1999), using the Maine DEP standardized methods and biological criteria (Davies and Tsomides 1997), key species of management interest (Warner 2005; Saunders et al. 2006), and native status (Halliwell 2005). The BCG is a conceptual model that describes how ecological attributes change in response to increasing levels of the *effect* of stressors (Davies and Jackson 2006; Figure 2). It is portrayed as a "gradient of condition" with descriptions about how key assemblage attributes are expected to change with increasing stressor effects in a succession of six levels from "as naturally occurs" to "severely degraded". Ten attributes that include characteristics of taxa representation, proportion, membership, condition, along with two functional categories are included for each of the six BCG levels. This template can be used to develop a model for aquatic assemblages that are representative of a specific region or aquatic ecotype. This provides an organized starting point for assuring that specific quantitative measures (e.g., IBI) that are derived from an effort like this study are conceptually sound and consistent with our best understanding about how aquatic ecosystems respond to increased stress effects. It also promotes the incremental measurement and characterization of biological assemblage data beyond comparatively simple "pass/fail" thresholds and it enables the

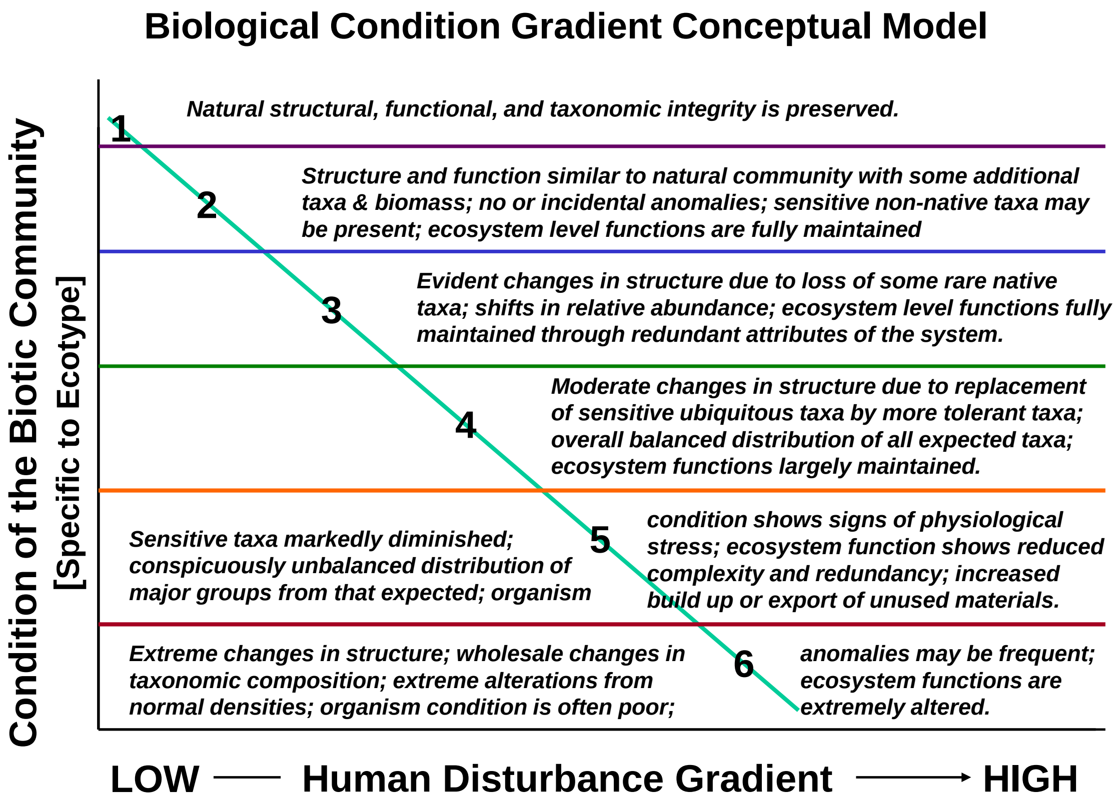


***Figure 2**. The Biological Condition Gradient (BCG) conceptual model and descriptive attributes for six levels of condition along a gradient of increasing disturbance (Davies and Jackson 2006).*

development of tiered expectations for specific water bodies. U.S. EPA (2005) described this as tiered aquatic life use (TALU), a concept that is emulated by the Maine DEP water quality standards and quantitative biological criteria (Davies et al. 1997).

In developing a BCG model for Maine's non-wadeable riverine fish assemblages we accessed general information about the historical fish assemblages relying on historical information and expert judgment in the process. We accomplished this via an ad hoc project advisory group comprised of U.S. EPA, U.S. F&WS, NOAA, the applicable Maine state agencies (DEP, IF&W, DMR), and other interested groups (Trout Unlimited, Penobscot Indian Nation). One important outcome of these discussions is the conclusion that the "as naturally occurs" fish assemblage in the moderate-high gradient riverine ecotype was largely comprised of native cold water and diadromous species. Based on discussions and using the results of the previous two reports (Yoder et al. 2006 a,b), we constructed a comparatively simple BCG for Maine's non-wadeable moderate-high gradient rivers (Figure 3). This reflects a qualitative method of visualizing what has happened in many instances to the "as naturally occurs" fish assemblage for this riverine ecotype in Maine through time. The current departures from tier 1 attributes and characteristics are the result of intensive and widespread modifications to water

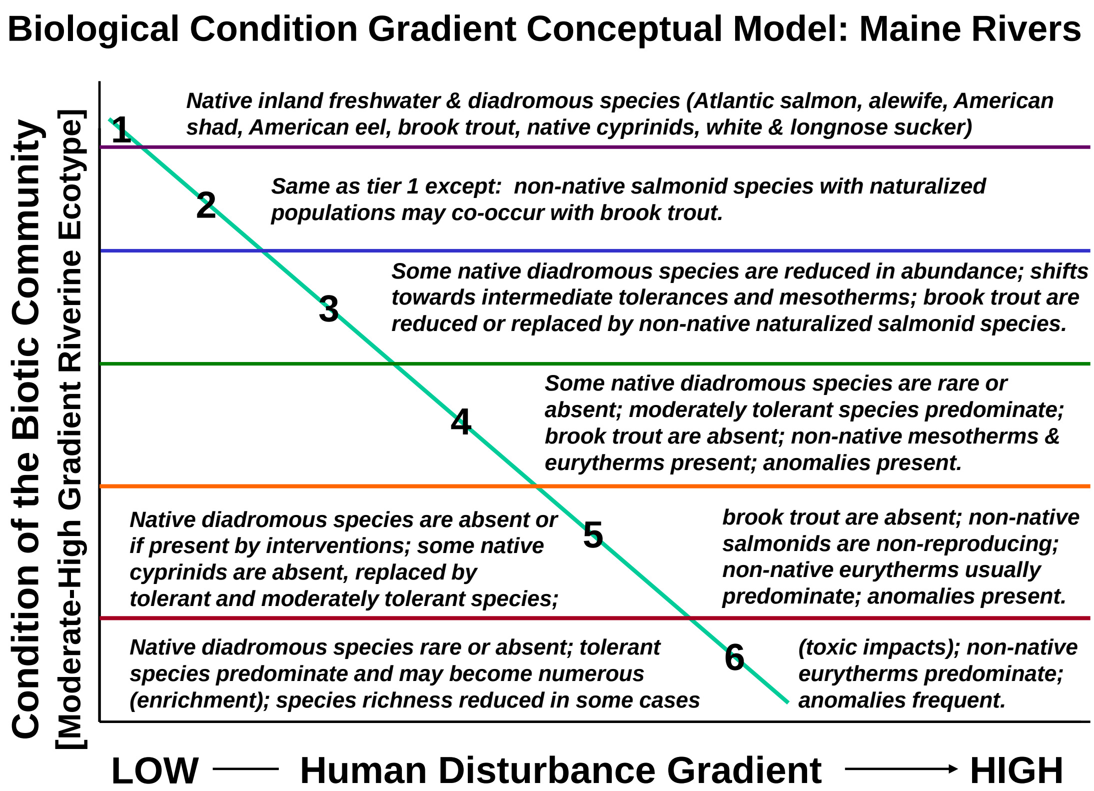


Figure 3. *A Biological Condition Gradient (BCG) model for fish assemblages representative of moderate-high gradient riverine habitats in Maine.*

quality, habitat, flow regime, and the native fauna via the introduction of non-indigenous species. This will be used to initially vet the efficacy of an interim fish IBI.

Establishing Reference Condition (Task 6)

The techniques for screening and selecting reference sites has evolved significantly during the past 20 years from a mostly qualitative process first described by Hughes et al. (1986) and used by some of the pioneering developers of numeric biological criteria (e.g., Ohio EPA 1987; Barbour et al. 1996) to a more quantitative process that is now used by U.S. EPA (Stoddard et al. 2006) and an increasing number of states. How reference sites are selected and used to develop reference condition are essential components of U.S. EPA's evaluation of the level of rigor exhibited by bioassessment programs (Yoder and Barbour 2009: U.S. EPA 2013). While most of these efforts have focused on wadeable streams, there are ample precedents for developing reference condition for large rivers (Hughes and Gammon 1987; Ohio EPA 1987; Lyons et al. 2001; Emery et al. 2003). The prevalence of legacy impacts in many non-wadeable rivers raises issues about the quality of the reference condition that contemporary sampling data represents. This is one reason why merging this process with the BCG framework is critical. However, it is also important to understand how the "best" and "better" non-wadeable sites within the domain of our sampling, in this case the state of Maine, currently perform so that the later task of reconciling conceptual goals with societal realities can be more effectively dealt with. This is especially important for setting what are in reality interim goals with the conceptual goals of the highest BCG tiers remaining the ultimate objective.

For the analyses included in this report we selected reference sites using a combination of position in the landscape and the intactness of the native fish fauna. The latter meant selecting sites that lacked blackbass (smallmouth and largemouth bass) and other non-indigenous species based on our growing knowledge about the impact of these introductions on native species assemblages that comprise the most sensitive metrics of the riverine IBI.

Deriving an Index for the Moderate-High Gradient Riverine Ecotype (Task 7)
This task includes two steps; 1) the selection and testing of candidate metrics, and 2) the derivation of an index for the cool-cold water, moderate-high gradient ecotype. These tasks have ample and recent precedence in North America and elsewhere. A growing body of information is now available for non-wadeable rivers (Yoder and Kulik 2003), some of which include similar baseline factors common to Maine rivers. These include the appropriate thermal baseline, metric testing and selection, and index development and testing. Developing metrics for a multimetric index involves sequential steps beginning with identifying candidate metrics, evaluating the responsiveness and relevance of those metrics, and deriving indices comprised of the "best" set of metrics for each ecotype and other strata that are embedded within the process (Hughes and Gammon 1987; Ohio EPA 1987; Lyons et al. 2001; Mebane et al. 2003; Emery et al. 2003).

Based on the compilation of data from 2002-7 about fish species distribution, relative abundance, and autecology in Maine's rivers, a partial list of candidate metrics was developed (Table 2). Some are common to other IBIs while some are unique to Maine. The remaining parts of this task include the further refinement and assignment of candidate metrics, testing each metric, and the derivation of a riverine IBI. Testing across available stressor gradients was accomplished herein.

IBI Metric Testing and Development

Data from a total of 352 boat or raft electrofishing samples were available based on the sampling conducted statewide during 2002-7. A multi-step process was employed to determine those metrics best suited to evaluate the condition of the non-wadeable fish assemblages. Principal Component Analysis (PCA) and Correlation Analysis (CORR) were utilized along with x-y plots, coefficients of variation, and multiple regression. All data analyses were conducted with the use of Statistica©8. A four-step process was followed to reduce a large suite of candidate metrics (n = 148) to a final set of 12 metrics that comprise an IBI for Maine's non-wadeable riverine fish assemblage (results in Appendix A). Table 2 is a categorical description of general metric categories from which the initial set of 148 candidate metrics was selected. An assessment of candidate metric suitability and selection was based on the following criteria:

- the metric reflects an important ecological role or function;
- the metric exhibits a sufficient range of measured values;
- the metric is not overly duplicative of other selected metrics; and,
- the metric is relevant to the cool-cold water, moderate-high gradient ecotype.

Correlation analysis was used first to determine which among the initial pool of candidate metrics were overly duplicative of one another. Some of the candidate metrics were simply variations of the same core attribute. An example is smallmouth bass age groups (adults, juveniles, young-of-year) based on numbers. In such cases, if the correlations were >P = 0.1, the strongest or highest quality metric was selected for further analysis and the others discarded. Principal Component Analysis (PCA) was then used to assess the behavior of the remaining metrics in relation to each other and Eigenvalues were used to measure the degree of variability explained by each factor. Finally, ecological reasoning was employed in the selection of the final set of 12 metrics and included considerations of the representativeness of certain well known assemblage attributes (e.g., DELT anomalies) and fulfilling the general structural and functional attributes that were intended by the original IBI guidance of Karr et al. (1986).

Metric calibration followed the methodology employed by Mebane et al. (2003) for Pacific Northwest rivers. Box-and-whisker plots of each metric were compared between reference sites, four ranges of the Qualitative Habitat Evaluation Index (QHEI), and a fifth category that included all sites with conductivity values >100 μS/cm (excluding brackish tidal sites). Reference sites were selected to represent minimally disturbed conditions for the moderate-high gradient riverine ecotype fish assemblage in Maine and primarily included sites that lacked blackbass and other non-indigenous species.

Reference Condition

Reference sites were selected in an attempt to reflect the natural fish assemblages that are representative of BCG level 1 and 2 conditions (see Figure 3). In addition to reflecting the absence of anthropogenic chemical and physical stressors, this also reflected the absence of non-indigenous species. Yoder et al. (2006 a,b) assigned the native status of the fish species that were either encountered in the 2002-5 sampling or reasonably expected to have occurred in recent times. We followed the definitions of Halliwell (2005) in describing the native status and in deriving candidate and final IBI metrics relevant to native status. Hence the presence of non-indigenous species was an additional factor in the selection of reference sites. Maine's rivers represent a unique situation in which the major river drainages are virtually contained within the state's boundaries and all are coastal drainages discharging to the Gulf of Maine. As such they are isolated from adjacent drainages such as the St. Lawrence-Great Lakes and the Connecticut River basins. This has greatly influenced the character of the Maine freshwater

***Table 2**. Candidate metric categories for further evaluation and possible inclusion in fish assemblage IBIs applicable to non-wadeable rivers in Maine.*

Candidate Metric	Expressed As[1]	Intent	Origin[2]
Taxonomic			
Sucker species	N	Long lived species	Original IBI metric
Cyprinid species	B	Important faunal component	Whittier et al. (2000)
Sunfish species	N	Water column inhabitant	Original IBI metric
Clupeid species	%	Diadromous component	None
Adult suckers	%[3]	Riverine run habitat	None
Ecological Role			
Stenothermic species	B	Cold water habitat specialists	Coldwater IBI metric
Steno + Mesothermic sp.	B	Cold & cool water habitat	None
Eurythermic species	B	Signal shift from cold water	None
Fluvial specialists	%	Riverine habitat dependency	Bain and Meixler (2000)
Fluvial dependents	%	Riverine habitat dependency	Bain and Meixler (2000)
Macrohabitat generalists	%	Reflect loss of riverine habitat	Bain and Meixler (2000)
Diadromous species	B	Original component of fauna	None
Native tidal species	B	Reflect tidal habitats	None
Reproduction and Recruitment			
Age classes across all species	N	Reproduction/recruitment	None
Salmonid age classes	B	Reproduction/recruitment	Mebane et al. (2003)
Non-guarding Lithophils	B	Sensitive to substrate quality	Hughes et al. (1998)
Functional Role			
Generalist feeders	%	Shift in food web	Halliwell et al. (1999)
Benthic insectivores	%	Specialist feeding guild	Langdon (2000)
Invertivores	%	General invertebrate feeder	Hughes et al. (1998)
Omnivores	%	Shift in food web	Original IBI metric
Top Carnivores	%	Food web endpoint	Original IBI metric
Piscivores	%	Food web endpoint	Hughes et al. (1998)
Environmental Tolerance			
Sensitive species	B	Tier 1-3 of BCG	Ohio EPA (1987)
Tolerant species	%	Tiers 4-6 of BCG	Many IBIs
%Common carp	%	Tiers 5-6 of BCG	Mebane et al. (2003)
Native Status			
Intercontinental origin	%	Most invasive of non-indigenous	None
Intra & Intercontinental	%	Broad def. of non-indigenous	Mebane et al. (2003)
All non-indigenous	%	Broadest def. of non-indigenous	None
Community Condition & Health			
CPUE (<tolerant/non-indig.)	N[3]	Assemblage production	Original IBI metric
DELT anomalies	%	Organism health	Ohio EPA (1987)

[1] N – number of species; % - proportion of individuals in sample; B – both.
[2] Precedence in prior IBIs: Original refers to Karr et al. (1986); None - metric not previously used.
[3] Based on numbers/km and biomass (kg/km) – will be evaluated separately.

fish fauna with some species that are common to these adjacent drainages being historically absent in Maine. An example is smallmouth and largemouth bass that are not indigenous to any Maine river system, but which were introduced in the latter part of the 19^{th} century becoming firmly established in several lakes and rivers (Warner 2005). A few rivers or sections of rivers have not yet been invaded by blackbass or other non-indigenous species and these also tended to represent minimally impacted conditions in terms of landscape, habitat, thermal, and flow modifications. Hence these were selected as the approximation of minimally disturbed reference for the metric derivation and testing analyses. In lieu of simply selecting all sites that lacked blackbass and non-indigenous species, we also selected reference sites on the basis of their location upstream from natural or human-made barriers that have thus far precluded these species. Minimally disturbed reference and a gradient of non-reference classes are defined as follows:

- "Minimally disturbed" reference sites lacking invasives and that anchor the present day high quality condition (BCG levels 1 or 2) – most of these sites were located upstream from natural or human-made barriers;
- Non-reference sites with conductivity $\geq$100 µS/cm intended to represent potentially polluted conditions (brackish tidal sites were excluded);
- The remaining non-reference sites were partitioned by QHEI ranges: $\leq$50; 51-75; 76-90; >90; this imparts a habitat gradient that reflects a commonly occurring impact in Maine's rivers.

These were then used to evaluate the responsiveness of candidate IBI metrics following the methodology of Mebane et al. (2003).

RESULTS AND DISCUSSION

IBI Metric Testing and Selection

A total of 148 candidate metrics were first evaluated using multivariate partitioning and correlation analysis to determine redundancy. From this analysis a subset of approximately 40 metrics emerged which were further analyzed for patterns and clustering. Four distinctive clusters of metrics were apparent in the principal components analysis (PCA) factor plot (Figure 4);

- "specialist" and cold-cool water metrics;
- "general" assemblage metrics consisting of assemblage richness, abundance, and common taxonomic guilds;
- "disturbance" indicative or negative metrics; and,
- a fourth and non-distinct cluster of candidate metrics, such as DELT anomalies, which were not strongly associated with other metric clusters and plotted near the center.

