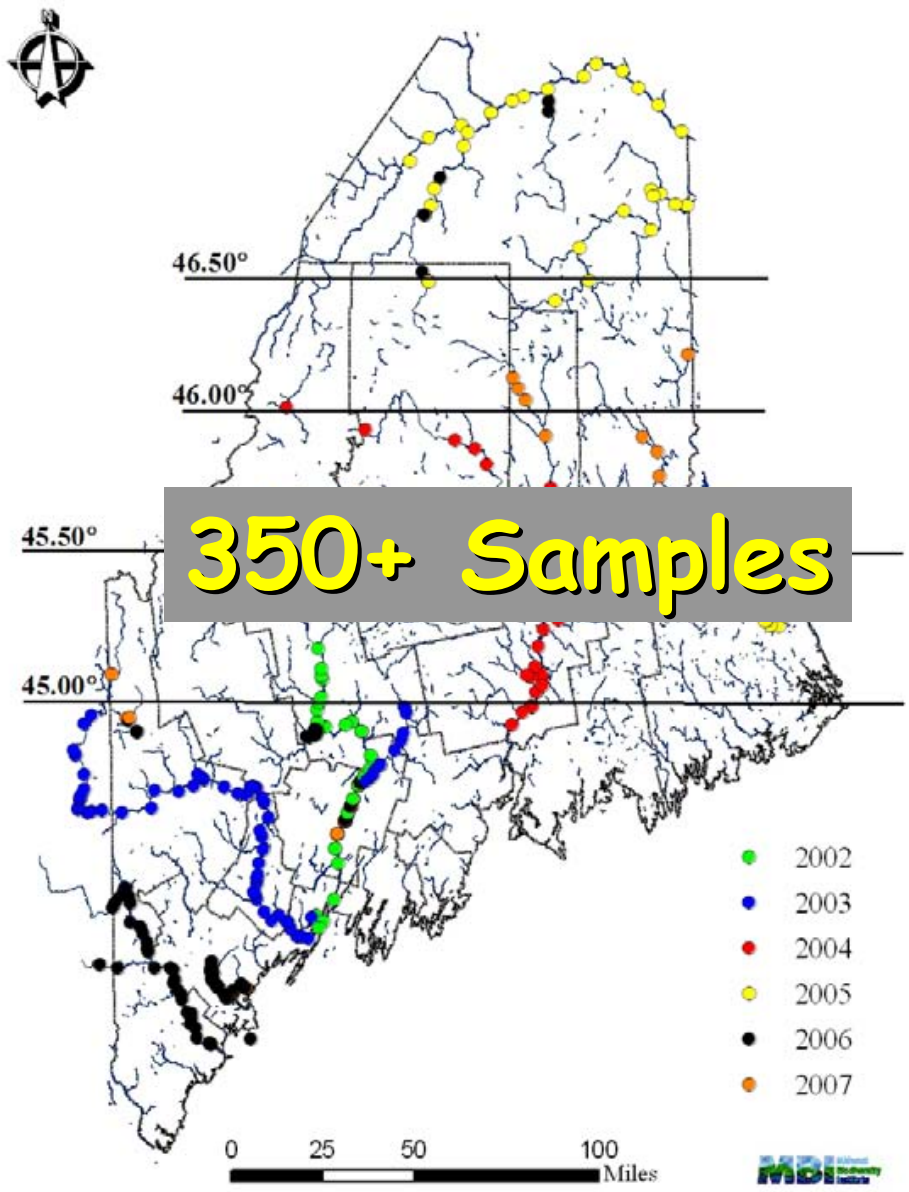
DEVELOPMENT OF AN INTERIM FISH ASSEMBLAGE ASSESSMENT INDEX FOR NON-WADEBALE RIVERS IN MAINE & NEW ENGLAND: 2002 - 2007

Chris O. Yoder
Center for Applied Bioassessment and Biocriteria
Midwest Biodiversity Institute
Columbus, OH

Brandon H. Kulik and Brian Apell
Kleinschmidt Energy and Water Resources
Pittsfield, ME

David B. Halliwell
Maine DEP
Augusta, ME



Kennebec River (2002-6)

- Wyman Dam to Merrymeeting Bay (30 sites, 2 test areas)
- Follow-up Waterville to Augusta (2002-6)

Androscoggin River (2003)

- Errol, NH to Merrymeeting Bay (51 sites)

Sebasticook River (2003)

- Douglas Pond to Winslow (9 sites)

Penobscot River (2004)

- N. Br. To Hamden (40 sites); included W. Br., E. Br., 5 additional tributaries

Northern Maine Rivers (2005-6)

- St. John (14 sites), Allagash (8 sites), Aroostook (10 sites), St. Croix (12 sites)

Southern Maine Rivers (2006)

- Presumpscot R., Saco R. (32 sites)

Miscellaneous Maine Rivers (2007)

- Mattawamkeag R., Rapid R., Moose R., Moosehead Outlets, Dead R., E. Br. Penobscot (22 sites)

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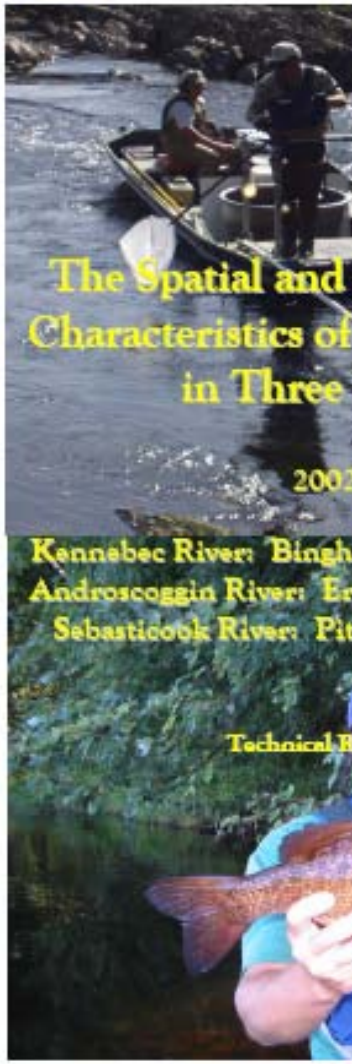
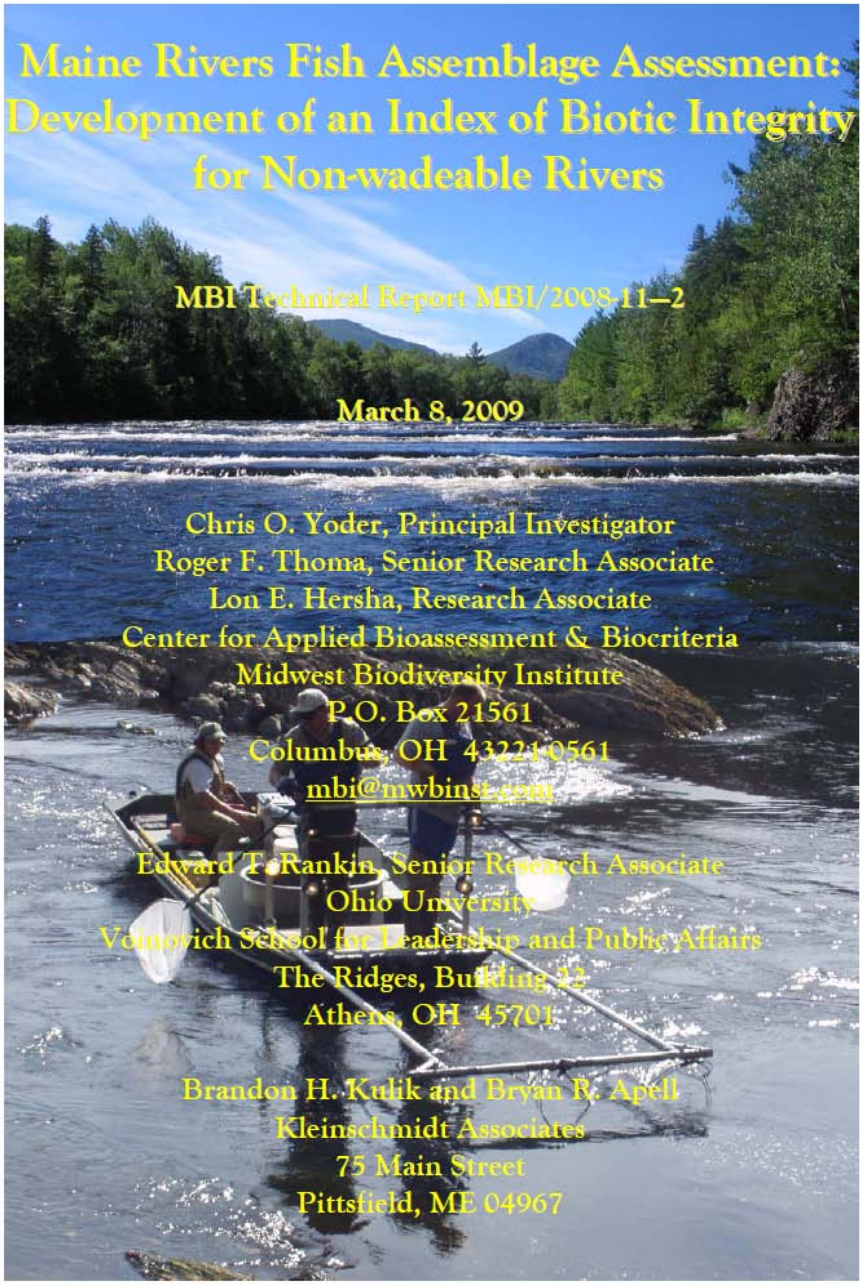
Midwest Biodiversity Institute
P.O. Box 21561
Columbus, OH 43221-0561





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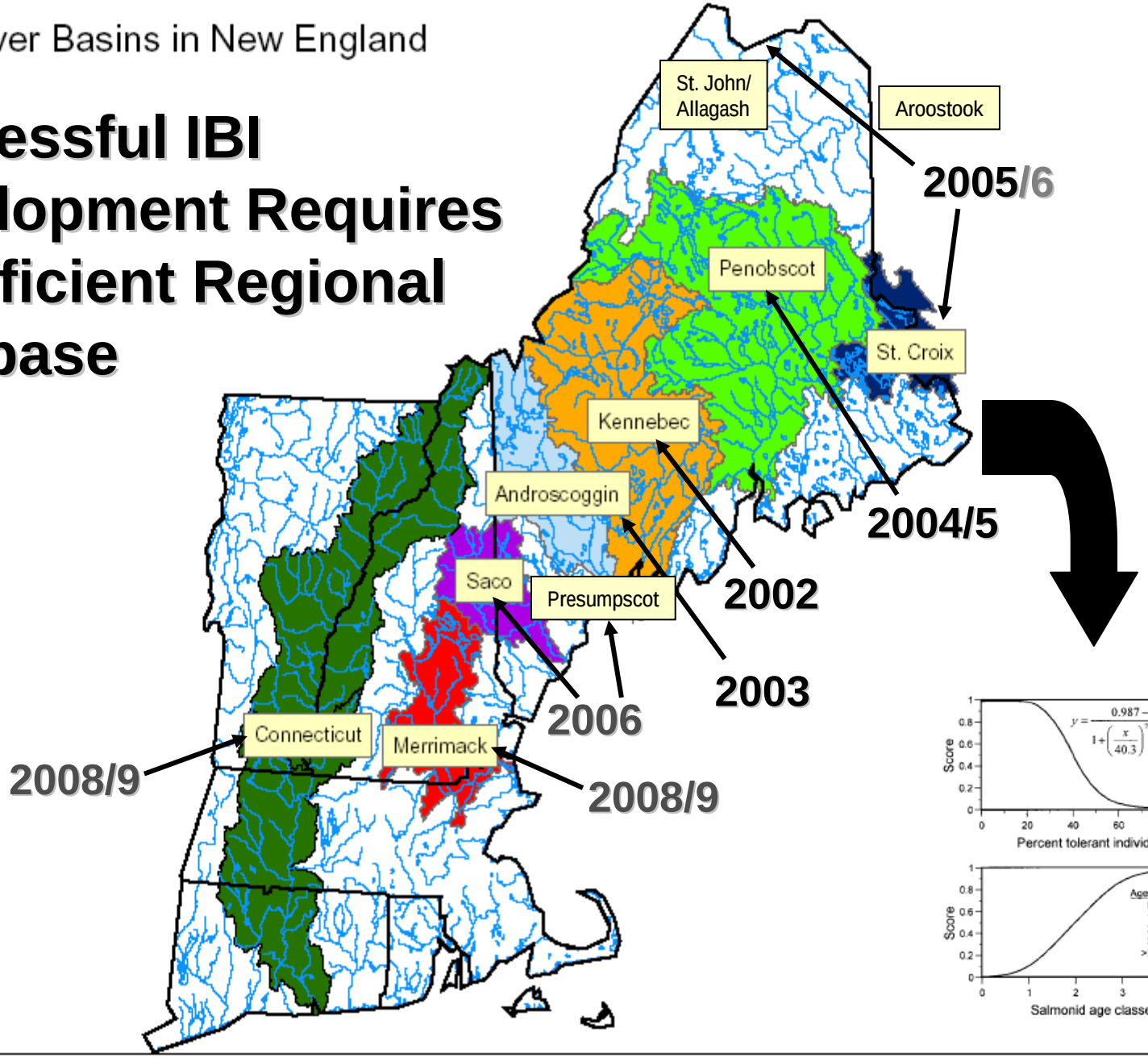
Major River Basins in New England

