Setting Site-Specific Aquatic Life Use Targets in Watersheds and Estuaries

An Effective Alternative to Numeric Nutrient Criteria ?

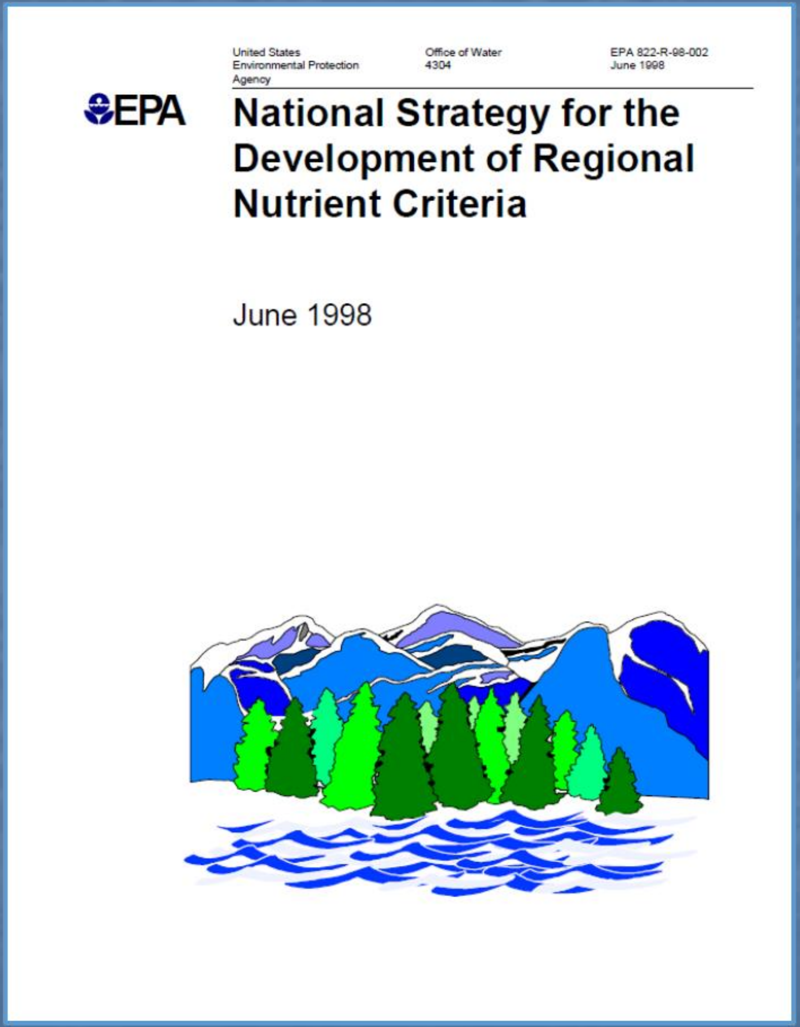
NEWEA 2021 Annual Conference
Watershed Management Session
2 February 2021

Earth at Night
More information available at:
http://antwrp.gsfc.nasa.gov/apod/ap001127.html

NASA Earth Observatory

Paul E. Stacey
FOOTPRINTS IN THE WATER
Working to Make Nature Great Again
FootprintsInTheWater@outlook.com

What Ever Happened to Nutrient Criteria?


United States Environmental Protection Agency | Office of Water 4304 | EPA 822-R-98-002 June 1998