Within these clusters of metrics, those deemed to best represent the cool-cold water, moderate-high gradient riverine ecotype were selected for further analysis. Values of each selected metric were plotted against drainage area and assessed for their range of variation. A total of 23 metrics with sufficient ranges were then plotted in accordance with the reference and non-reference classes previously described. An example of selected metric responsiveness to this gradient appears in Figure 4.

The final set of 12 metrics was determined based on the consideration of the metric responsiveness to the reference/non-reference gradient analysis and ecological role fulfillment and relevance to include:

1. native species richness;
2. number of native cyprinid species (excluding fallfish);
3. relative abundance of adult white/longnose suckers (based on biomass);
4. %native salmonids (based on numbers);
5. %benthic insectivores (based on numbers);
6. %blackbass (based on numbers);
7. %fluvial specialist/dependent species (based on numbers);
8. %macrohabitat generalists (based on numbers);
9. number of temperate stenothermic species;
10. number of non-guarding lithophilic species;
11. number of non-indigenous species; and,
12. %DELT anomalies.

These metrics provided adequate distinction on the PCA axes (Figure 4) and in the final correlation analysis (Appendix A). The rationale, derivation, and calibration of each are

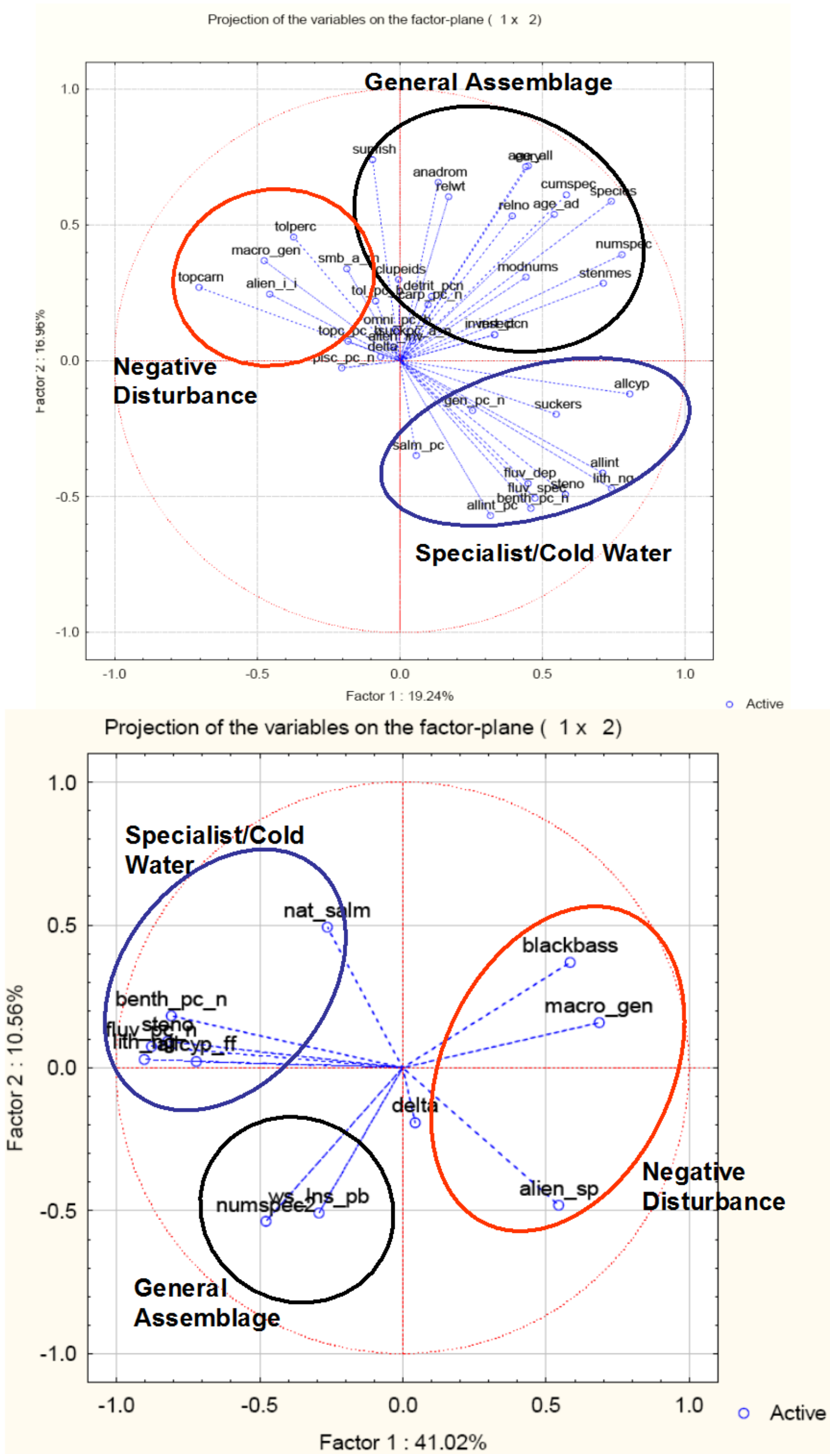


***Figure 4**. Clustering of 40 candidate metrics (upper) and 12 final metrics (lower) evaluated for relevance and applicability to Maine moderate-high gradient rivers based on principal components analysis (PCA). Three clusters labeled as specialist/cold water, general assemblage, and negative disturbance were drawn by eye.*

further described and include the calibration plots following Mebane et al. (2003).

After examining the relationship of each metric across the reference/non-reference gradient, cumulative histograms were developed following the practice of Mebane et al. (2003). These were then used to develop the calibration curves for each metric in accordance with a continuous scoring procedure. The calibration curve for each metric was selected based on the "best fit" of the resulting data points from three options – linear, logarithmic, and polynomial. The final calibration curves were adjusted if necessary to fit ecologically meaningful and logical insertion points on the Y_1 and Y_2 axes.

Native Species Richness

Species richness is a common metric included in fish IBIs and it generally functions as a positive indicator of assemblage condition, especially in warmwater streams and rivers with inherently species rich assemblages. By comparison, Maine river fish assemblages are comparatively species depauperate owing to geographic restrictions, post-glacial isolation, and the cool-cold water ecotype. A total of 60 species are listed as either occurring or potentially occurring in the non-wadeable rivers and bordering rivers of Maine (Table 1). Most cold water IBIs that have been developed elsewhere generally do not include a species richness metric because of the oftentimes ambiguous or even negative meaning of increases in *overall* species richness. In naturally depauperate cold water and coastal drainages increases in *overall* species richness are frequently due to the introduction of non-indigenous species that are present as the result of being able to adapt to otherwise marginal conditions for the native cold water fauna. Thus we considered and rejected *total* species richness for the above reasons.

For our purposes we used *native* species richness following the classifications of Halliwell (2005). This metric includes the 38 species designated as native (N) under the Native Status column in Table 1. It excludes the 3 species designated as exotic (E, exotic of intercontinental origin), the single unknown (U), and the 12 introduced species of intracontinental origin (IC) as defined by Halliwell (2005). As such some species that are now managed for recreational fisheries in Maine (e.g., brown and rainbow trout) are excluded from this metric. This metric includes the 6 species of interstate origin (IS) because of the ambiguity in determining exactly where these are native and where they are not in Maine.

The gradient of reference to non-reference indicates that this is a positive metric (i.e., its measured value increases along the BCG) and it would be expected to decline with a loss of assemblage integrity. The range among reference sites was fairly wide ranging from 6-17 species with a median of 11. We selected the linear calibration plot for scoring this metric (Figure 5). Manual adjustments to the scoring calibration include assigning a 0 metric score to metric values <3 and a metric score of 10 at metric values $\geq$15 (Table 3).

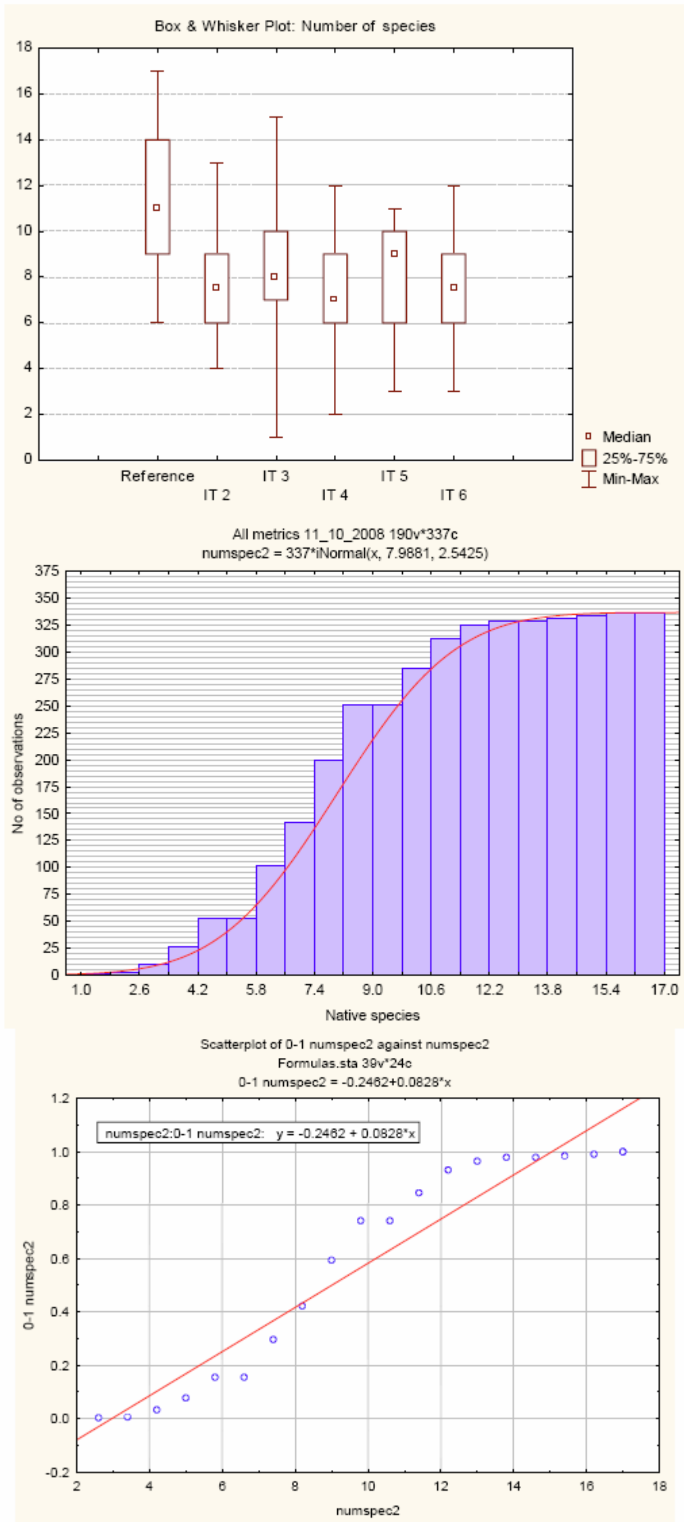


***Figure 5**. Maine non-wadeable rivers IBI metric calibration process for the number of native species (numspec2). **Upper**: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. **Middle**: Cumulative frequency histogram of number of native species recorded in 337 samples. **Lower**: Cumulative frequency plot with linear best fit line (y-axis is standardized to a 0-1 scale).*

Table 3. *Maine riverine IBI metrics with calibrated scoring equations and manual scoring adjustment criteria. Proportional (%) metrics are based on numbers unless indicated otherwise.*

Metric	Scoring Equation	Scoring Adjustments	
		Score = 0	**Score = 10**
Native Species Richness	10 * (-0.2462 + (0.0828*numspec2)))	<3 sp.	≥15 sp.
Native Cyprinid Species (excluding fallfish)	(10 * (0.4457 + (0.0109*allcyp_ff) - (0.00005629 * (allcyp_ff^{2}))))	Eq[4]	Eq
Adult white & longnose sucker abundance (biomass)	(10 * (0.3667 + (0.008*ws_lns_pb) - (0.000023592 * (ws_lns_pb^{2}))))	0	≥128 kg/km
%Native Salmonids	(10 * (0.9537 + (0.00000000039*nat_salm) - (0.000078892 * (nat_salm^{2}))))	0	≥20%
%Benthic Insectivores	10 * (0.010966*benth_pc_n)	0	≥91.2%
%Blackbass	10 - (10 * (-0.09684 + (0.5638*log10(blackbass))))	Eq	0
%Fluvial Specialist/ Dependent	(10 * (0.2775 + (0.0073*fluv_pc_n)))	0%	Eq
%Macrohabitat Generalists	10 - (10 * (0.1017 + (0.0096*macro_gen)))	>90%	Eq
Temperate Stenothermic Species	(10 * (0.7154 + (0.4047*(log10(steno)))))	0 sp.	>5 sp.
Non-guarding Lithophilic Species	(10 * (0.2979 + (0.8975*log10(lith_ng))))	<1	>10
Non-indigenous Species	10 - (10 * (0.1063 + (0.3271*Non-indigenous_sp) - (0.029*(Non-indigenous_sp^{2}))))	≥5	0
%DELT Anomalies	10 - (10 * (0.8965 + (0.1074*log10(delta))))	Eq	0

[4] No scoring adjustments are necessary; scoring determined by equation (Eq) across entire metric scoring range of 0-10.

Proportion of Native Cyprinid Species (excluding fallfish)

Members of the family Cyprinidae (minnows) are an expected and prominent part of the Maine fish assemblage. A total of 14 species are included in Table 1, of which 12 are confirmed as native in at least portions of the state. The native status of spottail shiner *(Notropis hudsonius)* is undetermined at present. Kircheis (1994) listed spottail shiner as probably an accidental introduction in Maine. Halliwell (2005) however, lists the status of this species as possibly native in southern Maine, thus its native status is presently undetermined. As with other taxonomically distinct groups, a few members are ubiquitous and others are comparatively disjunct or patchy in their distribution. Fallfish *(Semotilus corporalis)* and common shiner *(Luxilis cornutus)* are among the most numerous and widely distributed species encountered being present in nearly all of our collections. Golden shiner *(Notemigonus crysoleucas)* is common especially in certain riverine habitats such as low gradient and impounded sites, but can be expected to occur statewide. Other species such as Eastern blacknose dace *(Rhinichthys atratulus)* , lake chub *(Couesius plumbeus),* and creek chub *(Semotilus atromaculatus)* exhibited regionally distinct distributions. Others such as blacknose shiner *(Notropis heterolepis)*, bridle shiner *(Notropis bifrenatus),* northern redbelly dace *(Phoxinus eos)*, finescale dace *(Phoxinus neogaeus),* and pearl dace *(Margariscus margarita)* were comparatively rare, occurring at only a few sites.

While not a commonly employed metric in most IBIs, the prominence of Cyprinids in the Maine riverine fish assemblage was ample grounds for its inclusion. The reference and calibration results show that it behaves as a positive metric with the number of native Cyprinids increasing along the BCG (Figure 6). We tested this metric with fallfish included and its removal improved metric responsiveness, especially along the gradient of habitat quality. Fallfish are tolerant of both chemically and physically altered conditions and their exclusion better follows the intended role of this metric.

Relative Abundance of Adult White and Longnose Suckers (based on biomass)

This metric includes the relative abundance of adult white *(Catostomus commersonii)* and longnose *(Catostomus catostomus)* suckers based on biomass. Adults are defined as individuals weighing ≥1.0 kg (Yoder et al. 2006a). Only three species of Catostomidae occurred in our samples with creek chubsucker *(Erimyzon oblongus)* being found at one location in the upper Saco River. All three are native species and white sucker is among the three most ubiquitous fish species in our collections occurring at nearly all sampling locations. Longnose sucker was regionally distributed occurring mostly in the northern and western portions of Maine. This species is also classified as a stenotherm, whereas white sucker is a mesotherm and creek chubsucker is a eurytherm.

White sucker in particular can be tolerant to chemical pollution, habitat modification, and flow alteration. However, under such alterations we found it to occur mostly as juvenile or young-of-year life stages, with large adults being less common or absent altogether. Adults demonstrated a preference for deep and swift flowing run habitats as did adult longnose sucker. This is analogous to other "round bodied" Catostomidae

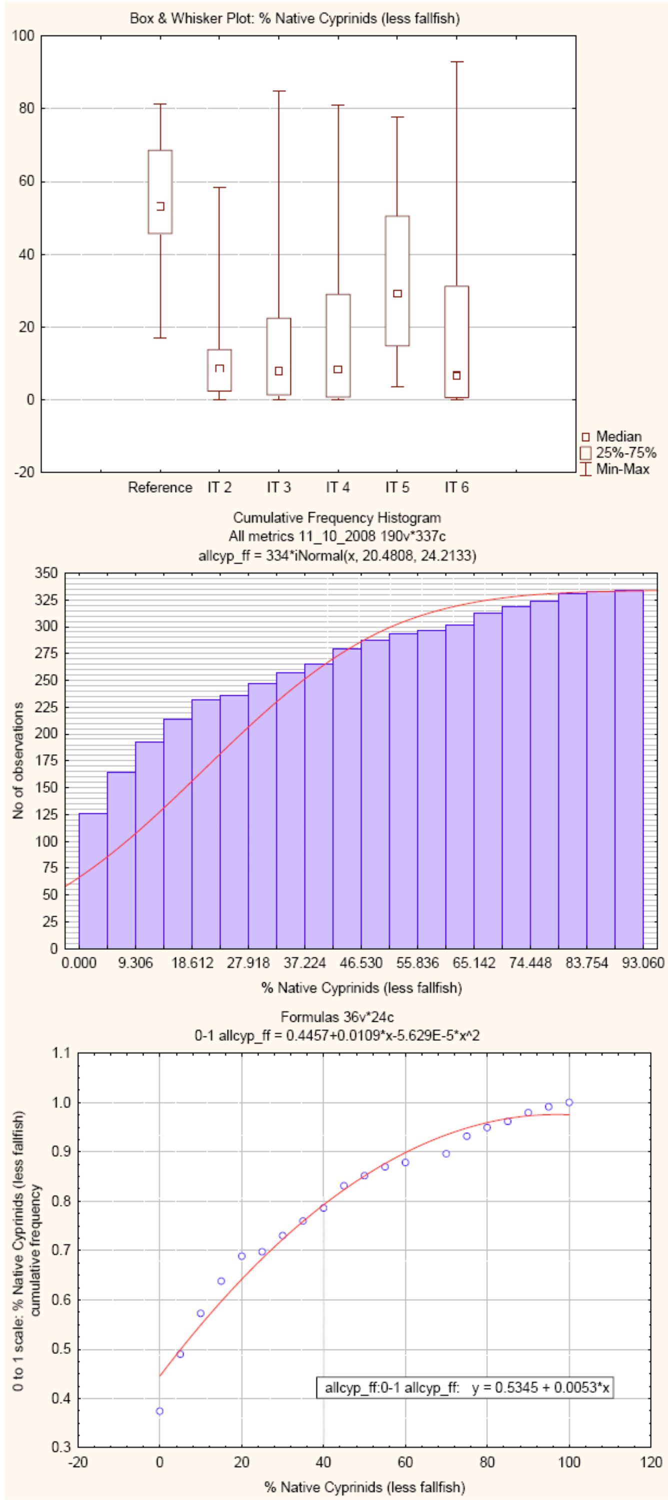


***Figure 6**. Maine non-wadeable rivers IBI metric calibration process for the proportion of native Cyprinidae (less fallfish; allcyp_ff). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of proportion of Cyprinidae (less fallfish) recorded in 337 samples. Lower: Cumulative frequency plot with polynomial best fit line (y-axis is standardized to a 0-1 scale).*