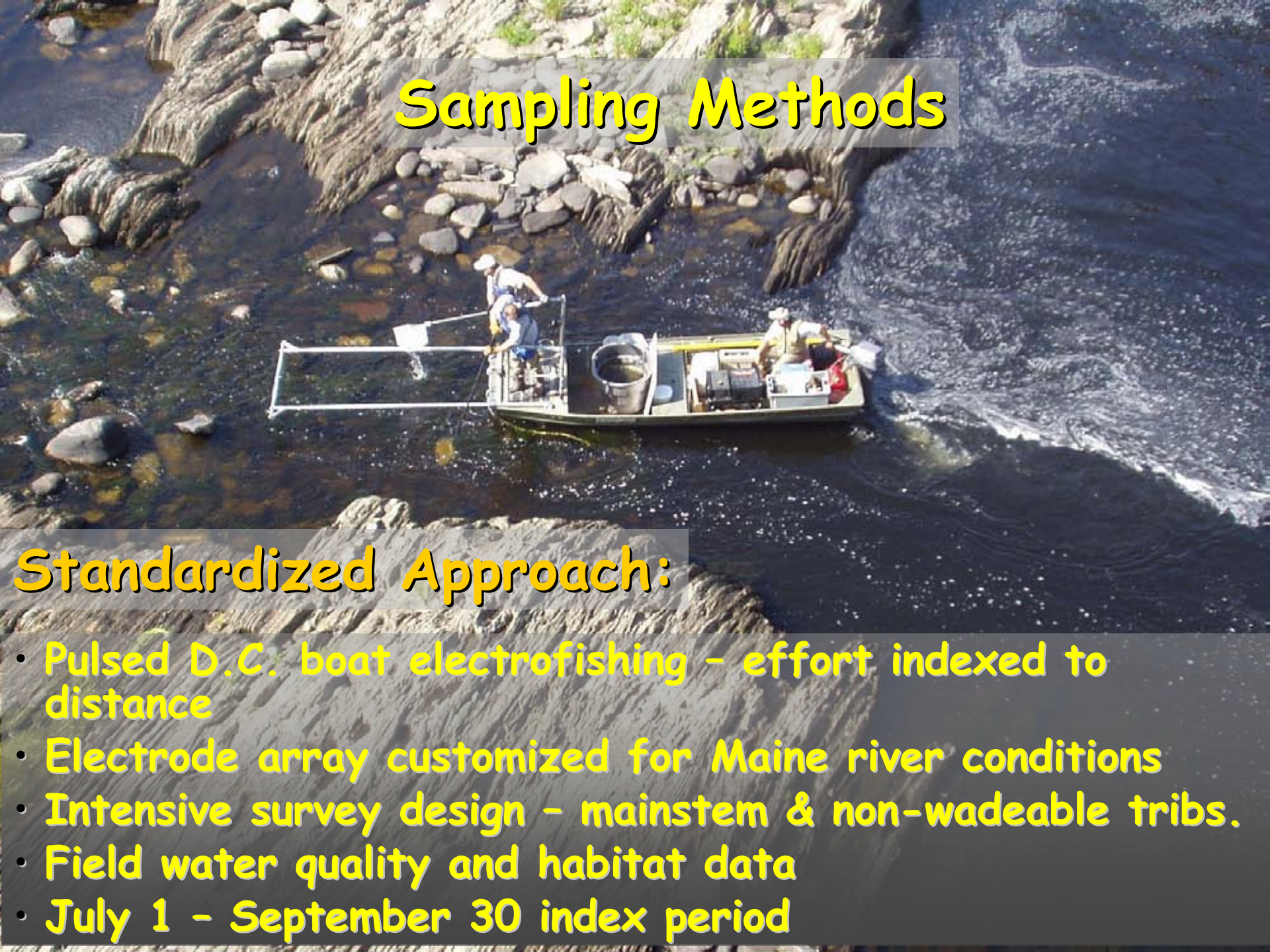
Successful IBI Development Requires a Sufficient Regional Database



Why Knowledge of the Fish Assemblage is Important

Current Issues:

- **Limited Knowledge of Extant Fauna** – limited mostly to managed species (especially trout and salmon); need to document relative abundance of co-occurring native and alien species and their respective influence.
- **Naturally Depauperate Fauna** – cold water, coastal drainages – "how will these respond?"
- **Assess Potential Conflicts with High Profile Restoration Goals** – do non-native species pose an unintentional deterrent?

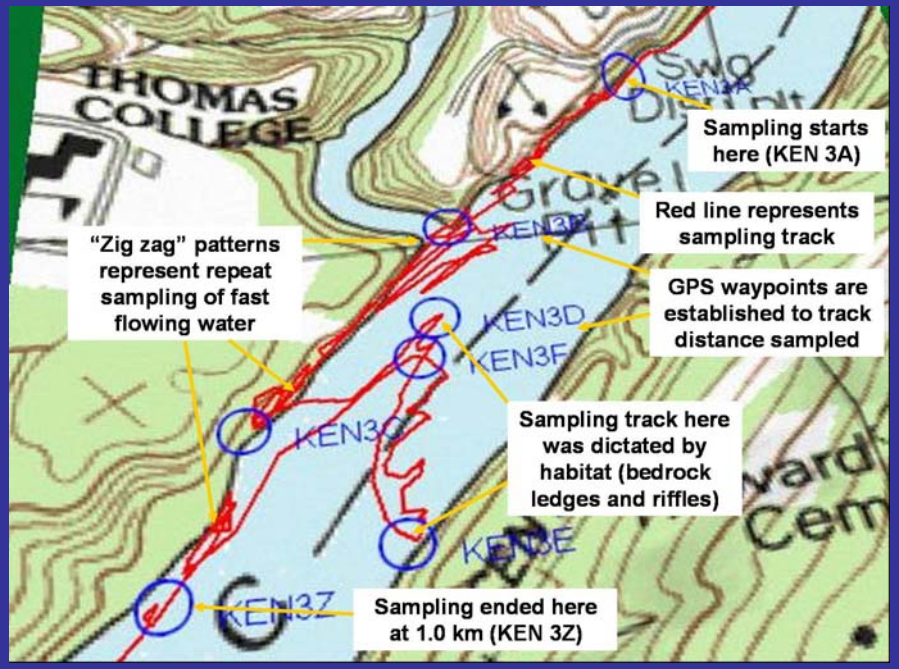


Sampling Methods

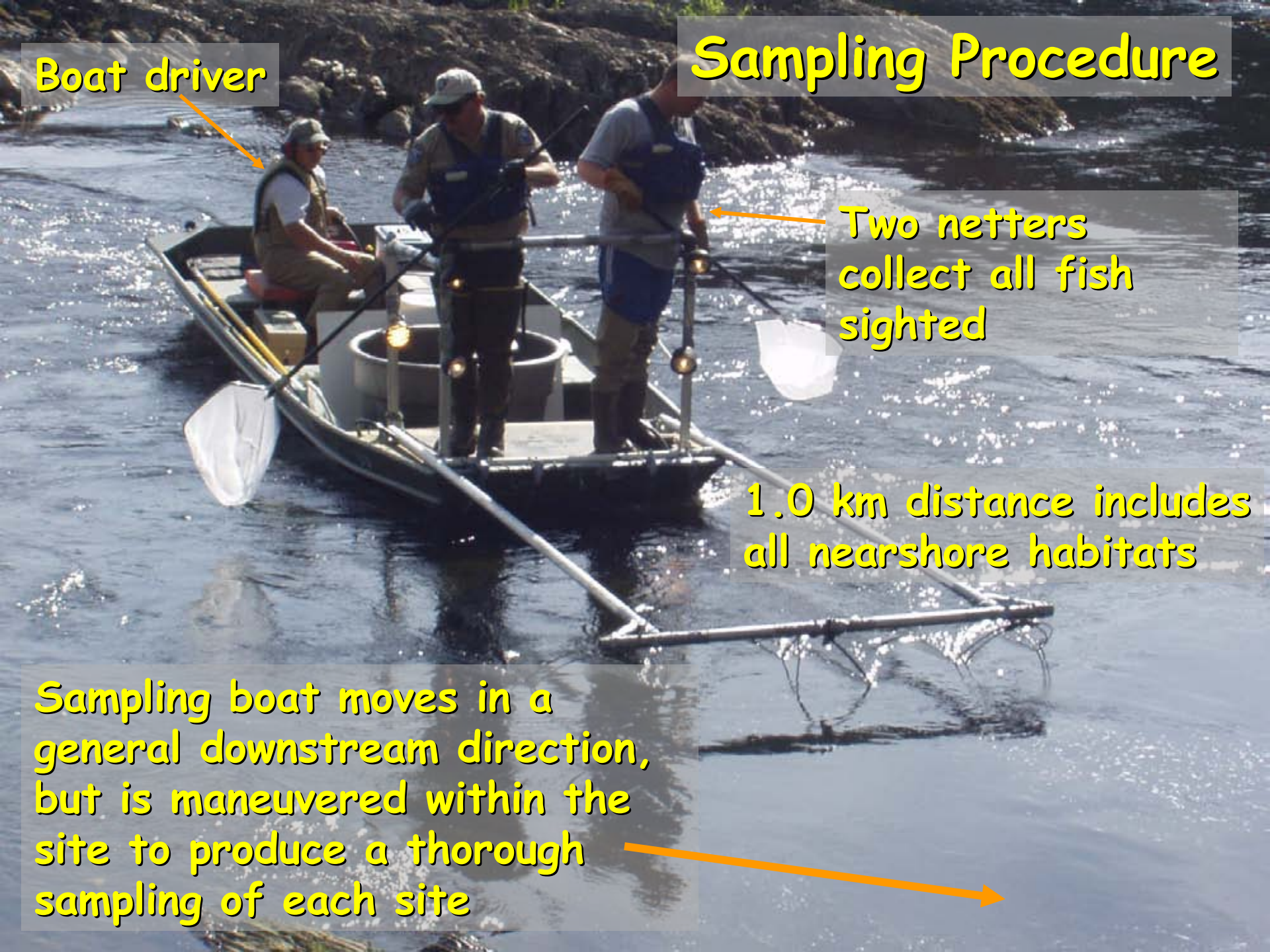
Standardized Approach:

