Natural Flow Regime and Aquatic Resource Protection Approaches in the Northeast

Ralph Abele
EPA Region 1

Evolution of Streamflow Efforts in New England 1970-2013

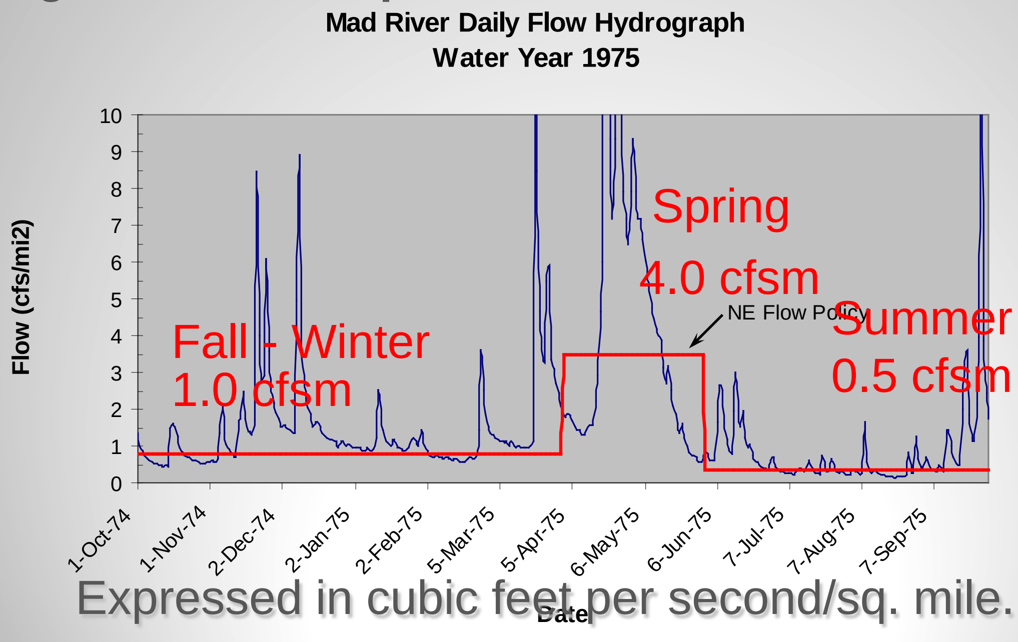
- **First phase - Hydro-relicensing, snow making cases: 1979-mid nineties**
  - FWS Aquatic Base Flow – "default standard"
  - Detailed , site specific study methods such as IFIM
  - Key State/Federal regulatory cases and decisions
- **Second phase : Natural Flow Paradigm, ELOHA Era 1997-present**
  - EPA letters to NE states re. flow and WQS
  - Quinebaug studies (CT and MA)
  - State-specific ABFs: ME,MA,CT,RI and VT
  - Focus on fluvial species, methods to predict unaltered flow at ungaged locations
  - ELOHA, multi-variate studies which look at flow, impervious cover, dams etc.

U.S. Fish & Wildlife Service

Conserving the Nature of America

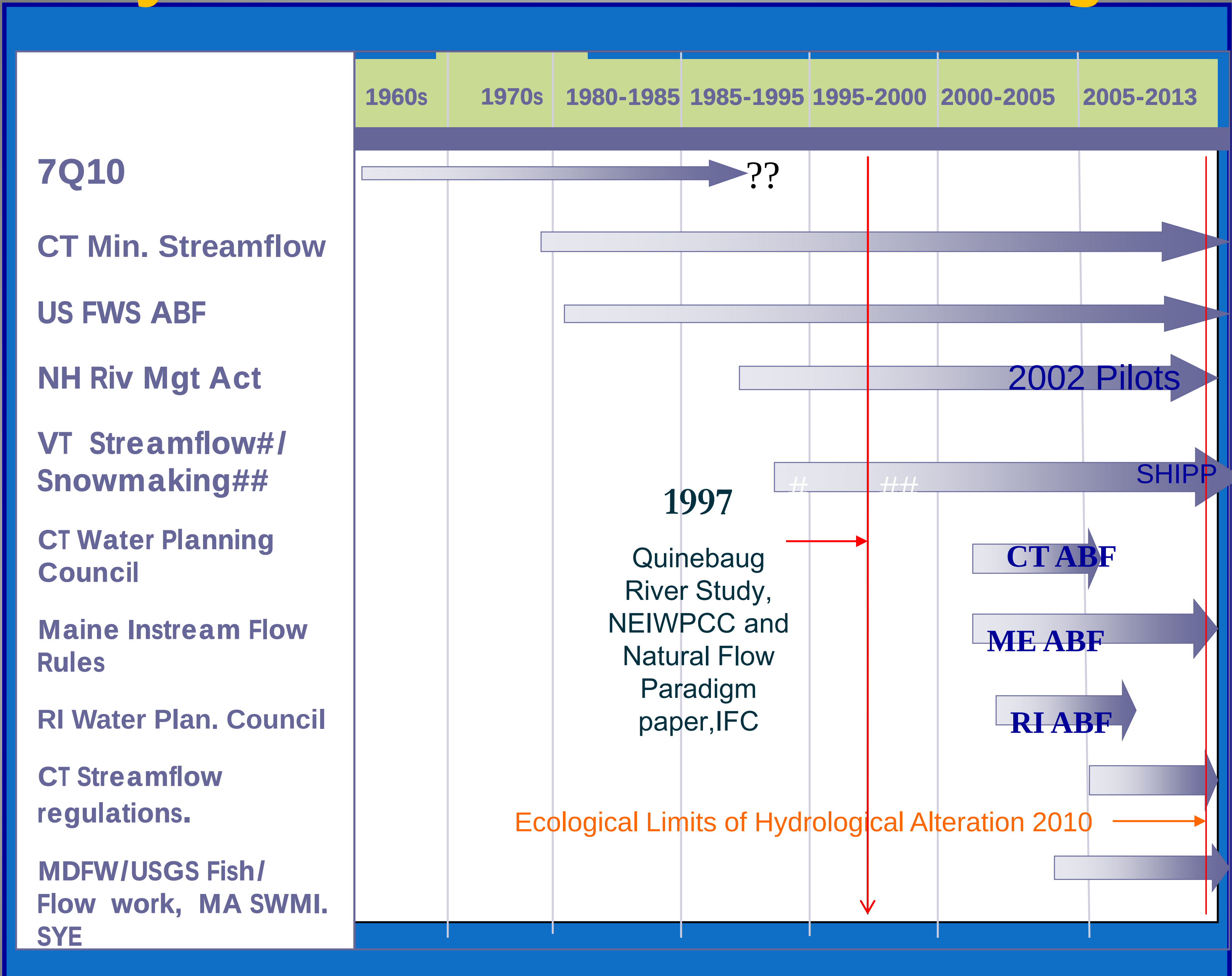
New England Flow Policy Assumptions:

- Historical median flows during spawning and incubation periods will protect reproduction (Fall/Winter and Spring)
- Gage records come from 48 watersheds across NE where flow is unregulated.
- Aquatic life has evolved to survive "typical" low flows in August - called Aquatic Base Flow or "ABF"



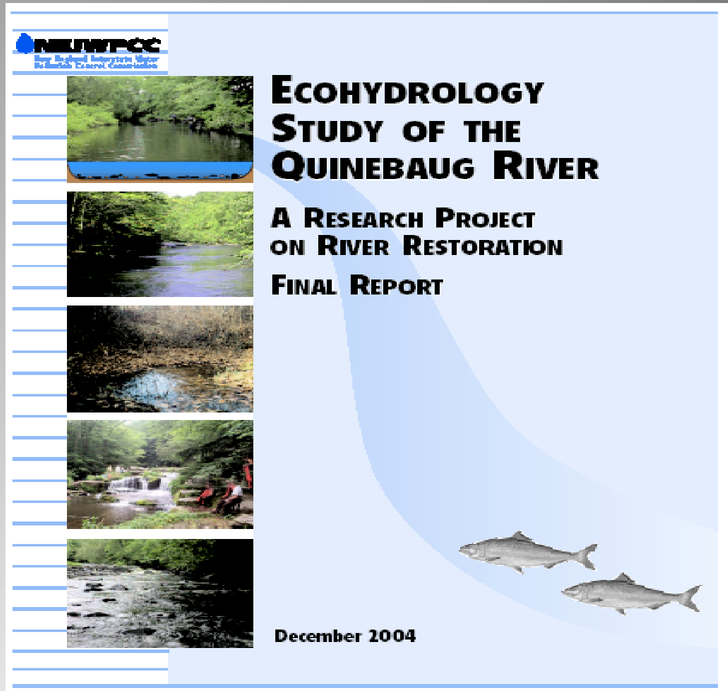
Expressed in cubic feet per second/sq. mile. (cfsm)

History of Streamflow Efforts in New England



Millennium Power Project Quinebaug Studies 2000-2004

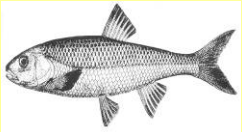
MesoHABSIM

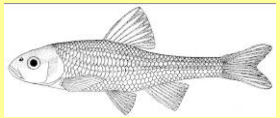


Target Fish Approach

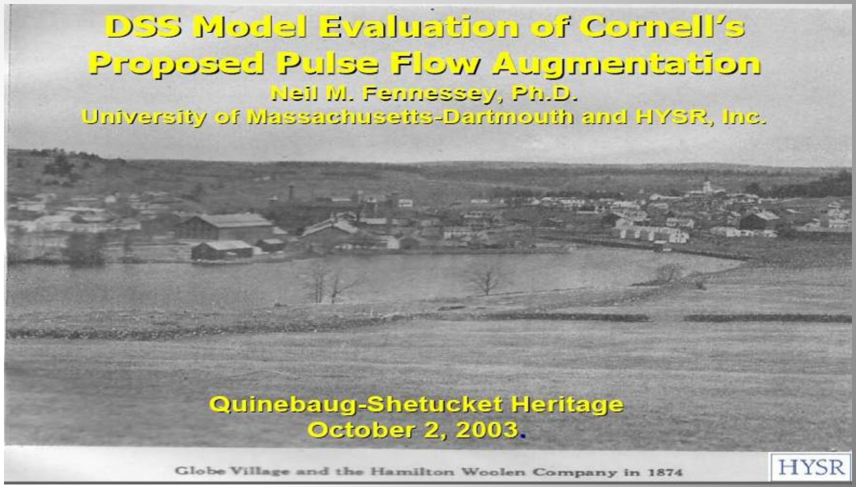
Defining a Target Fish Community for Planning and Evaluating Enhancement of the Quinebaug River in Massachusetts and Connecticut

Dr. Mark Bain and Marci Meixler, Cornell University With the data and guidance of MA F&W, CT DEP & MA DEP





Ungaged daily streamflow (QPPQ)



By 2010 every New England state has the natural flow language in statute, regulation or policy

- Vermont (2000): WQS – Hydrology criteria
- Maine (2001-): *Maine LD 1488, Section 470-E Water Use Standards*, DEP Instream Flows &Pond Water Levels (2005)
- Massachusetts (2004-): MA Water Policy, Index Streamflows (2008), Sustainable Water Mgt. Initiative 2012
- Rhode Island (2005): Modified Aquatic Base Flow for Rhode Island, Streamflow Depletion Methodology (2010)
- Connecticut (2005 -): *An Act Concerning The Minimum Water Flow Regulations (2005* Streamflow Regulations (2011)
- New Hampshire (2008): River Management Act -Souhegan River Protected Instream Flow, Draft Lamprey PIF (2009)

Ch. 587, Maine Department of Environmental Protection - Microsoft Internet Explorer

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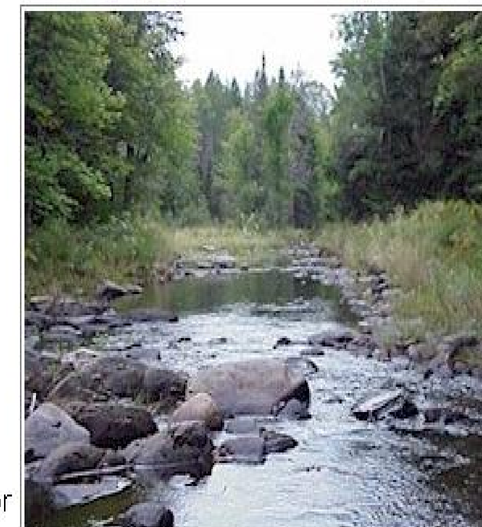
L&W Home > Monitoring & Assessment > SWUP > Ch. 587

Ch. 587. In-stream Flows and Lake and Pond Water Levels



Major substantive rule. Effective date: August 24, 2007.

Contact: Dave Courtemanch 287-7789.

Final adopted rule

- TEXT of Chapter 587
- Resolve, Ch. 63
- PL, Ch. 235

The final rule reflects modifications from the provisionally adopted rule as required by the legislative approval of these major substantive rules. These modifications are described in Resolve, Regarding Legislative Review of Portions of Chapter 587: In-stream Flow and Lake and Pond Water Levels, a Major Substantive Rule of the Department of Environmental Protection (Resolves 2007 Ch. 63). In the course of t legislative review process changes were also made to the enabling statute, Title 38, Section 470-H. These changes can be found in An Act To Coordinate the Implementation of the In-stream Flow and Water Level Rules among the Department of Environmental Protection, the Drinking Water Program of the Department of and Human Services and the Public Utilities Commission (P.L. 2007 Ch. 235).