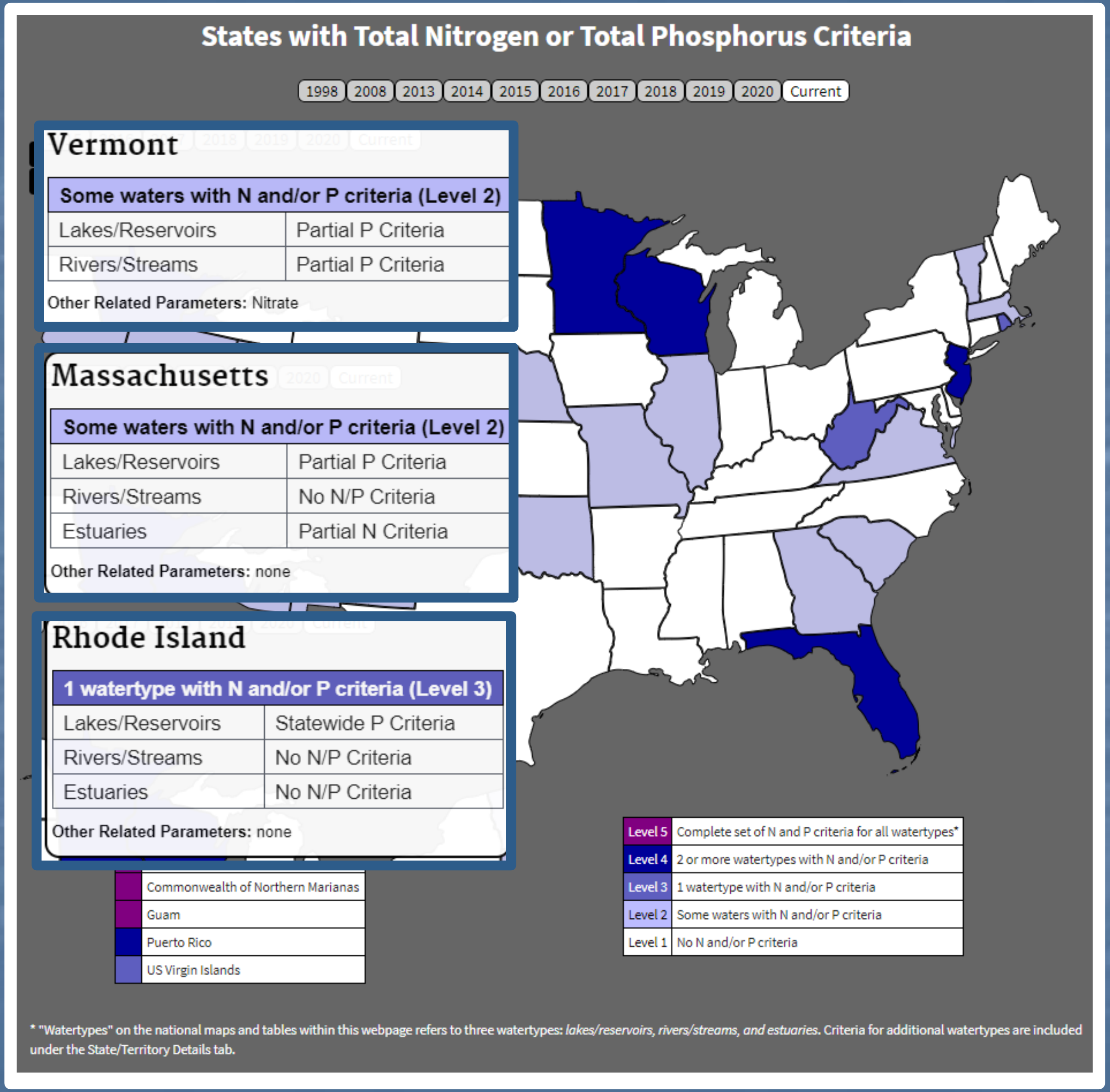
EPA

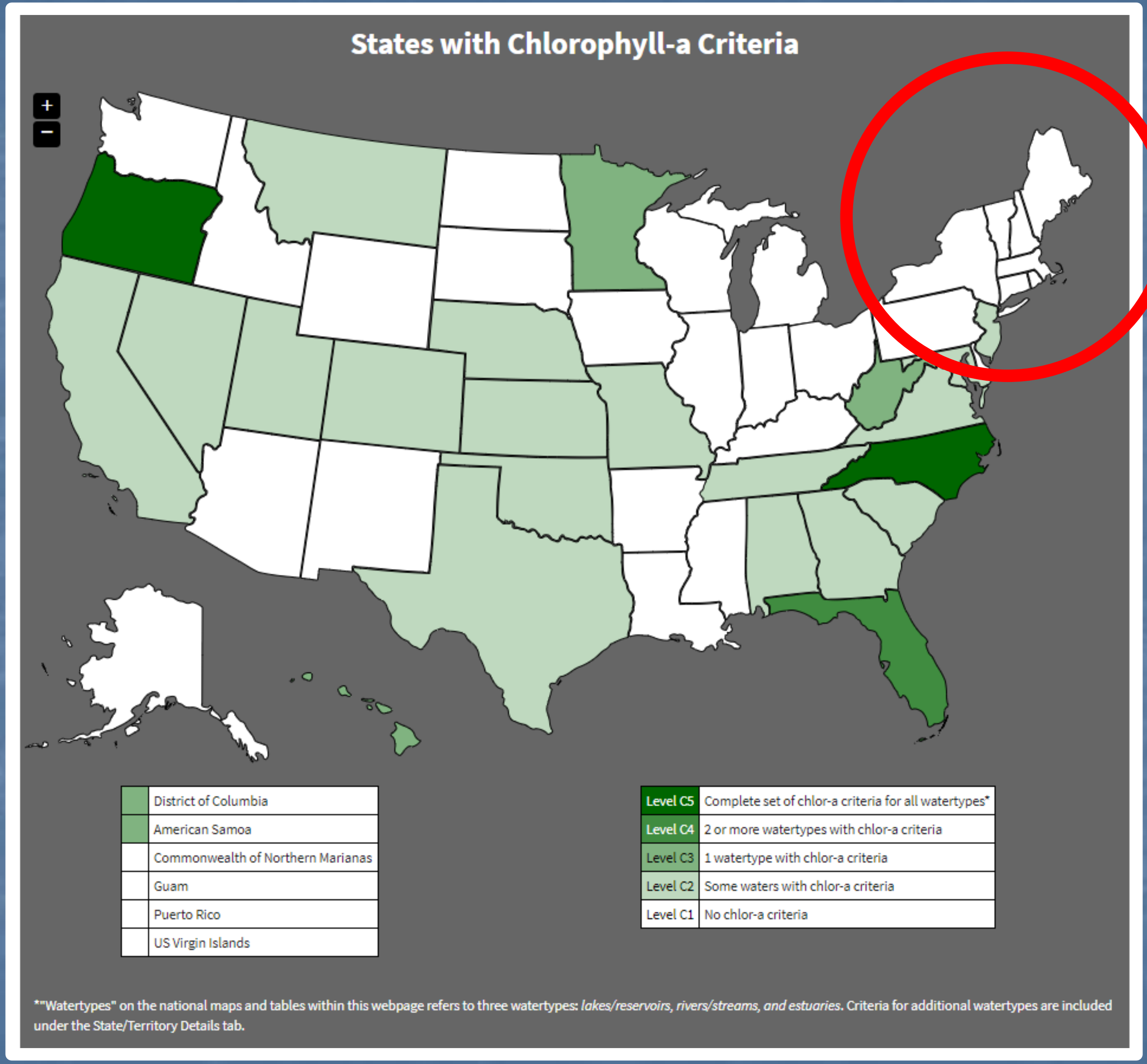
National Strategy for the Development of Regional Nutrient Criteria