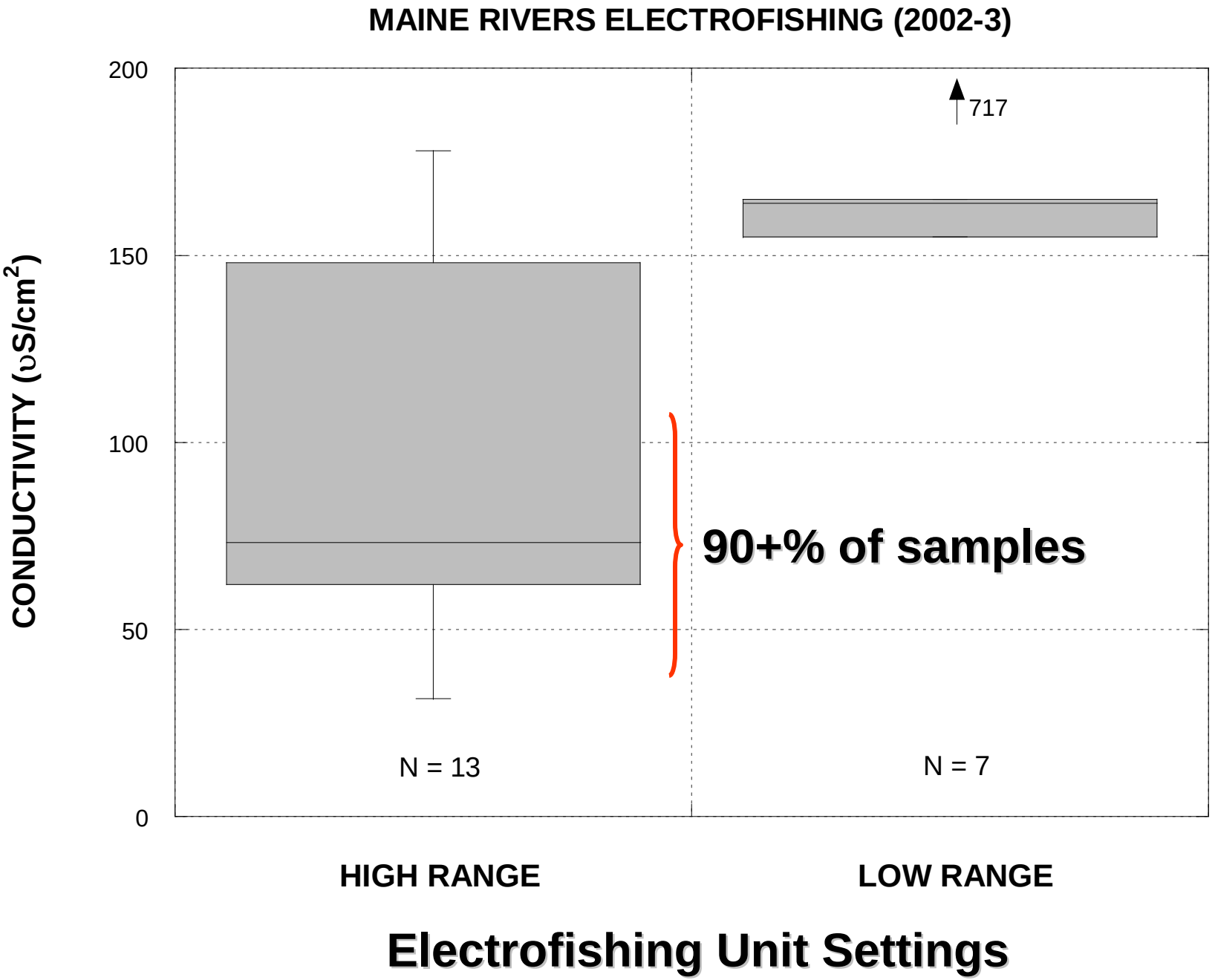
- Pulsed D.C. boat electrofishing – effort indexed to distance
- Electrode array customized for Maine river conditions
- Intensive survey design – mainstem & non-wadeable tribs.
- Field water quality and habitat data
- July 1 – September 30 index period

- Sampling guided by a QAPP
- Standardized sampling to yield comparable data
- All representative habitat types within each site



- Geo-referenced sample site location and sample track
- Fish are identified to species, enumerated, and weighed
- DELT anomalies recorded


Sampling Procedure
Boat driver
Two netters collect all fish sighted
1.0 km distance includes all nearshore habitats
Sampling boat moves in a general downstream direction, but is maneuvered within the site to produce a thorough sampling of each site


MAINE RIVERS ELECTROFISHING (2002-3)
CONDUCTIVITY (υS/cm²)
200
150
100
50
0
717
90+% of samples
N = 13
N = 7
HIGH RANGE
LOW RANGE
Electrofishing Unit Settings

Developed in 2005 to Access Medium Sized and Shallower Rivers

Launching & Retrieving

Smith-Root 2.5 GPP Unit

Qualitative Habitat Evaluation Index Field Sheet

QHEI Score: ____

River Code: ____ *RM:* ____ *Stream:* ____

Site Code: ____ *Project Code:* ____ *Location:* ____

Date: ____ *Scorer:* ____ *Latitude:* ____ *Longitude:* ____

1.) SUBSTRATE (Check ONLY Two Substrate TYPE BOXES; Estimate % percent

TYPE	POOL	RIFFLE		POOL	RIFFLE
☐ ☐ -BLDR/SLBS [10]			☐ ☐ -GRAVEL [7]		
☐ ☐ -Lg BOULD [10]			☐ ☐ -SAND [6]		
☐ ☐ -BOULDER [9]			☐ ☐ -BEDROCK [5]		
☐ ☐ -COBBLE [8]			☐ ☐ -DETRITUS [3]		
☐ ☐ -HARDPAN [4]			☐ ☐ -ARTIFICIAL [0]		
☐ ☐ -MUCK [2]			☐ ☐ -SILT [2]		

NUMBER OF SUBSTRATE TYPES:
(High Quality Only, Score 5 or >)
☐ -4 or More [2]
☐ -3 or Less [0]

SUBSTRATE ORIGIN
Check ONE (OR 2 & AVERAGE)
☐ -LIMESTONE [1]
☐ -TILLS [1]
☐ -WETLANDS [0]
☐ -HARDPAN [0]
☐ -SANDSTONE [0]
☐ -RIP / RAP [0]
☐ -LACUSTRINE [0]
☐ -SHALE [-1]
☐ -COAL FINES [-2]

SUBSTRATE QUALITY
Check ONE (OR 2 & AVERAGE)
SILT:
☐ -SILT HEAVY [-2]
☐ -SILT MODERATE [-1]
☐ -SILT NORMAL [0]
☐ -SILT FREE [1]
EMBEDDED NESS:
☐ -EXTENSIVE [-2]
☐ -MODERATE [-1]
☐ -NORMAL [0]
☐ -NONE [1]

Substrate ____ Max 20

COMMENTS: ____

2.) INSTREAM COVER (Give each cover type a score of 0 to 3; see back for instructions)

(Structure)
____ UNDERCUT BANKS [1]
____ OVERHANGING VEGETATION [1]
____ SHALLOWS (IN SLOW WATER) [1]
____ ROOTMATS [1]

TYPE: Score All That Occur
____ POOLS > 70 cm [2]
____ ROOTWADS [1]
____ BOULDERS [1]

____ OXBOWS, BACKWATERS [1]
____ AQUATIC MACROPHYTES [1]
____ LOGS OR WOODY DEBRIS [1]

AMOUNT: (Check ONLY one or check 2 and AVERAGE)
☐ -EXTENSIVE > 75% [11]
☐ -MODERATE 25 - 75% [7]
☐ -SPARSE 5 - 25% [3]
☐ -NEARLY ABSENT < 5% [1]

Cover ____ Max 20

COMMENTS: ____

3.) CHANNEL MORPHOLOGY: (Check ONLY one PER Category OR check 2 and AVERAGE)

SINUOSITY
☐ -HIGH [4]
☐ -MODERATE [3]
☐ -LOW [2]
☐ -NONE [1]

DEVELOPMENT
☐ -EXCELLENT [7]
☐ -GOOD [5]
☐ -FAIR [3]
☐ -POOR [1]

CHANNELIZATION
☐ -NONE [6]
☐ -RECOVERED [4]
☐ -RECOVERING [3]
☐ -RECENT OR NO RECOVERY [1]
☐ -IMPOUNDED [-1]

STABILTIY
☐ -HIGH [3]
☐ -MODERATE [2]
☐ -LOW [1]

MODIFICATIONS / OTHER
☐ -SNAGGING
☐ -RELOCATION
☐ -CANOPY REMOVAL
☐ -DREDGING
☐ -ONE SIDE CHANNEL MODIFICATIONS
☐ -IMPOUNDMENT
☐ -ISLAND
☐ -LEVEED
☐ -BANK SHAPING

Channel ____ Max 20

COMMENTS: ____

4.) RIPARIAN ZONE AND BANK EROSION (check ONE box PER bank or check 2 and AVERAGE per bank)

River Right Looking Downstream

RIPARIAN WIDTH
L R (Per Bank)
☐ ☐ -VERY WIDE > 100m [5]
☐ ☐ -WIDE > 50m [4]
☐ ☐ -MODERATE 10 - 50m [3]
☐ ☐ -NARROW 5 - 10m [2]
☐ ☐ -VERY NARROW < 5m [1]
☐ ☐ -NONE [0]

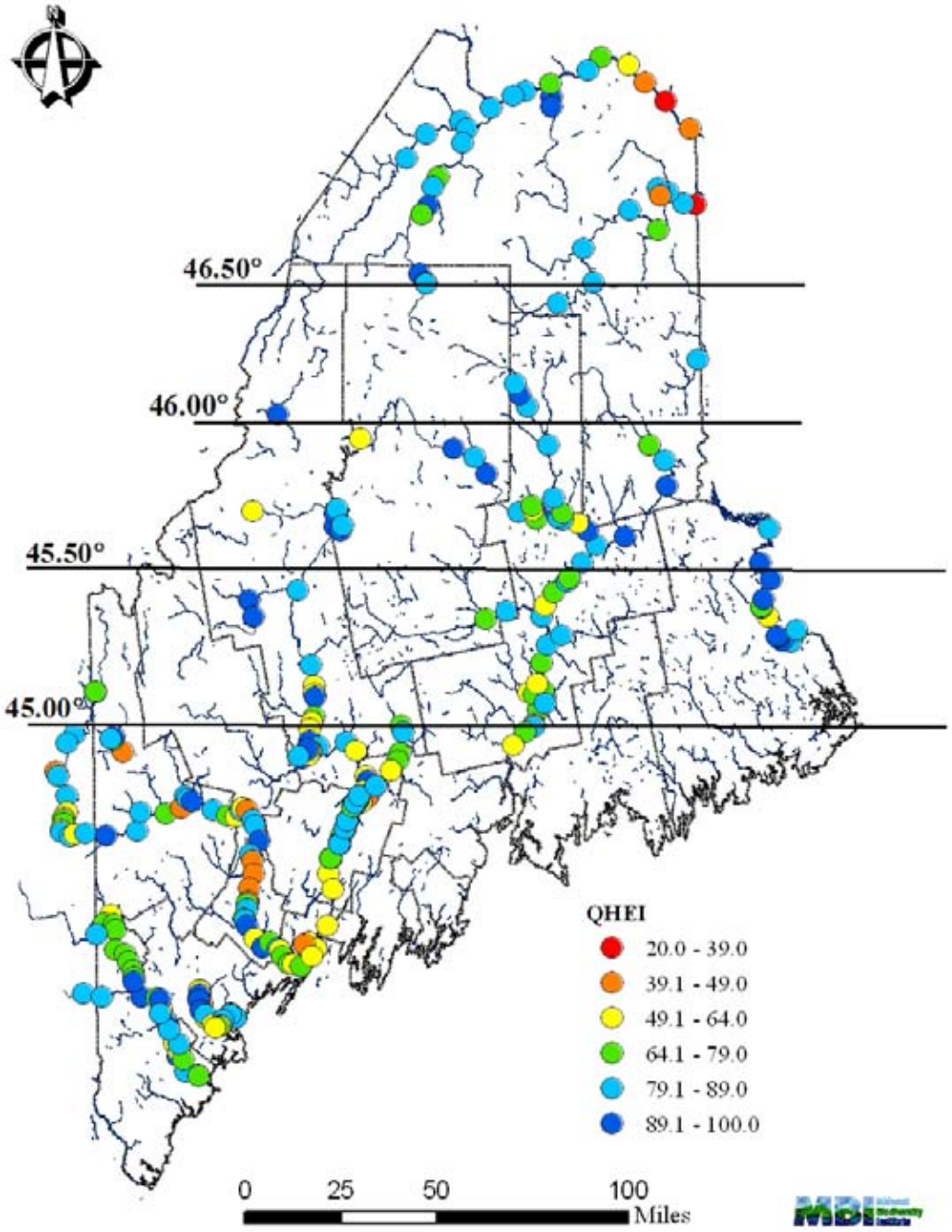
FLOOD PLAIN QUALITY (*PAST 100 Meter RIPARIAN*)
L R (Most Predominant Per Bank)
☐ ☐ -FOREST, SWAMP [3]
☐ ☐ -SHRUB OR OLD FIELD [2]
☐ ☐ -RESIDENTIAL, PARK, NEW FIELD [1]
☐ ☐ -FENCED PASTURE [1]

L R
☐ ☐ -CONSERVATION TILLAGE [1]
☐ ☐ -URBAN OR INDUSTRIAL [0]
☐ ☐ -OPEN PASTURE, ROWCROP [0]
☐ ☐ -MINING / CONSTRUCTION [0]

BANK EROSION
L R (Per Bank)
☐ ☐ -NONE / LITTLE [3]
☐ ☐ -MODERATE [2]
☐ ☐ -HEAVY / SEVERE [1]