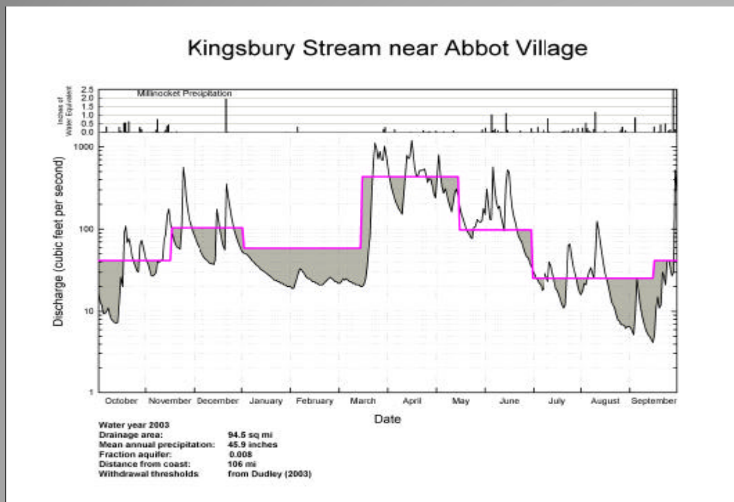
Maine DEP WQS Classes and Criteria

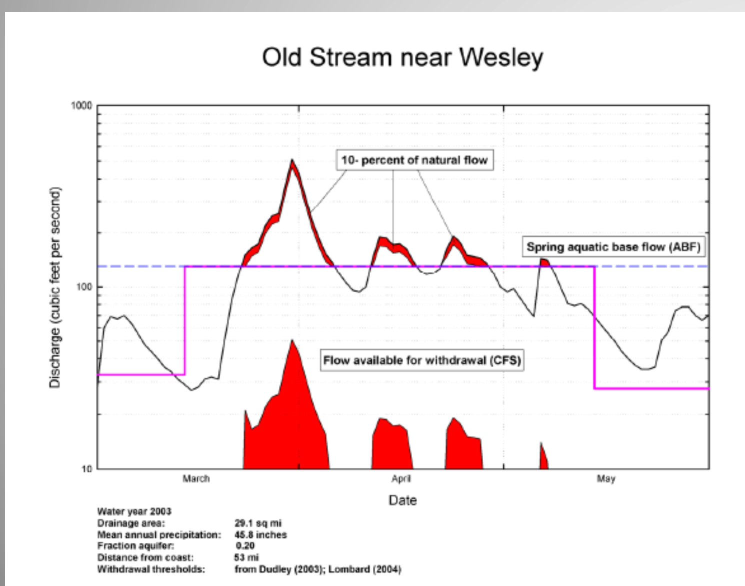
	Numeric Criteria		Narrative Criteria	
	Dissolved Oxygen	**Bacteria (*E. coli*)**	**Habitat**	**Aquatic Life (Biological)**
Class AA	as naturally occurs	as naturally occurs	free flowing and natural	as naturally occurs
Class A	7 ppm; or 75% sat.	as naturally occurs	natural	as naturally occurs
Class B	7 ppm; or 75% sat.	64-GM 236/100 ml (instan-taneous)	unimpaired	support all aquatic species indigenous to the receiving water; no detrimental changes to the resident biological community
Class C	5 ppm; or 60% sat.; 30-day avg. 6.5 ppm	126-GM 236/100 ml (instan-taneous)	habitat for fish and other aquatic life	maintain the structure and function of the resident biological community

Non-attainment (NA) stream does not meet minimum criteria

(Tom Danielson, Maine DEP)

Maine DEP definition of "Seasonal Aquatic Base Flow"



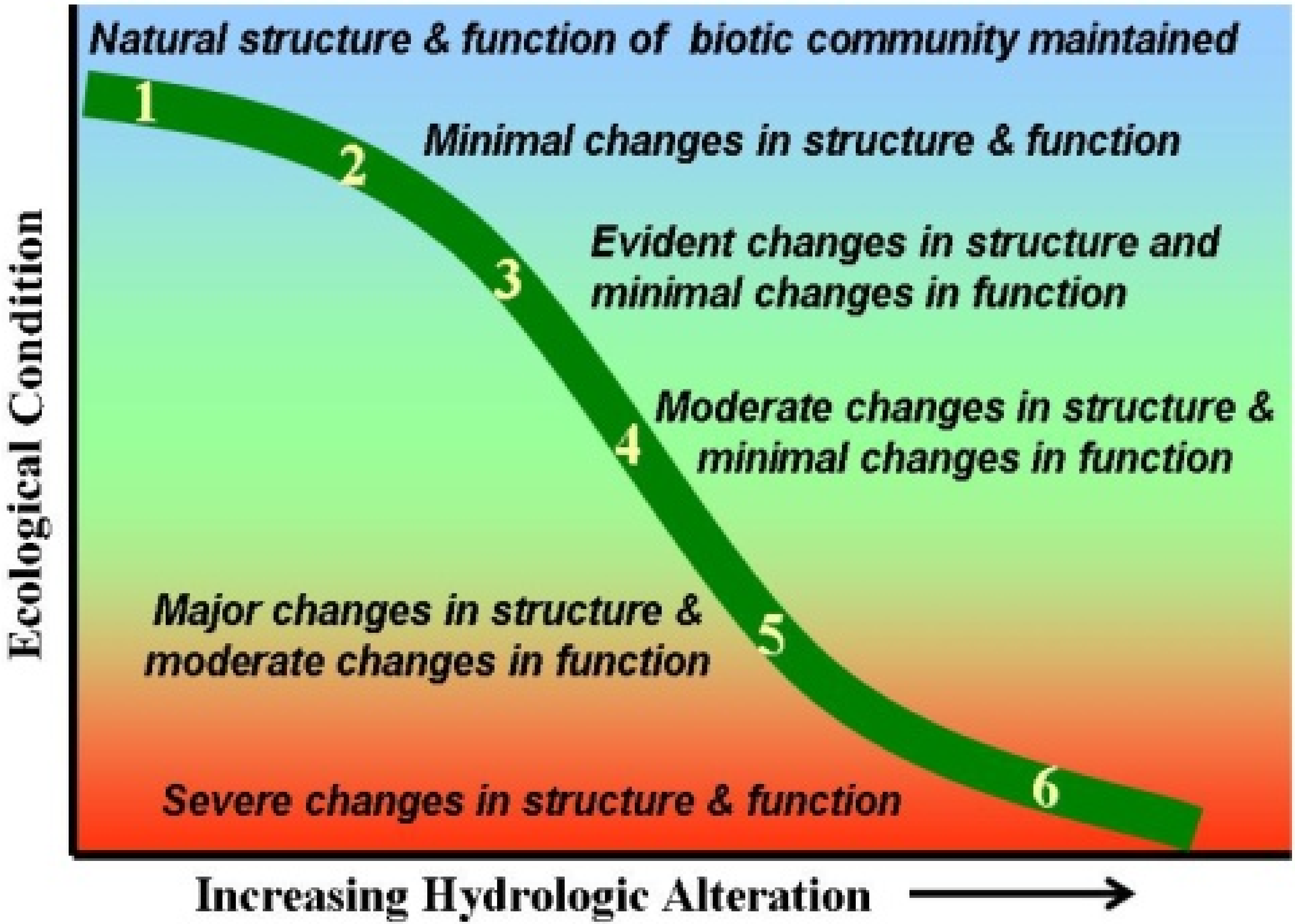


- Seasonal ABF is a median flow value for following six seasons:
  - <u>Winter</u> (Jan.1 to March 15, use Feb. median flow)
  - <u>Spring</u> (March 16 to May 15, use April median flow)
  - <u>Early Summer</u> (May 16 to June 30, use June median flow)
  - <u>Summer</u> (July 1 to Sept. 15, use August median flow)
  - <u>Fall</u> (Sept. 16 to Nov. 15, use October median flow)
  - <u>Early Winter</u> (Nov. 16 – Dec 31, use December median flow.)

Allowable alterations from narrative standards

- Class AA waters
  - When natural flow > spring or early winter ABF, maintain 90% of natural flow
  - When natural flow in any other season > 1.1 times season ABF, maintain 90% of natural flow
- Class A waters
  - May not be maintained at or below seasonal ABF for more than two consecutive seasons
- Class B and C
  - May not be less than seasonal ABF

Biological Condition Gradient (Davies and Jackson, 2006)



Connecticut Public Act 05-142

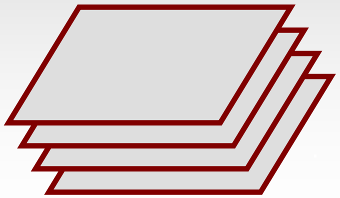
An Act Concerning the Minimum Water Flow Regulations

- Commissioner to Adopt Flow Regulations:
  - Apply to all rivers and streams
  - Be based on best available science
  - Preserve and protect natural aquatic life and wildlife
  - Promote and protect public recreation
  - Be based, to the maximum extent practicable, on natural variations of flows and water levels – while providing for the needs and requirements of public health, flood control, industry, public utilities, water supply, public safety, agriculture, and other lawful uses
  - By December 31, 2006

(CT DEP, 2009)

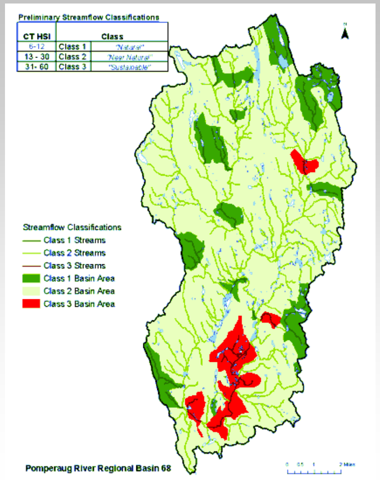
The Commissioner Shall Adopt Stream Flow Classifications

Consider Factors Indicative of the Degree of Human Alteration of Natural Stream Flow



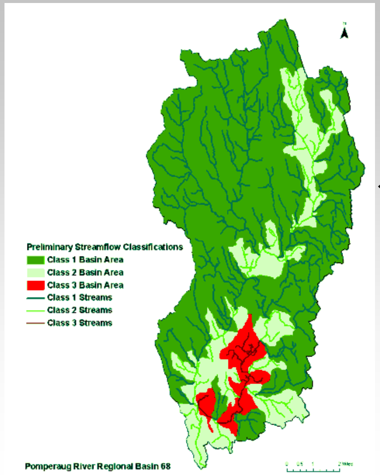
Diversions
Dams
Impervious Cover
Return Flow
Unique Factors

Develop Draft Stream Flow Classes



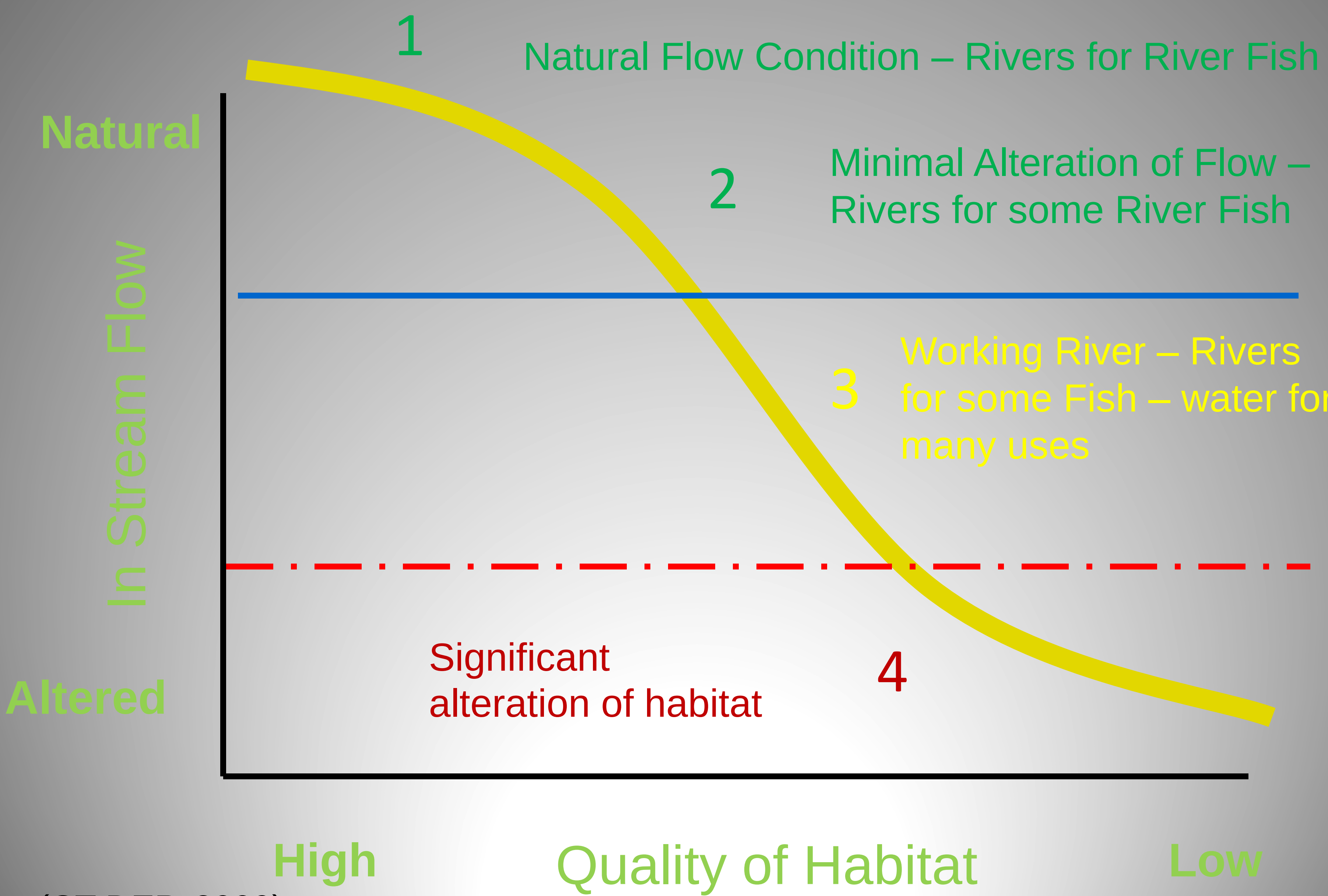
Propose Stream Flow Classifications, Public Notice, and Solicit Comment

Adopt Stream Flow Classifications



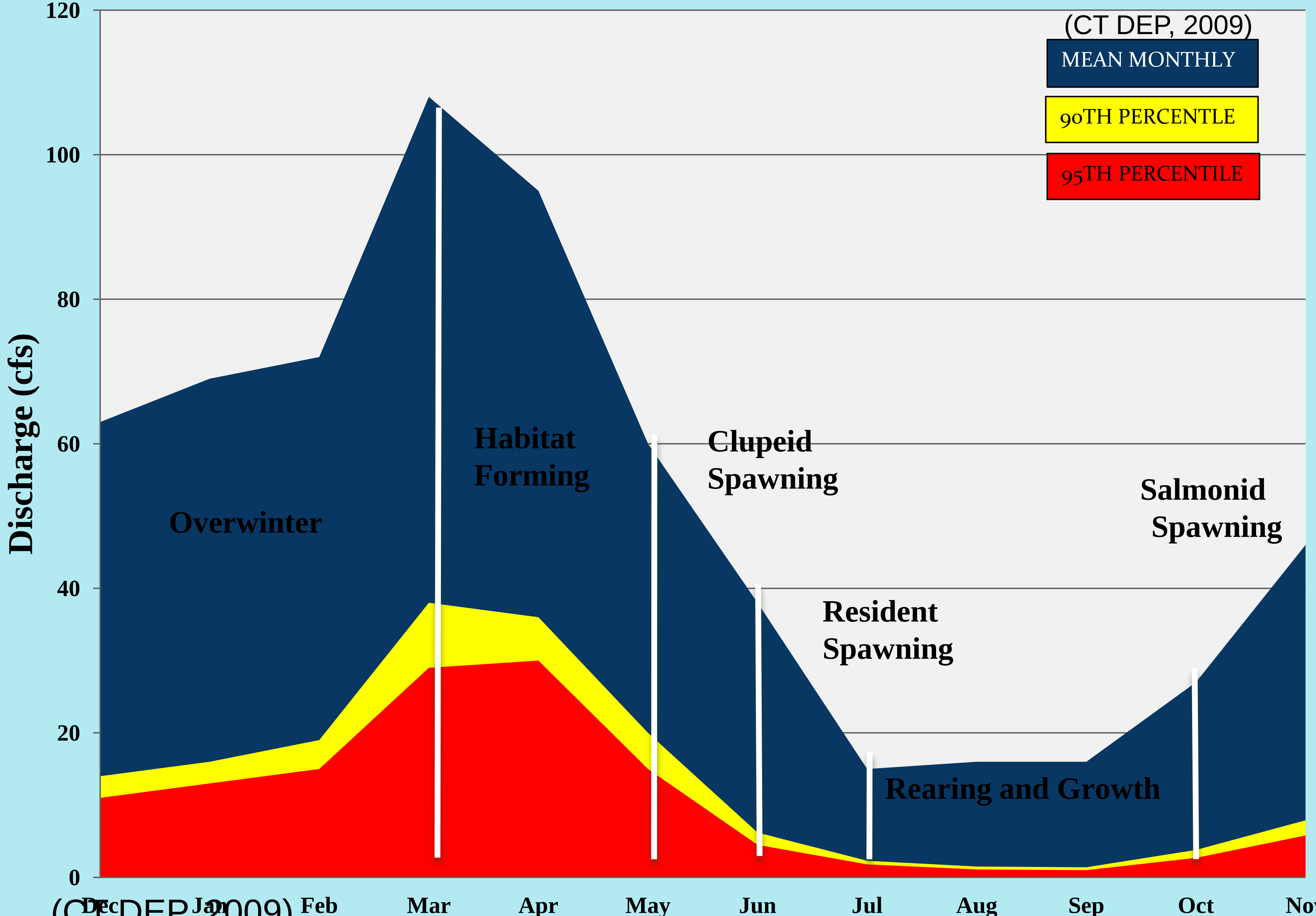
(CT DEP, 2009)