June 1998

The goal was for the States/Tribes to establish these criteria as part of their water quality standards *<u>within three years of completion of the guidance</u>* i.e., by the end of the calendar year *<u>2003</u>*

Nutrient Criteria Adoption Status





United States Government Accountability Office
Report to Congressional Requesters

December 2013

CLEAN WATER ACT

Changes Needed If Key EPA Program Is to Help Fulfill the Nation's Water Quality Goals

- **Pollutants had been reduced in many waters, but *<u>few impaired water bodies have fully attained water quality standards.</u>***

GAO-14-80

United States Government Accountability Office
Report to the Honorable Sheldon Whitehouse, U.S. Senate

October 2017

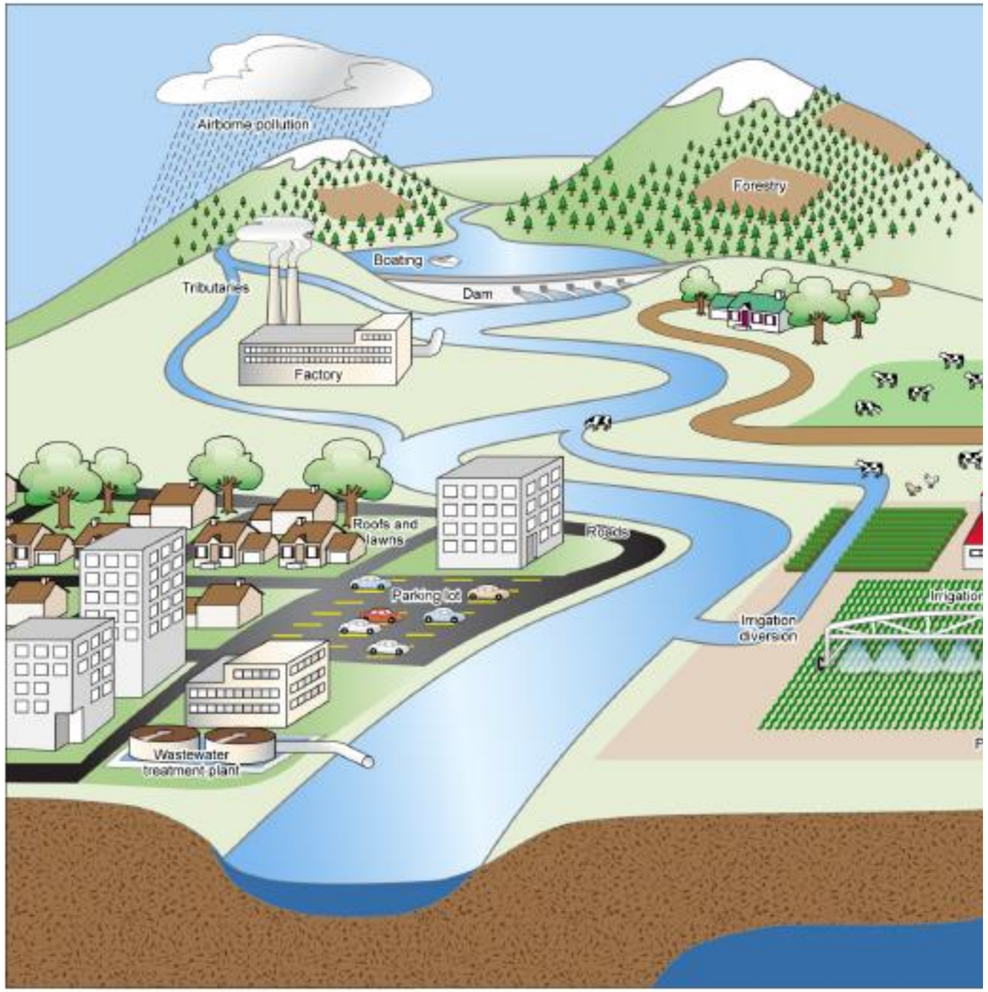
WATER POLLUTION

Some States Have Trading Programs to Help Address Nutrient Pollution, but Use Has Been Limited

- ***The importance of nutrient discharge limits***
- ***The challenges and uncertainties of nonpoint source nutrient reductions***