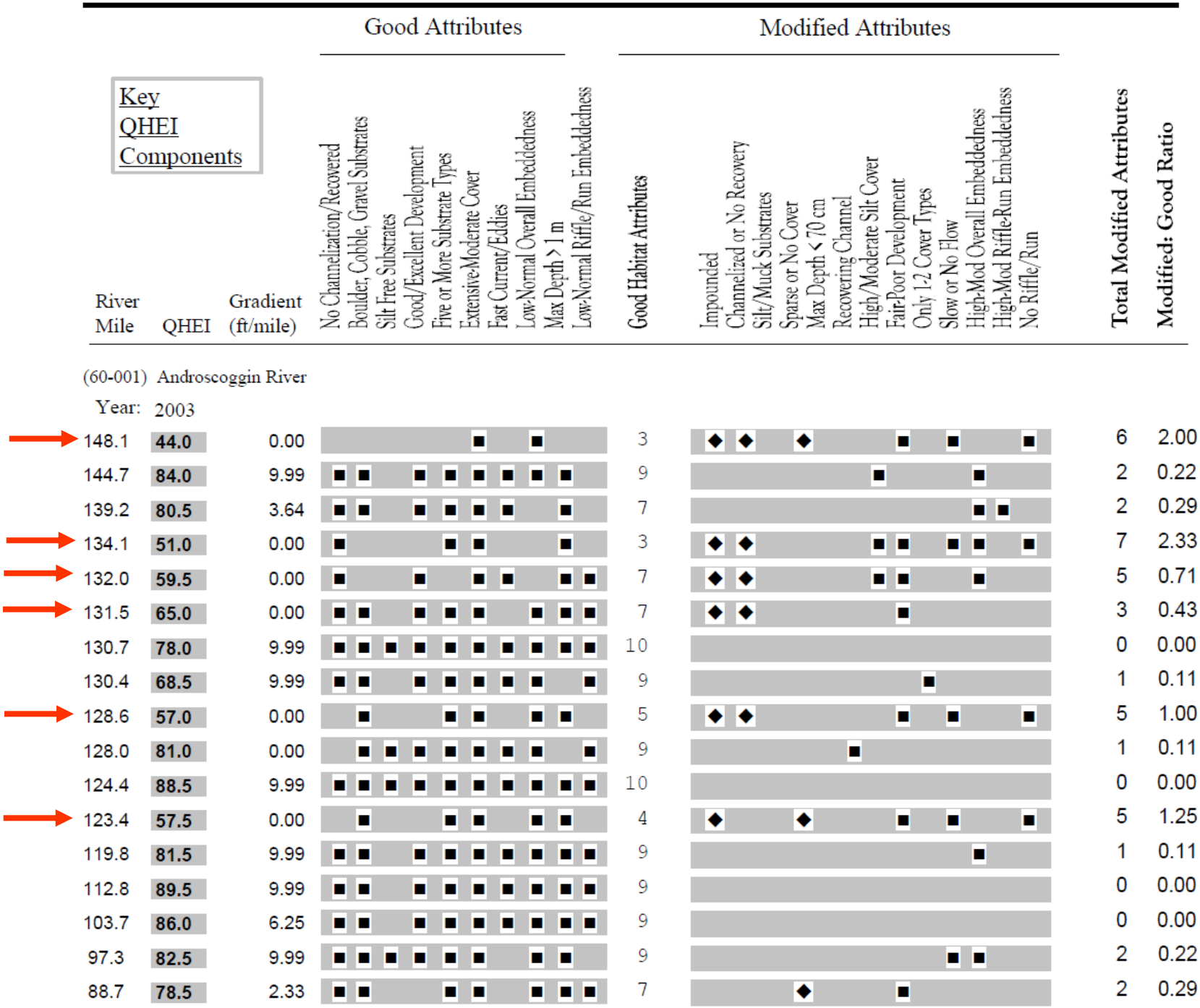
Riparian ____ Max 10

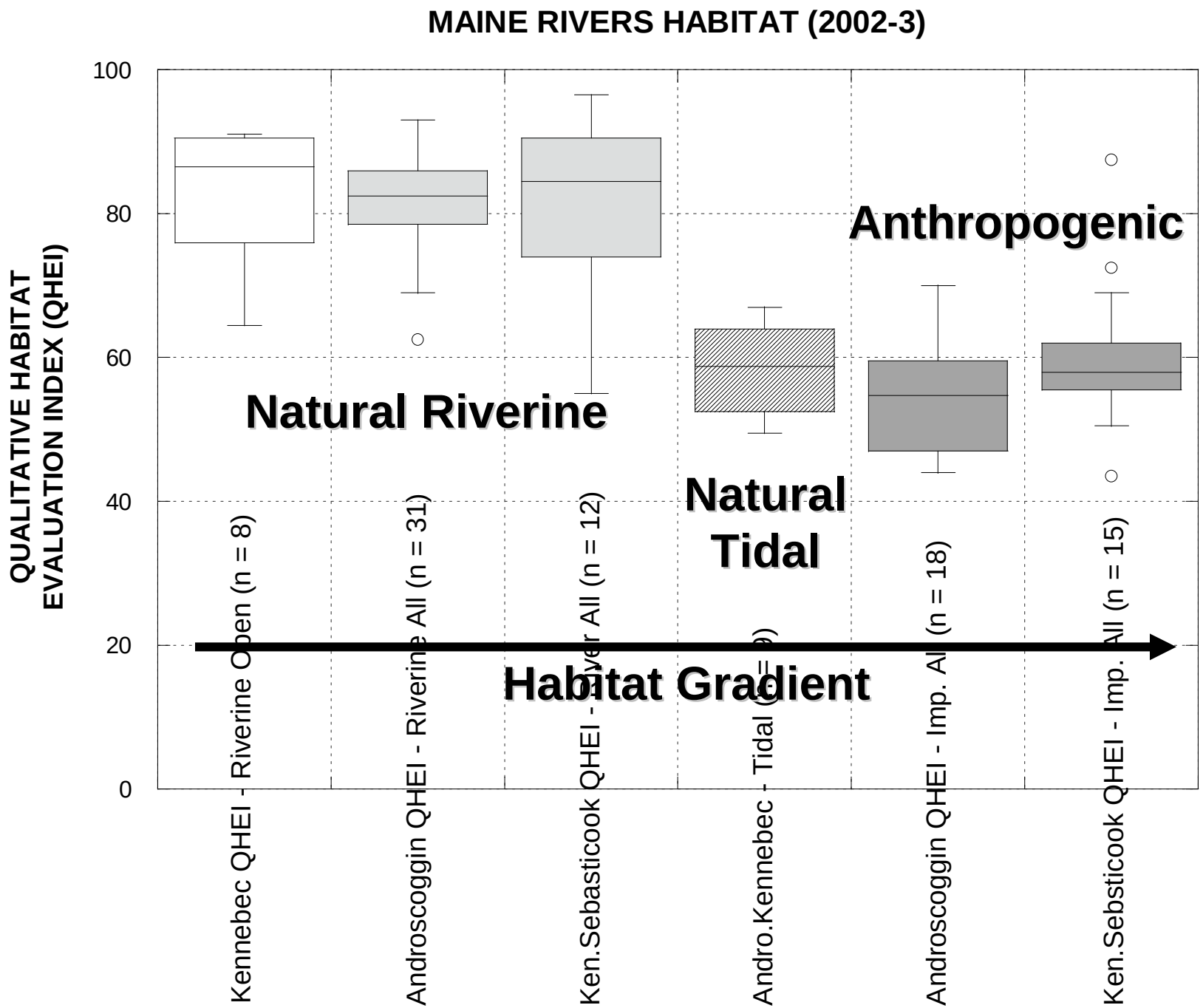
COMMENTS: ____



Maine Rivers Fish Assemblage Assessment: 2002-7

Table A-4 (continued).




MAINE RIVERS HABITAT (2002-3)
QUALITATIVE HABITAT EVALUATION INDEX (QHEI)
100
80
60
40
20
0
Natural Riverine
Natural Tidal
Anthropogenic
Habitat Gradient
Kennebec QHEI - Riverine Open (n = 8)
Androscoggin QHEI - Riverine All (n = 31)
Ken.Sebasticook QHEI - Riverine All (n = 12)
Andro.Kennebec - Tidal (n = 9)
Androscoggin QHEI - Imp. All (n = 18)
Ken.Sebsticook QHEI - Imp. All (n = 15)

IBI Project Status

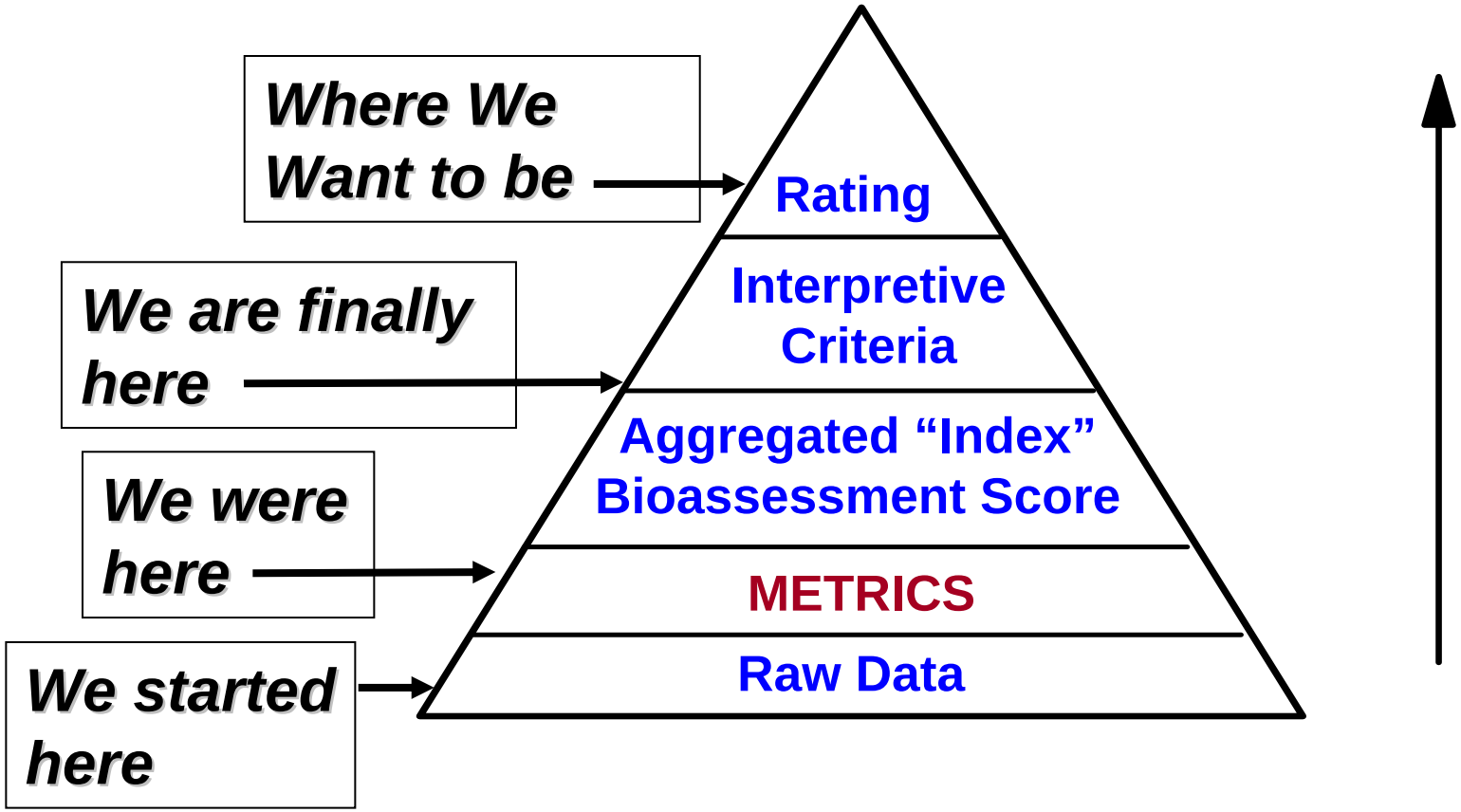
Development of standardized field methods:

- Single-gear approach – 16' boat & 14' raft
- Yields relative abundance data - #s, biomass
- Logistics and remote access procedures
- Gradient of large river habitat "types"