Proposed Stream Flow Classification



(CT DEP, 2009)

Mt Hope River
Typical Annual Hydrograph with Six Bioperiods

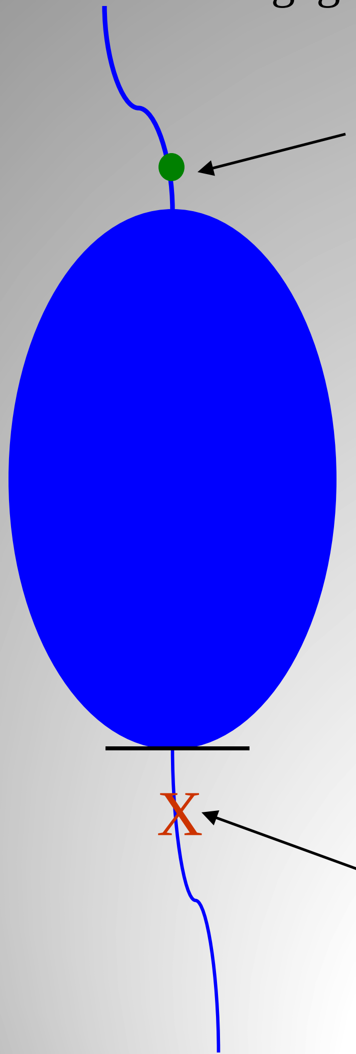


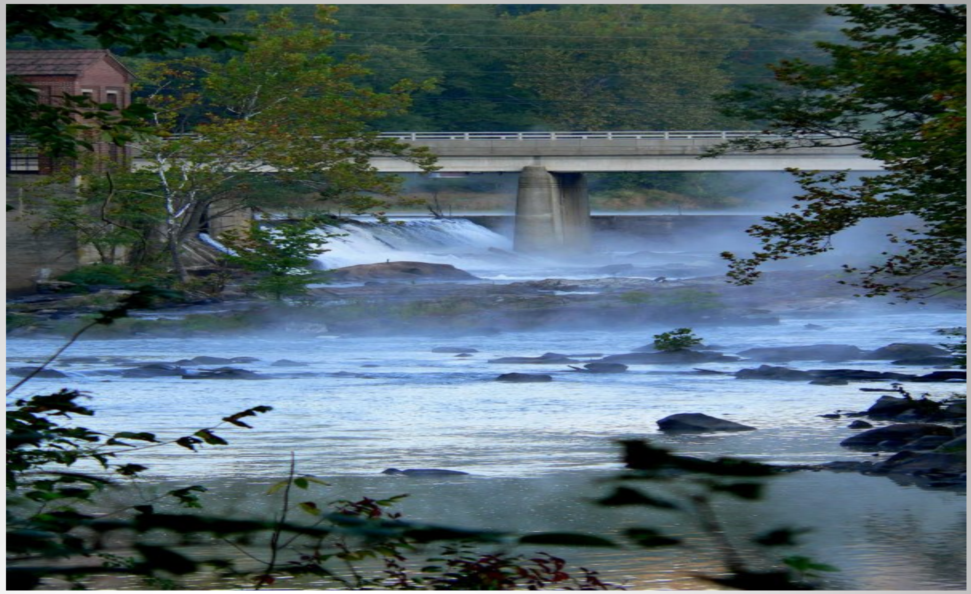
(CT DEP, 2009)

Proposed 2009 CT DEP Adaptive Release Rules for Reservoirs

1. <u>TRIGGER Flows</u> based on two week flow average at reference gage

Streamflow Gage
(or Use Surrogate USGS Gage)





2. **RELEASE Flows** for each bioperiod (normal and wet conditions)

(CT DEP, 2009)

CT Flow Release Rule

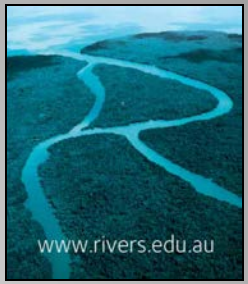
	0-5 years	5-10 years	10+ years
Class 1	Run of River operation only	Run of River operation only	Run of River operation only
Class 2	Existing Practice	75% of Natural Inflow	75% of Natural Inflow
Class 3	Existing Practice	Low-Level Release Rule Plus Drought Triggers	Multi-Level Release Rule plus Drought Triggers
Class 4	Existing Practice	Existing Practice or 0.1 cfsm or alternative acceptable to Commissioner	Existing Practice or 0.1 cfsm or alternative acceptable to Commissioner

CT DEP

The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards

Freshwater Biology, 2009

Angela Arthington, ARI
LeRoy Poff, CSU
Brian Richter, TNC
Stuart Bunn, ARI
Robert Naiman, UW
Colin Apse
Eloise Kendy
Andrew Warner
Robert Jacobson
*Mary Freeman
Brian Bledsoe
Kevin Rogers
Rebecca Tharme
Mike Acreman
James Henriksen
David Merritt
Julian Olden
Jay O'Keeffe
Jonathan Kennen



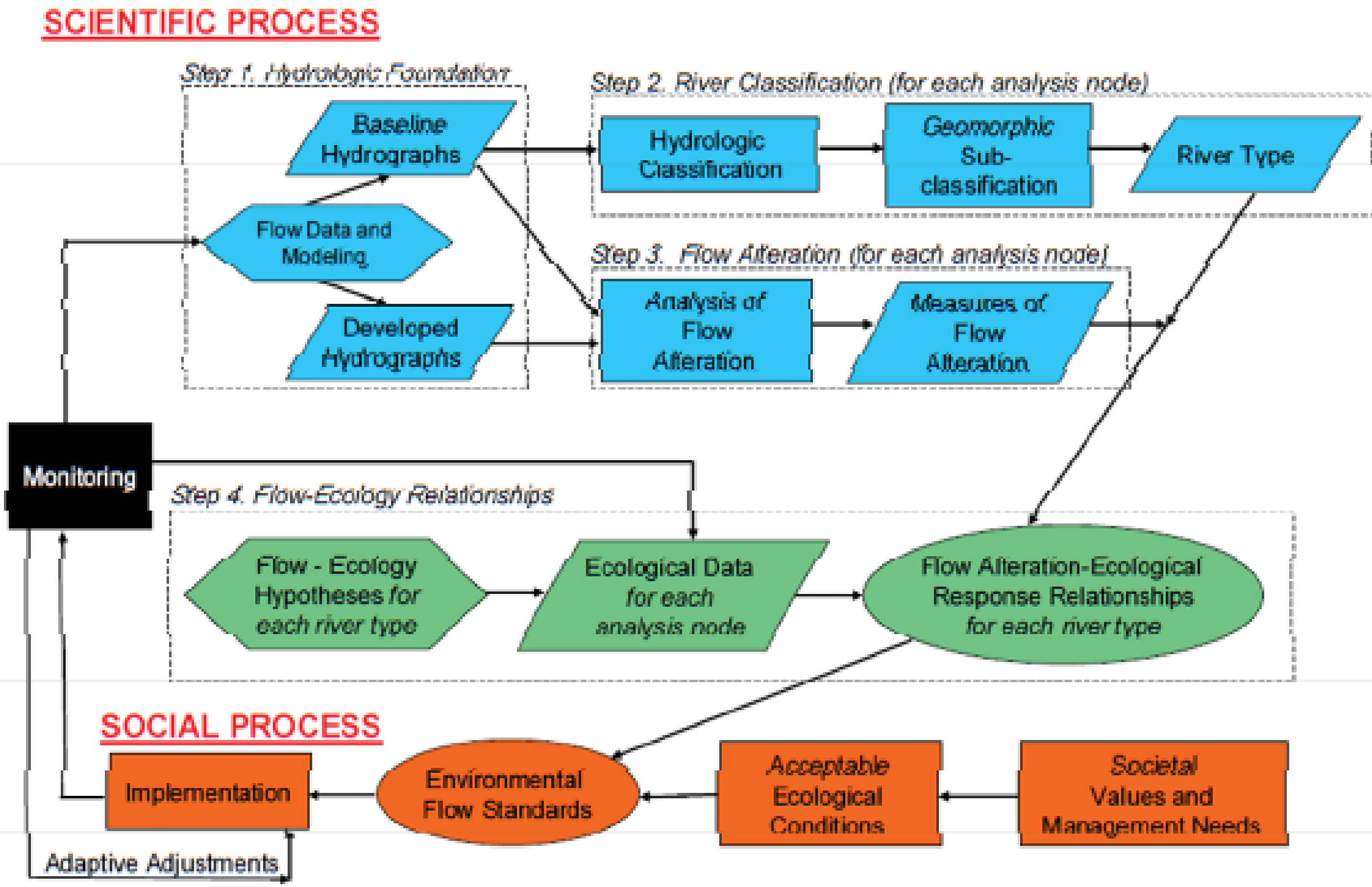
Australian Rivers Institute

Griffith University

The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

Colorado State University
U.S. Geological Survey
USDA Forest Service
University of Washington, Seattle
University of the Witwatersrand, SA
Centre for Ecology and Hydrology, UK
UNESCO-IHA, The Netherlands
IWMI, Sri Lanka

ELOHA



(USGS, 2012)

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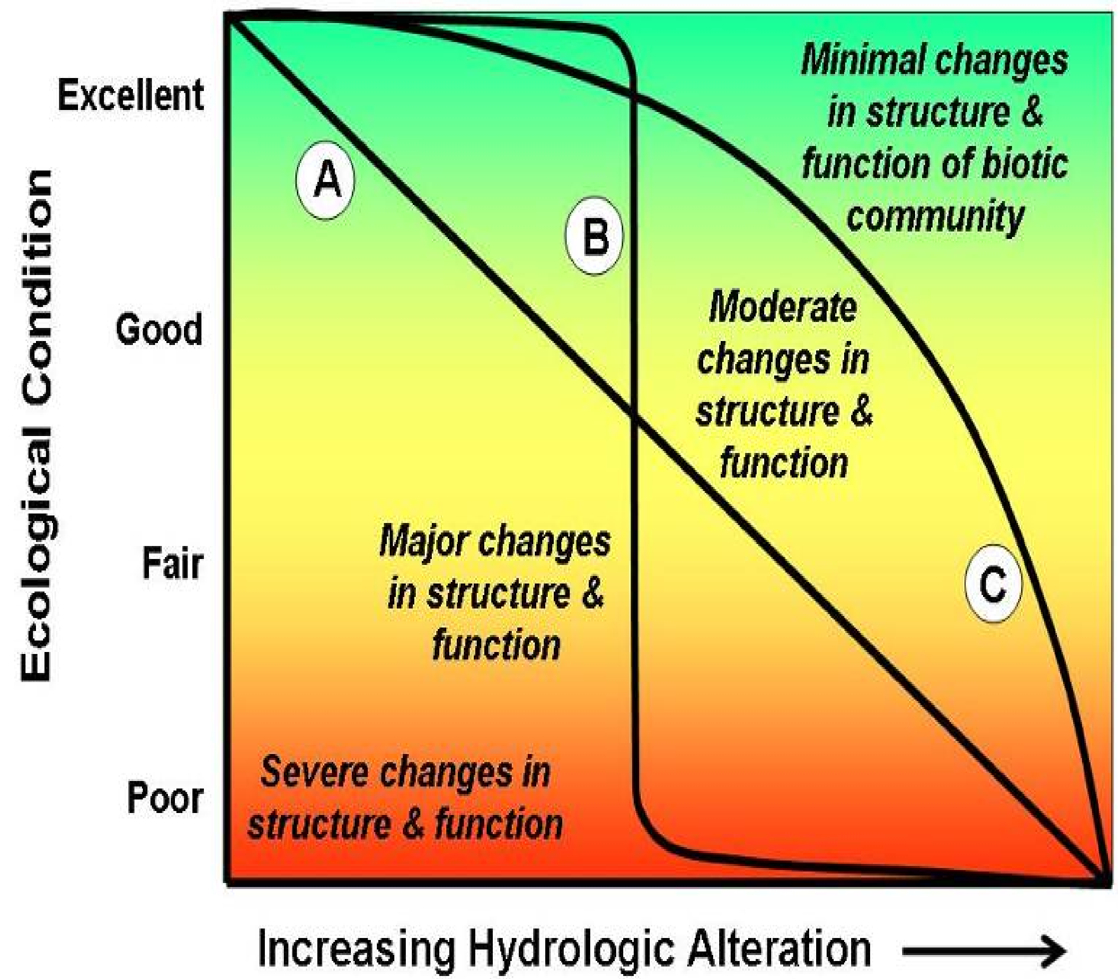
Defining ecosystem needs for water

The Flow – Ecology Response Curve:

How much ecological change occurs in response to each incremental alteration of the flow regime? Are there limits or thresholds?