GAO-18-84

Figure 1: Sources of Nutrient Pollution to Water Bodies



Source: GAO. | GAO-18-84

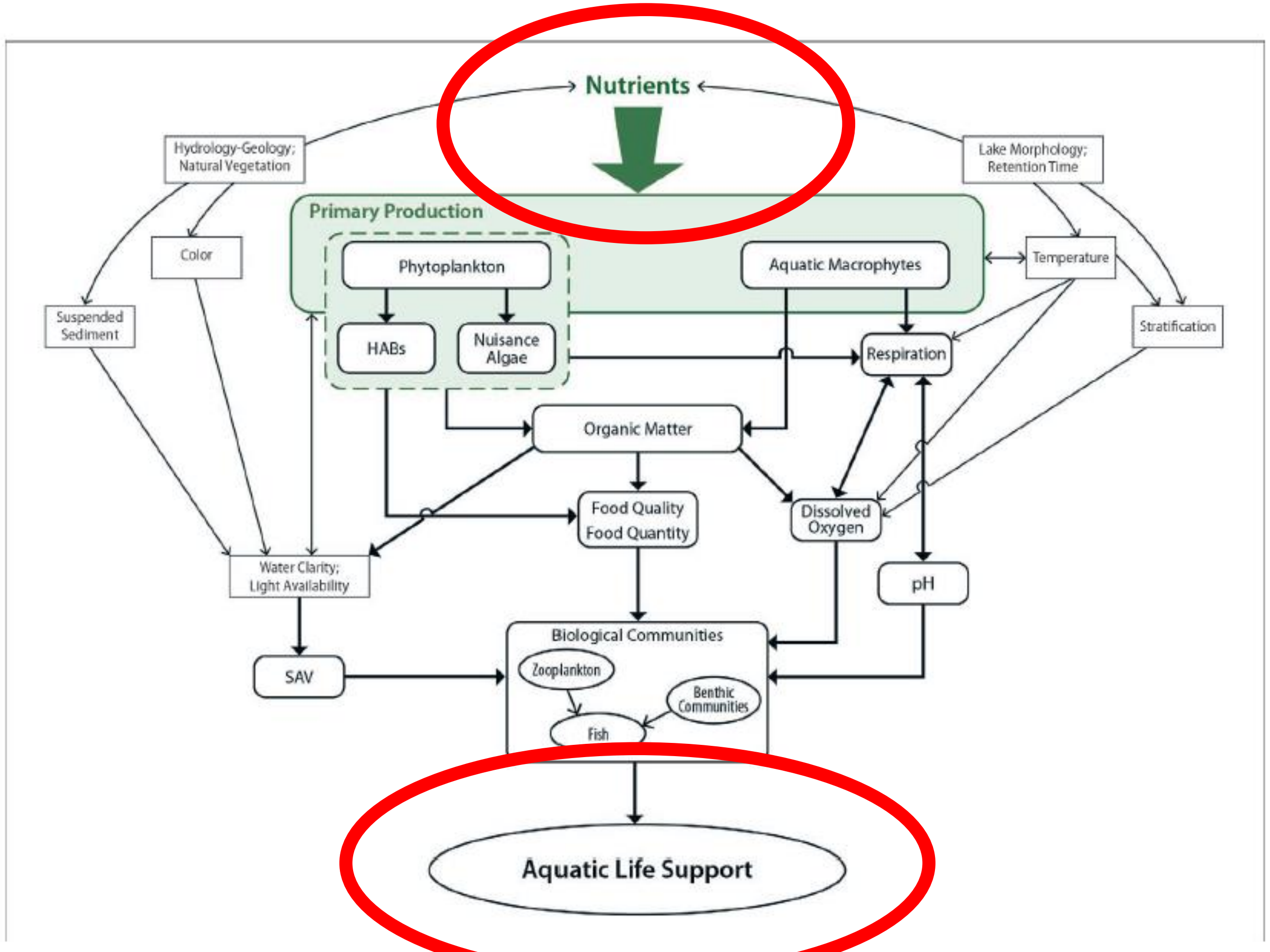
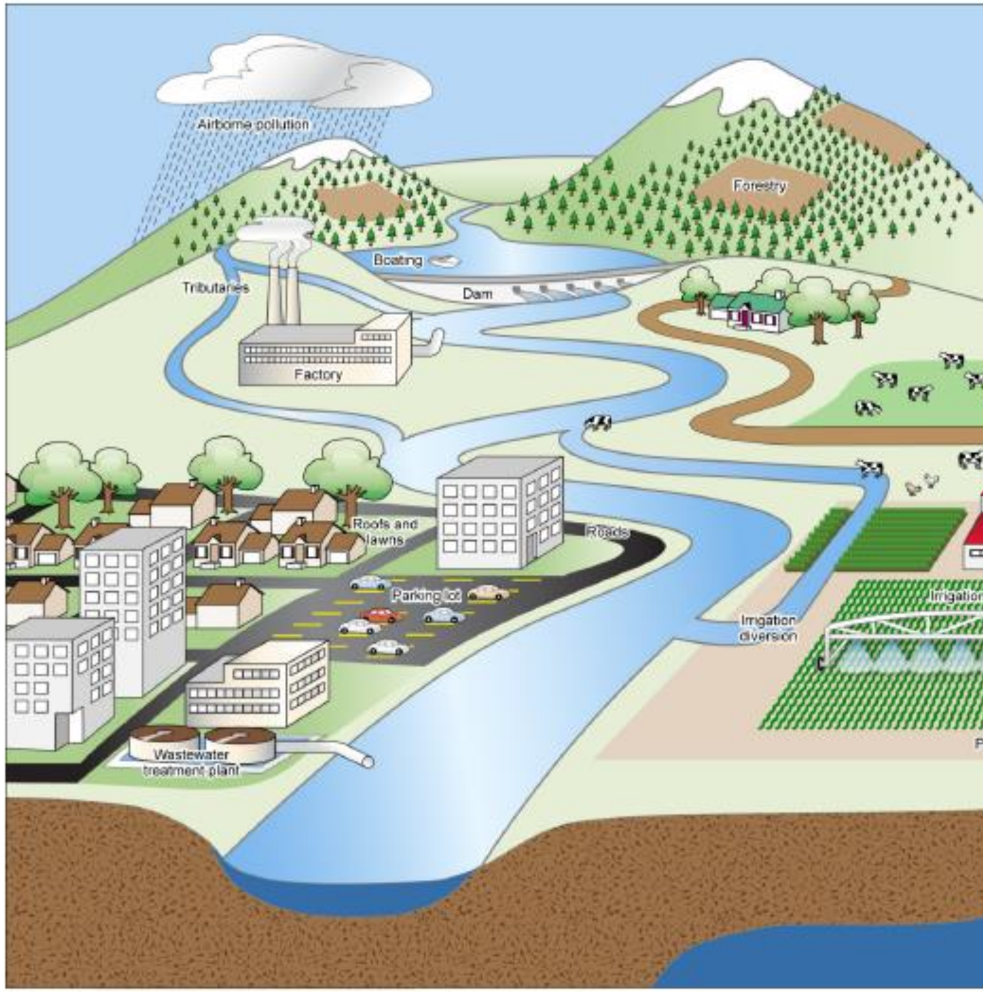


Figure 1. Conceptual model linking increased nutrients to aquatic life use (*Source*: US EPA 2010a).

What's Wrong with this Picture?