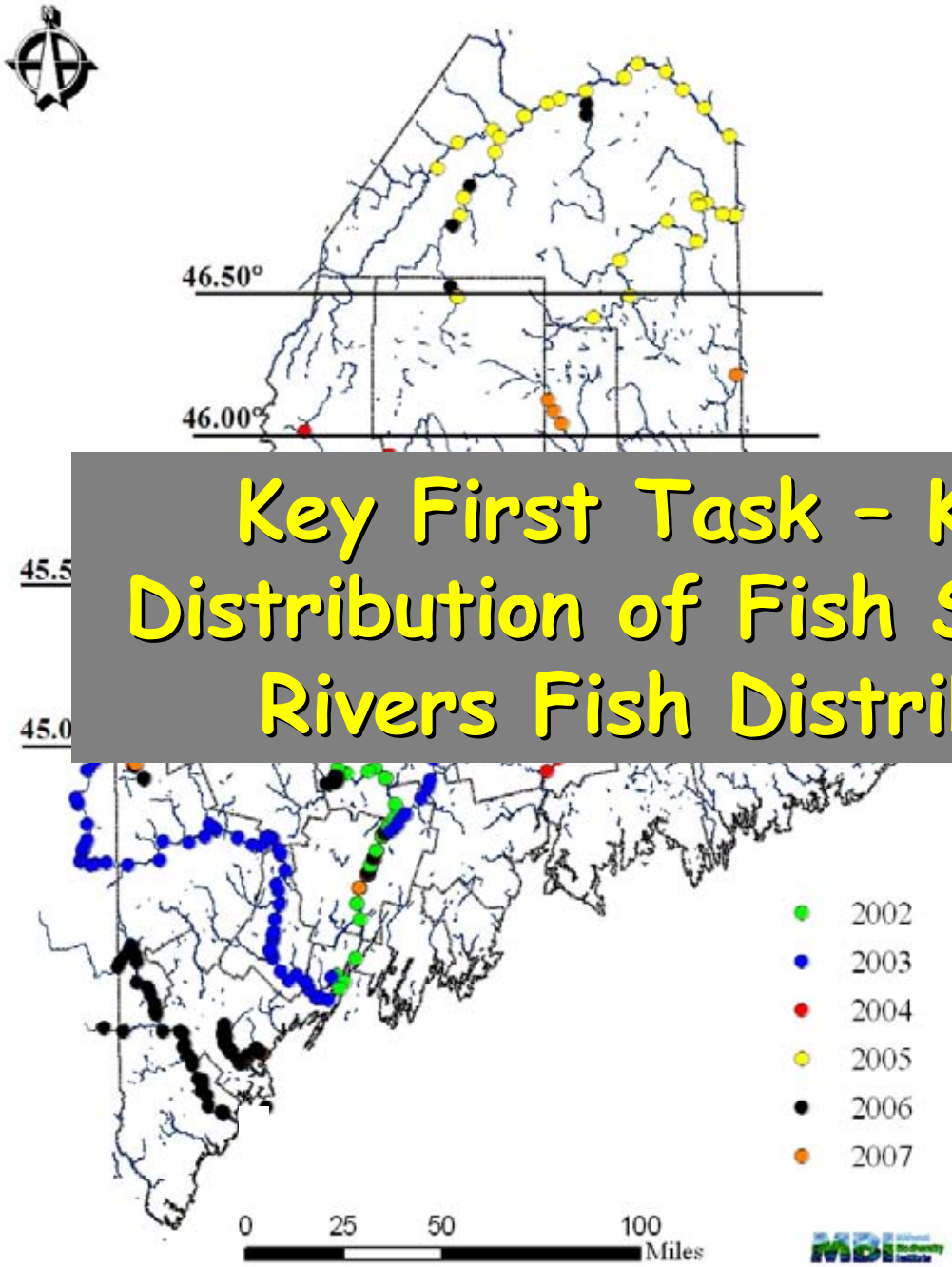
Data Analysis (2007-8):

- Distribution & abundance of key species
- Analysis of core stressors – habitat, T (°C)
- Autecology of each species – pre-IBI
- Multivariate analysis – expose gradients
- "Interim" IBI derivation – metrics & scoring

Data Manipulation Hierarchy of Field Collected Biological Samples



Maine Rivers Fish Assemblage Assessment: 2002-7



Key First Task – Know Current Distribution of Fish Species: Maine Rivers Fish Distribution Atlas

Cold Water Species: Salmon and Trout

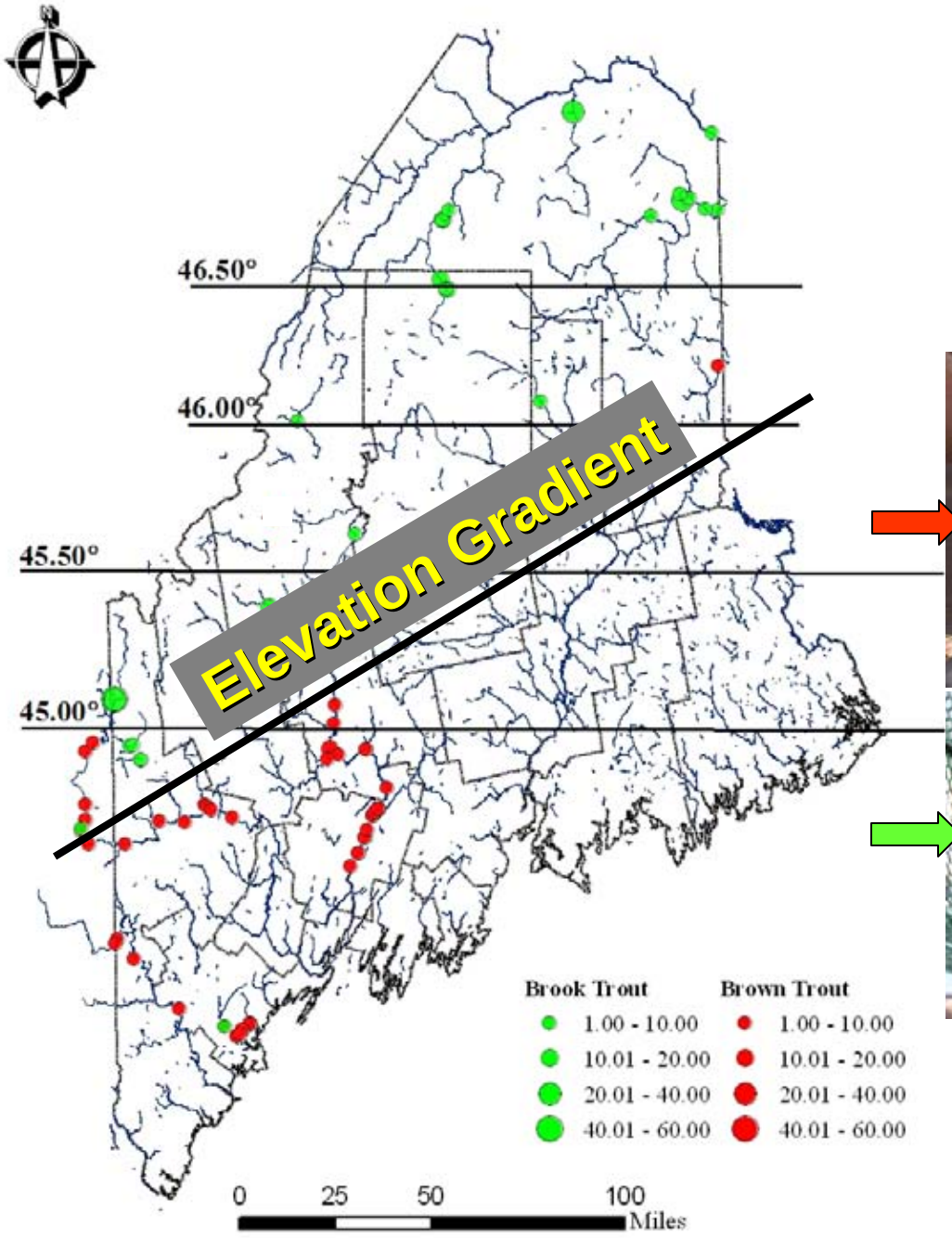
Landlocked salmon
(Intracontinental Introduced)

Rainbow trout
(Intercontinental Introduced)

Brook trout
(Indigenous Native)

Brown trout
(Intercontinental Introduced)

Maine Rivers Fish Assemblage Assessment: 2002-7



Cold Water Species: Non-Salmonids (Indigenous Natives)

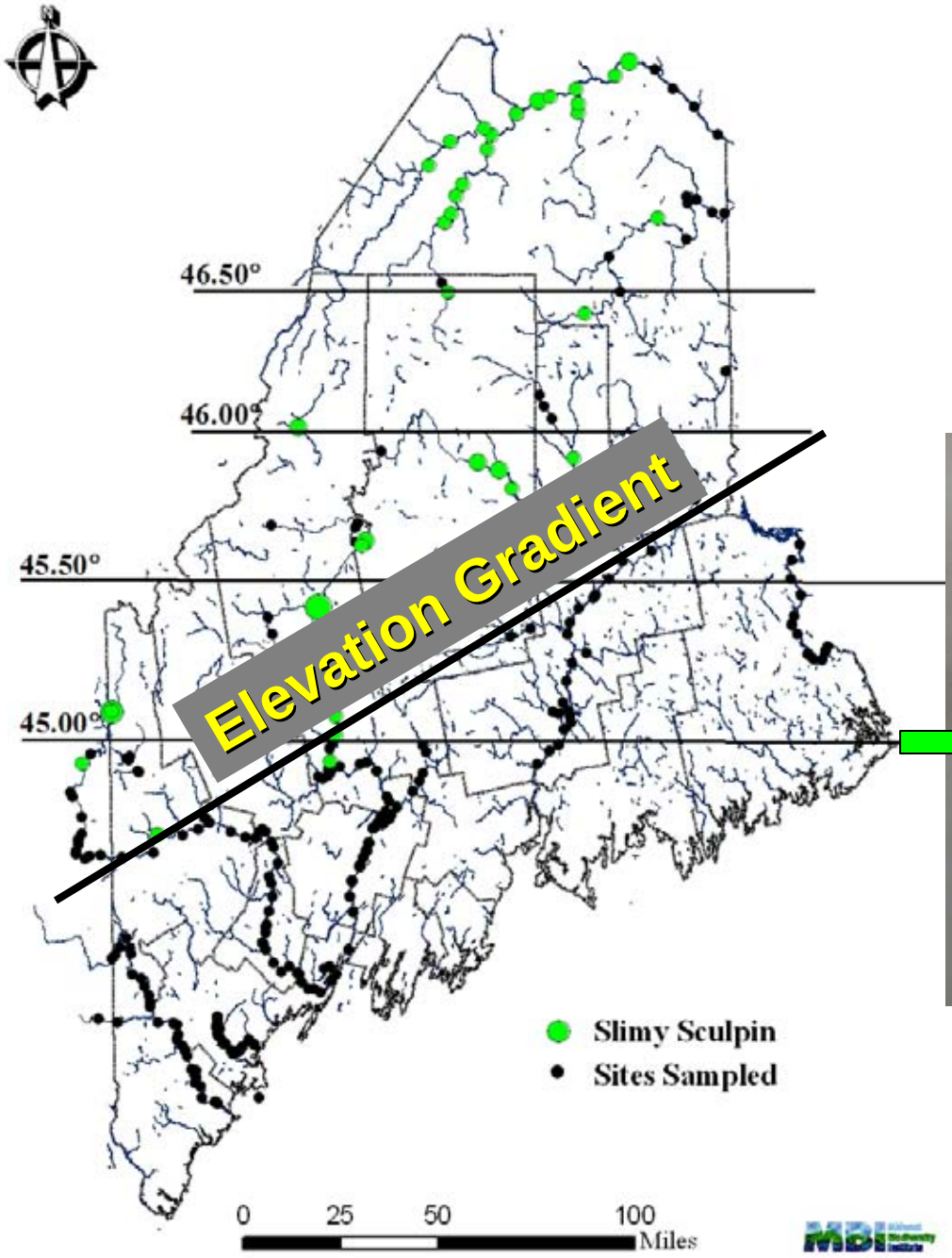
Common white sucker
(adult life stage)