Reference flows | River types | Degree flow alteration | Ecological response curves | Ecological targets | Enviro. flow targets | Implement program

A suite of six environmental flow tools used to frame new water management policy in Michigan

P.W. Seelbach, MDNR, Ann Arbor MI

T.G. Zorn, MDNR, Marquette, MI

J.W. Allan, Consumers Energy Co., Jackson, MI

D.A. Hamilton, MDEQ, Lansing, MI

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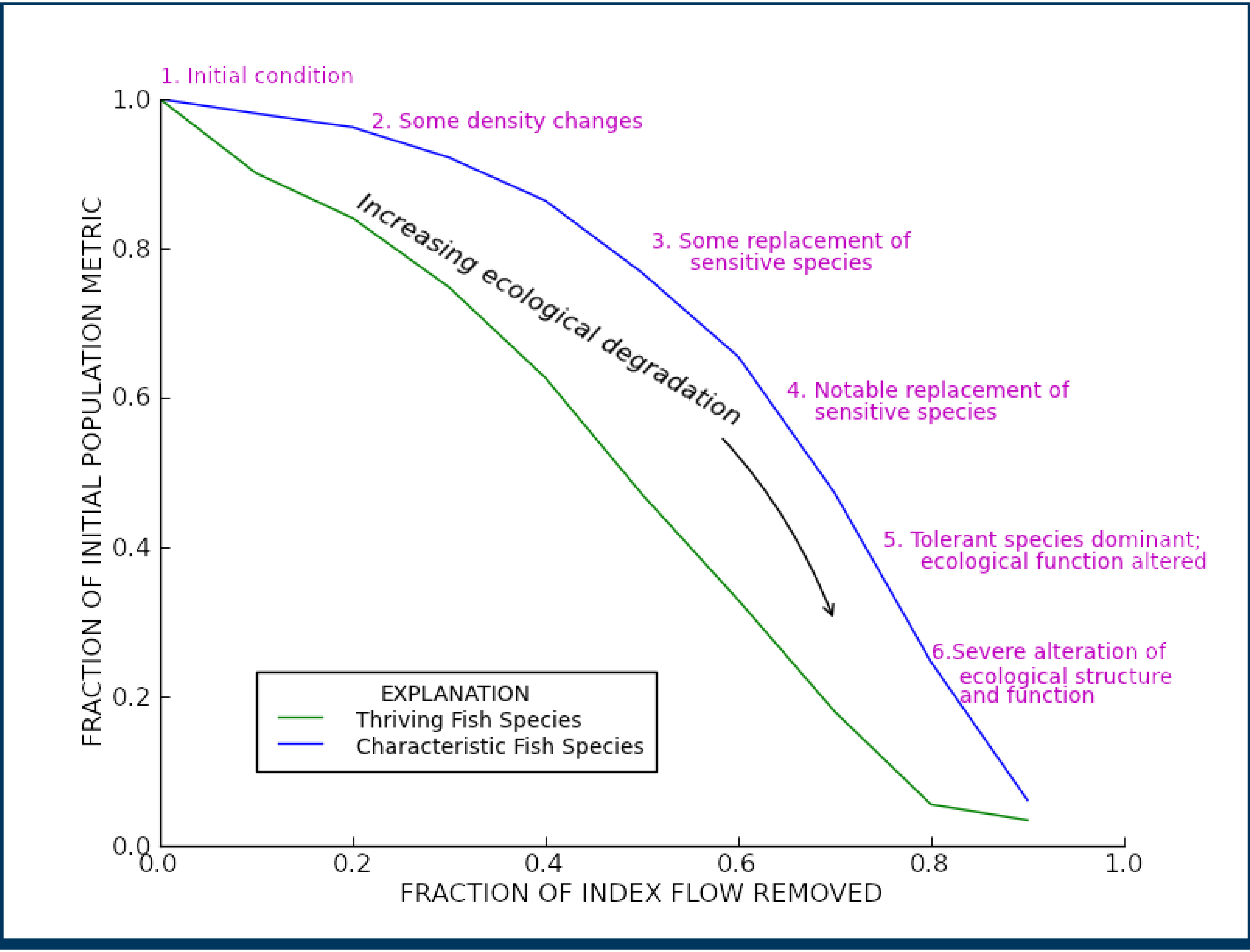
DEQ MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

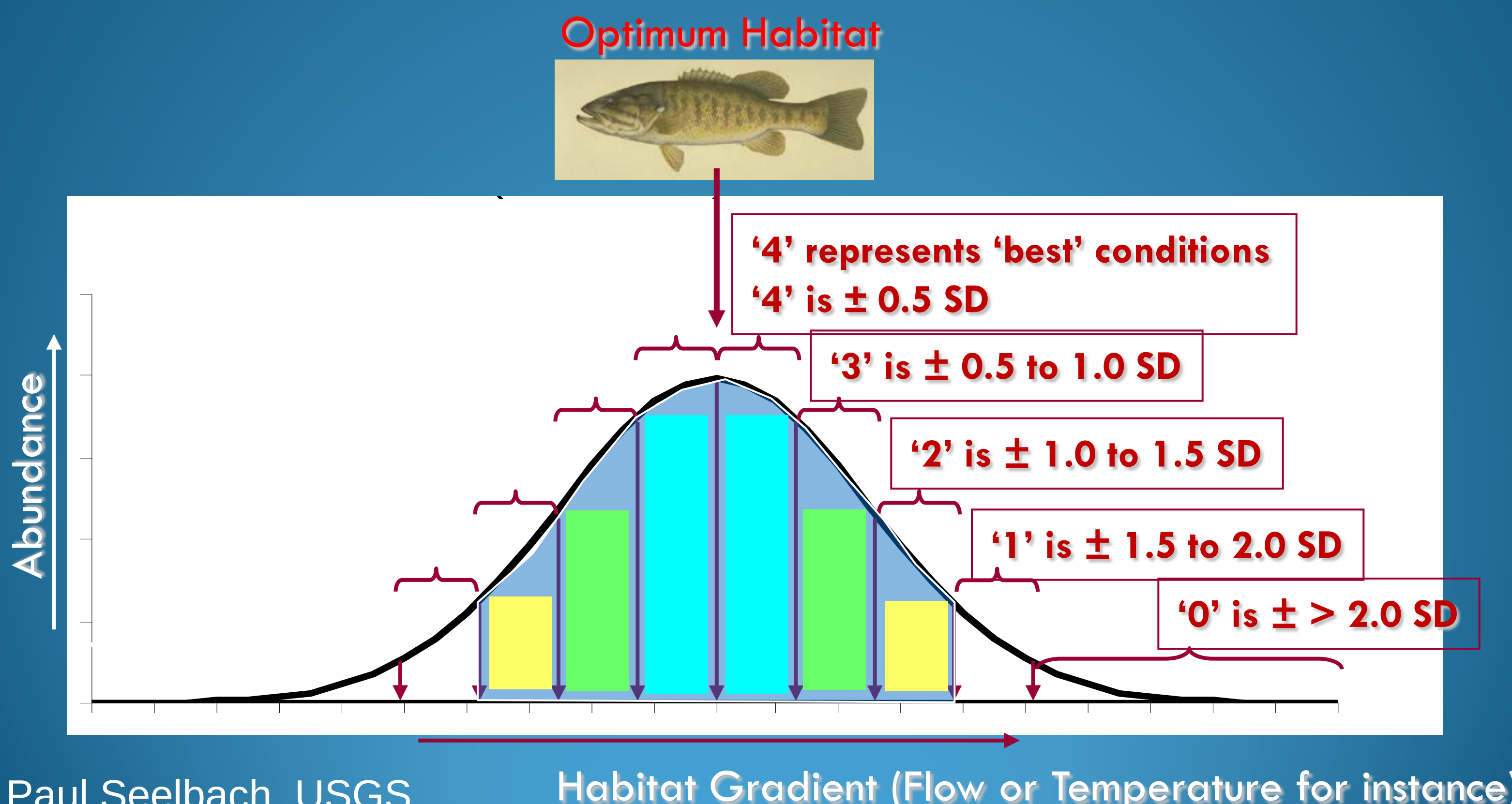
Defining Adverse Impact



Reference flows | River types | Degree flow alteration | **Ecological response curves** | ological rgets | Enviro. flow targets | Implement program

Statewide habitat suitability info: flow and temperature)

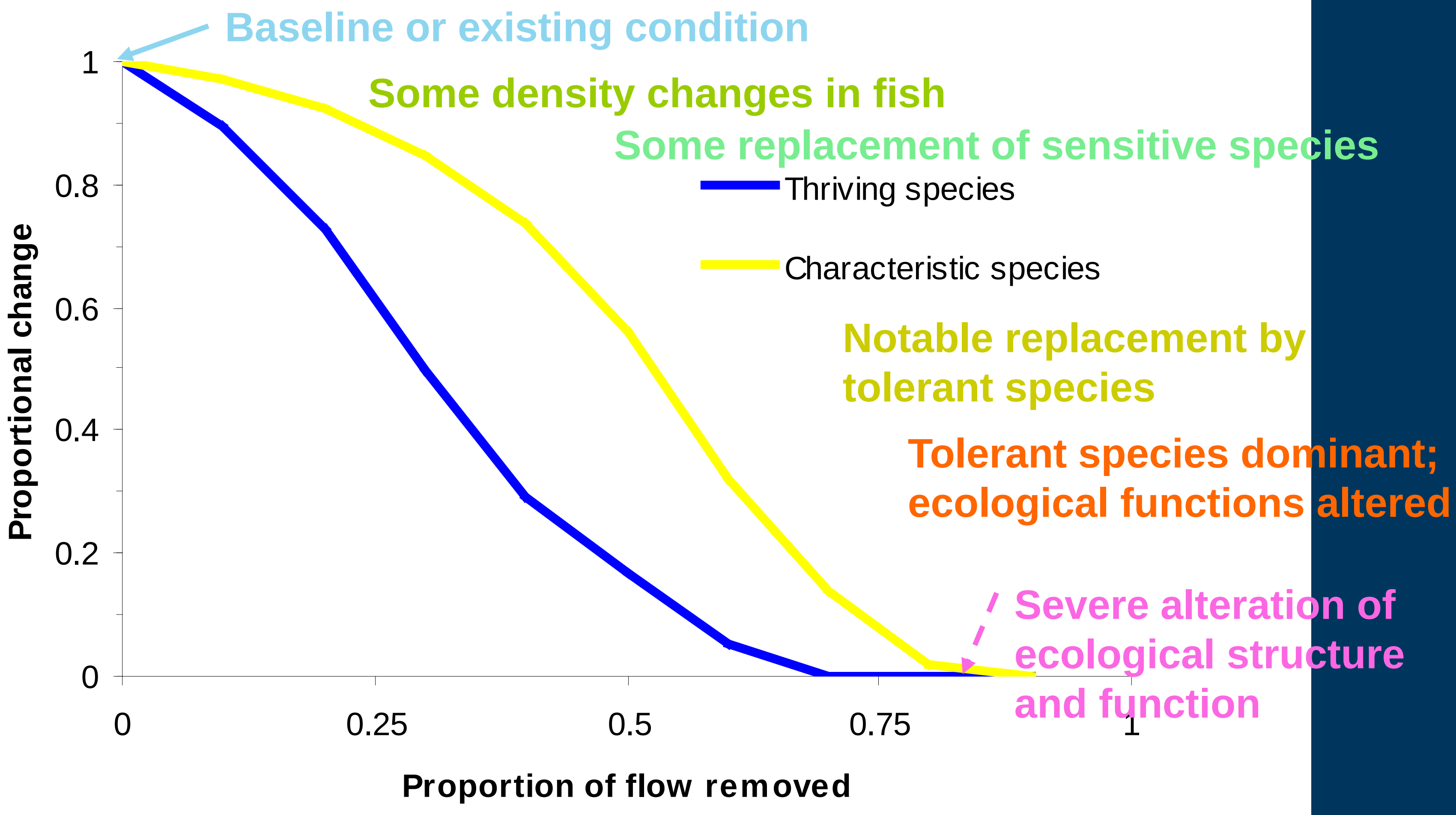
Rank scores per normal distribution; 60+ species



Source: Paul Seelbach, USGS

Fish assemblage response curves

- Averages of ~20 segments for river type
- Interpretive criteria from Davies and Jackson 2006



ARI flow reductions defined in Michigan law

Red = ARI; Blue = BC line

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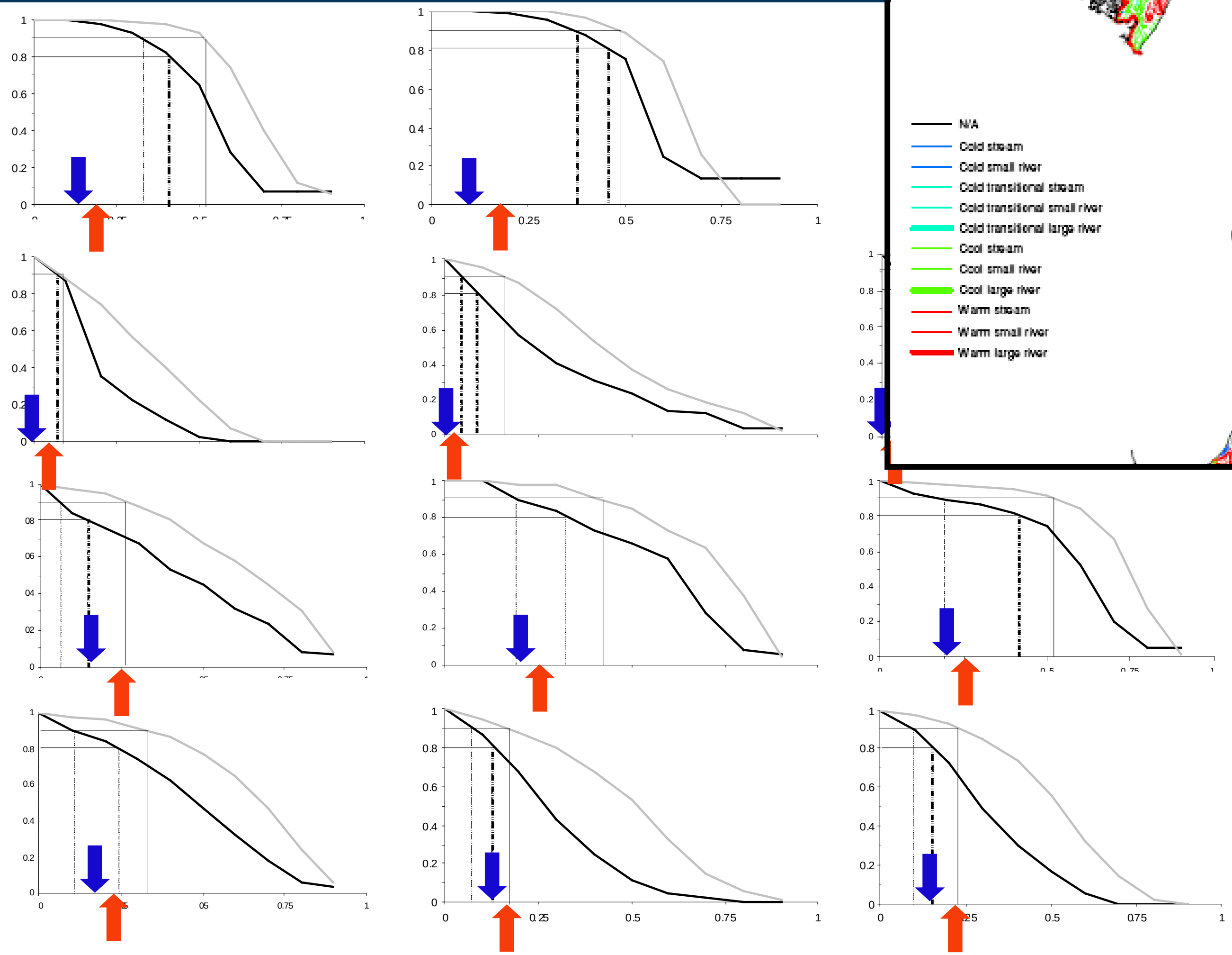
Cold