Figure 1: Sources of Nutrient Pollution to Water Bodies



Source: GAO. | GAO-18-84

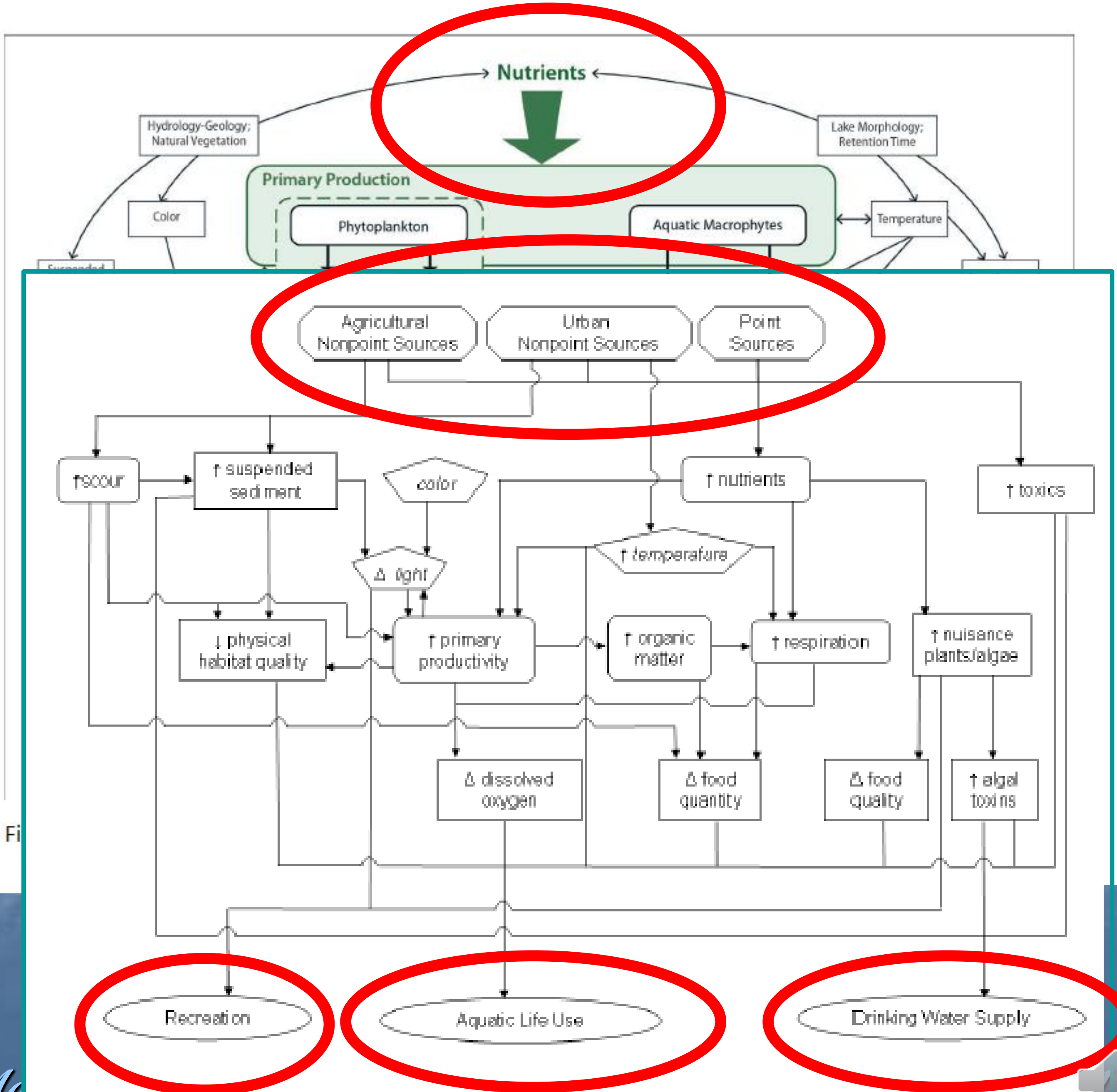
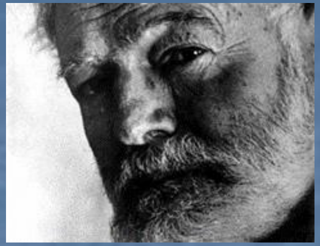


Figure 2-2. Conceptual model diagram for streams. See text for explanation of shapes and symbols.

What’s Wrong with this Picture?

Is it Just Nutrients?