Slimy sculpin

Lake chub

Burbot

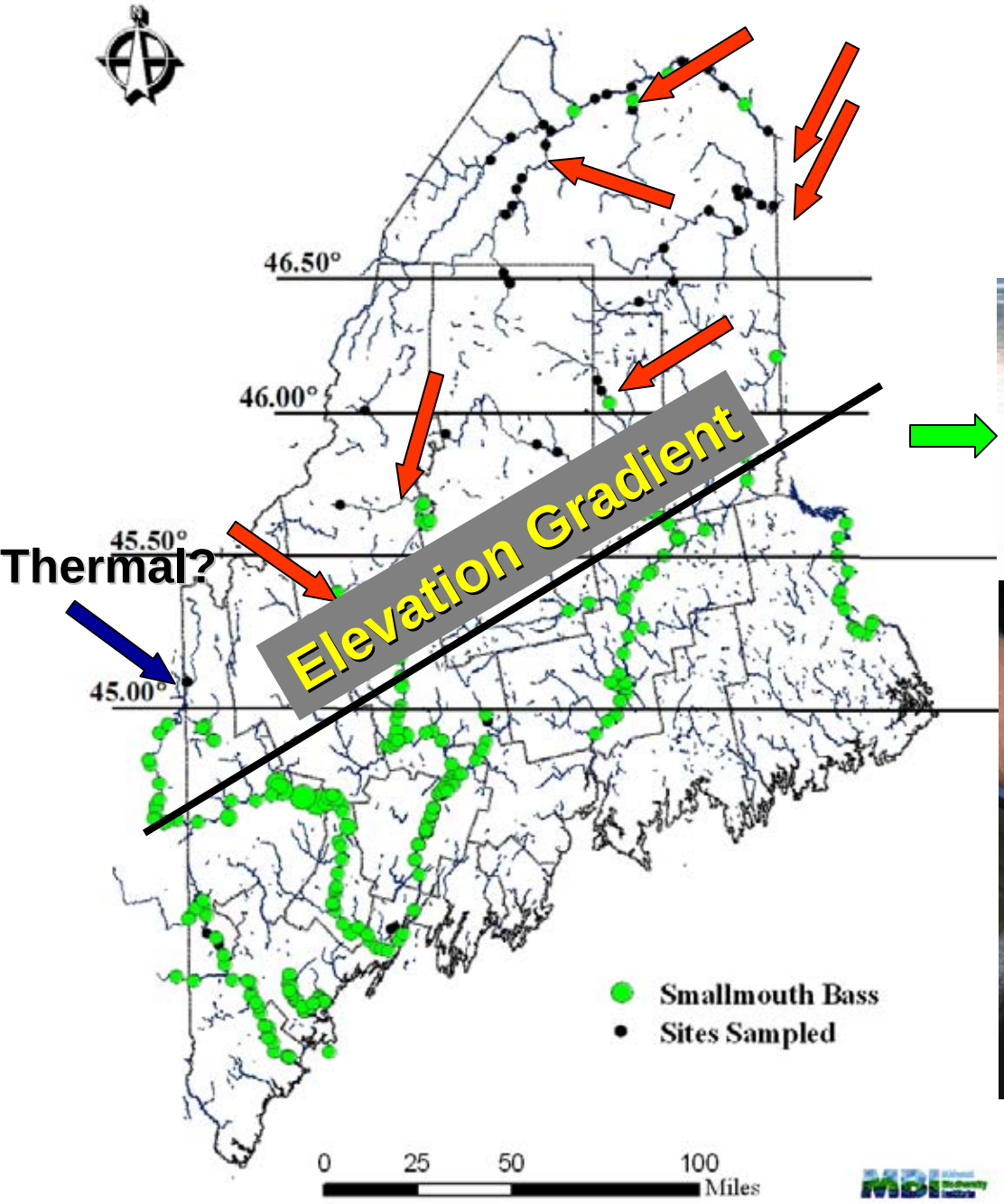
Maine Rivers Fish Assemblage Assessment: 2002-7



Warmwater Species

Smallmouth bass (adult life stage)
(Introduced Naturalized c. 1870)

Maine Rivers Fish Assemblage Assessment: 2002-7



Physical barriers

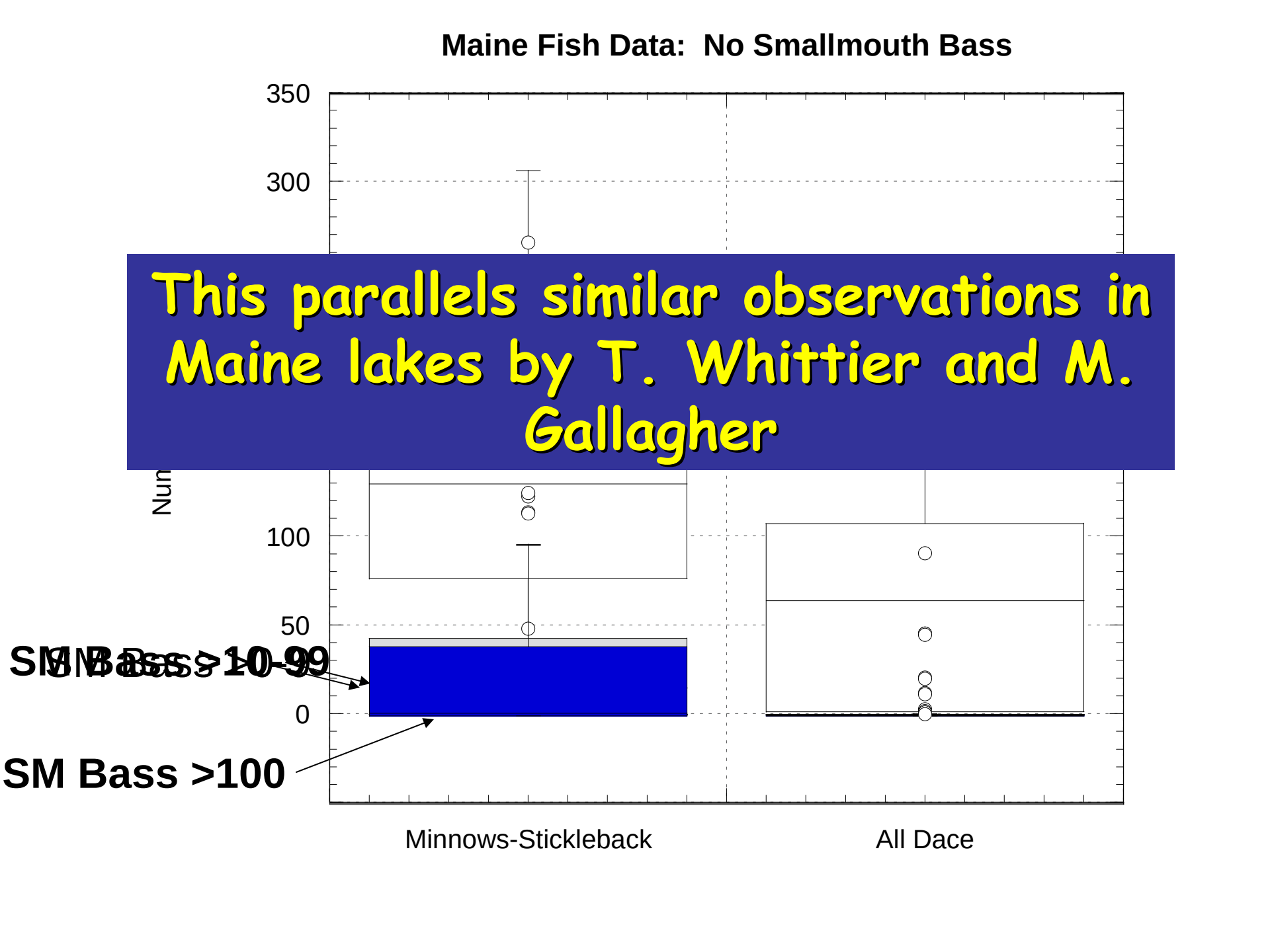
Definitions of Non-indigenous Species Based on Origins (after Halliwell 2005)

- Intercontinental origin – usually referred to as "alien" species
- Intracontinental origin – species can become naturalized (e.g., smallmouth bass, rainbow trout)
- Intraregional origin – usually interstate or nearby New England transplants
- Managed introduced – deliberate stocking for recreational purposes

Assessing the Impact of Alien Species

Current Issues:

- **Refined Designations of Non-native Species** – effects of each are not equal and some have become a permanent part of the resource.
- **Improved Understanding of Impacts** – impacts are different to cold and warmwater faunas; influence can be misinterpreted, especially with increases in overall species richness.

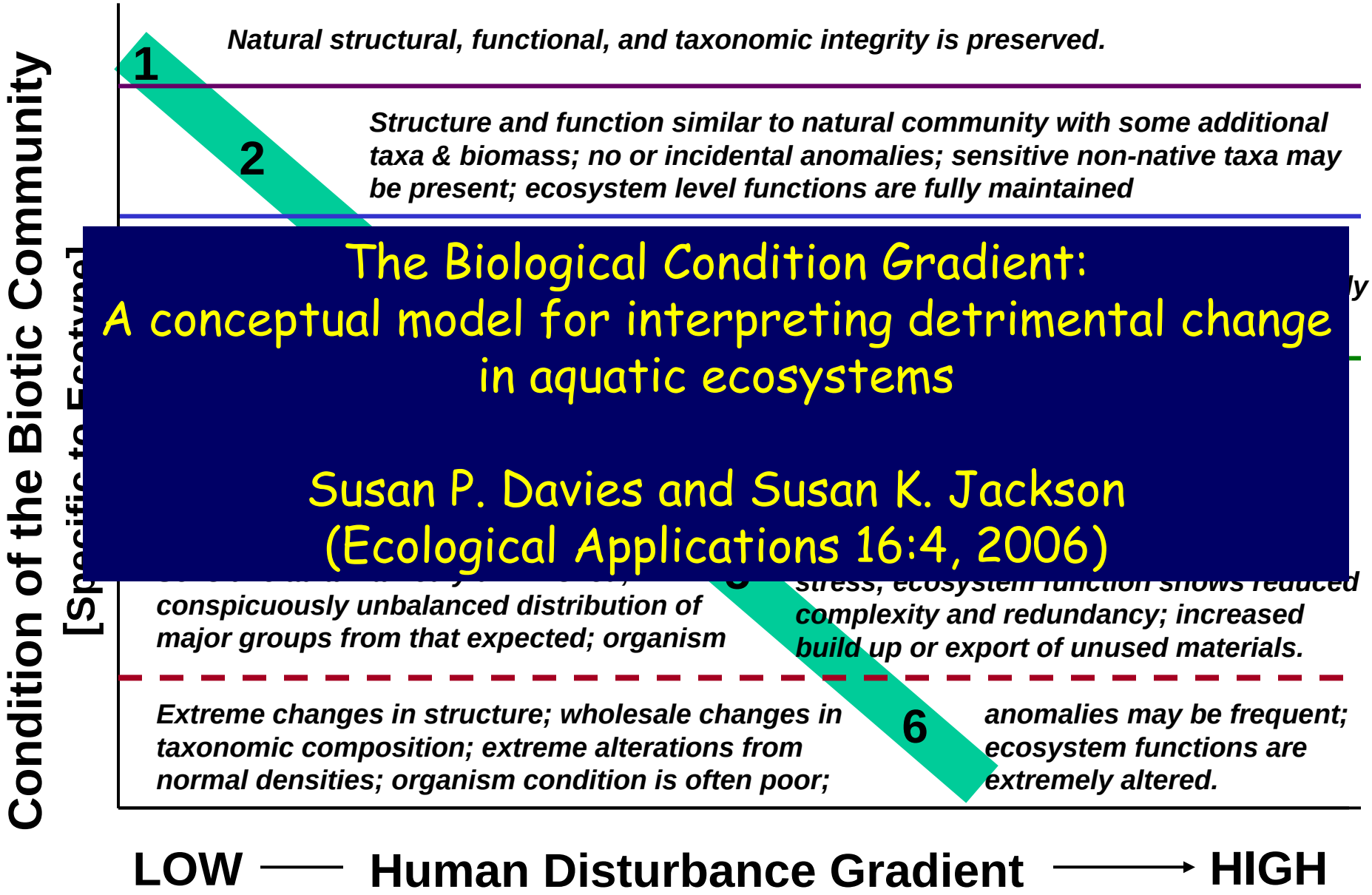

Maine Fish Data: No Smallmouth Bass
350
300
100
50
0
Num
This parallels similar observations in Maine lakes by T. Whittier and M. Gallagher
SM Bass >10-99
SM Bass >100
Minnows-Stickleback
All Dace

Checklist of Fish Assemblage/IBI Development Tasks

- Develop an effective & systematic sampling method (2001-3)
- Develop a sufficient spatial & temporal database (2002-6)
- Autecology of extant fauna & metric development (2005-6)
- Classify riverine ecotypes (2006-7)
- Establish "reference condition" – BCG (2007-8)
- Derive and test IBIs with reference and independent test sites (2008)

Tiered Aquatic Life Use Conceptual Model: Draft Biological Tiers

(10/22 draft)



The Biological Condition Gradient: A conceptual model for interpreting detrimental change in aquatic ecosystems

Susan P. Davies and Susan K. Jackson
(Ecological Applications 16:4, 2006)

Cold Water Assemblages

The "assumed baseline" for the Biological Condition Gradient applicable to Maine's large rivers