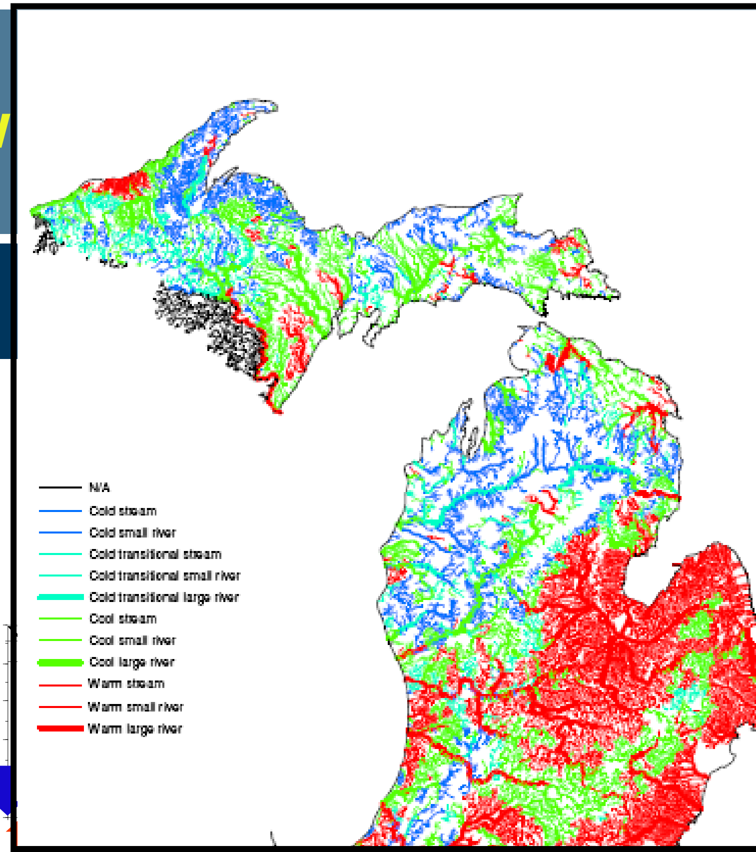
C-Trans

W-Trans

Warm



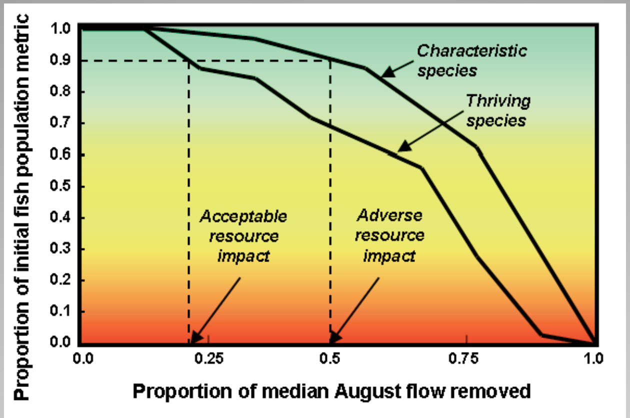
Streams **Sm Rivers** **Lg Rivers**



Ecological Limits of Hydrologic Alteration (ELOHA)

Environmental Flows for Regional Water Management

Poff et al.



THE SCIENTIFIC PROCESS

Developing Flow Alteration-Ecological Response Relationships

1. **Build a hydrologic foundation**
   (Streamstats, HSPF models, Index gage report, Sustainable Yield Estimator (SYE))

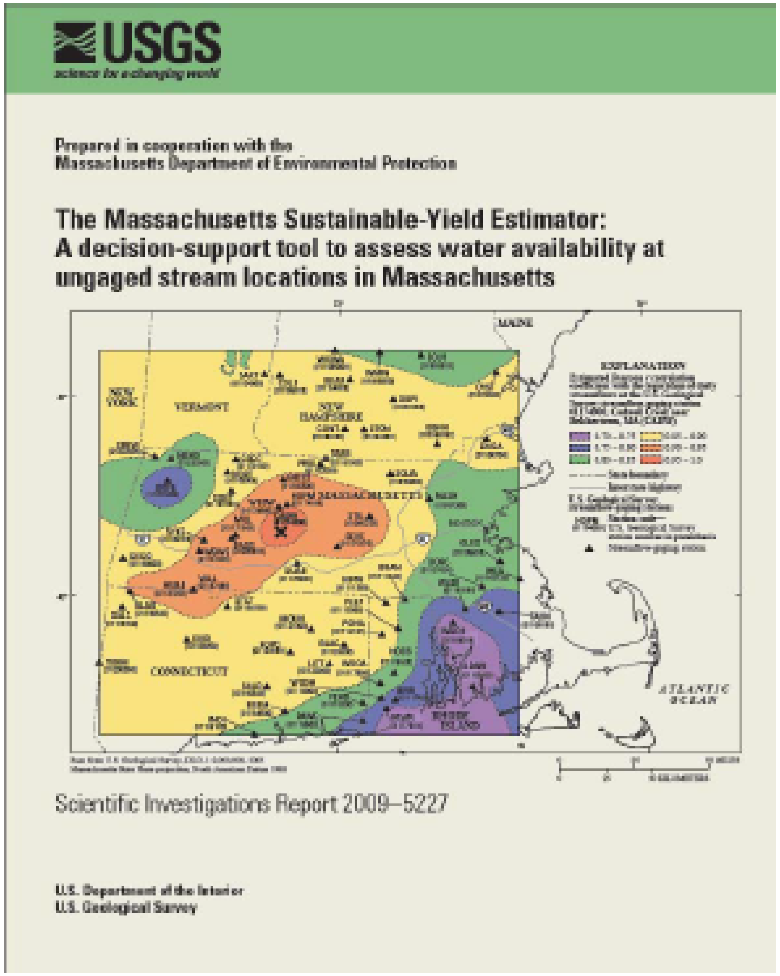
2. **Classify River Segments**
   (Flow Indices report)

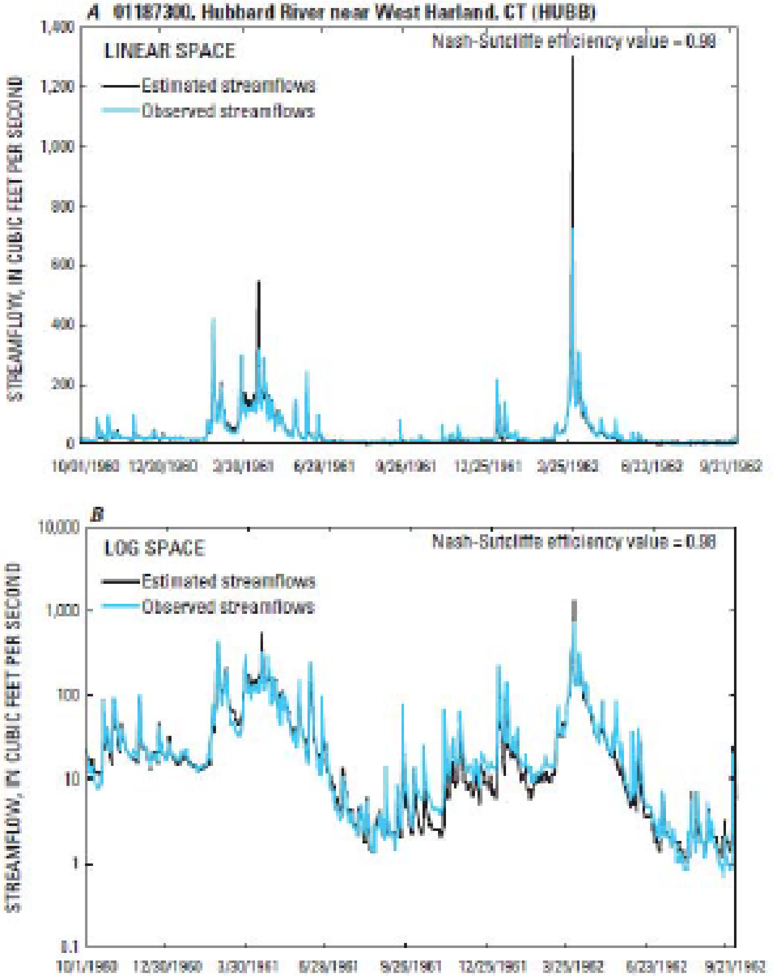
3. **Compute Hydrologic Alteration**
   (SYE, Stressed Basin project, HSPF models)

4. **Develop flow-alteration-ecological response relationships**
   (recent 3-basin effort, new habitat project)

(USGS, 2008)

- The Sustainable-Yield Estimator provides a screening–level tool to estimate unregulated and regulated daily mean streamflow (1960-2004) for ungaged sites



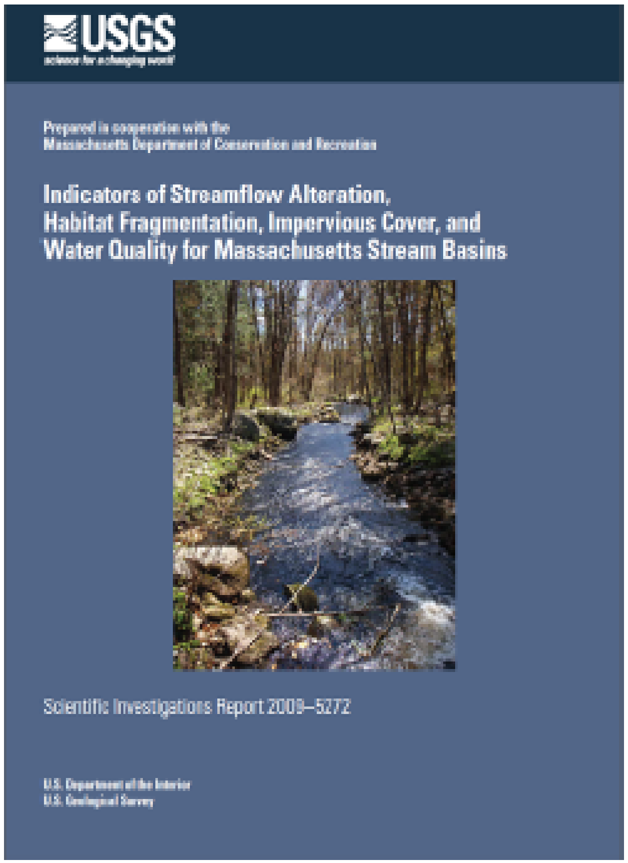


A similar SYE tool has been developed for the CT River Basin, and are underway in PA and MI

(USGS, 2012)

Building a hydrologic foundation – mapping existing conditions

- The Mass Indicators project mapped streamflow and stressor conditions across MA and is the principal driver of water planning in the state



40 Indicators of Streamflow Alteration, Habitat Fragmentation, Impervious Cover, and Water Quality for Massachusetts

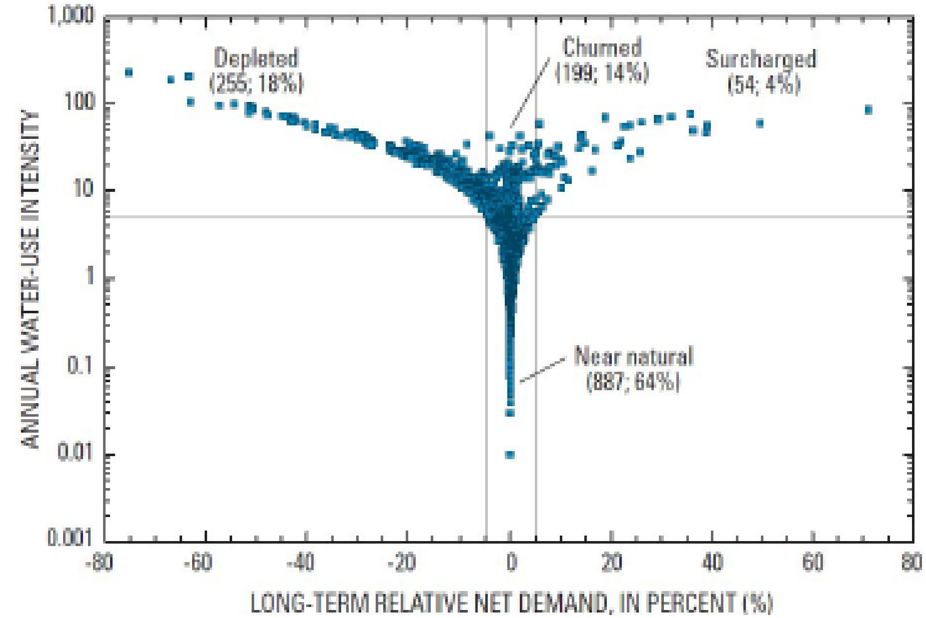
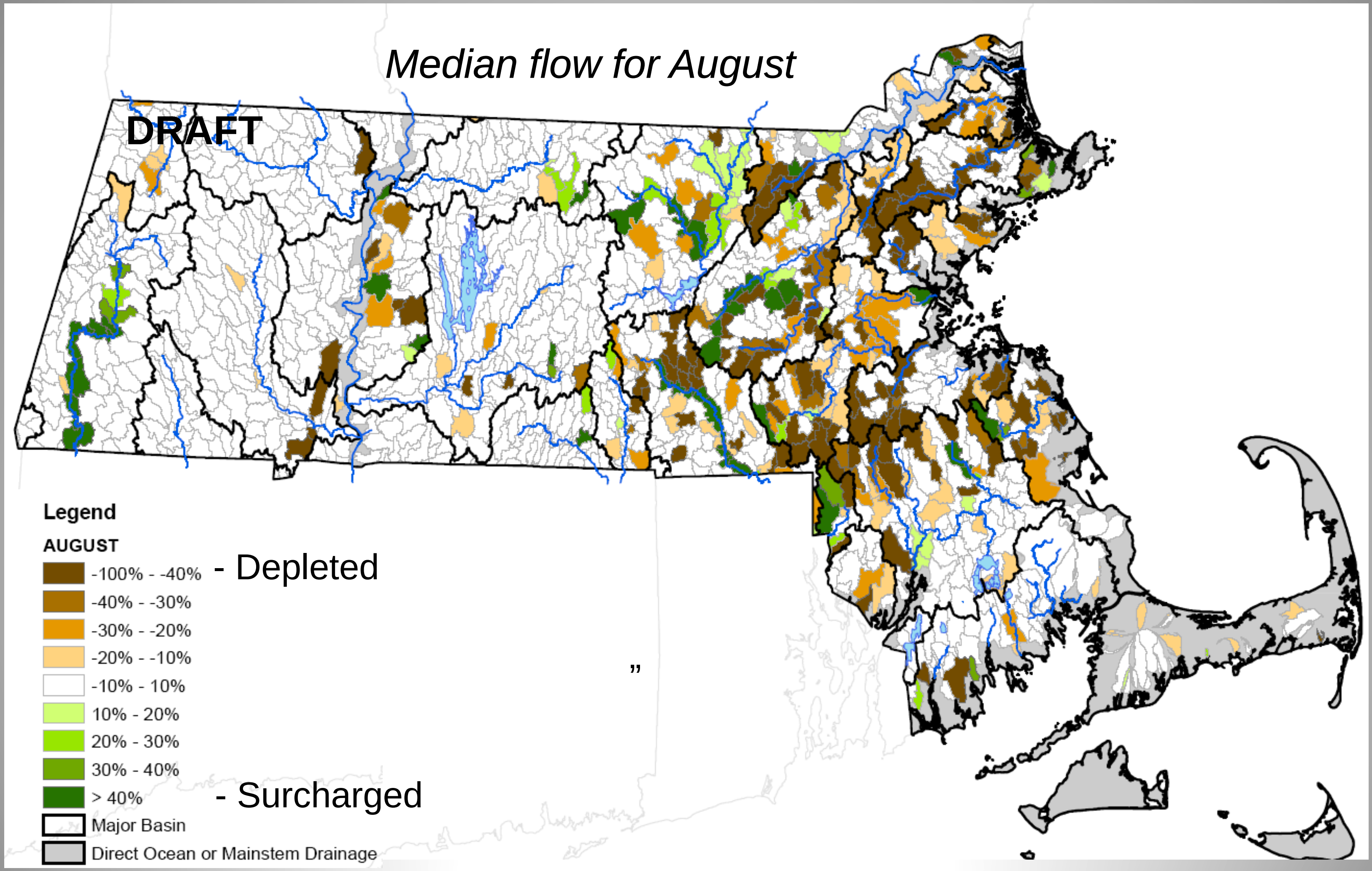


Figure 16. Relation of long-term relative net demand to water-use intensity, water-use scenario 2. Number of subbasins and groundwater contributing areas in each water-use-regime class, and percentage of the total in each class, are given in parentheses.