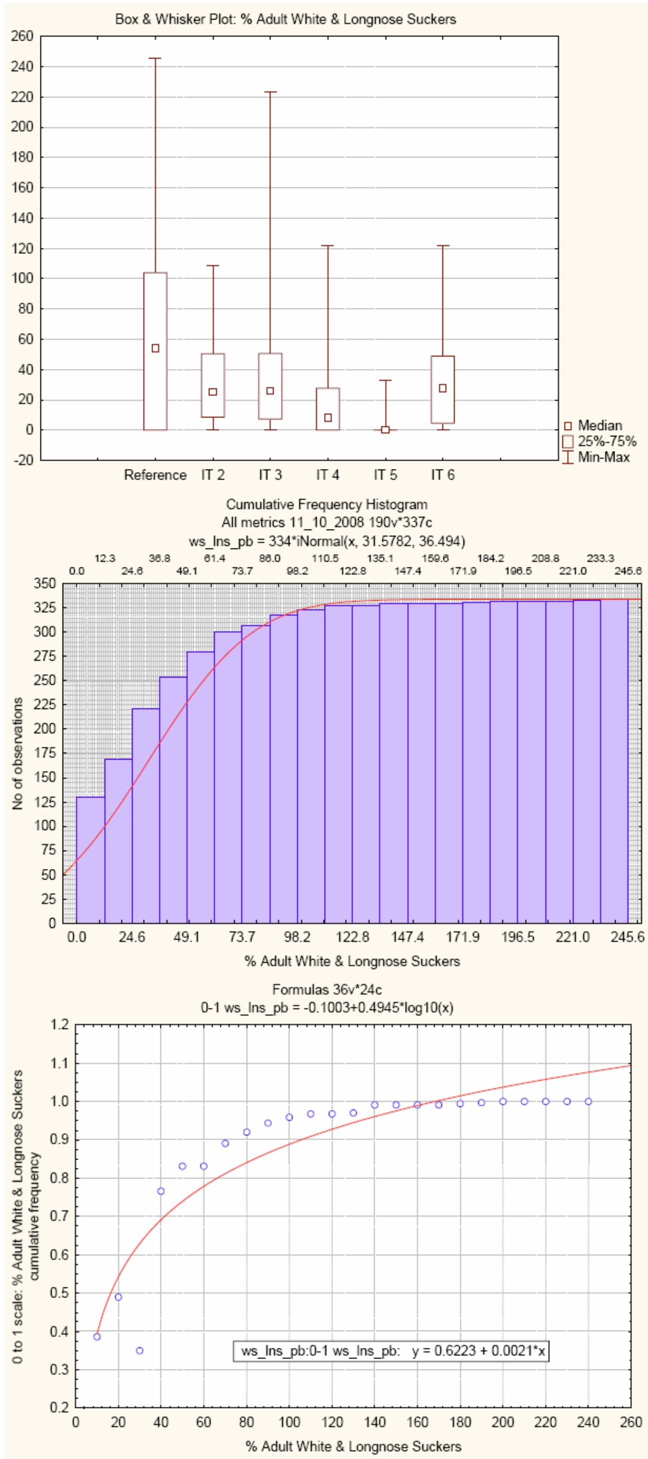


Figure 7. *Maine non-wadeable rivers IBI metric calibration process for the proportion of adult white and longnose suckers based on biomass (ws_lns_pb). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of adult white and longnose suckers based on biomass recorded in 337 samples. Lower: Cumulative frequency plot with polynomial best fit line (y-axis is standardized to a 0-1 scale).*

that comprise a positive metric in large river warmwater IBIs (Ohio EPA 1987; Lyons et al. 2001). The reference and calibration results confirm this as a positive metric (Figure 7). The calibration curve was adjusted so that 0 kg/km equates to a 0 metric score and $\geq$128 kg/km equals the maximum metric score of 10.

Proportion of Native Salmonids (based on numbers)

This metric is comprised of the three native Salmonidae that occur in non-wadeable rivers in Maine, brook trout *(Salvelinus fontinalis)*, round whitefish *(Prosopium cylindraceum),* and sea run Atlantic salmon *(Salmo salar),* the latter excluding the introduced landlocked strain. The intent of this metric is to reflect the BCG Level 1 condition of the "as naturally occurs" native fauna. As a result it excludes all other non-indigenous Salmonidae including brown trout *(Salmo trutta)*, rainbow trout *(Oncorhynchus mykiss),* and landlocked Atlantic salmon. Brown trout are an exotic of intercontinental origin, rainbow trout are introduced of intracontinental origin, and landlocked salmon are widely introduced hence they were excluded from this metric. All of these species are classified as stenotherms.

The reference and calibration results show that this is a positive metric (Figure 8). These species were absent at some of the reference sites owing to the fact that some reference sites are not completely reflective of the conditions that are consistent with BCG Level 1 quality, hence this was taken into account in the calibration of this metric. Scoring adjustments included 0% as a 0 metric score and $\geq$20% the maximum metric score of 10.

Proportion of Benthic Insectivores (based on numbers)

This metric includes species classified as benthic insectivores (Table 1) following the assignments of Goldstein and Simon (1999). It includes what are regarded a specialist insectivores, i.e., those species that are narrowly dependent on benthic insectivory and which cannot adapt to alternate strategies as can more generalized insectivores. Species included as benthic insectivores are lake chub *(Couesius plumbeus),* Eastern blacknose dace *(Rhinichthys atratulus),* longnose dace *(Rhinichthys cataractae),* longnose sucker *(Catostomus catostomus),* and slimy sculpin *(Cottus cognatus).*

The reference and calibration results indicate that this is a positive metric with very a distinct separation of reference from the gradient of impacted sites (Figure 9). This metric is comprised entirely of native species and reflects the functional attributes of the upper levels of the BCG. Scoring adjustments include 0% equating to a metric score of 0 and $\geq$91.2% equating to the maximum metric score of 10.

Proportion of Blackbass (based on numbers)

This metric includes the two blackbass species that we encountered, smallmouth bass *(Micropterus dolomieu)* and largemouth bass *(Micropterus salmoides).* Both are non-indigenous species of intracontinental origin. Their history and status in Maine has been documented by Warner (2005). These species were legally stocked by the state of

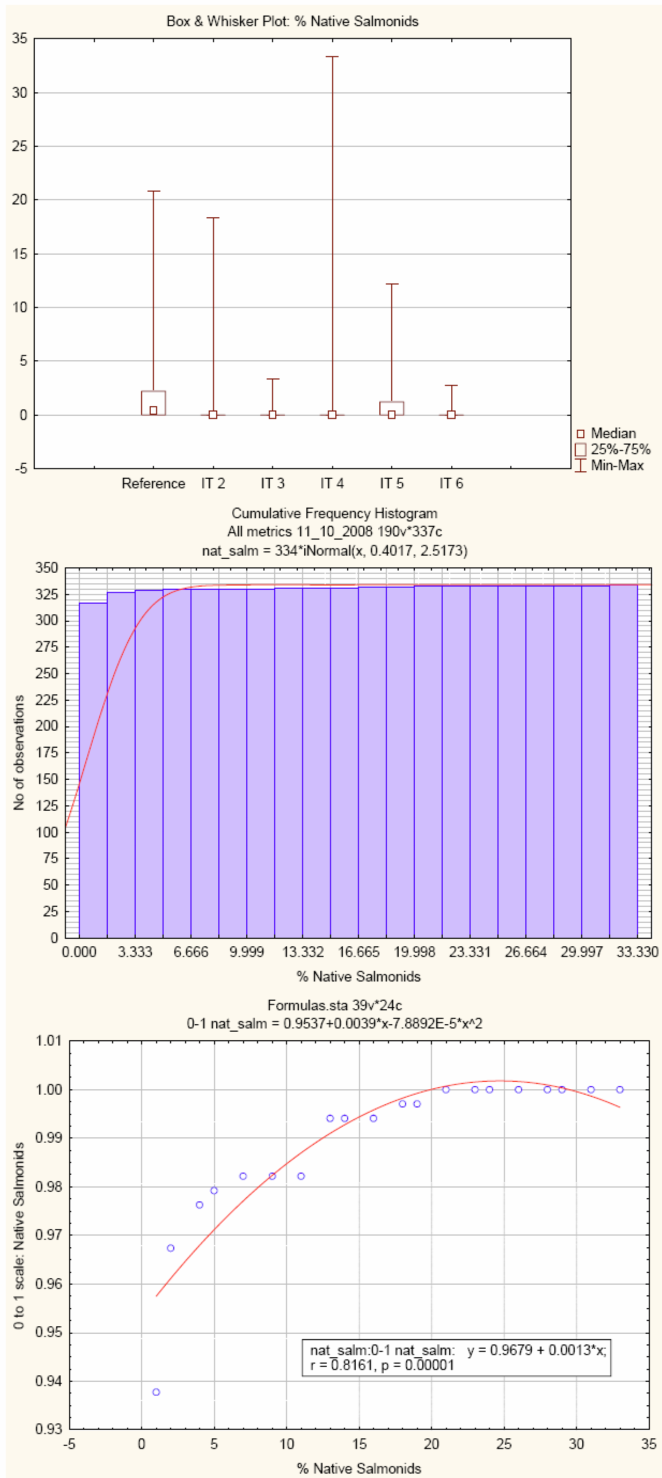


***Figure 8**. Maine non-wadeable rivers IBI metric calibration process for the proportion of native Salmonids (nat_salm). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of native Salmonids recorded in 337 samples. Lower: Cumulative frequency plot with polynomial best fit line (y-axis is standardized to a 0-1 scale).*

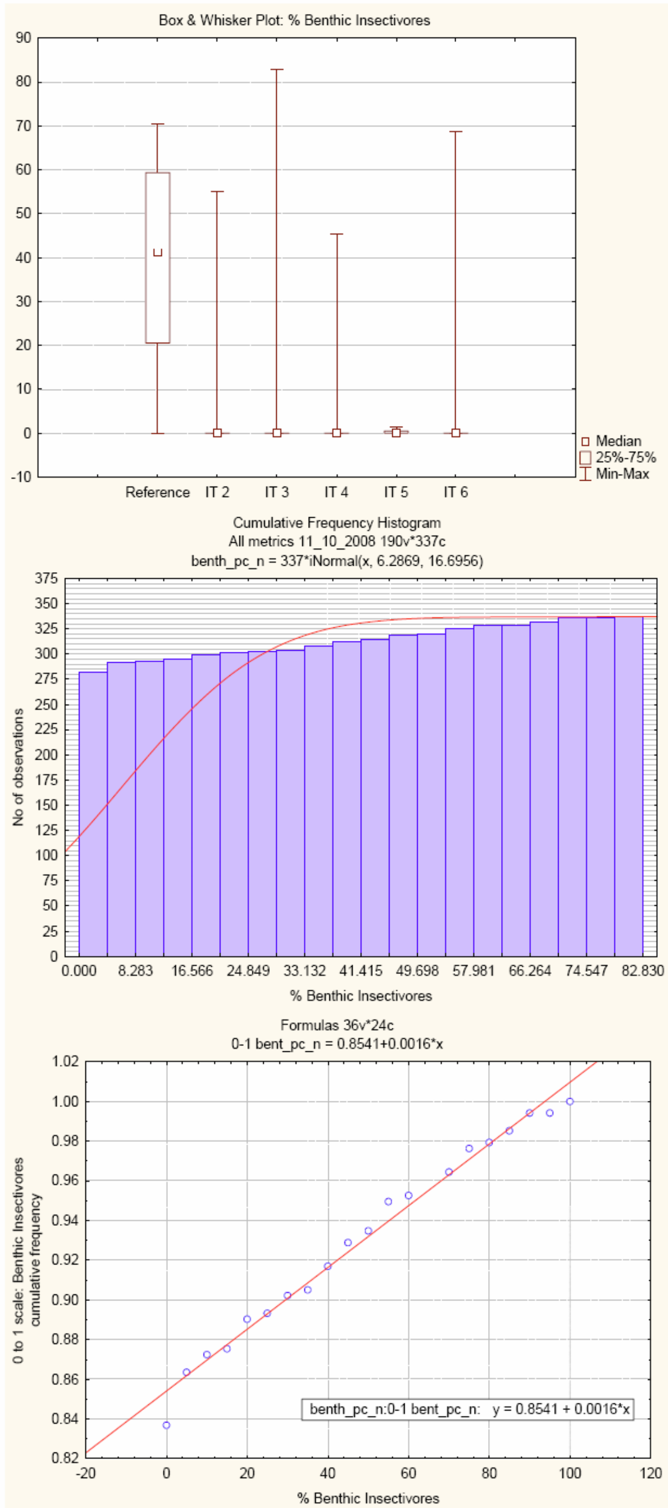


Figure 9. *Maine non-wadeable rivers IBI metric calibration process for the proportion of benthic insectivores (benth_pc). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of benthic insectivores recorded in 337 samples. Lower: Cumulative frequency plot with linear best fit line (y-axis is standardized to a 0-1 scale).*

Maine in 51 water bodies between 1868 and 1881 and have since become well established with reproducing populations in numerous rivers and lakes in southern and central Maine. In some southern and central Maine rivers smallmouth bass are the predominant species by numbers. Since the mid-1980s they have either been illegally transplanted within the state or they have invaded by natural means thus further expanding their range. Natural and human-made barriers in selected northern rivers have precluded their establishment thus far. The "minimally impacted" reference sites used herein are entirely contained within these river segments.

The negative effects of blackbass on native brook trout and cyprinid populations via general competition and direct predation have been documented in a number of lakes, streams, and rivers (Whittier et al. 2000, 2001; Warner 2005). It is also hypothesized that warmer water temperatures will present increasingly advantageous conditions favoring these species. As such it remains a significant management challenge for preserving native fish assemblages in Maine rivers. Recent information that indicates a potential negative effect of smallmouth and largemouth bass on native species (Jackson 2005) has also been implicated in Maine lakes (M. Gallagher, personal communication). Our own observations in Maine rivers during 2002-7 indicate a negative impact on native Cyprinids and other small species such as sticklebacks. The apparent adverse impact of blackbass on these native species is evident with their mere presence (Figure 10). Reduced numbers of small Cyprinidae and sticklebacks are evident as smallmouth bass abundance exceeds as few as 10 individuals/km and becomes increasingly pronounced at abundances >100/km. The expectation is that blackbasses would not be present in BCG Level 1 or 2 only becoming established in Level 4. The reference and calibration results confirm this as a negative metric (Figure 11). No scoring adjustments outside of a zero value equaling a 0 metric score were necessary.

Proportion of Fluvial Specialist and Dependent Species (based on numbers)

This metric is based on the original concept of fluvial guilds by Bain and Meixler (2000, 2008) in support of the Target Fish Community approach. It is a combination of the two fluvial guilds and results from the metric testing of the guilds both independently and combined. The intent of this metric is to reflect a dependency on a natural riverine flow regime and habitat characteristics, hence it is a positive metric. The reference and calibration results verify it as a positive metric with a very distinct separation of reference from the gradient of non-reference sites (Figure 12). This metric is also a functional replacement for the intolerant metric that is usually a component of other IBIs, particularly for warmwater ecotypes. This guild was assigned to 16 fish species of which only 2 are non-indigenous (Table 1). We made assignments for species not included by Bain and Meixler (2000) based on their classification rationale. No scoring adjustments outside of a zero value equaling a 0 metric score were necessary.

Proportion of Macrohabitat Generalist Species (based on numbers)

This metric is also based on the original development of fluvial guilds by Bain and Meixler (2000, 2008) in support of the Target Fish Community approach. The intent of

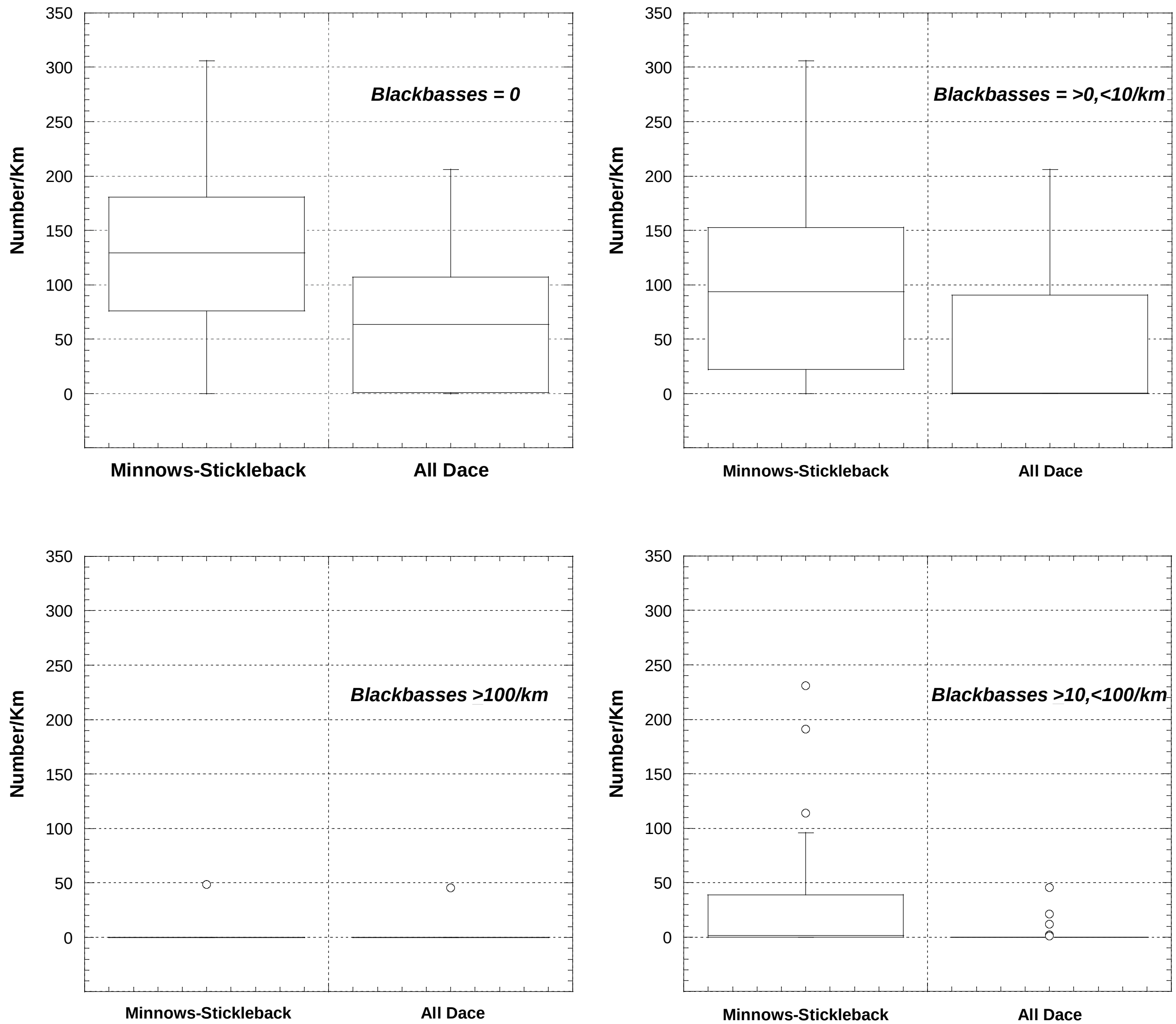


***Figure 10**. Relative abundance of small Cyprinidae (Minnows) species (Couesius, Notropis, Semotilus) and sticklebacks (Gasterosteus, Pungitius) and dace species (Phoxinus, Rhinichthys, Margariscus) when smallmouth bass abundance was 0, >0 and <10, ≥10 and <100, and ≥100 individuals/km (increasing clockwise from upper left) at all Maine non-wadeable riverine sampling sites during 2002-7.*