Tiered Aquatic Life Use Conceptual Model: Maine Rivers

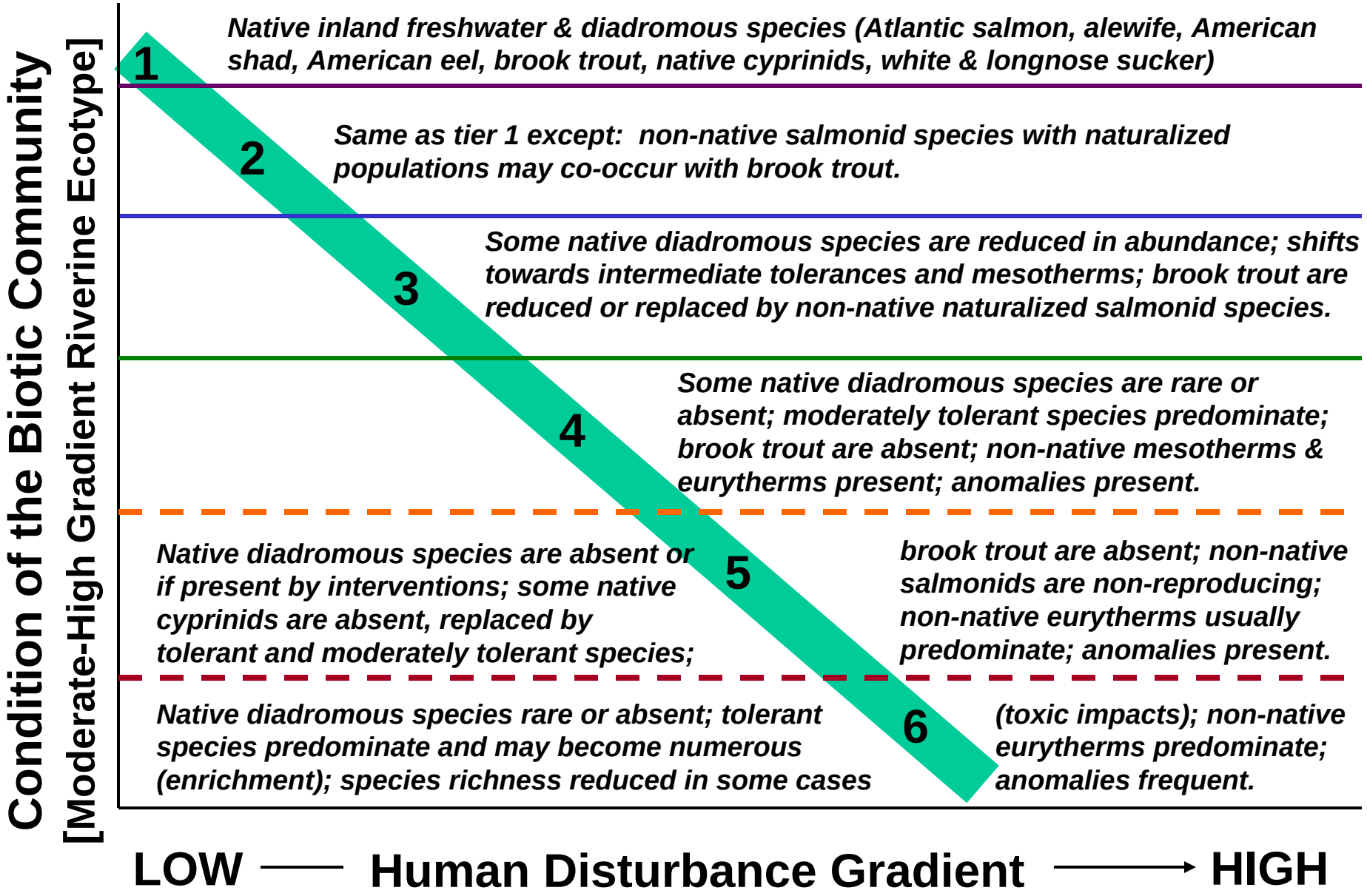


Table 1. Native, tolerance, habitat, foraging, and reproductive guild designations and other notes on the distribution and occurrence of 60 fish species documented or suspected to occur in Maine non-wadeable rivers. Sources for guild and metric assignments appear in the footnotes (scientific nomenclature adheres to Nelson et al. 2004).

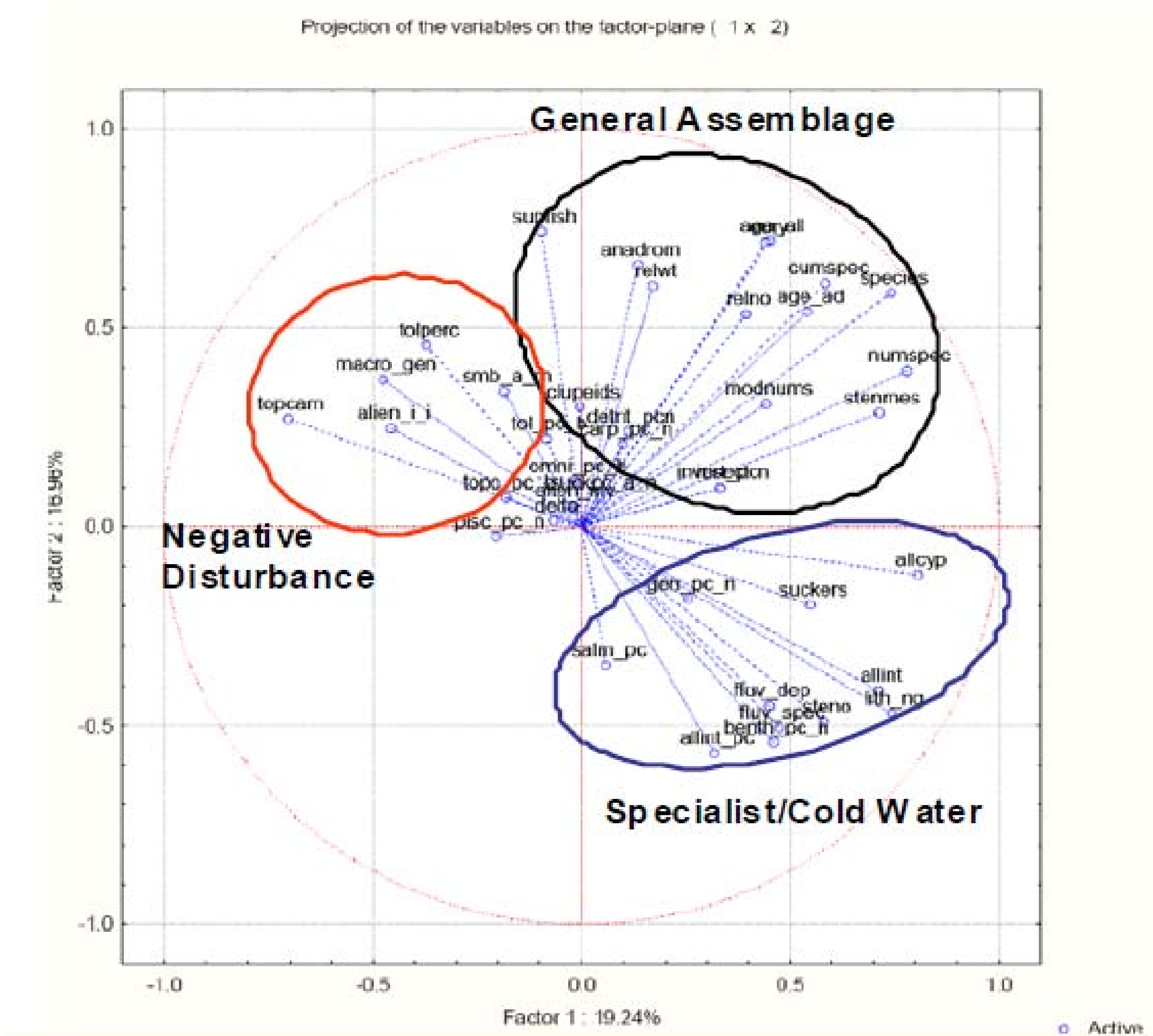
Species	Native Status[1]	Environmental Tolerance[2]	Target Fish Classification[3]	Common Habitat(s)[4]	Spatial Occurrence[5]	Thermal Guild[6]	Foraging Guild[7]	Reproductive Guild[8]	Habitat Guild[9]	Notes
Petromyzondi										
Sea lamprey (*P*										nocoetes.
Acipenseridae										
Shortnose sturg										R. 2006.
Atlantic sturge										2005 and.
Anguillidae										
American eel (*A*										
Clupeidae										
Blueback herri										d.
Alewife (*Alosa*										lected.
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	
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.

[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; MO – macrohabitat generalist; A – anadromous; [ ] - 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

Detailed autecology of known and potential species – 60 recorded thus far in Maine's rivers

Candidate Metric Selection and Testing

- 148 candidate metrics identified
- Pared to 40 metrics in step one
- PCA revealed 4 "clusters"
- "specialist and cold water metrics
- "general" assemblage metrics
- "disturbance" indicative metrics
- "non-distinct" clusters, but ecologically relevant (e.g., DELT anomalies)
- Reduced to final 12 metrics for the Interim IBI


Projection of the variables on the factor-plane (1 x 2)
General Assemblage
Negative Disturbance
Specialist/Cold Water
Factor 1 : 19.24%
Factor 2 : 16.96%
tolperc
macro_gen
topcarn
alien_i_i
anadrom
relwt
cumspec
species
relno
age_ad
numspec
modnums
stenmes
clupeids
allcyp
suckers
salm_pc
allint
fluv_dep
steno
allint_pc
Active

"Traditional" IBI vs. Interim Maine IBI

"Traditional IBI Metrics:

1. Native species richness
2. Darter Species
3. Sucker Species
4. Sunfish Species
5. %Intolerant species
6. %Tolerant species
7. %Omnivores
8. %Insectivores
9. %Top carnivores
10. %Hybrids
11. %Diseased individuals
12. Number of individuals

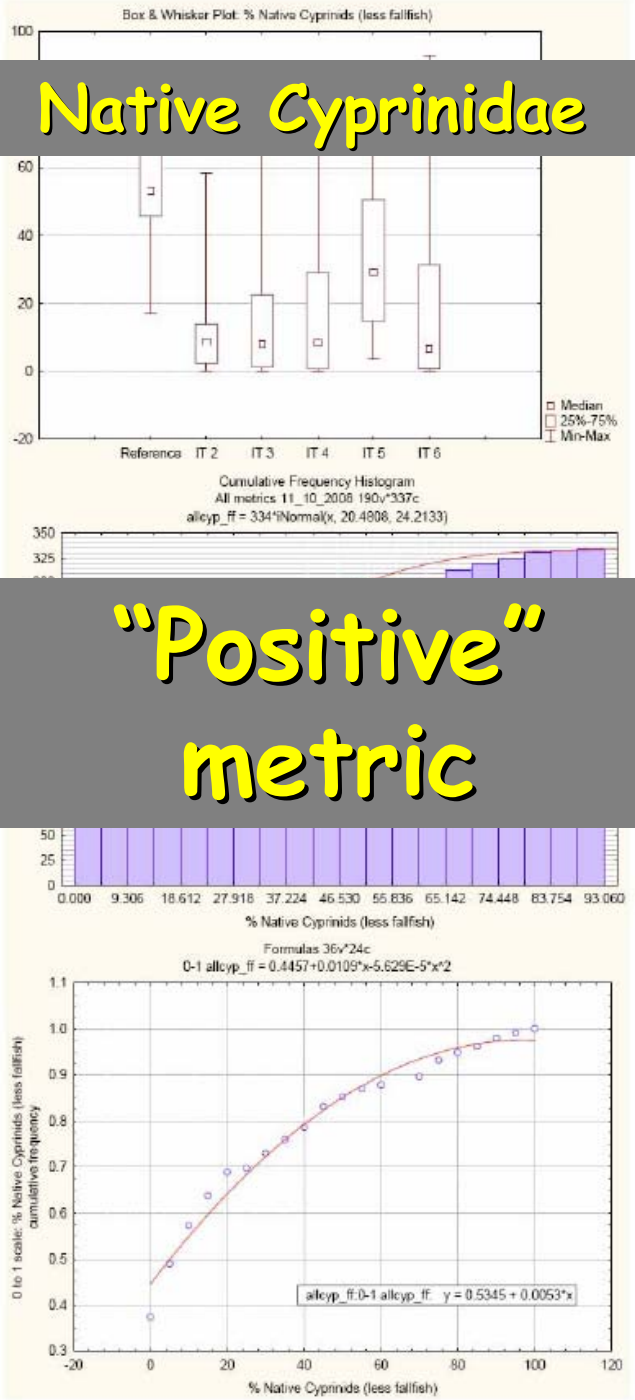
Interim Maine IBI Metrics:

1. Indigenous species richness
2. Native cyprinids (less fallfish)
3. %Adult white/longnose biomass
4. %Blackbass
5. %Fluvial specialist/dependent
6. %Macrohabitat generalists
7. %Benthic insectivores
8. Temperature stenotherms
9. %Native salmonids
10. Non-guarding lithophils
11. %DELT anomalies
12. Non-indigenous species