(USGS, 2012)

Opportunity to develop Flow-alteration-ecological response relations:

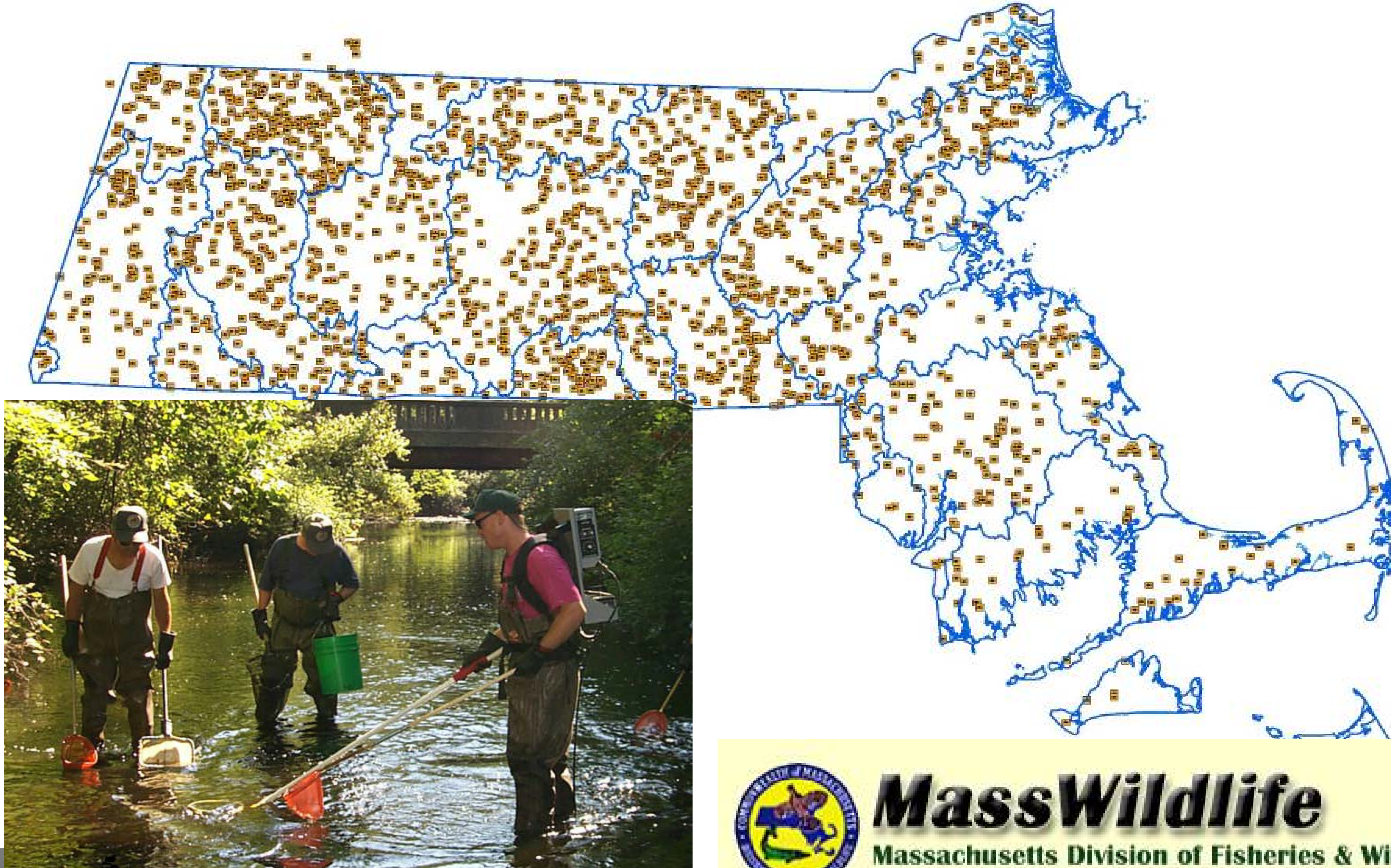
• **FLOW ALTERATION**: the USGS **Mass. Water Indicators project** has developed an approach for using unimpacted and impacted streamflows determined by the SYE, to calculate percent flow alteration for sub-basins in Massachusetts.



(USGS, 2009)

Fish community response used to understand flow alteration effects

- **FISH DATA**: The Massachusetts Division of Fisheries and Wildlife maintains a statewide fish database on lakes, ponds, streams, and rivers



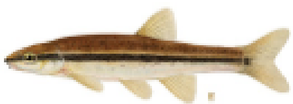
MassWildlife

Massachusetts Division of Fisheries & Wildlife

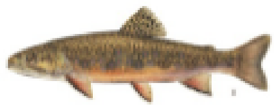
- **FISH HABITAT- USE CLASSIFICATION –** indicates species sensitive to flow alteration

Fluvial Specialists (FS)

Require flowing water for all portions of their life cycle



Blacknose dace

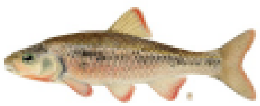


brook trout

Fluvial Dependents (FD)

Need flowing water for some portion of their life cycle

white sucker



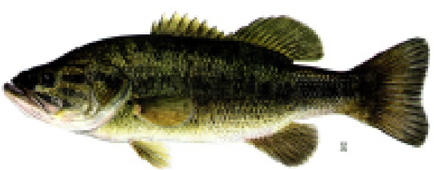
common shiner

Fluvial species

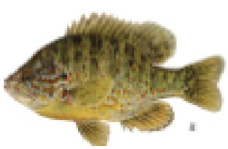
White Sucker	Common shiner
Blacknose dace	Tessellated darter
Brook trout	Slimy sculpin
Longnose dace	Brown trout
Fallfish	Creek chub

Macrohabitat Generalists (MG)

Can live in flowing or ponded water conditions



largemouth bass



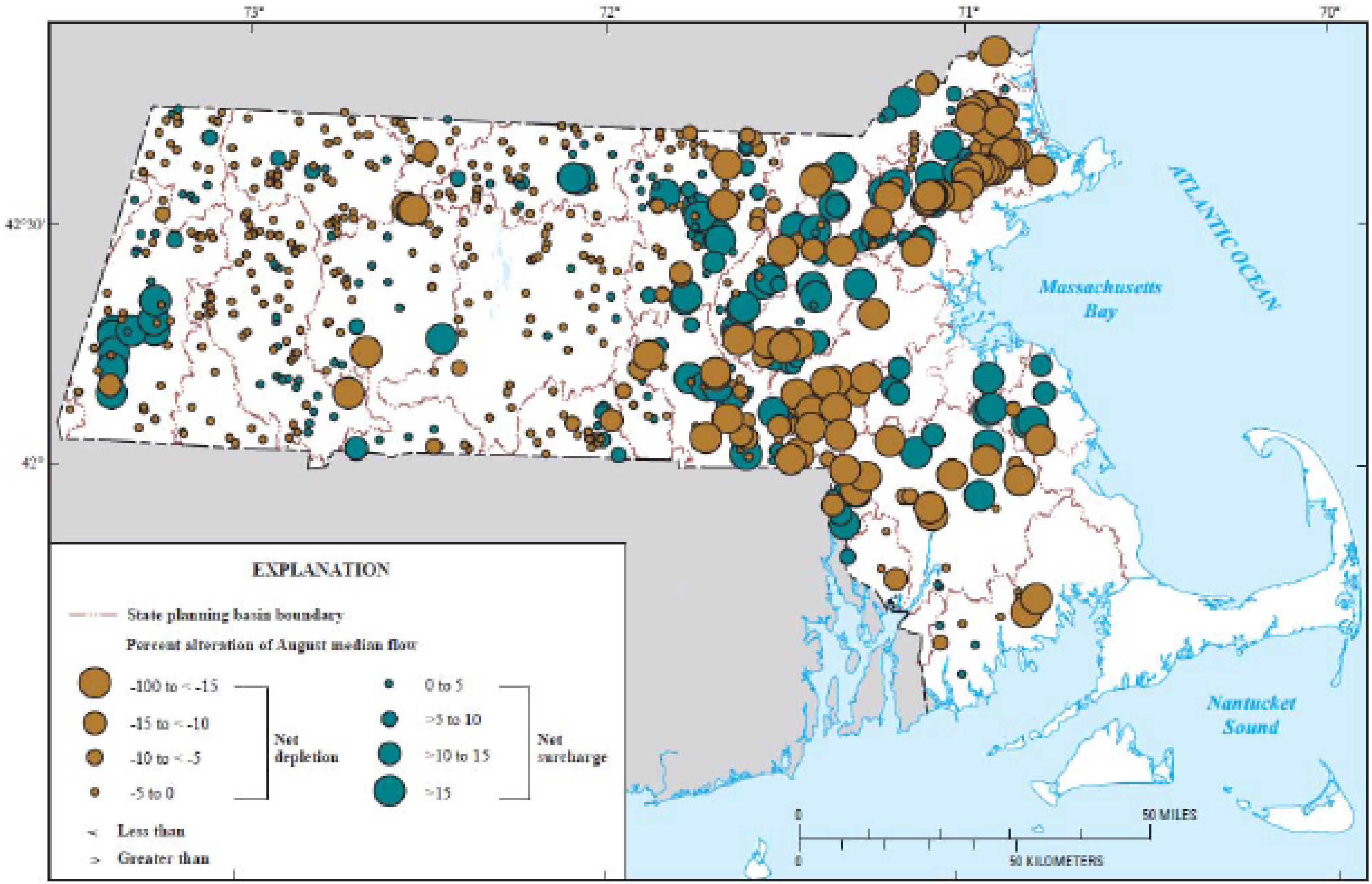
pumpkinseed

Generalist species

Pumpkinseed	Yellow bullhead
Bluegill	Brown bullhead
Largemouth bass	Golden shiner
American eel	Yellow perch
Redfin pickerel	Redbreast sunfish
Chain pickerel	

(USGS, 2012)

- The fish sampling sites represented a range of flow alteration conditions

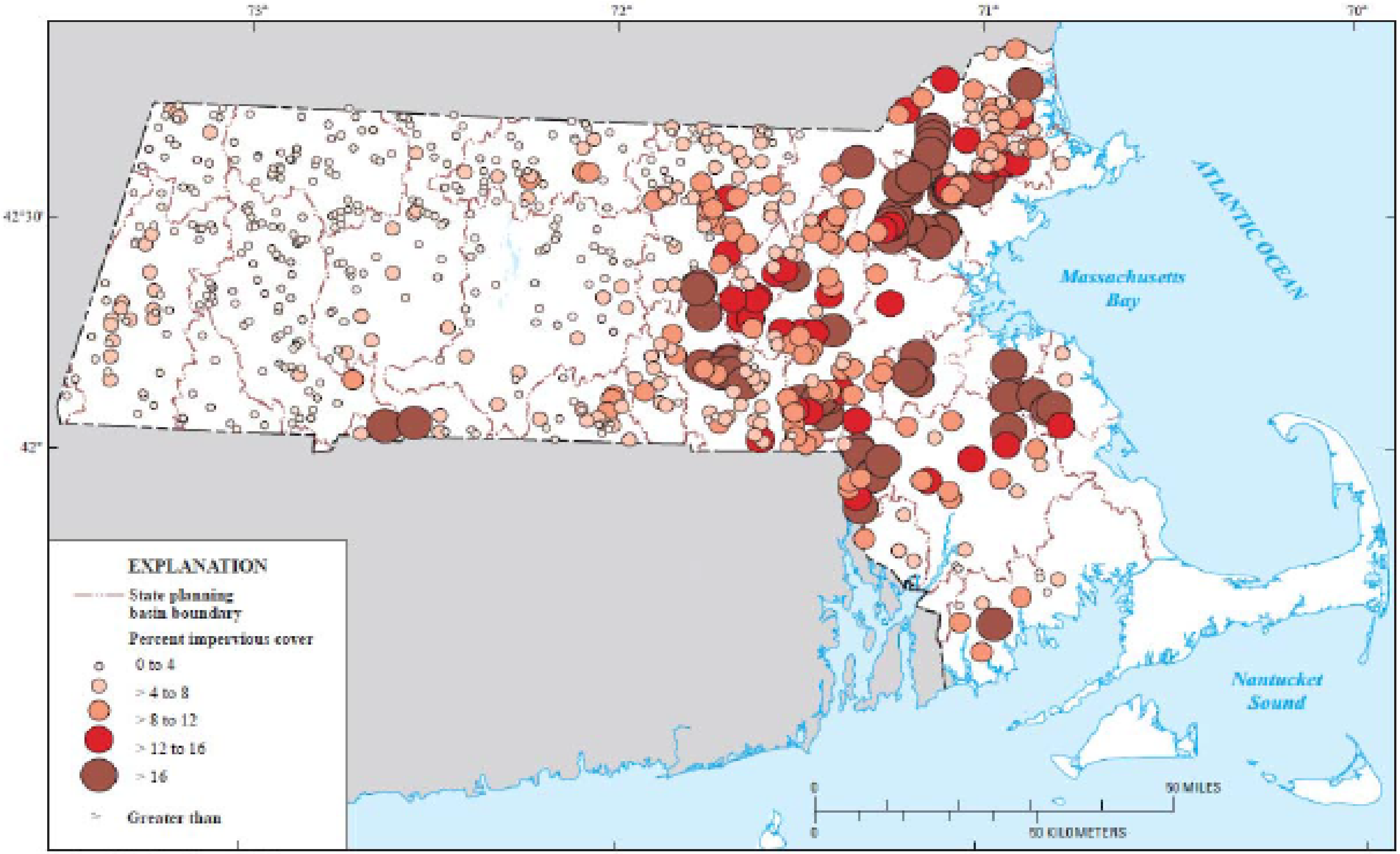


Base from U.S. Geological Survey digital data,
Massachusetts State Plane, zone 4151,1991, 1:25,000

Figure 7. Percent alteration of August median flows at 669 fish-sampling sites in Massachusetts streams.

(USGS, 2012)

- …and a range of impervious cover conditions.



Base from U.S. Geological Survey digital data. Massachusetts State Plane, zone 4151, 1991, 1:25,000

Figure 5. Impervious cover for contributing areas to 669 fish-sampling sites in Massachusetts. Impervious cover data from 2005 (Massachusetts Office of Geographic and Environmental Information, 2007).