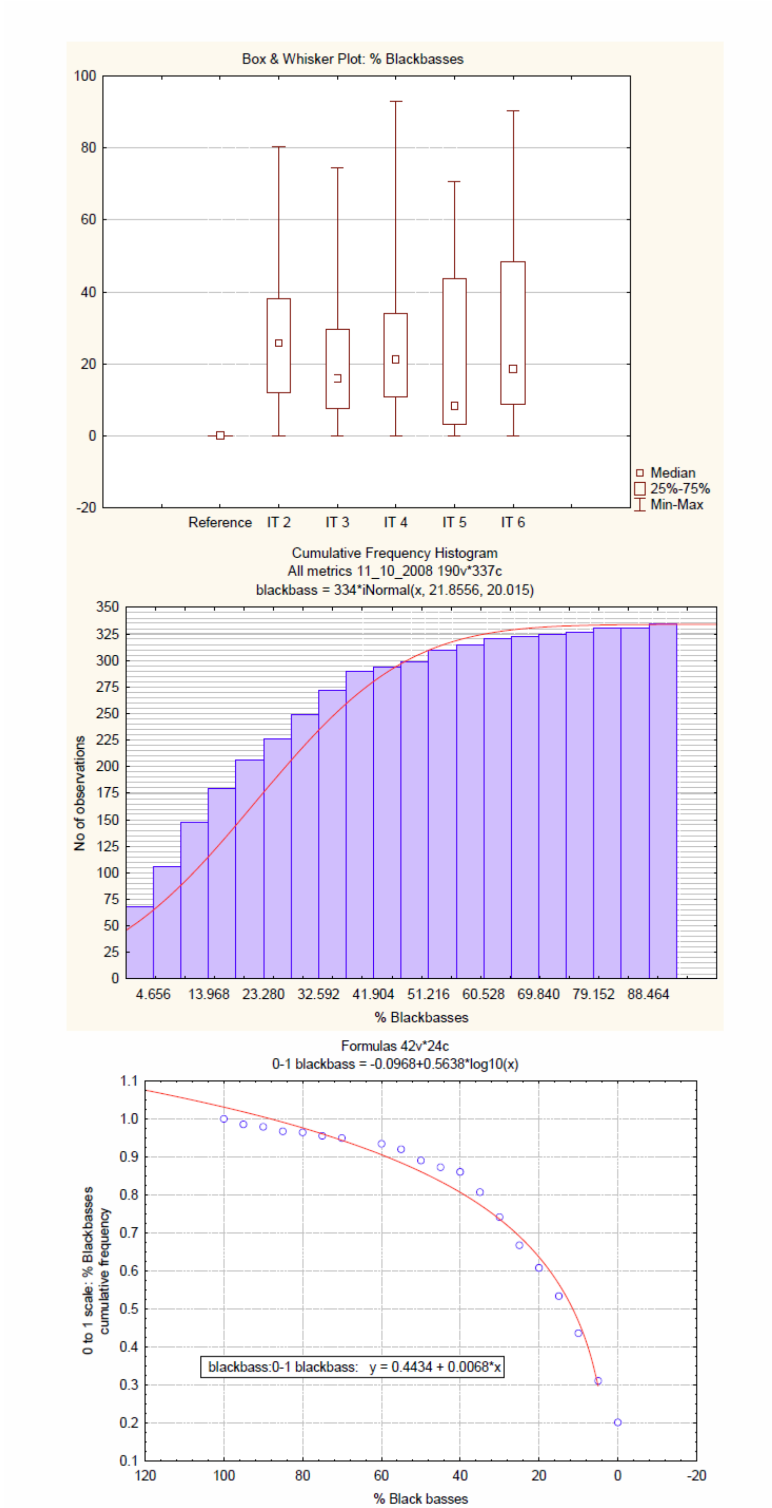


***Figure 11**. Maine non-wadeable rivers IBI metric calibration process for the proportion of blackbass. Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of blackbass recorded in 337 samples. Lower: Cumulative frequency plot with log_{10} best fit line (y-axis is standardized to a 0-1 scale).*

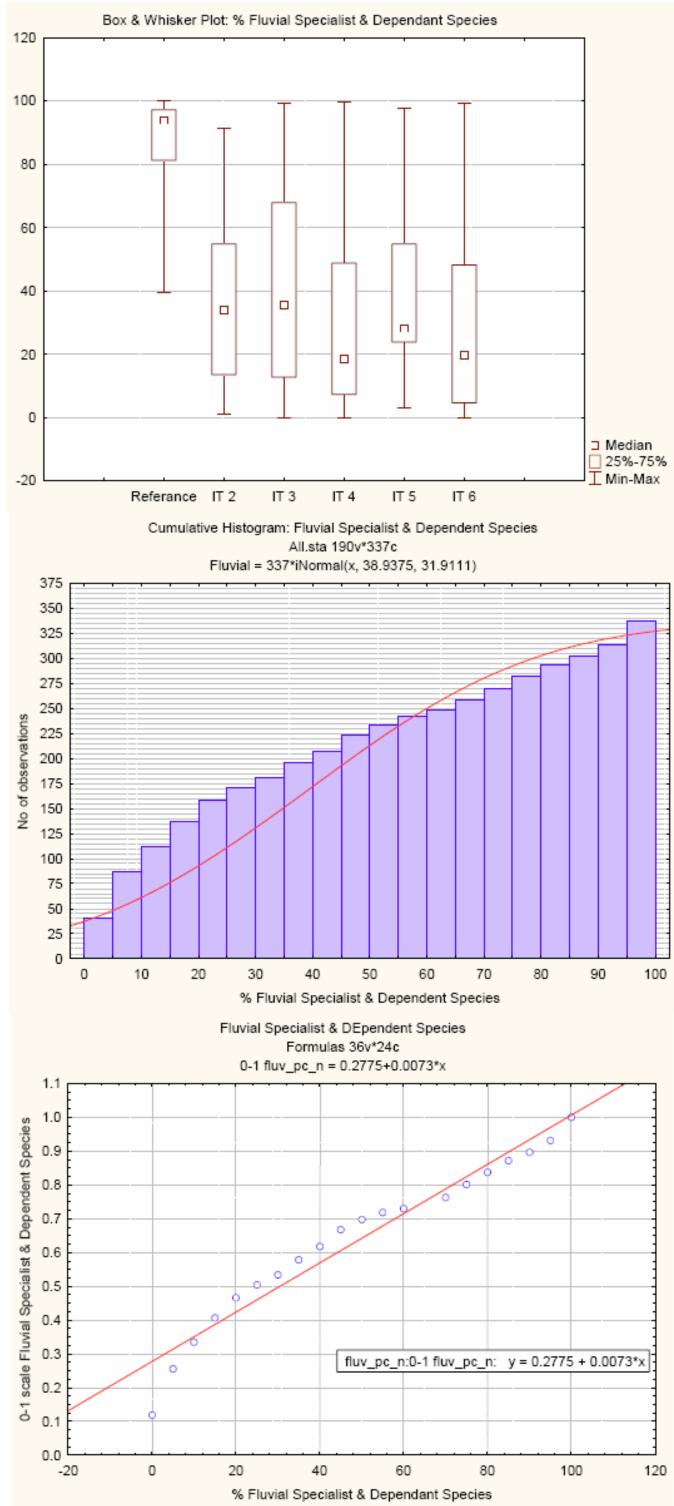


Figure 12*. Maine non-wadeable rivers IBI metric calibration process for the proportion of fluvial specialist and dependent species (fluv_pc_n). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of fluvial specialist and dependent species recorded in 337 samples. Lower: Cumulative frequency plot with linear best fit line (y-axis is standardized to a 0-1 scale).*

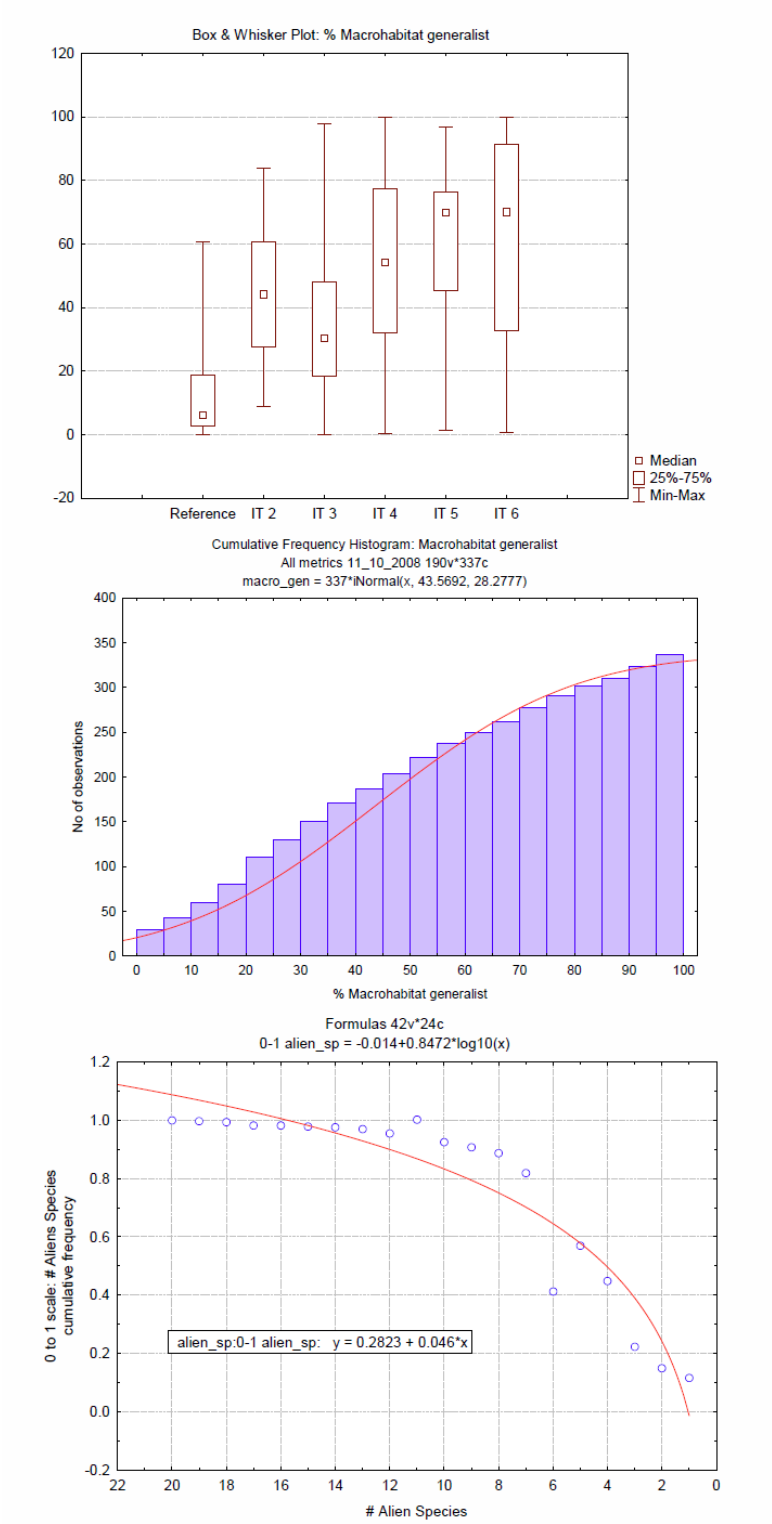


***Figure 13**. Maine non-wadeable rivers IBI metric calibration process for the proportion of macrohabitat generalist species (macro_gen). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of macrohabitat generalist species recorded in 337 samples. Lower: Cumulative frequency plot with linear best fit line (y-axis is standardized to a 0-1 scale).*

this metric is the opposite of the fluvial specialist and dependent metric and includes species that are tolerant of both flow and habitat alterations. The reference and calibration results verify that this is a negative metric with a very distinct separation of reference from non-reference sites and a gradient within the latter as well (Figure 13). It is also a functional replacement for the tolerant metric that is a common metric of other IBIs, particularly for warmwater ecotypes. This guild was assigned to 29 fish species of which 13 species are either exotics of intercontinental origin or introduced of intracontinental origin (Table 1). We made assignments for species not included by Bain and Meixler (2000) based on our understanding of their classification rationale. No scoring adjustments outside of a zero value equaling a 0 metric score were necessary.

Number of Temperate Stenothermic Species

Hokanson (1977) described a temperature based classification scheme that categorizes fish species as temperate stenotherms, mesotherms, or eurytherms (Table 4). The more common descriptions are cold, cool, and warm water species. Of the remaining inland freshwater species that were encountered in our study, some are obvious and well known members of one of these guilds while others are not as well defined. We relied on the latitudinal distribution of these species (Yoder et al. 2006b) as a criterion for inclusion in a particular thermal guild when other information was lacking. This is intended as a positive metric that is representative of BCG Levels 1 and 2.

Stenothermic species are commonly referred to as cold water species having comparatively narrow thermal requirements. We tested a combination of stenothermic and mesothermic species, but stenotherms alone better fit the intended role of this metric. A total of 11 species are classified as stenotherms of which all except rainbow and brown trout are native (Table 1). The reference and calibration results verify that this is a positive metric with a very distinct separation of reference from non-reference sites (Figure 14). This metric is also a functional replacement for the intolerant metric, in this case focusing on temperature intolerance. Scoring adjustments included assigning a metric score of 10 at $\geq$5 stenothermic species.

Number of Non-guarding Lithophilic Species

This metric is intended to represent the spawning habit of species that do not protect or otherwise care for their eggs, hence making them vulnerable to both direct and indirect effects of habitat and substrate modifications. It is based on the assignments of Ohio EPA (1987) and Hughes et al. (1998) and includes 14 native fish species (Table 1). The reference and calibration results verify that this is a positive metric with a very distinct separation of reference from non-reference (Figure 15). Scoring adjustments included assigning a metric score of 10 at $\geq$6 non-guarding lithophilic species.

Number of Non-indigenous Species

This metric has seen increased emphasis in recent IBIs, particularly in the Western U.S. where the invasion and consequences of non-indigenous species has been used as a

Table 4. Temperature classification of temperate climate fish species with specific reference to selected Maine river species (after Hokanson 1977). Non-indigenous species are denoted with an asterisk (*).

Classification	Criteria/Thresholds	Maine River Species
Temperate stenotherm	Gonadal growth (summer) <20°C Spawning (fall to spring) <15°C Physiological optimum <20°C UUILT[5] <26°C	Brook trout, round whitefish, rainbow & brown trout*, land-locked salmon
Temperate mesotherm	Gonadal growth (fall & winter) <12°C Spawning (spring) 3-23°C Physiological optimum 20-28°C UUILT[1] 28-34°C	White sucker, yellow perch, northern pike*, muskellunge*, no. red-belly dace
Temperate eurytherm	Gonadal growth (long days) >12°C Spawning (spring to fall) 15-32°C Physiological optimum >28°C UUILT[1] >34°C	Redbreast sunfish, pump-kinseed sunfish, small mouth bass*, largemouth bass*, common carp*

metric. It includes the 3 species designated as exotic (E, exotic of intercontinental origin) and the 12 introduced species of intracontinental origin (IC) as defined by Halliwell (2005). On a species count basis it accounts for more than 40% of the riverine fish species in Maine (Table 1). The reference and calibration results verify that this is a negative metric with a very distinct separation of reference from non-reference (Figure 16). There is a visible gradient with habitat in the same direction. Scoring adjustments included assigning a metric score of 0 at ≥12 non-indigenous species.

Proportion of DELT Anomalies (based on numbers)

This metric consists of the proportion (by numbers) of individual fish that exhibit deformities, erosions, lesions, or tumors (DELTs) based upon visual inspection. An external anomaly is defined as the presence of a visible skin, extremity (fin, barbel, operculum), skeletal, or subcutaneous disfigurement, and is expressed as the weighted percentage of affected fish among all fish enumerated. Light and heavy infestations are noted for certain types of anomalies and follow the guidance in Ohio EPA (1989, 1996) and Sanders et al. (1999). The frequency of DELT anomalies is a good indication of chronic stress caused by biological agents, intermittent stresses, and chemical contaminants (Yoder and Rankin 1995; Yoder and DeShon 2003). It is a metric that is included in most

[5] Ultimate Upper Incipient Lethal Temperature (UUILT) after Fry (1947).