All things truly wicked start from innocence.
Ernest Hemingway

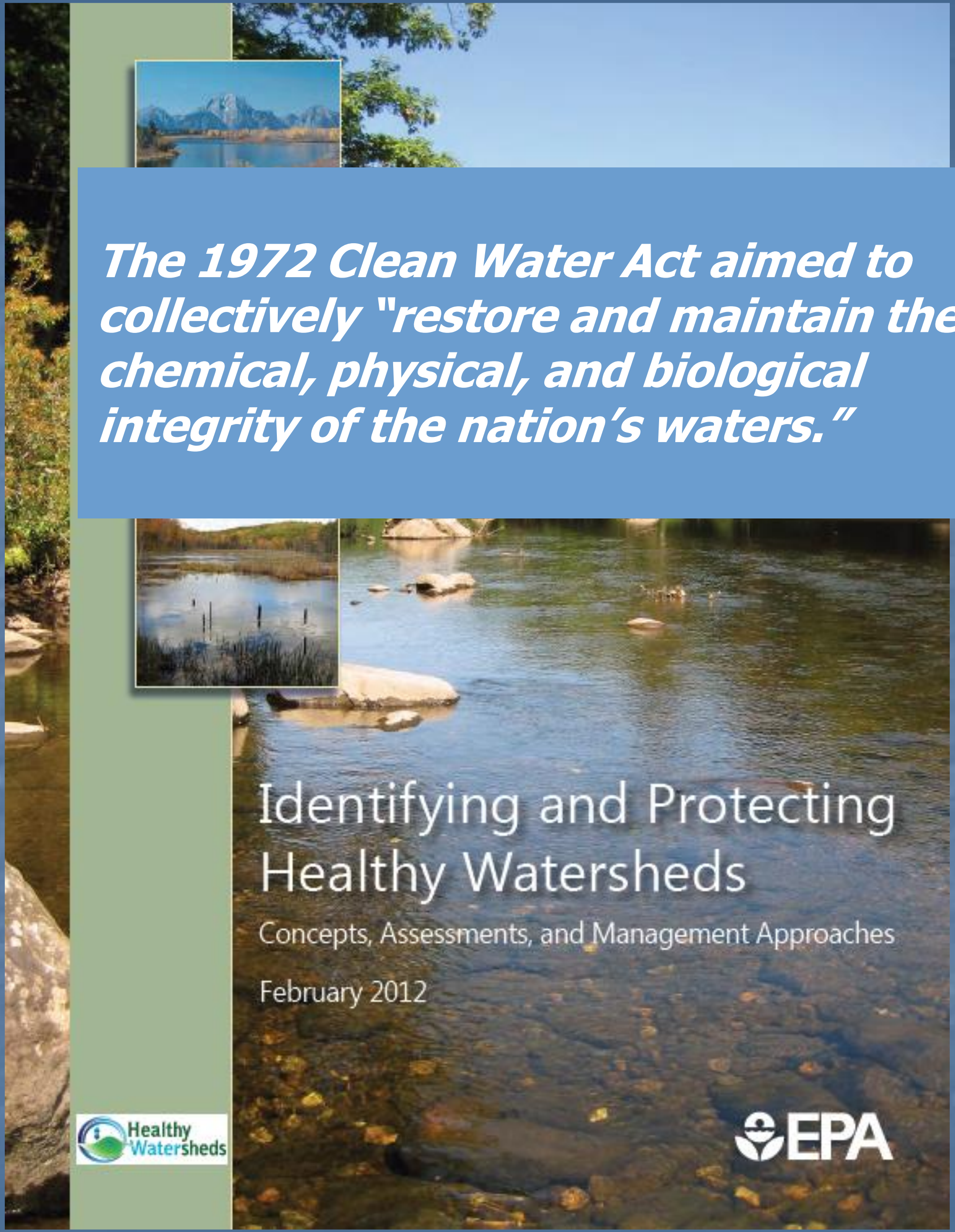
Wicked Problems

Drivers of Ecosystem Change

- **Climate Change**
- **Development**
- **Food and Fiber Production**
- **Resource Extraction and Relocation (Water, Minerals, Energy)**
- **Ecosystem Instability (Invasives, Extinctions, Pestilence)**




The 1972 Clean Water Act aimed to collectively "restore and maintain the chemical, physical, and biological integrity of the nation's waters."