(USGS, 2012)

Over 150 potential variables were evaluated using PCA, of these15 Variables were retained to use as candidate variables for regression models

Natural basin characteristics

1. Drainage area
2. Channel slope
3. Percent sand and gravel

Land-cover/Land-use variables

1. Percent forest
2. Percent wetland in buffer
3. Percent impervious cover
4. Percent agriculture in buffer

Flow alteration metrics

1. Percent alteration of August median flow from groundwater withdrawals
2. Percent alteration of August median flow from surface-water returns
3. Percent alteration of mean annual flow from surface-water withdrawals
4. Percent alteration of mean annual flow for net depleted sites

Dam/impoundment metrics

1. Dam density
2. Percent open water in the contributing area.
3. Length of undammed stream reach in network
4. Length of undammed stream reach upstream of the sample site along centerline,

(USGS, 2012)

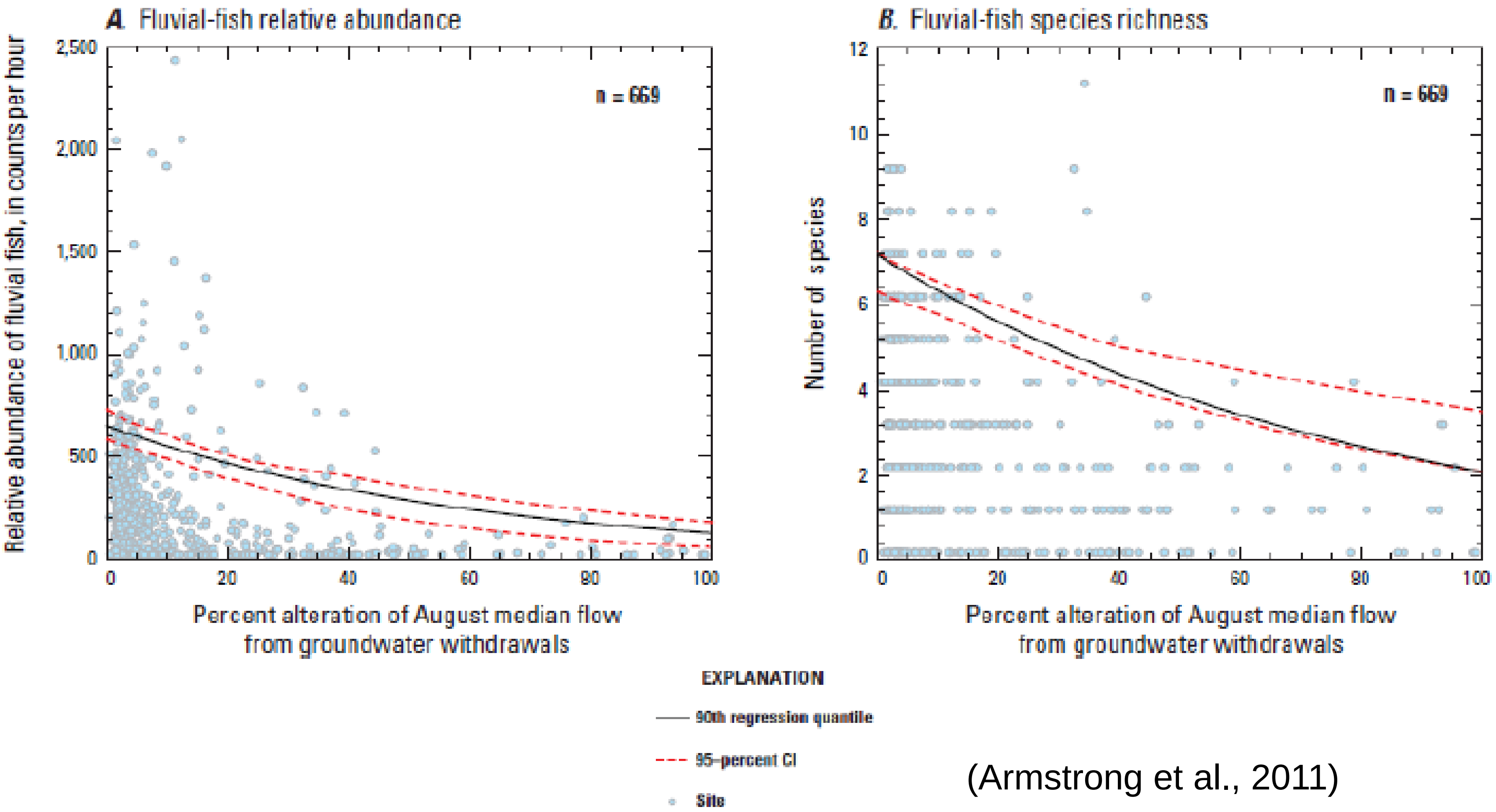
Significant variables in USGS report on factors influencing fish assemblages in MA (2012)

A. Significant variables and coefficients				
Model	**Independent variable**	**Coefficient**	**SE**	***p*-value**
Variable pool for models including percent impervious cover				
Fluvial-fish species richness	Intercept	1.7911	0.0664	<0.0010
	DA	0.0011	0.0004	0.0037
	CHSLP	-0.0968	0.0206	<0.0010
	UdamTmi	0.0008	0.0002	0.0009
	pBWet_al	-0.0262	0.0029	<0.0010
	IC	-0.0557	0.0063	<0.0010
Fluvial-fish relative abundance	Intercept	6.1523	0.0942	<0.0010
	CHSLP	-0.0840	0.0361	0.0202
	AUGgwWp	-0.0091	0.0042	0.0286
	pBWet_al	-0.0289	0.0059	<0.0010
	IC	-0.0373	0.0132	0.0047
Brook trout relative abundance	Intercept	4.9336	0.2012	<0.0010
	DA	-0.1291	0.0256	<0.0010
	pCOW	-0.2172	0.0948	0.0223
	IC	-0.0916	0.0305	0.0028

(Armstrong et al., 2011)

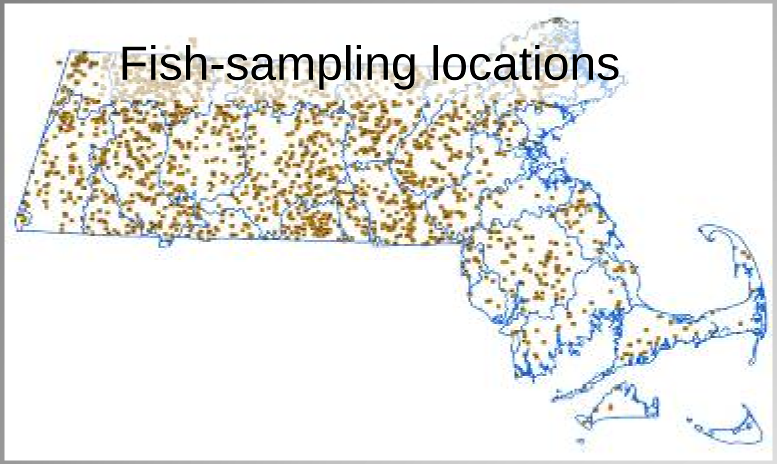
Flow alteration

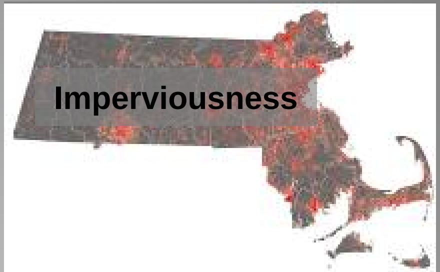
• Quantile regression shows that relative abundance and species richness **decrease** with increasing flow alteration from groundwater withdrawals

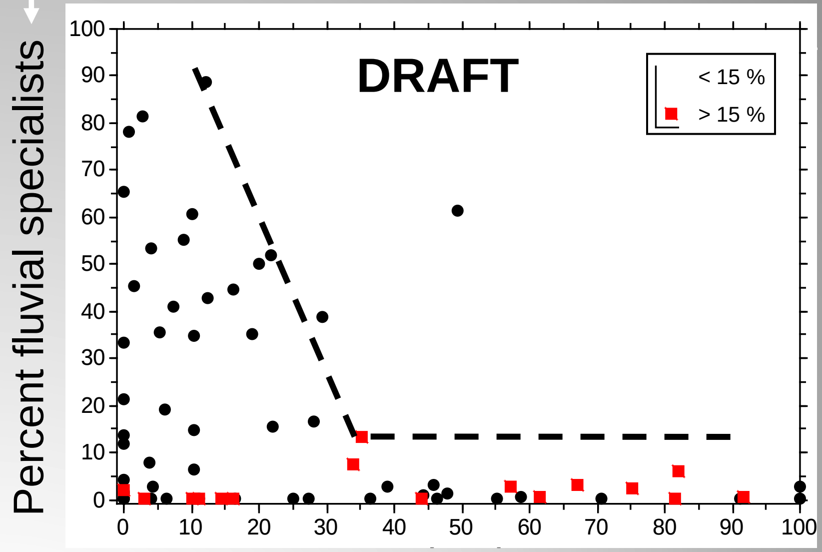


(Armstrong et al., 2011)

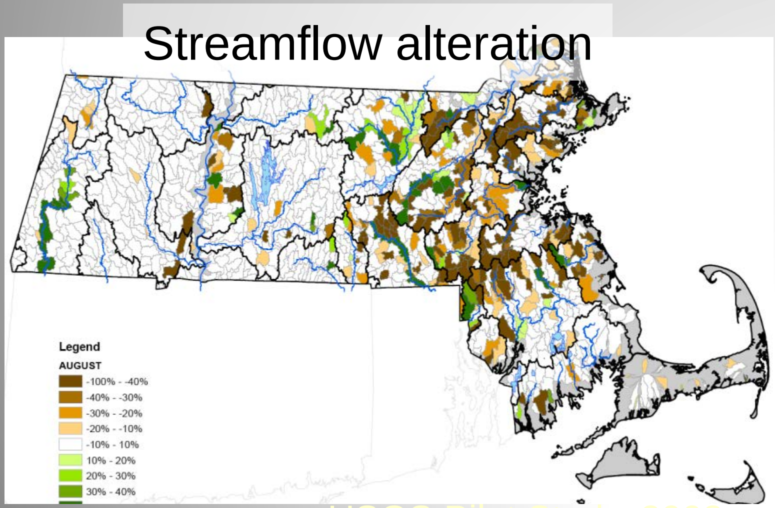
Massachusetts Sustainable Water Management Initiative - Streamflow Standards and Safe Yield





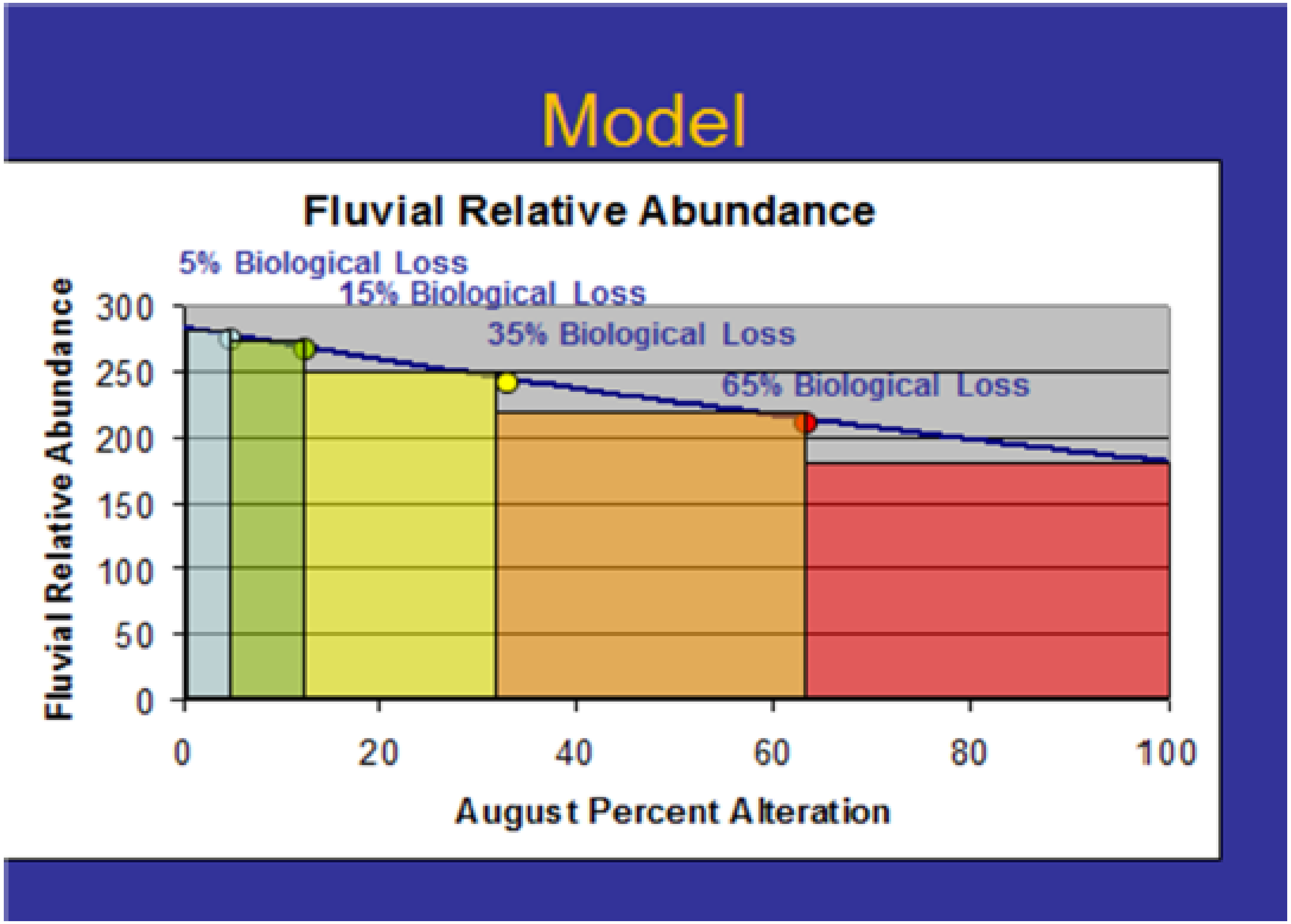


Percent net flow alteration (August) for nested basins



USGS Pilot Study, 2008

(graphics from USGS)


Model
Fluvial Relative Abundance
5% Biological Loss
15% Biological Loss
35% Biological Loss
65% Biological Loss
Fluvial Relative Abundance
300
250
200
150
100
50
0
0
20
40
60
80
100
August Percent Alteration

MA SWMI, 2012

Category Descriptions

Figure 2

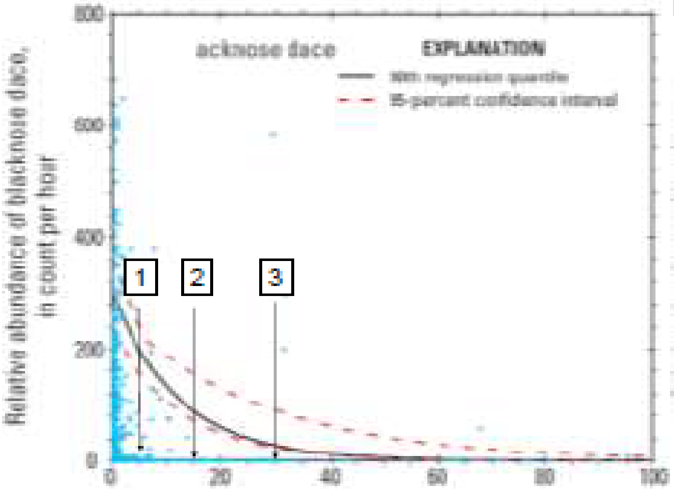
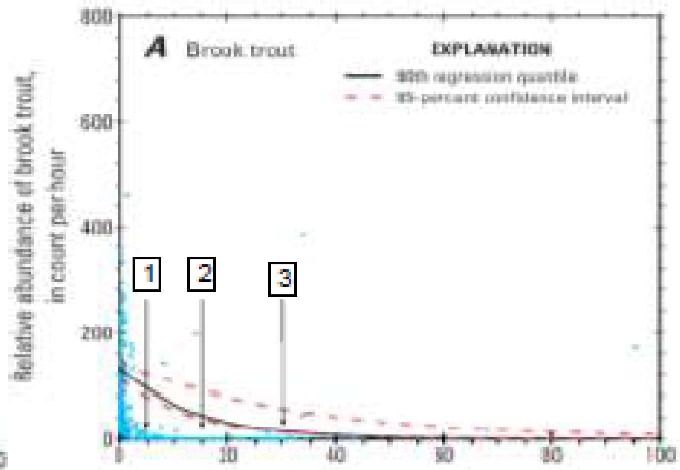


Figure 3



Percent alteration of August median flow at net depleted sites.