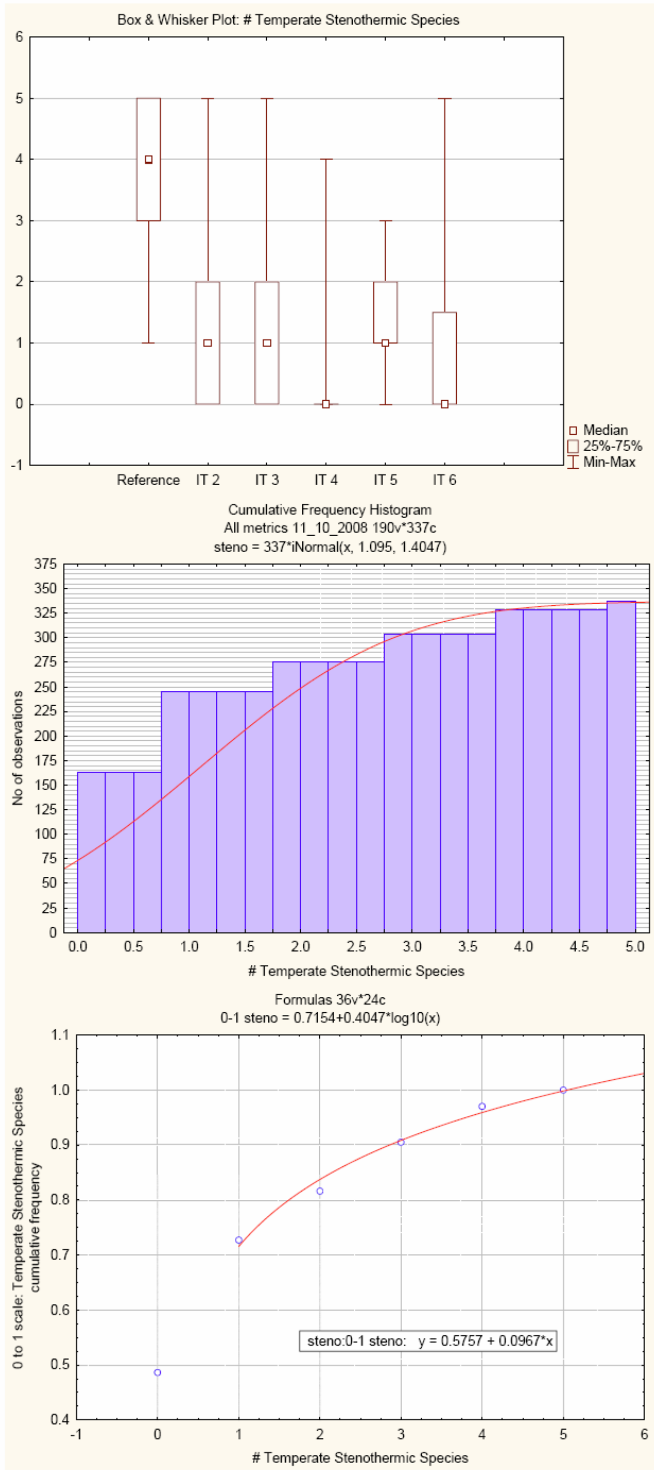


***Figure 14**. Maine non-wadeable rivers IBI metric calibration process for the number of temperate stenothermic species (steno). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of temperate stenothermic species recorded in 337 samples. Lower: Cumulative frequency plot with polynomial best fit line (y-axis is standardized to a 0-1 scale).*

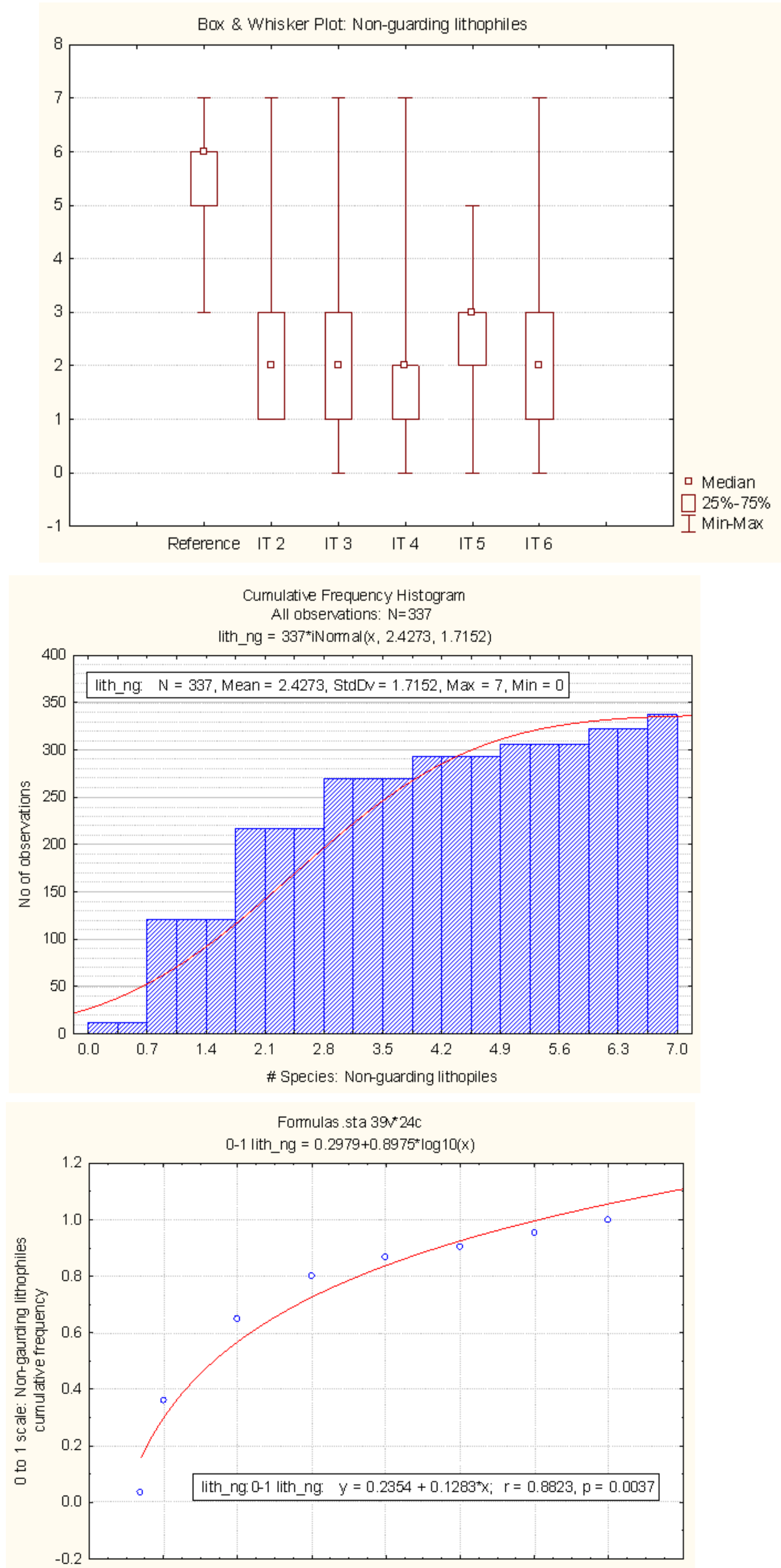


Figure 15. *Maine non-wadeable rivers IBI metric calibration process for the number of non-guarding lithophilic species (lith_ng). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of number of non-guarding lithophilic species recorded in 337 samples. Lower: Cumulative frequency plot with polynomial best fit line (y-axis is standardized to a 0-1 scale).*

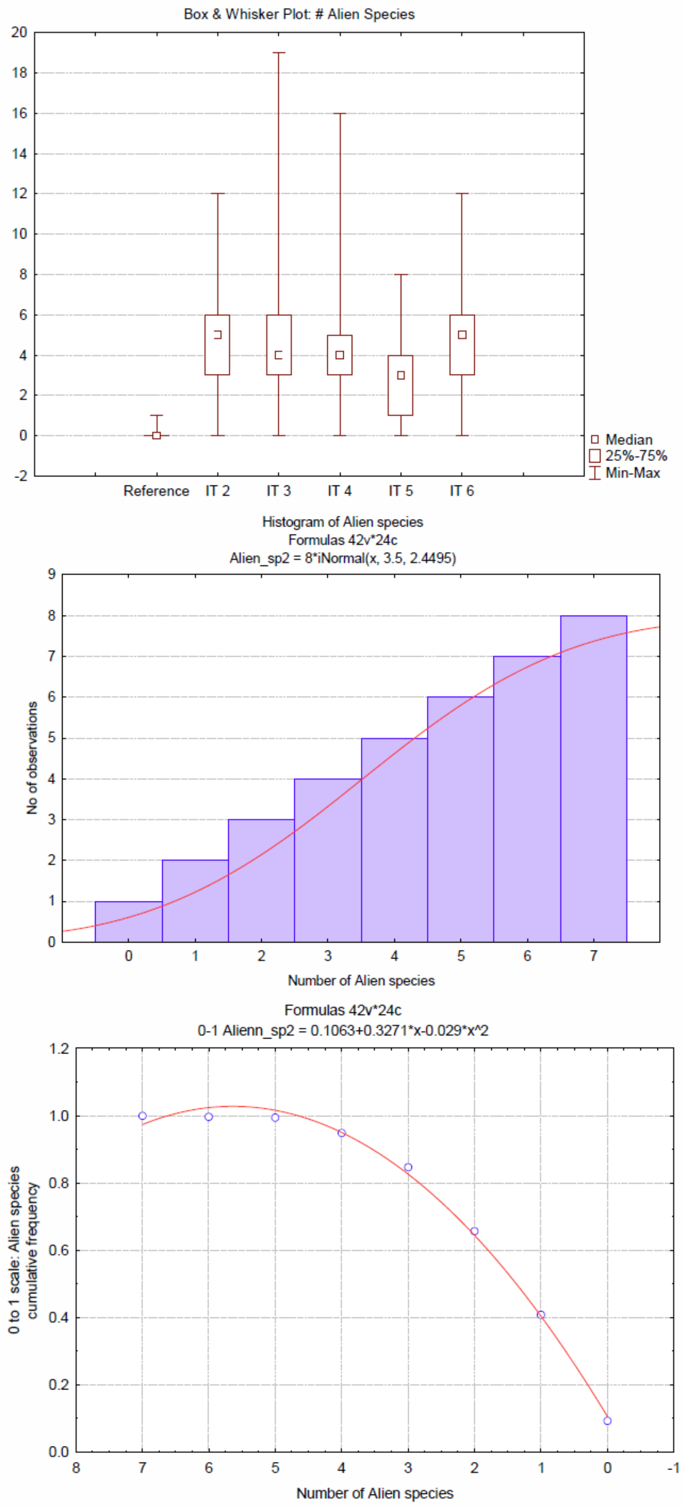


***Figure 16**. Maine non-wadeable rivers IBI metric calibration process for the number of non-indigenous species (non-indigenous_sp). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of number of non-indigenous species recorded in 337 samples. Lower: Cumulative frequency plot with polynomial best fit lines (y-axis is standardized to a 0-1 scale).*

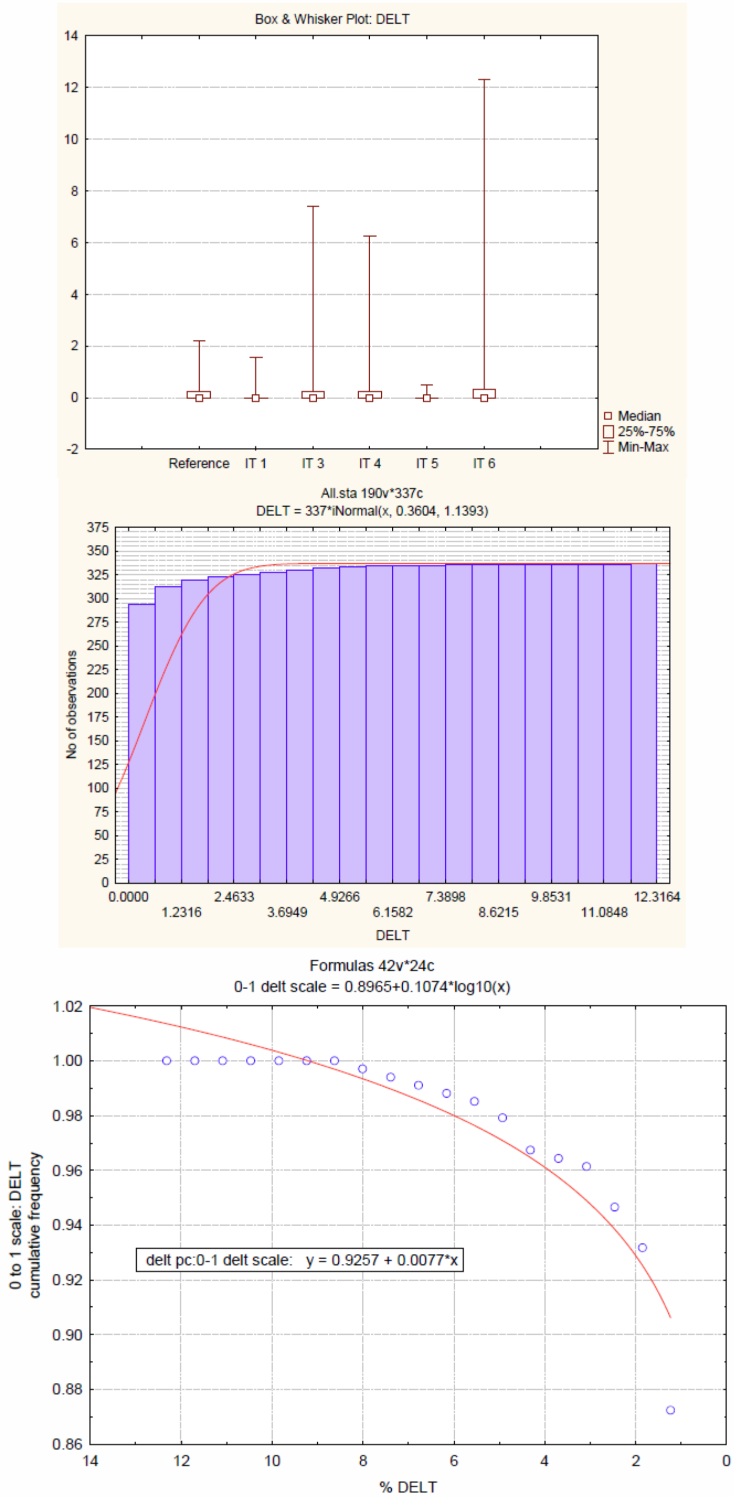


***Figure 17**. Maine non-wadeable rivers IBI metric calibration process for the %DELT anomalies (DELT). Upper: Box and whisker plot of reference site and impacted site types (IT = impact type) 2 – 6. Middle: Cumulative frequency histogram of number of DELT anomalies recorded in 337 samples. Lower: Cumulative frequency plot with log_{10} best fit line (y-axis is standardized to a 0-1 scale).*

other large river fish assemblage IBIs that have been developed across the U.S. Because of its utility in diagnosing categorical stressors it is an essential metric for any IBI.

The reference and calibration results do not strongly indicate a direction of response for this metric (Figure 17), which is sometimes cited as a reason for its exclusion from IBIs. However, this is an example of a metric that should always be included because of the unique role it fulfills as an indication of chronic and acute stress and exposure (Yoder and Rankin 1995; Sanders et al. 1999). While we did not observe an obvious gradient in the DELT data across Maine, there were localized occurrences of DELTs greater than an incidental occurrence. The environmental conditions that would have made DELTs more apparent have been greatly diminished over the past 20-30 years due to pollution controls. Metric scoring is based on the expectation that BCG Level 1-3 assemblages would exhibit 0% DELTs, with some accrual of a low proportion of DELTs being expected in Levels 4 and 5, and marked increases only in Level 6. Higher proportions of DELTs would be expected only under the most extreme combinations of sublethal and acute stresses.

Calculation of Riverine IBI Scores

Programming to calculate riverine IBI scores for individual electrofishing samples incorporates the derivation and calibration results for the interim final IBI metrics. We developed Maine ECOS as the set of programs that support the entry, storage, retrieval, and calculation of metrics and indices. This was adapted from the original programming of the Ohio ECOS data management system. The programming presently exists in FoxPro and outputs are exported in a variety of formats including Excel files and Adobe Acrobat reports. Equations for each of the 12 final riverine IBI metrics were developed from the calibration plots (Figures 5-9, 11-17) and include making adjustments at the y^1 and y^2 terminus of each plot to limit each metric scoring range from 0 to 10 (Table 3). The Maine ECOS programming was then used to calculate riverine IBI scores (range 0-100). The Maine ECOS reports are in a columnar format arranged in a descending order by river code, river mile, and date. Columns include the river mile, sampler type, sampling date, drainage area, IBI metrics, the IBI score, and a modified index of well-being score (Appendix Table B-1).

River Specific IBI Results

We plotted the range of IBI scores for major riverine segments that were sampled during 2002-7 as an initial exploration of the performance of the riverine IBI (Figure 18). These segments were aggregated to generally reflect similar geographic settings, thermal similarities, level of disturbance, and reaches including effective barriers to the movements of diadromous and other species. All tidal influenced sites were excluded as this represents a distinctive ecotype that the riverine IBI does not adequately represent. The riverine IBI produced an observed range of 13-92 among 19 major river segments in Maine. This IBI was purposely developed to provide an empirical measurement of the BCG developed for a cool-coldwater, moderate-high gradient river ecotype in Maine (see Figure 2). As such fish assemblages that exhibit "as naturally occurs" attributes should produce the highest IBI scores. We estimated the boundaries for the six BCG levels based on initial estimates of the congruence of the qualitative attributes of the Maine Rivers BCG and the riverine IBI metrics and scores (Figure 18). The position of each BCG level is anchored by our estimate of the minimum IBI for Level 1, which we have concluded does not exist in any of the samples. Further and more detailed analysis of theoretical assemblages with a more thoroughly tested IBI is needed to verify this.

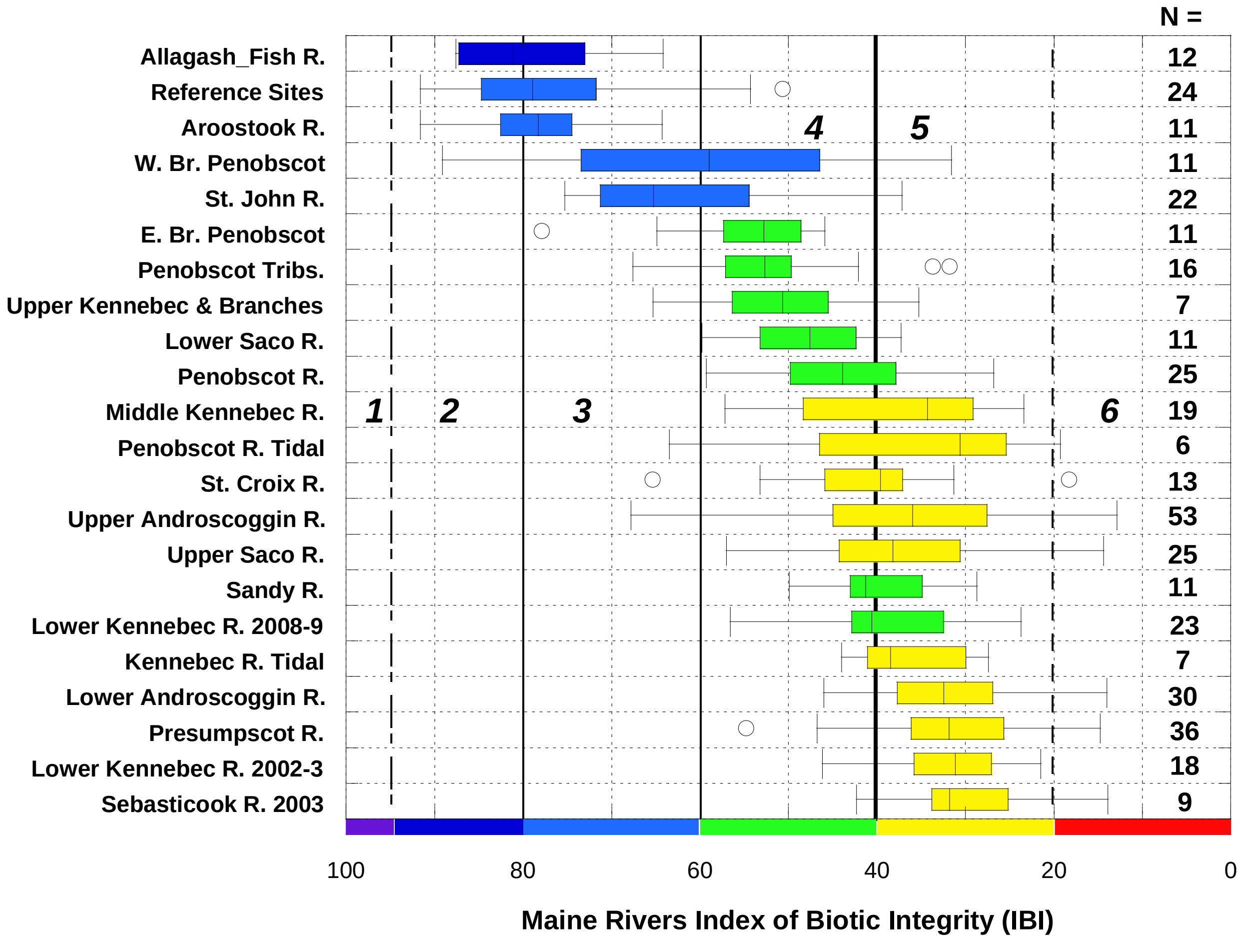


Figure 18. *Box-and-whisker plots of Maine River IBI values by 22 major river segments sampled during 2002-8 arranged by 75th percentile values from highest to lowest (N for each is shown). The approximate BCG level (1-6) represented by ranges of the riverine IBI are depicted and color coded based on the median IBI.*

However, given the extent of the historical disturbances to Maine's non-wadeable rivers by logging and hydrological alterations this seems a reasonable conclusion. The distribution of riverine IBI scores among the remaining BCG Levels 2-6 also seems reasonable. The "minimally impacted" and biologically most intact sites and reaches represented BCG Level 2, more typical sites represented Level 3, most sites represented Level 4, and the majority of the remaining sites represented Level V, the latter including some of the most intensively altered rivers in Maine. Very few individual sites were indicative of Level 6 which seems reasonable in that the most of the extreme chemical impacts that usually result in this condition have been abated by CWA mandated and Maine WQS based controls on point sources (Davies et al. 1999). Furthermore, Maine lacks some of the extreme legacy impacts that are commonplace to other parts of the industrialized and agricultural parts of the U.S. and which have precipitated biological assemblage responses characteristic of Level 6 (Yoder and Rankin 1995; Yoder and DeShon 2003; Yoder et al. 2005).