Metric Descriptions

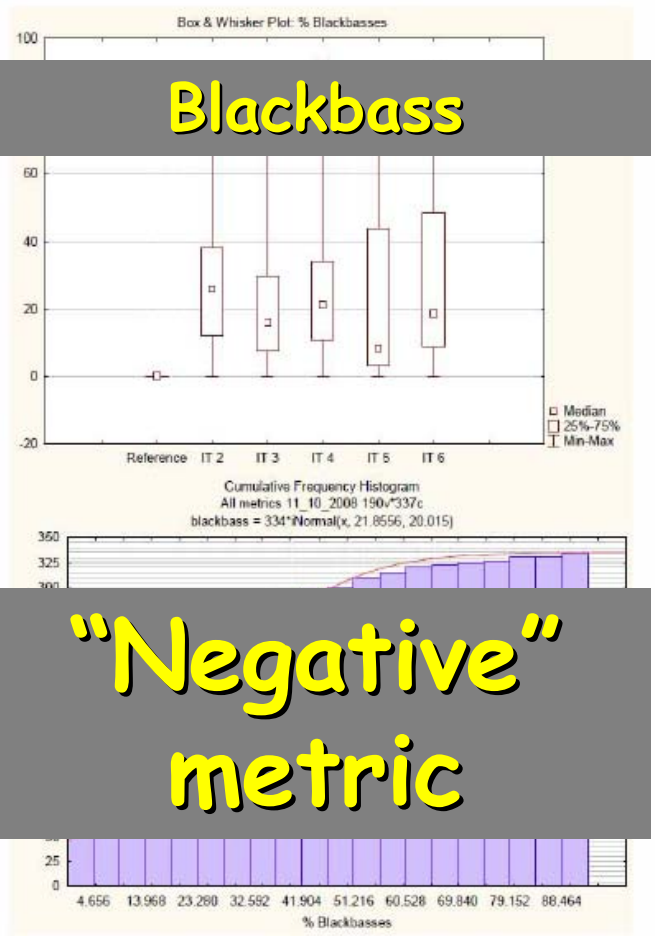
- Native Species – excludes non-indigenous sp.
- %Native Cyprinidae – excludes fallfish
- White/longnose sucker biomass – adults only
- %Native Salmonids – excludes introductions
- %Benthic insectivores – Goldstein & Simon (1999)
- %Blackbass – cast as a "negative" metric
- %Fluvial Spec./Dependent – Bain & Meixler (2008)
- %Macrohabitat Generalist – Bain & Meixler (2008)
- %Stenotherms – Hokanson (1977); Halliwell (1999)
- Non-guarding Lithophils – Hughes et al. (1998)
- Non-indigenous Species – after Halliwell (2005)
- %DELT – deformities, erosions, lesions, tumors

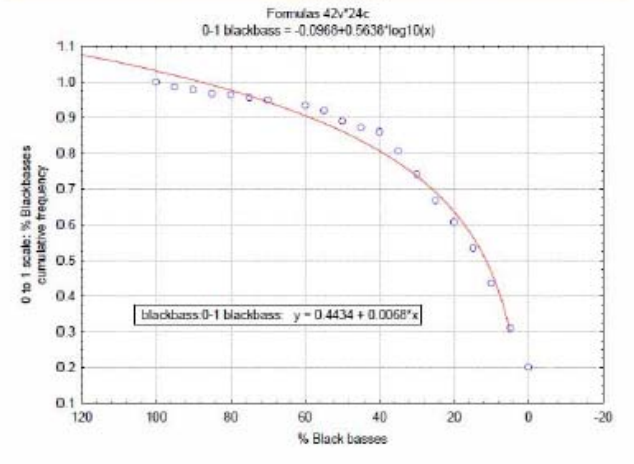
Native Cyprinidae



"Positive" metric

Blackbass





"Negative" metric

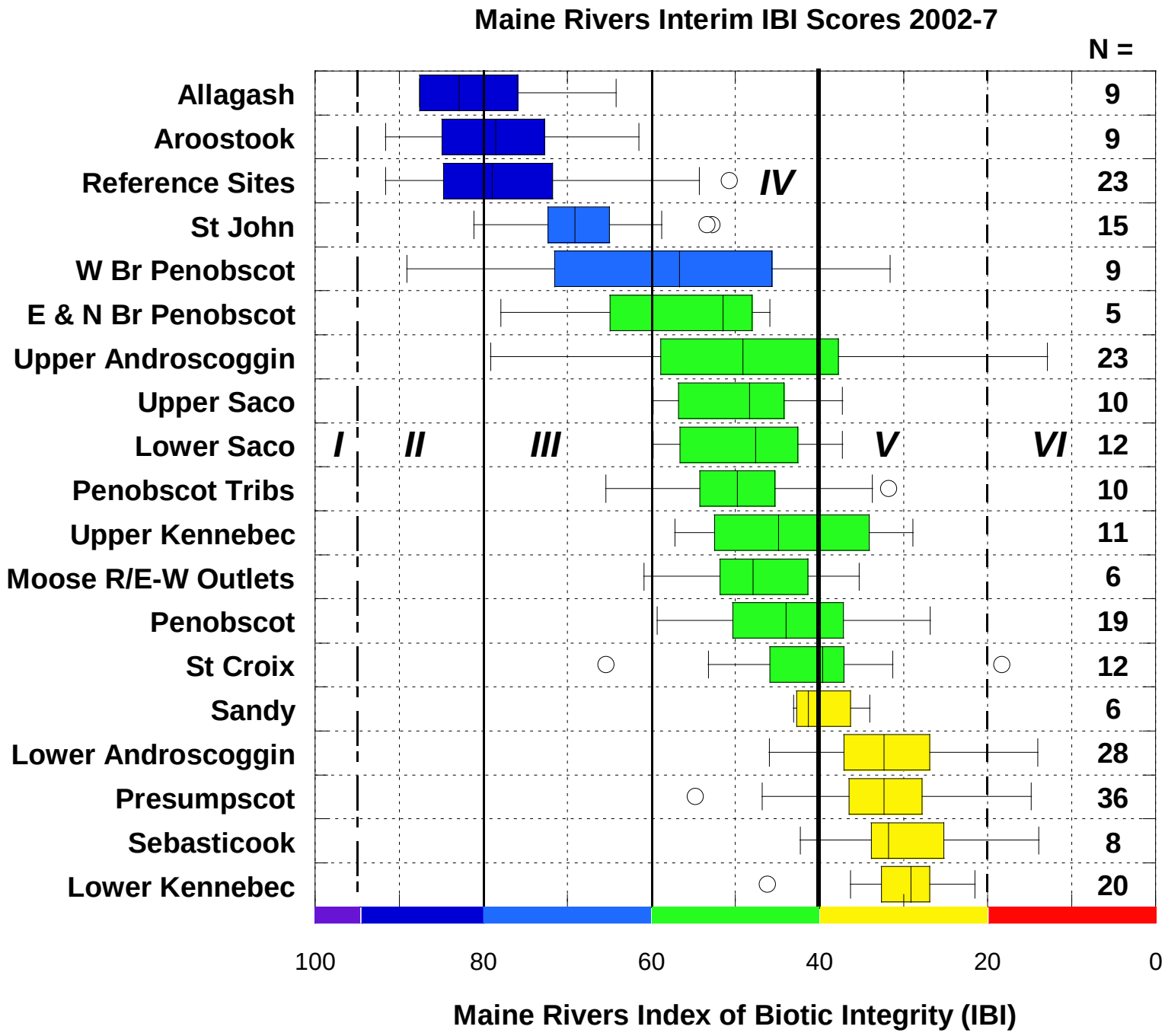
Metric Calibration Process

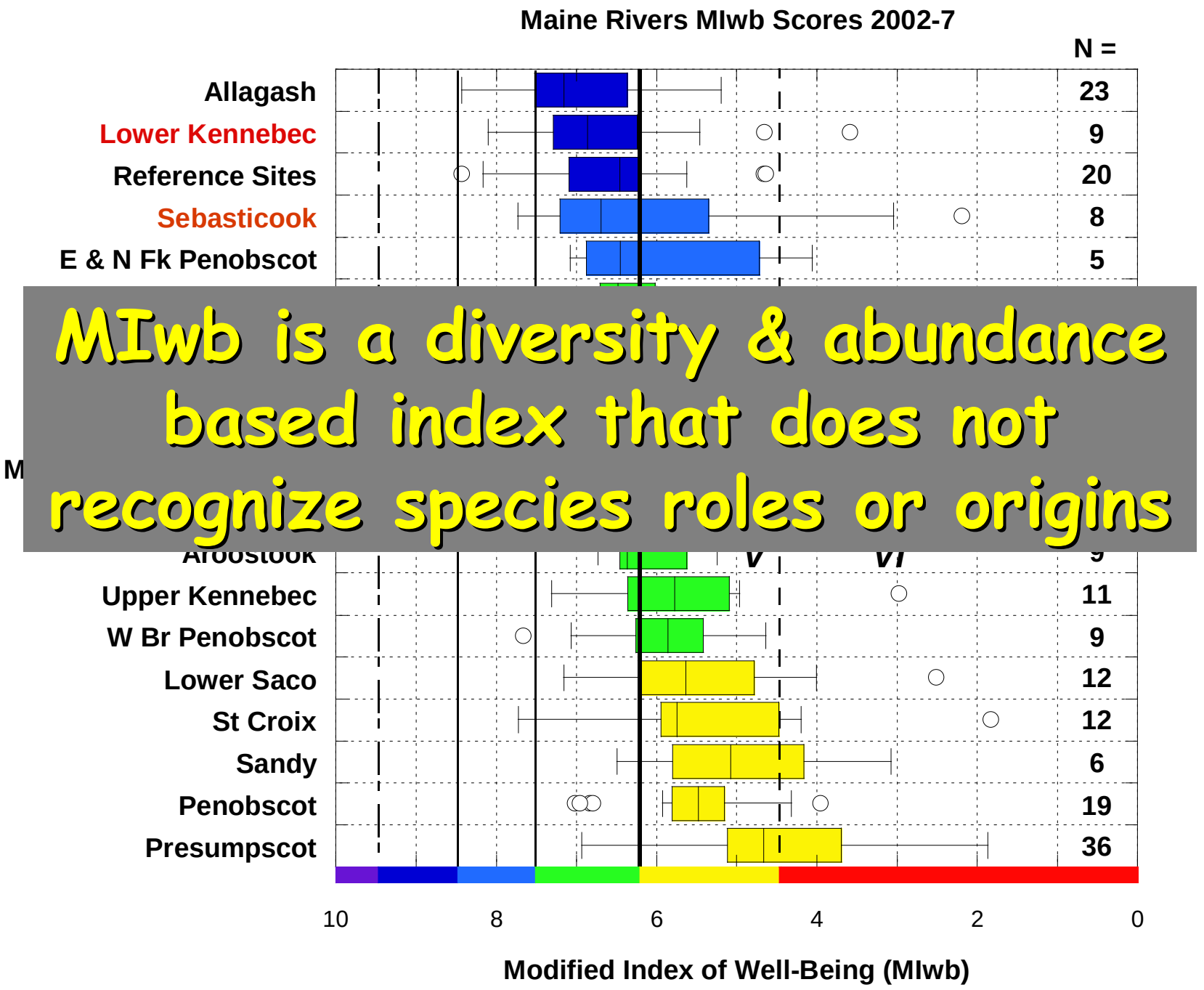
- Followed Mebane et al. (2003) methodology
- Box plots: reference vs. non-reference sites
- Non-ref: four ranges of QHEI + conductivity >100 $\mu S/cm^2$
- Extracted scoring "curves" from cumulative histograms of each metric
- Used "best fit" of linear, polynomial, and logarithmic plots
- Final scoring criteria were adjusted to fit Y_1 and Y_2 insertions (and to preclude "ecological nonsense")

Interim Maine Rivers IBI Metrics & Scoring

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[1]	Eq
Adult white & longnose sucker 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

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


Maine Rivers Interim IBI Scores 2002-7
N =
Allagash
Aroostook
Reference Sites
St John
W Br Penobscot
E & N Br Penobscot
Upper Androscoggin
Upper Saco
Lower Saco
Penobscot Tribs
Upper Kennebec
Moose R/E-W Outlets
Penobscot
St Croix
Sandy
Lower Androscoggin
Presumpscot
Sebasticook
Lower Kennebec
9
9
23
15
9
5
23
10
12
10
11
6
19
12
6
28
36
8
20
I
II
III
IV
V
VI
100
80
60
40
20
0
Maine Rivers Index of Biotic Integrity (IBI)


Maine Rivers MIwb Scores 2002-7
N =
Allagash
Lower Kennebec
Reference Sites
Sebasticook
E & N Fk Penobscot
23
9
20
8
5
MIwb is a diversity & abundance based index that does not recognize species roles or origins
Aroostook
Upper Kennebec
W Br Penobscot
Lower Saco
St Croix
Sandy
Penobscot
Presumpscot
11
9
12
12
6
19
36
10
8
6
4
2
0
Modified Index of Well-Being (MIwb)

Maine IBI Development: Are We There Yet?

- Not quite – what's left?
- More complete testing of borderline metrics
- Deal with diadromous issue – "bonus points"?
- More analysis of spatial data– clarify the "elevation gradient"
- More detailed analysis of stressor gradients – hydromodification in particular
- Localized areas of impact – need to perform more complete stressor diagnosis
- Identify potential policy implications?

Our Thanks to the Project Cooperators

- U.S. EPA, Region I – project sponsor
- Maine DEP
- Maine IF&W
- Maine DMR
- Maine DOC
- Allagash Wilderness Waterway
- US F&WS
- Penobscot Indian Nation
- Casco Bay Estuary Partnership
- Harvard MCZ
- Maine North Woods
- Private Land Owners
- And many, many others!