Figures 2, 3. Decreases in the 90th quantile for relative abundance of blacknose dace and brook trout in relation to increasing percent alteration of the August median flow. *(graphs modified from Armstrong, et al., 2010)*

Category 1 (0-5% Alteration of the Range of Fluvial Fish Abundance)

High Quality aquatic habitat, relatively unimpacted by human alteration based on IC and flow alteration

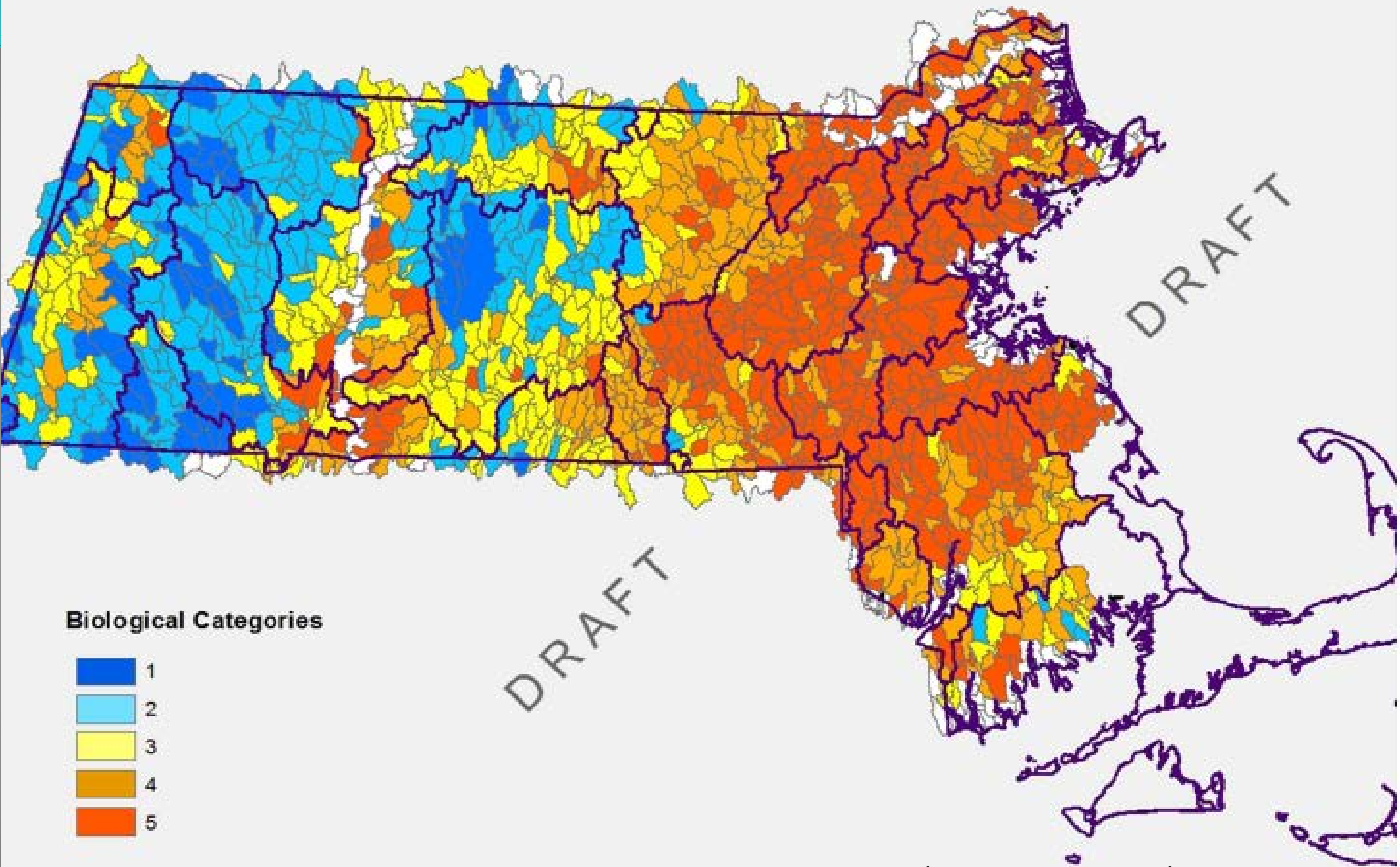
Category 2 (5-15% Alteration of the Range of Fluvial Fish Abundance)

Quality fishery resources with good species diversity and balanced, adaptive fish communities. Likelihood of species loss continues

Category 3 (15-35% Alteration of the Range of Fluvial Fish Abundance)

Exhibited considerable change in structure of community. More tolerant species likely to dominate community

Biological Categories Using Final USGS Results

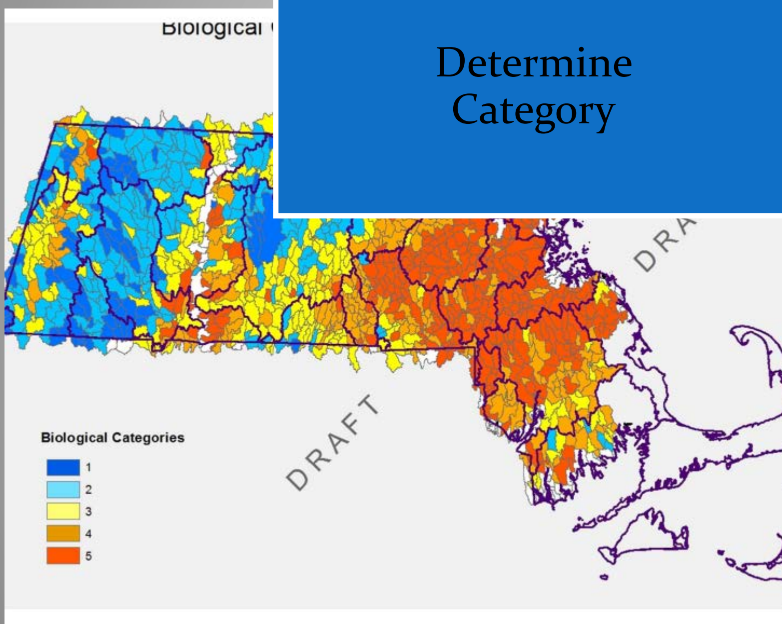


(MA SWMI, 2012)

Key Metrics in MA SWMI Process – Biological Category and Flow Alteration Level

Biological Categories

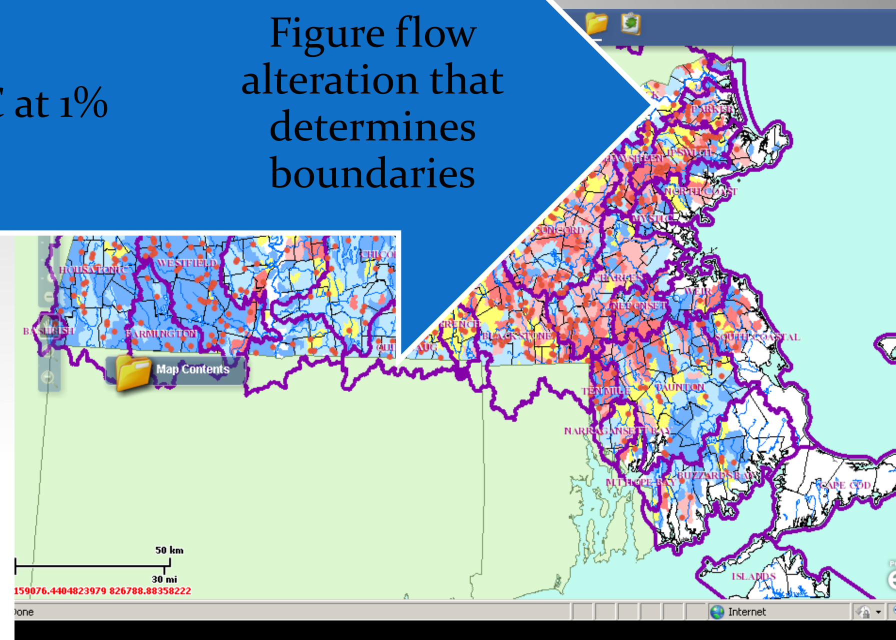
Median August Flow Alteration



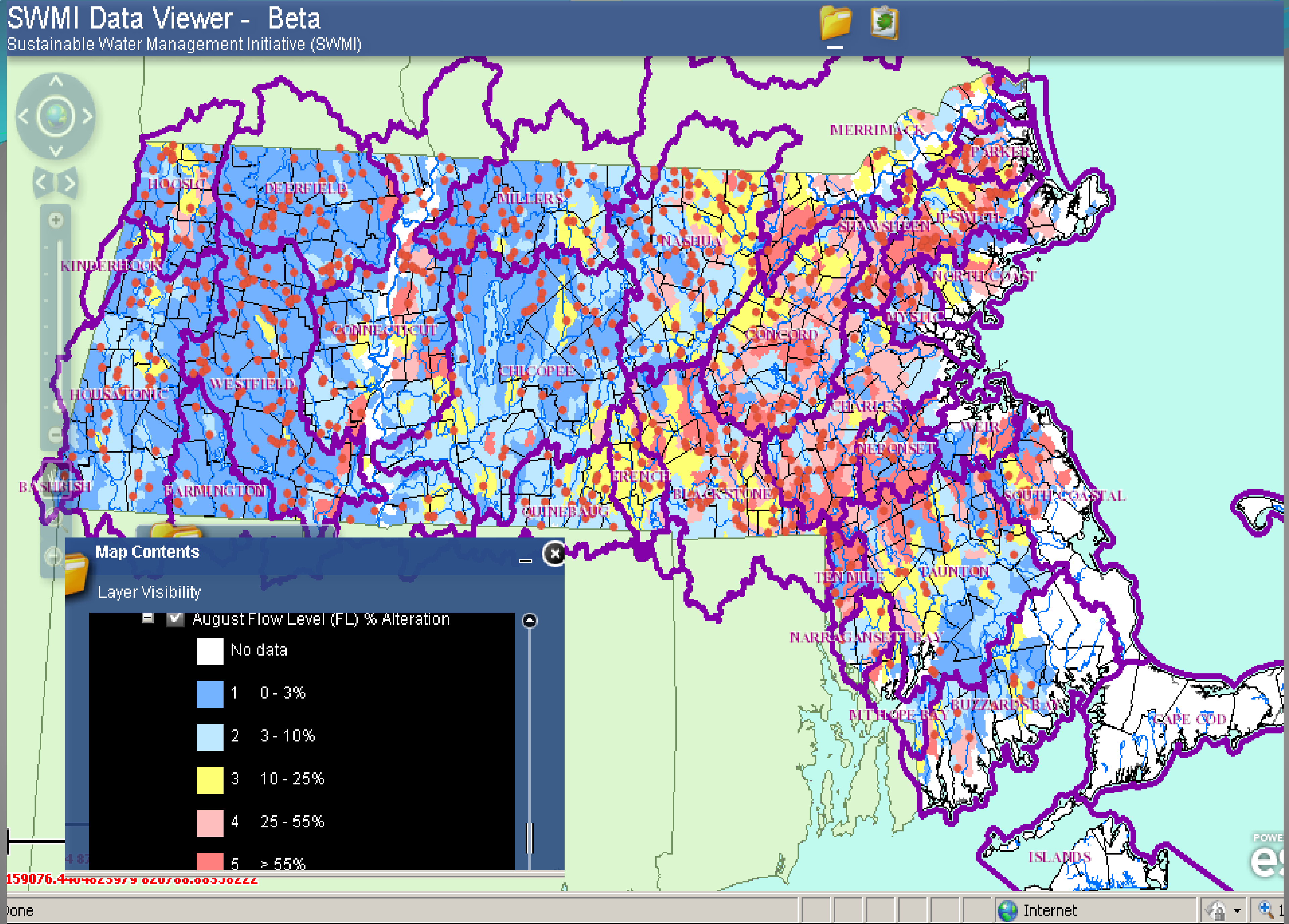
Determine Category

Set IC at 1%

Figure flow alteration that determines boundaries



(Graphics from MA SWMI, 2012)


SWMI Data Viewer - Beta
Sustainable Water Management Initiative (SWMI)
MERRIMACK
PARKER
HOOSIC
DEERFIELD
MILLERS
IPSWICH
SHAWSHEEN
NASHUA
KINDERHOOK
NORTH COASTAL
MYSTIC
CONNECTICUT
CONCORD
CHICOPEE
WESTFIELD
HOUSATONIC
CHARLES
WEIR
NEPONSET
FARMINGTON
FRENCH
BLACKSTONE
QUINEBAUG
SOUTH COASTAL
TEN MILE
TAUNTON
NARRAGANSETT BAY
BUZZARDS BAY
MT HOPE BAY
CAPE COD
ISLANDS
Map Contents
Layer Visibility
August Flow Level (FL) % Alteration
No data
1 0 - 3%
2 3 - 10%
3 10 - 25%
4 25 - 55%
5 > 55%
Internet

Draft Recommendation: Seasonal Streamflow Criteria

Flow Levels	August Flow Level (Range of % Alteration due to groundwater withdrawal)	Seasonal Streamflow Criteria: % allowable alteration of estimated unimpacted median flow			
		Aug	Oct	Jan	April
1	0 to < 3%	3%	3%	3%	3%
2	3 to <10%	10%	5%	3%	3%
3	10 to < 25%	25%	15%	10%	10%
4	25 to <55%	Feasible mitigation and improvement			
5	55% or greater				

1) More consistent with current water use patterns
2) Still protective of natural hydrograph
3) 4% of basins > seasonal percents

(MA SWMI, 2012)

ELOHA Projects in the Northeast

CT River Basin

MA SWMI process

CT Streamflow Regulations

Great Lakes

Delaware Basin

Susquehanna

Upper Ohio

Potomac

Virginia

Acknowledgements

Slides prepared by the following individuals are included in this presentation. Permission to use them is acknowledged.

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