Based on our on-site knowledge about Maine's rivers and the intensive field observations made at 100s of sites during 2002-7, the riverine IBI results depicted in Figure 18 seem reasonable for the most part. However, there were some results that potentially illustrate where the riverine IBI needs further refinements. The BCG model that we developed assumes a cold water assemblage paradigm for moderate-high gradient rivers. This was based partially on the consensus of biologists involved in the ad hoc interagency advisory panel that was convened for this project and the spatial analyses conducted in the 2005 project report (Yoder et al. 2006b). Hence the riverine IBI is expected to function best for river reaches that exemplify the attributes of this ecotype. However, two other distinctive ecotypes were encountered, warmwater, low gradient riverine and tidal fresh-brackish water habitats. An inspection of Appendix Table B-1 shows that the riverine IBI scores in the latter ecotype were consistently in BCG Levels 4 and 5. Hence we could conclude that the riverine IBI is not completely functional for these ecotypes, an unsurprising conclusion given what we know about the ecology of the fish assemblages in these ecotypes. The performance of the riverine IBI at low gradient sites is less ambiguous with most sites indicating Level 4 conditions. However, the character of the potential fish assemblage is such that their true potential is probably not as accurately assessed with this IBI. At this point we feel it is more conservative to exclude these ecotypes from applications of the riverine IBI until further exploratory analyses are performed.

Future Developmental Issues and Needs

A remaining uncertainty with the riverine IBI concerns its application in river reaches with either extant or historical diadromous fish assemblages. Restoration of diadromous species is a high priority for several agencies that were part of the ad hoc project advisory group. Again, the emphasis of the development of the riverine IBI was on the "core" freshwater assemblage of the cool-coldwater, moderate-high gradient ecotype. Hence the IBI is best suited to data that best exemplifies the expected members of this assemblage. While we initially tested a selection of diadromous metrics, most were found to be unresponsive to the reference and impact gradient and were thus eliminated from consideration. We acknowledge that this was an expected result given the lack of occurrence of species representative of this guild to be present in sufficient numbers from most samples and their comparative absence at the reference sites. The reference sites were purposely located upstream from natural and man-made passage barriers primarily to exclude blackbass and other non-indigenous species. Seven of the rivers with the lowest IBIs have existing or potential diadromous fish populations (Figure 18). However, we also expect these rivers to have the potential for supporting the core freshwater fish assemblage consistent with the cool-coldwater, moderate-high cold water ecotype as depicted by the BCG. A reason that these rivers exhibit comparatively low riverine IBI scores is an abundance of smallmouth bass and a higher proportion of non-indigenous species. These rivers are also comparatively more modified in terms of flow and habitat impacts and they occur south and east of the elevation gradient that seems to correspond to a greatly reduced magnitude of negative impacts in the highest scoring rivers. The low IBI scores in lower Kennebec River is a potentially disappointing result especially given the increased density and biomass of fish that occurred in the 17 mile Waterville-Augusta segment following the Edwards Dam removal (Yoder et al. 2006a). The core freshwater fish assemblage results bear a direct correspondence with the lower BCG Levels. For example, the stocking of brown trout on a put-and-take basis is a BCG Level V attribute in the BCG narrative and this was likewise a characteristic of other river segments that scored in this IBI range. The core freshwater assemblage is predominated in part by smallmouth bass and some sites have the highest proportions of non-indigenous species statewide. Hence this explains the low IBI scores and establishing the relationship of that to diadromous assemblage restoration goals seems important, especially given the reported importance of assemblage interactions (Saunders et al. 2006).

If an IBI is to be a useful gauge for measuring progress made with diadromous and other native fish assemblage restoration efforts, it will need to include direct and indirect connections to the attributes that are consistent with the factors that influence these species. On the side of the argument that the riverine IBI is adequate for this purpose is that it seems responsive to the biological and physical stressors that are directly relevant to the restoration of diadromous assemblages. Certainly the presence of blackbass (smallmouth and largemouth bass) is one factor that must be considered as a potentially negative influence as is the influence of other non-indigenous species. The lack of native cool-cold water assemblage attributes in the lower reaches of coastal draining rivers and their “replacement” by put-and-take fisheries for hatchery reared Salmonids such as brown trout and landlocked Atlantic salmon is a Level V attribute in the BCG (see Figure 2). However, the removal of the Edwards Dam as an impassable barrier in the lower Kennebec River has contributed to a partial restoration of diadromous assemblages that are not fully reflected in the riverine IBI. Hence, we recommend that this aspect be more closely examined and, if necessary, become better developed in subsequent versions of the Maine Rivers IBI. Perhaps the most meaningful manner to address this issue is to develop a supplemental diadromous metric or metrics that are additive to the core freshwater fish assemblage represented by the riverine IBI. This would more accurately reflect the additive value of an improved diadromous assemblage while not penalizing river segments that naturally lack diadromous species.

Addendum: Rationale and Development of Diadromous IBI Metrics and Scoring

A supplemental set of four diadromous metrics (Table 5) were developed and tested in 2011 in response to a recommendation in the 2008 IBI development report. This was done to better highlight and assesses the quality of the diadromous part of the fish assemblage in Maine rivers where they have historically had access. It also more directly incorporates the attributes of the BCG (Figure 3) that directly pertain to the diadromous component of the fish assemblage in the IBI. The resulting diadromous IBI (DIBI) is calculated as a standalone score and is additive to the riverine IBI in keeping with the BCG and to maintain the distinction between the “core” freshwater fish assemblage and the temporal influx or “pulse” of several diadromous species that varies seasonally. As such the analyses and displays of the results are done as the riverine IBI and the riverine IBI (ME IBI) + diadromous IBI (DIBI).

The DIBI consists of four metrics that include fish species designated as anadromous (A) and catadromous (C) in Table 1. These metrics were developed based on their ecological relevance and role. One metric is based on the number of diadromous species and the other three are based on the relative abundance of all diadromous species, one commonly occurring species, and a commonly occurring family. The calibration of each metric followed the continuous method used for the riverine IBI metrics and utilized data from Maine river reaches where diadromous species have had historical access. However, there was no vetting against a gradient of reference and non-reference sites as this approach had already ruled out diadromous metrics in the original exploration and reduction of possible ME IBI metrics. All four metrics are positive in that the metric score increases as the measured value of the metric increases. While these attributes of the fish assemblage are responsive to some of the stressors in that original gradient, their purpose is to measure the prominence of the diadromous part of the fish assemblage as an additive measure to the riverine ME IBI. The rationale for each of the four metrics and their calibration follow.

Number of Diadromous Species

This metric includes all diadromous species present at a site for which 10 species are so designated in Table 1. Of these 10 species, nine (9) are anadromous and a single species (American eel) is catadromous. This metric includes diadromous species that have occurred either sporadically or in very low numbers such as Atlantic and Shortnose sturgeon and sea run Atlantic salmon. The calibration curve is based on a linear relationship (Figure 19). Metric scoring adjustments include a metric score of 10 at ≥5 diadromous species (Table 4).

Number of American Eel

America eel *(Anguilla rostrata)* is the lone catadromous fish species in Maine (i.e., it is marine spawned returning to freshwater as post-larvae) and is dependent on making passage to salt water as mature adults and returning to freshwater as post-larvae where they grow to adulthood. This was the single-most abundant diadromous species in the

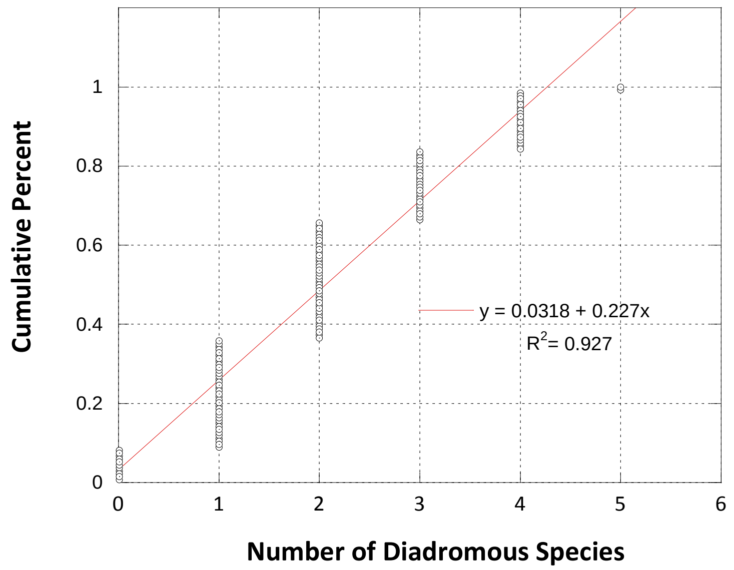
***Table 5**. Diadromous IBI metrics intended to represent the diadromous component of a riverine fish assemblage in Maine and New England expressed as the Diadromous IBI (DIBI). These are additive to the ME IBI in the NELR REMAP analyses.*

Metric	Scoring Equation	Scoring Adjustments	
		Score = 0	**Score = 10**
Diadromous Species Richness	Score = 0.0318 + 0.227*(Diadromous Species Richness)	0	>5 sp.
Number of American Eel	Score = 0.0689 + 0.2*(Log Eel Rel. No.) + 0.0616*(Log Eel Rel. No.)	0	>389/Km
Number of Clupeidae	Score = 0.832*Log10(Rel. No. Clupeids)^ (0.269)	0	>96/Km
Number of Diadromous Fish (all diadromous species)	Score = 0.0522 + 0.168*(Log(Diad Rel. No.) + 0.0644^(Log(Diad Rel. No.))	0	>560/Km

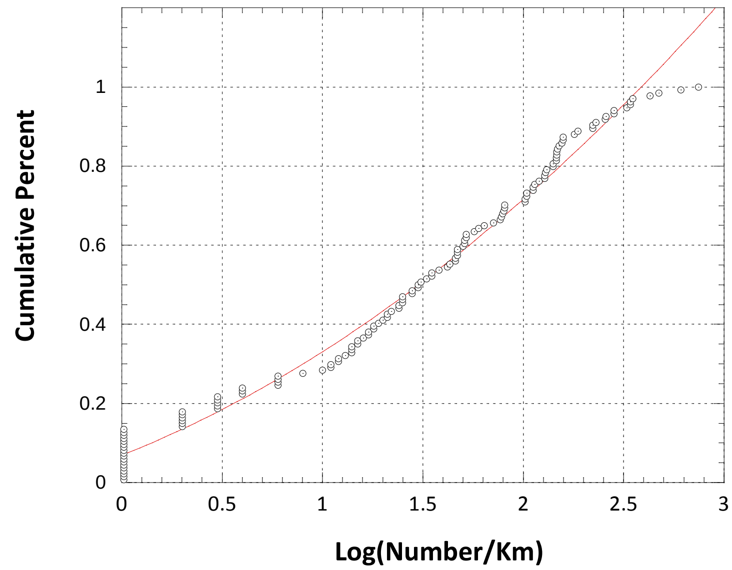
2002-7 surveys especially in the upper reaches of rivers where other diadromous species were either in very low abundance or absent altogether. American eels are able to scale natural falls and dams that are impassible to most other diadromous species, but this is not invariable. Because of their design, certain dams present more difficult barriers to passage and this is reflected in their low abundance or absence in some Maine rivers. Passage assisting devices such as eel ladders are placed at selected dams during periods of peak upstream movements. Many other factors outside of the freshwater realm can also affect American eel abundance in rivers and hence their contribution to this metric. The calibration curve is logarithmic (Figure 19) and metric scoring adjustments include a metric score of 10 at >389/km (Table 4).

Numbers of Clupeidae

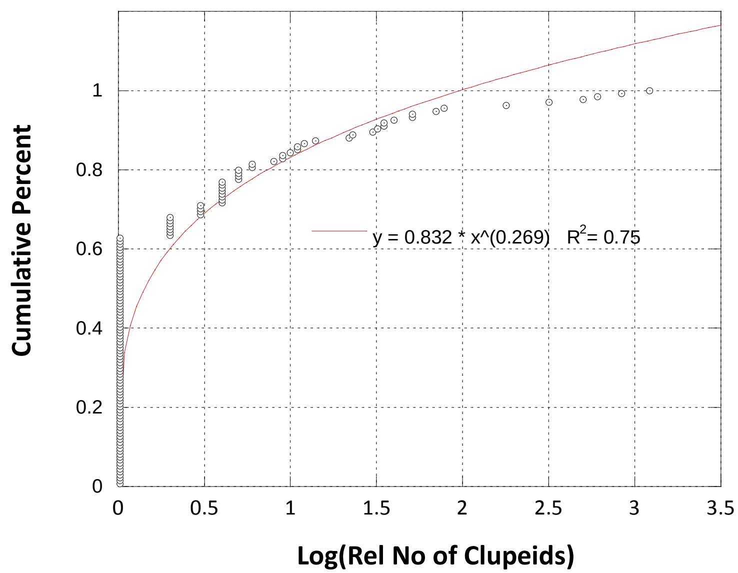
The herring family (Clupeidae) is represented in Maine rivers by three species of river herring, alewife *(Alosa pseudoharengus),* blueback herring *(Alosa aestivalis),* and American shad *(Alosa sapidissima*). These are almost always represented by young-of-year individuals of all 3 species that were spawned in a river or as out migrating y-o-y alewife from ponds and lakes. Any adults usually occur during the early summer and in very low numbers. River herring numbers in electrofishing samples can vary widely and from week to week during the peak of the out migration in late September and early October. However, y-o-y of all 3 species can be collected as early as late July- early



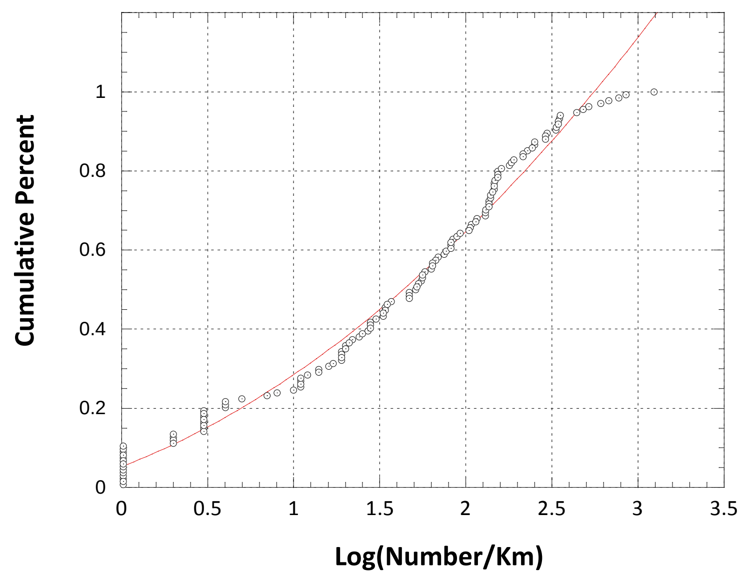
Cumulative Percent
Number of Diadromous Species
y = 0.0318 + 0.227x
R^2= 0.927



Cumulative Percent
Log(Number/Km)



Cumulative Percent
Log(Rel No of Clupeids)
y = 0.832 * x^(0.269) R^2= 0.75



Cumulative Percent
Log(Number/Km)

August. The calibration curve is both polynomial and logarithmic (Figure 19) and metric scoring adjustments include a metric score of 10 at $\geq$96/km (Table 4).

Numbers of Diadromous Fish
This metric includes the sum total of all diadromous fish among the 10 diadromous species that are present in a sample. The calibration curve is logarithmic (Figure 19) and metric scoring adjustments include a metric score of 10 at $\geq$560/km (Table 4).

Calculation of DIBI Scores

Programming to calculate DIBI scores for individual electrofishing samples was accomplished based on the derivation and calibration of the just described DIBI. The routines are stored in Maine ECOS where the entry, storage, retrieval, and calculation of metrics and indices are accomplished. The programming currently exists in FoxPro and outputs are exported in a variety of formats including Excel and Adobe Acrobat. Equations for each of the 4 DIBI metrics were developed from the continuous calibration plots and include adjustments (if necessary) at the upper and lower terminus of each plot to normalize each to metric scoring ranges from 0 to 10 (Figure 19).

River Specific Riverine and Diadromous IBI Results
The frequency distribution of riverine ME IBI scores and with the supplemental diadromous metrics (ME IBI + DIBI) added were plotted as overlapping box-and-whisker plots for 22 Maine riverine segments (Figure 20) each of which were used for the initial exploration of the performance of the riverine ME IBI in Figure 18. Figure 20 orders these same river segments in accordance with the Maine IBI + DIBI and includes the ME IBI alone for comparison. The top seven rivers were unchanged and all except the West and East Branches of the Penobscot and the mainstem tributaries had very few or no diadromous fish species. The Lower Kennebec River 2002-3 ranked 21st out of 22 rivers for the ME IBI, but moved to seventh highest when the DIBI was added to the ME IBI. The freshwater tidal segment of the Kennebec ranked 11th with the DIBI added compared to 18th for the ME IBI alone. The remaining rivers changed little in terms of rank when the DIBI was added. However, the DIBI moved one river from BCG Level 5 to Level 2 (Lower Kennebec 2002-3), three rivers from BCG Level 3 to Level 2, and 12 rivers from BCG Level 5 to Level 4. Only three rivers with historical diadromous species access showed no change in BCG Level.

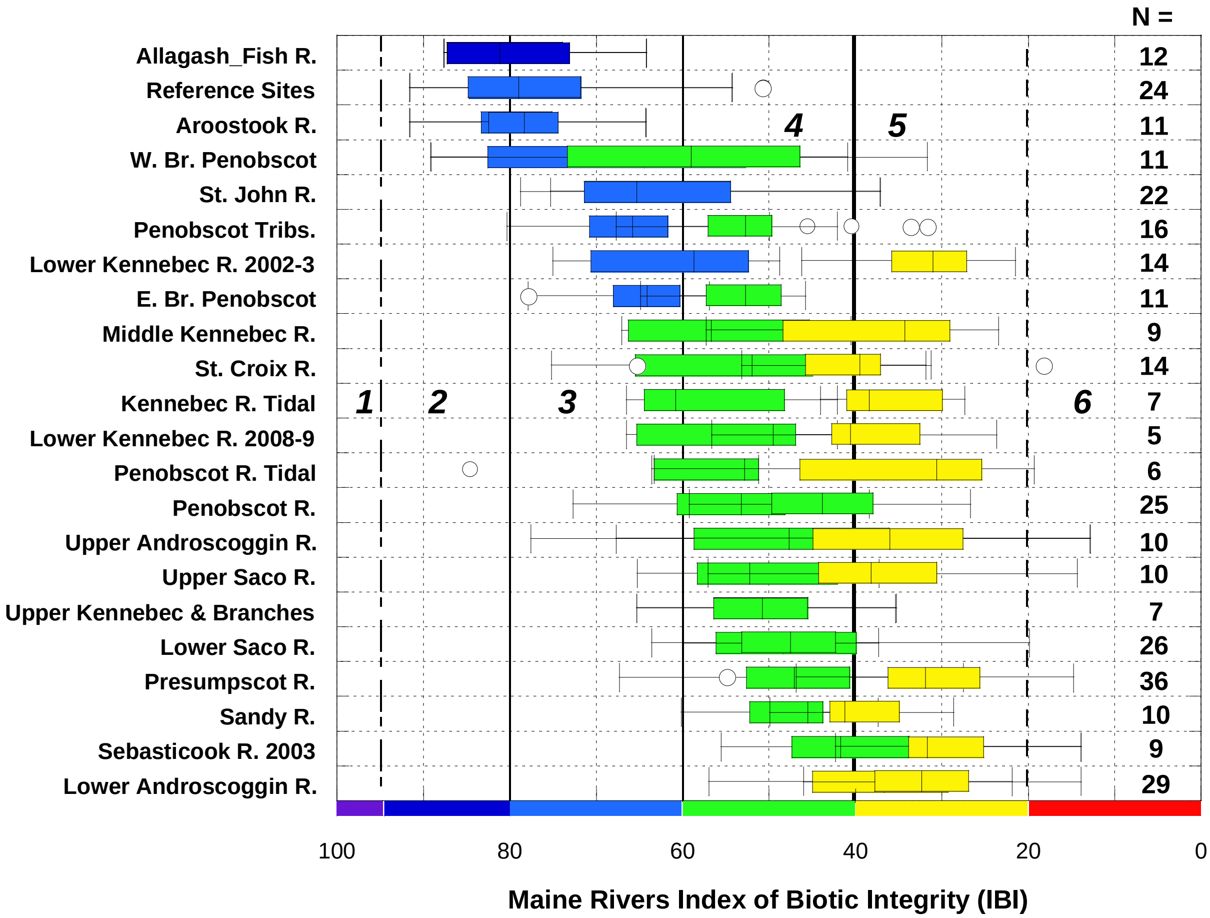


***Figure 20**. Overlay of box-and-whisker plots of ME IBI and ME IBI+ DIBI values by major river segment arranged by 75th percentile values of the ME IBI + DIBI from highest to lowest (N for each is shown). The approximate BCG level (1-6) represented by ranges of the ME IBI + DIBI and ME IBI are depicted and color coded.*

These results show the effect of adding the DIBI in terms of IBI rank and BCG Level, the latter reflecting the addition of a significant component of Maine River fish assemblages. It also shows how altered the core freshwater fish assemblages of all the coastal draining rivers in central and southern Maine have become, especially as compared to the BCG Level 2 condition of northern Maine rivers even without having diadromous species potential. Keeping the DIBI and Maine IBI as separately calibrated indices allows the differences between the core freshwater and diadromous assemblages to be made apparent. It also affords the opportunity to evaluate the potential positive influence of improved diadromous assemblages on the core freshwater assemblage, a benefit that is under-emphasized by most restoration programs that are focused on one or two diadromous fish species.

Assessment of River Reach-Level Impacts: Dam Removals

In an effort to document how the fish assemblage and riverine IBI respond to the improved habitat and access for diadromous fish, the lower Kennebec River has been sampled annually since 2002 and the lower Sebasticook River since 2009. This sampling also provides the data to develop and test the DIBI in its role as being additive to the riverine IBI.

Lower Kennebec River

The Kennebec River has been sampled at 7-8 locations between the Lockwood Dam in Waterville and the head of tide in Augusta since 2002 through 2015. At least two sampling passes between July-August and September-October have been conducted annually as a follow-up to document the effects of the removal of the Edwards Dam in Augusta. The initial results of the 2002 sampling were reported by Yoder et al. (2006a) and showed significant increases in the numbers and biomass of resident freshwater and diadromous species compared to segments located upstream from the series of dams beginning with the Lockwood Dam. While there was no pre-removal assemblage data collected from the former Edwards Dam impoundment, the 2002 data from the impoundments upstream from the Lockwood and Shawmut dams was deemed a sufficient analog to serve as a proxy for the pre-removal fish assemblage in the Edwards dam impoundment. The initial assessment of the more immediate response of the fish assemblage showed an order of magnitude increase in assemblage numbers and biomass in 2002 one year after dam removal (Yoder et al. 2006a). The response of the riverine IBI is visualized by box-and-whisker plots of the frequency of IBI scores among the 7-8 locations (all passes combined) by year with the 2002 Shawmut impoundment sites serving as the pre-removal results (Figure 21). The response in the riverine IBI was latent by comparison showing clearly elevated IBI scores beginning in 2004 and with a slight overall increase through 2015 with some inter-annual variations. The post-2003 riverine IBI scores are representative of BCG Levels 4 and 5 whereas the 2002 and upstream impoundment results were all with Level 5. While there was a detectable positive effect of the dam removal, the core freshwater fish assemblage is highly modified by upstream hydrological and thermal alterations and introduced warmwater species, thus the condition reflected from 2004 forward is about as good as can be expected for the core freshwater assemblage in the lower Kennebec River.

The response of the DIBI showed an improvement almost immediately with the 2002 DIBI in the Lockwood to Augusta segment clearly higher than the upstream impoundments. With a couple of exceptions this difference persisted through 2015 with the ME IBI + DIBI consistently at Level 3 of the BCG. The DIBI also seemed to normalize the wide variations in individual species abundances, especially for alewife and blueback herring (Figure 22) that were extremely variable and dependent on the timing of the annual outmigration of young-of-year fish. Timing of sampling is critical as a one week period between sampling passes can be the difference in collecting a few or even no individuals or hundreds to thousands of individuals at every site. This was especially true in 2014 when sampling passes one week apart produced widely different catch rates. Variations also occurred between years as evidenced between 2014 and 2015, the latter being affected by a major flood event that precluded sampling during the peak of the outmigration. However, as river herring (especially alewife) become more widely established in the Kennebec and Sebasticook drainages, the probability of their capture has increased throughout the July-October seasonal index period.

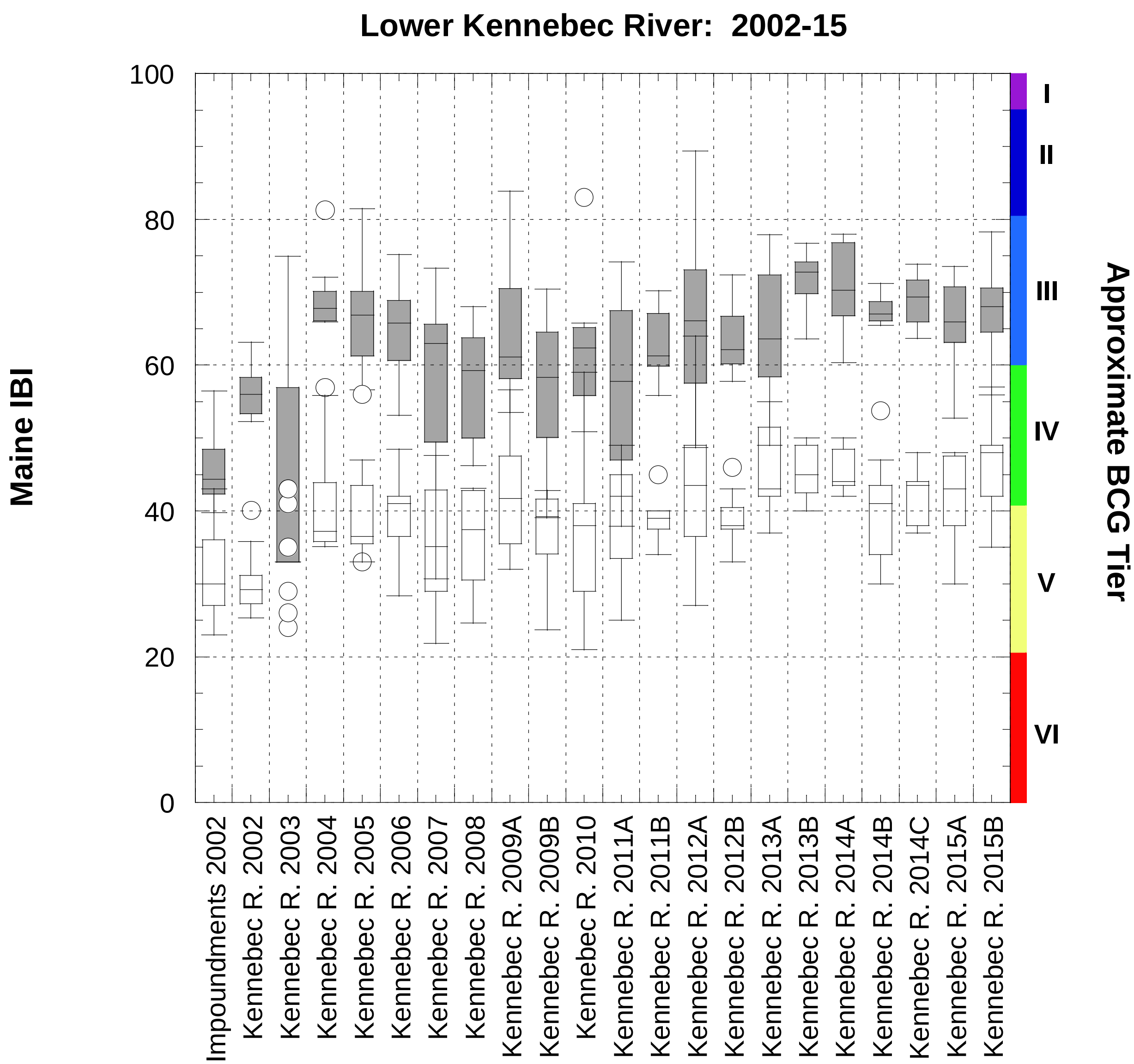


***Figure 21**. Box-and-whisker plots of Maine River IBI and ME IBI+ DIBI values by year in the lower Kennebec River 2002-2015 between Lockwood Dam in Waterville, ME and the head-of-tide in Augusta, ME. The approximate BCG level (1-6) represented by ranges of the ME IBI + DIBI and ME IBI are depicted and color coded on the y2 axis.*

Lower Sebasticook River

A baseline assessment of what was then an impounded riverine habitat was conducted at three sites upstream from the Ft. Halifax dam in 2003. The dam was removed in 2008 as part of a FERC relicensing agreement to improve access for river herring to their historic spawning areas in the Sebasticook River drainage. The Ft. Halifax dam removal was coupled with improved fish passage at two upstream dams. The results of sampling

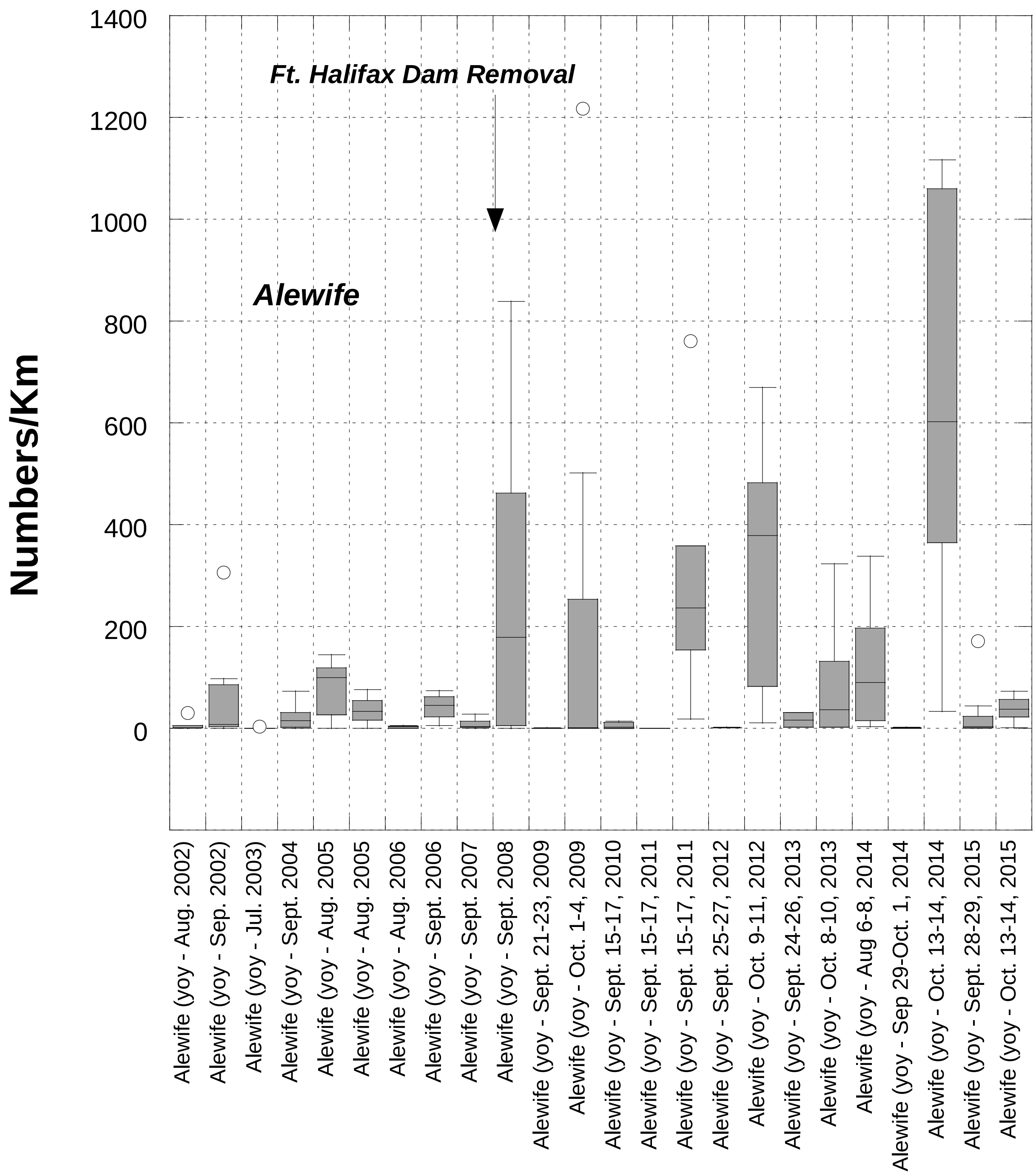


***Figure 22**. Box-and-whisker plots of alewife (Alosa pseudoharengus) by year in the lower Kennebec River 2002-2015 between Lockwood Dam in Waterville, ME and the head-of-tide in Augusta, ME. Results are for individual sampling passes over 2-3 consecutive days. Note the wide variations in abundance between sampling periods within the same year in 2014 and between years.*

particularly so with the latter (Figure 23). The modest improvement in the riverine IBI reflected improved riverine habitat for resident freshwater species, but the capacity for additional improvement is limited by historic alterations in the flow and thermal regimes and the introduction of non-native species such as smallmouth and largemouth bass, northern pike, and other non-native Centrarchids. The D-IBI showed a comparatively larger increase due to improved access by diadromous species and river herring in particular after 2008. These results show not only the improved access, but the success of these species finding and reproducing in their historic spawning habitats. By including the D-IBI, the assessment results are a better representation of the BCG level corresponding to the strong improvement in the diadromous species that comprise BCG attribute X.

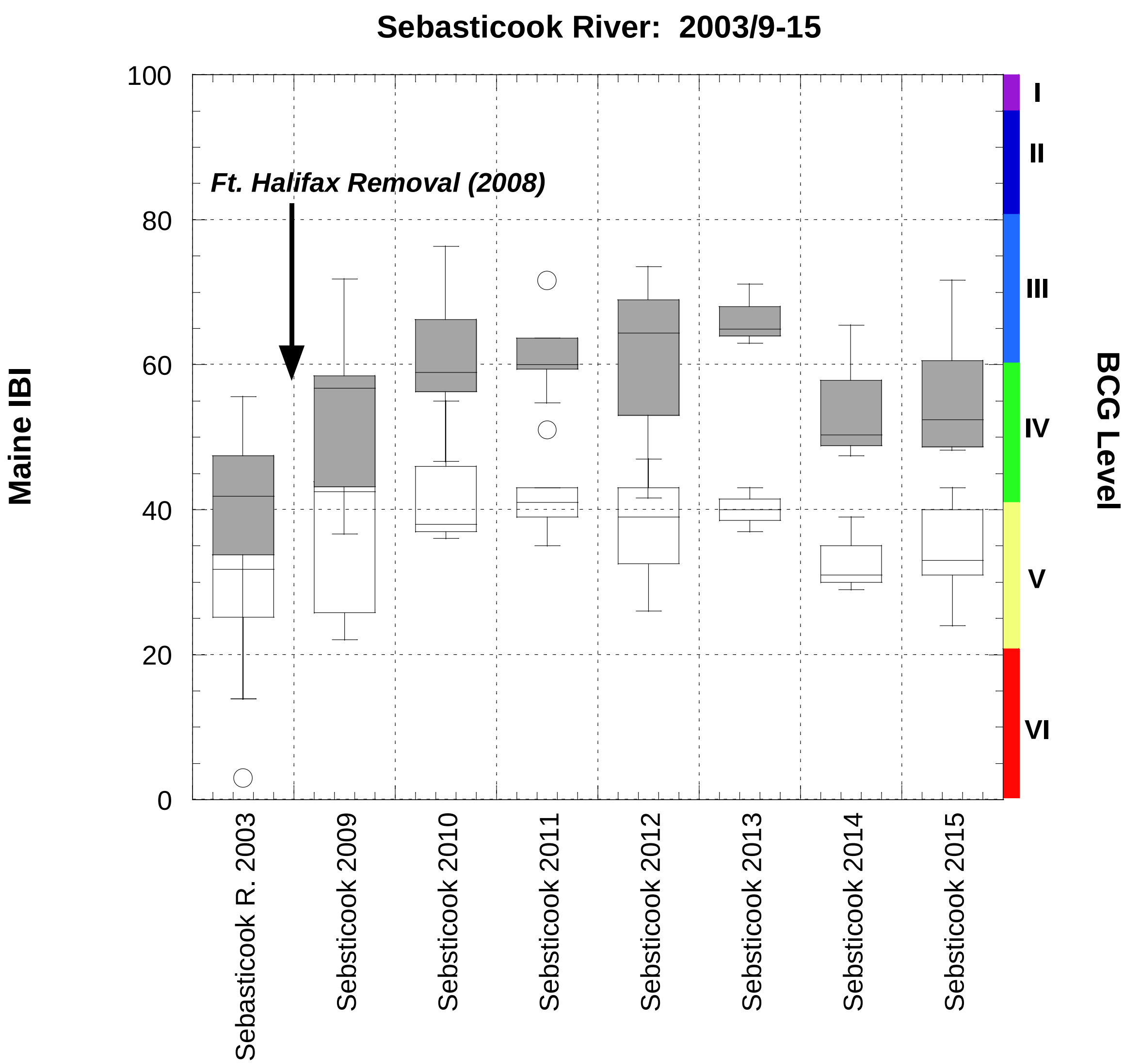


***Figure 23**. Box-and-whisker plots of Maine River IBI and ME IBI+ DIBI values by year in the lower Sebasticook River 2002-2015 between Benton Falls Dam Winslow, ME. The approximate BCG level (1-6) represented by ranges of the ME IBI + DIBI and ME IBI are depicted and color coded on the y2 axis.*

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Maine Rivers Fish Assemblage Assessment: Development of an Index of Biotic Integrity for Non-wadeable Rivers

Appendix A

IBI Metric Testing Analyses

Correlation Matrices
Covariance Analysis
Eigen Values for PCA Factors

Appendix Table A-1. Correlation coefficients for 23 candidate Maine River IBI

Correlations (ME10_8 in Imported from C:\Documents and Settings\roger f thoma\My Docur
Marked correlations are significant at p < .00500
N=353 (Casewise deletion of missing data)

Variable	Means	Std.Dev.	relno	cumspec	smb_a_rn	tolperc	topcarn	delta
relno	368.7122	316.0889	1.000000	0.415429	0.251670	0.023883	-0.188997	-0.088603
cumspec	10.7932	3.4352	0.415429	1.000000	0.000290	0.193732	-0.140191	-0.045284
smb_a_rn	13.9285	17.0146	0.251670	0.000290	1.000000	-0.014858	0.305150	-0.041707
tolperc	22.8858	23.3697	0.023883	0.193732	-0.014858	1.000000	0.528527	0.006221
topcarn	46.8798	26.5681	-0.188997	-0.140191	0.305150	0.528527	1.000000	0.052088
delta	0.3618	1.1189	-0.088603	-0.045284	-0.041707	0.006221	0.052088	1.000000
ws_adultrn	13.3681	23.1863	0.381536	0.324214	0.168635	0.106726	0.003669	0.097687
ws_adultpb	25.1659	25.5298	0.079519	0.151910	-0.011915	0.003195	-0.061409	0.155257
allint	1.5014	1.7664	-0.004332	0.144017	-0.230269	-0.413713	-0.454311	-0.052617
allcyp	2.6771	1.5678	0.267913	0.383712	-0.194204	-0.356280	-0.619222	-0.047243
allcyp_pc	31.3064	27.1752	0.181714	0.041453	-0.240986	-0.536665	-0.835699	-0.125961
clupeids	2.1905	6.8353	0.071266	0.228166	-0.030238	0.047950	-0.011393	0.047088
macro_gen	43.5359	28.1461	0.078660	-0.166623	0.252216	0.044285	0.326382	-0.039252
age_all	16.7507	7.0923	0.466314	0.701346	0.243435	0.163991	-0.025396	-0.045387
salm_pc	1.9371	7.1742	-0.176696	-0.133809	-0.126905	-0.190033	0.048780	0.041906
fluv_dep	22.1631	21.3529	-0.119617	-0.062680	-0.277323	-0.491876	-0.558112	0.070596
fluv_spec	15.4961	18.7629	-0.044308	-0.075301	-0.128170	-0.479803	-0.551646	-0.090772
stenmes	4.7904	1.7857	0.246828	0.553272	-0.189446	-0.202539	-0.389367	-0.020839
eury	5.2805	2.1355	0.478252	0.722423	0.154956	0.232186	-0.090694	-0.037101
lith_ng	2.3824	1.7017	-0.033147	0.068967	-0.272522	-0.511349	-0.609034	-0.042308
benth_pc_n	6.0019	16.3643	-0.123391	-0.055209	-0.255330	-0.335954	-0.456519	-0.075990
alien_all	35.8974	24.5721	0.036447	-0.239099	0.268007	-0.083418	0.443161	-0.004250
suckpc_a_b	25.3049	25.5842	0.077335	0.153852	-0.013967	0.000012	-0.064805	0.157572

Correlations (ME10_8 in Imported from C:\Documents and Settings\roger f thoma\My Docur
Marked correlations are significant at p < .00500
N=353 (Casewise deletion of missing data)

Variable	ws_adultrn	ws_adultpb	allint	allcyp	allcyp_pc	clupeids	macro_gen
relno	0.381536	0.079519	-0.004332	0.267913	0.181714	0.071266	0.078660
cumspec	0.324214	0.151910	0.144017	0.383712	0.041453	0.228166	-0.166623
smb_a_rn	0.168635	-0.011915	-0.230269	-0.194204	-0.240986	-0.030238	0.252216
tolperc	0.106726	0.003195	-0.413713	-0.356280	-0.536665	0.047950	0.044285
topcarn	0.003669	-0.061409	-0.454311	-0.619222	-0.835699	-0.011393	0.326382
delta	0.097687	0.155257	-0.052617	-0.047243	-0.125961	0.047088	-0.039252
ws_adultrn	1.000000	0.681125	0.028322	0.102932	-0.120594	0.088185	-0.127891
ws_adultpb	0.681125	1.000000	0.155932	0.123342	-0.055908	0.039675	-0.194678
allint	0.028322	0.155932	1.000000	0.593123	0.487140	-0.129442	-0.537358
allcyp	0.102932	0.123342	0.593123	1.000000	0.610460	-0.106291	-0.321790
allcyp_pc	-0.120594	-0.055908	0.487140	0.610460	1.000000	-0.221032	-0.372933
clupeids	0.088185	0.039675	-0.129442	-0.106291	-0.221032	1.000000	-0.068018
macro_gen	-0.127891	-0.194678	-0.537358	-0.321790	-0.372933	-0.068018	1.000000
age_all	0.323208	0.102902	-0.023783	0.237249	-0.065736	0.158640	0.093149
salm_pc	-0.077657	0.002368	0.289876	0.056947	-0.041515	-0.067779	-0.189666
fluv_dep	-0.016909	0.094011	0.537588	0.442922	0.544394	-0.210914	-0.546112
fluv_spec	-0.054011	0.084687	0.549742	0.438411	0.654167	-0.192414	-0.502203
stenmes	0.198875	0.205587	0.679189	0.495297	0.310181	0.104734	-0.363158
eury	0.290565	0.057915	-0.232452	0.368246	-0.005169	0.085246	0.196707
lith_ng	-0.049921	0.108442	0.847112	0.691710	0.628033	-0.150076	-0.468599
benth_pc_n	-0.071983	0.096150	0.727107	0.433884	0.461925	-0.117629	-0.454620
alien_all	-0.119119	-0.158105	-0.412674	-0.323127	-0.316456	-0.097805	0.864401
suckpc_a_b	0.678928	0.999129	0.161326	0.125746	-0.052026	0.037844	-0.196988

Appendix Table A-1. continued.

Variable	Correlations (ME10_8 in Imported from C:\Documents and Settings\roger f thoma\My Docur Marked correlations are significant at p < .00500 N=353 (Casewise deletion of missing data)							
	age_all	salm_pc	fluv_dep	fluv_spec	stenmes	eury	lith_ng	benth_pc_n
relno	*0.466314*	*-0.176696*	-0.119617	-0.044308	*0.246828*	*0.478252*	-0.033147	-0.123391
cumspec	*0.701346*	-0.133809	-0.062680	-0.075301	*0.553272*	*0.722423*	0.068967	-0.055209
smb_a_rn	*0.243435*	-0.126905	*-0.277323*	-0.128170	*-0.189446*	*0.154956*	*-0.272522*	*-0.255330*
tolperc	*0.163991*	*-0.190033*	*-0.491876*	*-0.479803*	*-0.202539*	*0.232186*	*-0.511349*	*-0.335954*
topcarn	-0.025396	0.048780	*-0.558112*	*-0.551646*	*-0.389367*	-0.090694	*-0.609034*	*-0.456519*
delta	-0.045387	0.041906	0.070596	-0.090772	-0.020839	-0.037101	-0.042308	-0.075990
ws_adultrn	*0.323208*	-0.077657	-0.016909	-0.054011	*0.198875*	*0.290565*	-0.049921	-0.071983
ws_adultpb	0.102902	0.002368	0.094011	0.084687	*0.205587*	0.057915	0.108442	0.096150
allint	-0.023783	*0.289876*	*0.537588*	*0.549742*	*0.679189*	*-0.232452*	*0.847112*	*0.727107*
allcyp	*0.237249*	0.056947	*0.442922*	*0.438411*	*0.495297*	*0.368246*	*0.691710*	*0.433884*
allcyp_pc	-0.065736	-0.041515	*0.544394*	*0.654167*	*0.310181*	-0.005169	*0.628033*	*0.461925*
clupeids	*0.158640*	-0.067779	*-0.210914*	*-0.192414*	0.104734	0.085246	*-0.150076*	-0.117629
macro_gen	0.093149	*-0.189666*	*-0.546112*	*-0.502203*	*-0.363158*	*0.196707*	*-0.468599*	*-0.454620*
age_all	1.000000	-0.138680	*-0.165356*	-0.138845	*0.413303*	*0.715717*	-0.065517	*-0.183600*
salm_pc	-0.138680	1.000000	*0.329148*	0.116344	0.100374	*-0.224855*	*0.165528*	*0.195151*
fluv_dep	*-0.165356*	*0.329148*	1.000000	*0.255195*	*0.334766*	*-0.194537*	*0.611914*	*0.402964*
fluv_spec	-0.138845	0.116344	*0.255195*	1.000000	*0.264977*	*-0.210539*	*0.601629*	*0.586063*
stenmes	*0.413303*	0.100374	*0.334766*	*0.264977*	1.000000	0.142851	*0.593912*	*0.396951*
eury	*0.715717*	*-0.224855*	*-0.194537*	*-0.210539*	0.142851	1.000000	*-0.182038*	*-0.321925*
lith_ng	-0.065517	*0.165528*	*0.611914*	*0.601629*	*0.593912*	*-0.182038*	1.000000	*0.731409*
benth_pc_n	*-0.183600*	*0.195151*	*0.402964*	*0.586063*	*0.396951*	*-0.321925*	*0.731409*	1.000000
alien_all	0.021168	0.074758	*-0.421790*	*-0.406773*	*-0.317088*	0.045136	*-0.389698*	*-0.396613*
suckpc_a_b	0.103994	0.001627	0.096638	0.089830	*0.210084*	0.057448	0.117416	0.098027

Variable	Correlations (ME10_8 in Imported from C:\Documents and Settings\roger f thoma\My Docur Marked correlations are significant at p < .00500 N=353 (Casewise deletion of missing data)	
	alien_all	suckpc_a_b
relno	0.036447	0.077335
cumspec	*-0.239099*	*0.153852*
smb_a_rn	*0.268007*	-0.013967
tolperc	-0.083418	0.000012
topcarn	*0.443161*	-0.064805
delta	-0.004250	*0.157572*
ws_adultrn	-0.119119	*0.678928*
ws_adultpb	*-0.158105*	*0.999129*
allint	*-0.412674*	*0.161326*
allcyp	*-0.323127*	0.125746
allcyp_pc	*-0.316456*	-0.052026
clupeids	-0.097805	0.037844
macro_gen	*0.864401*	*-0.196988*
age_all	0.021168	0.103994
salm_pc	0.074758	0.001627
fluv_dep	*-0.421790*	0.096638
fluv_spec	*-0.406773*	0.089830
stenmes	*-0.317088*	*0.210084*
eury	0.045136	0.057448
lith_ng	*-0.389698*	0.117416
benth_pc_n	*-0.396613*	0.098027
alien_all	1.000000	*-0.159825*
suckpc_a_b	*-0.159825*	1.000000

Appendix Table A-2. Correlation and covariance analysis of final 12 Maine River IBI metrics.

Table CORR. Correlation analysis of the 12 metrics selected for the Maine fish community Index of Biological Diversity.

	Means	Std.Dev.	DELT	# Native species	% Macro-habitat generalist	% Fluvial dependent / specialist species	# Temperate stenothermic species	# Non-guarding lithophilic species	% Benthic insectivores	% Blackbass	% Native cyprinids (less fallfish)	% Native salmonids	% Adult white & longnose suckers	# Alien species
DELT	0.3636	1.1439	1.0000	-0.0238	-0.0421	-0.0048	-0.0368	-0.0417	-0.0773	0.0274	-0.1132	-0.0364	0.0968	-0.0445
# native species	7.9850	2.5415	-0.0238	1.0000	-0.2027	0.3036	0.3441	0.4735	0.2286	-0.4332	0.3722	0.0307	0.1664	0.0103
% Macrohabitat generalist	43.3707	28.1858	-0.0421	-0.2027	1.0000	-0.6931	-0.4500	-0.4887	-0.4663	0.5670	-0.2870	-0.1478	-0.2390	0.2785
% Fluvial dependent/specialist species	39.0711	31.9499	-0.0048	0.3036	-0.6931	1.0000	0.6982	0.7685	0.6164	-0.4257	0.5829	0.2153	0.2101	-0.4937
# Temperate stenothermic species	1.0988	1.4097	-0.0368	0.3441	-0.4500	0.6982	1.0000	0.8504	0.6887	-0.2144	0.4729	0.2190	0.2855	-0.3715
# Non-guarding lithophilic species	2.4371	1.7174	-0.0417	0.4735	-0.4887	0.7685	0.8504	1.0000	0.7359	-0.3577	0.6050	0.1672	0.2411	-0.4603
% Benthic insectivores	6.3433	16.7599	-0.0773	0.2286	-0.4663	0.6164	0.6887	0.7359	1.0000	-0.3453	0.5755	0.2220	0.2013	-0.4286
% Blackbass	21.8556	20.0150	0.0274	-0.4332	0.5670	-0.4257	-0.2144	-0.3577	-0.3453	1.0000	-0.4960	-0.1077	-0.1451	0.2164
% Native cyprinids (less fallfish)	20.4808	24.2133	-0.1132	0.3722	-0.2870	0.5829	0.4729	0.6050	0.5755	-0.4960	1.0000	0.0909	0.0466	-0.3799
% Native salmonids	0.4017	2.5173	-0.0364	0.0307	-0.1478	0.2153	0.2190	0.1672	0.2220	-0.1077	0.0909	1.0000	-0.0611	-0.1864
% Adult white & longnose suckers	31.5782	36.4940	0.0968	0.1664	-0.2390	0.2101	0.2855	0.2411	0.2013	-0.1451	0.0466	-0.0611	1.0000	-0.0144
# Alien species	4.3533	3.0601	-0.0445	0.0103	0.2785	-0.4937	-0.3715	-0.4603	-0.4286	0.2164	-0.3799	-0.1864	-0.0144	1.0000

Table CVall. Covariance analysis of 12 Maine fish community IBI metrics, all sites.

	Valid N	Mean	Minimum	Maximum	Variance	Std.Dev.	Coef.Var.
DELT	337	0.360	0.000	12.316	1.298	1.139	316.167
# native species	337	7.988	1.000	17.000	6.464	2.542	31.828
% Macrohabitat generalist	337	43.569	0.000	100.000	799.631	28.278	64.903
% Fluvial dependent/specialist species	337	38.938	0.000	100.000	1018.317	31.911	81.955
# Temperate stenothermic species	337	1.095	0.000	5.000	1.973	1.405	128.286
# Non-guarding lithophilic species	337	2.427	0.000	7.000	2.942	1.715	70.662
% Benthic insectivores	337	6.287	0.000	82.830	278.744	16.696	265.564
% Blackbass	334	21.856	0.000	93.120	400.600	20.015	91.578
% Native cyprinids (less fallfish)	334	20.481	0.000	93.060	586.283	24.213	118.224
% Native salmonids	334	0.402	0.000	33.330	6.337	2.517	626.654
% Adult white & longnose suckers	334	31.578	0.000	245.610	1331.813	36.494	115.567
# Alien species	334	4.353	0.000	19.000	9.364	3.060	70.294

Appendix Table A-2. continued

Table CVref. Covariance analysis of 12 Maine fish community IBI metrics, reference sites only.

	Valid N	Mean	Minimum	Maximum	Variance	Std.Dev.	Coef.Var.
DELT	23	0.279	0.000	2.182	0.351	0.593	212.681
# native species	23	11.391	6.000	17.000	8.522	2.919	25.627
% Macrohabitat generalist	23	13.915	0.000	60.550	300.356	17.331	124.550
% Fluvial dependent/specialist species	23	85.673	39.450	100.000	311.015	17.636	20.585
# Temperate stenothermic species	23	3.478	1.000	5.000	1.625	1.275	36.644
# Non-guarding lithophilic species	23	5.435	3.000	7.000	1.530	1.237	22.757
% Benthic insectivores	23	39.303	0.000	70.560	525.924	22.933	58.350
% Blackbass	23	0.000	0.000	0.000	0.000	0.000	0.000
% Native cyprinids (less fallfish)	23	55.100	17.050	81.220	291.541	17.075	30.988
% Native salmonids	23	1.950	0.000	20.800	19.457	4.411	226.157
% Adult white & longnose suckers	23	66.453	0.000	245.610	4439.657	66.631	100.267
# Alien species	23	0.043	0.000	1.000	0.043	0.209	479.583

Appendix Table A-3. Eigen values for Principal Components Analysis factors 1 through 12.

Table EIGEN. Eigenvalues for PCA factors 1 thru 12.

	Eigenvalue	% Total	Cumulative	Cumulative
Factor 1	4.922463	41.02052	4.92246	41.0205
Factor 2	1.267067	10.55889	6.18953	51.5794
Factor 3	1.151565	9.59638	7.34109	61.1758
Factor 4	1.006421	8.38684	8.34752	69.5626
Factor 5	0.892238	7.43531	9.23975	76.9980
Factor 6	0.838657	6.98881	10.07841	83.9868
Factor 7	0.608252	5.06877	10.68666	89.0555
Factor 8	0.489718	4.08098	11.17638	93.1365
Factor 9	0.349341	2.91118	11.52572	96.0477
Factor 10	0.226120	1.88433	11.75184	97.9320
Factor 11	0.142174	1.18478	11.89402	99.1168
Factor 12	0.105984	0.88320	12.00000	100.0000