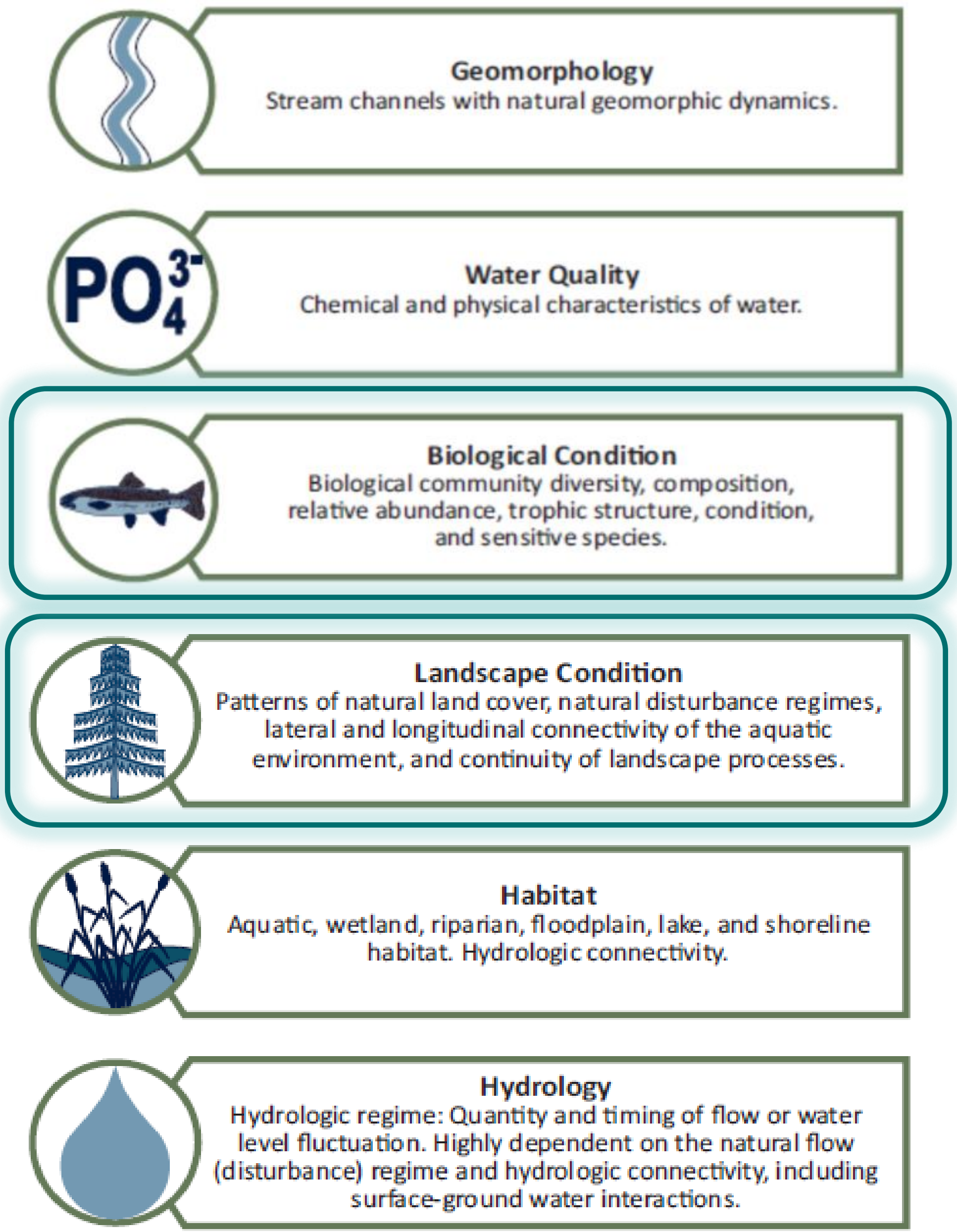
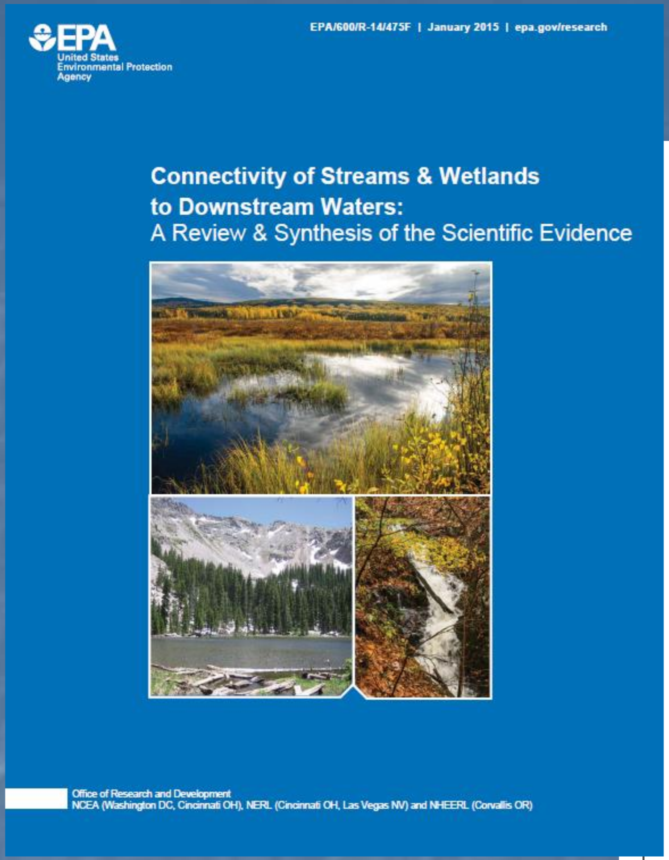
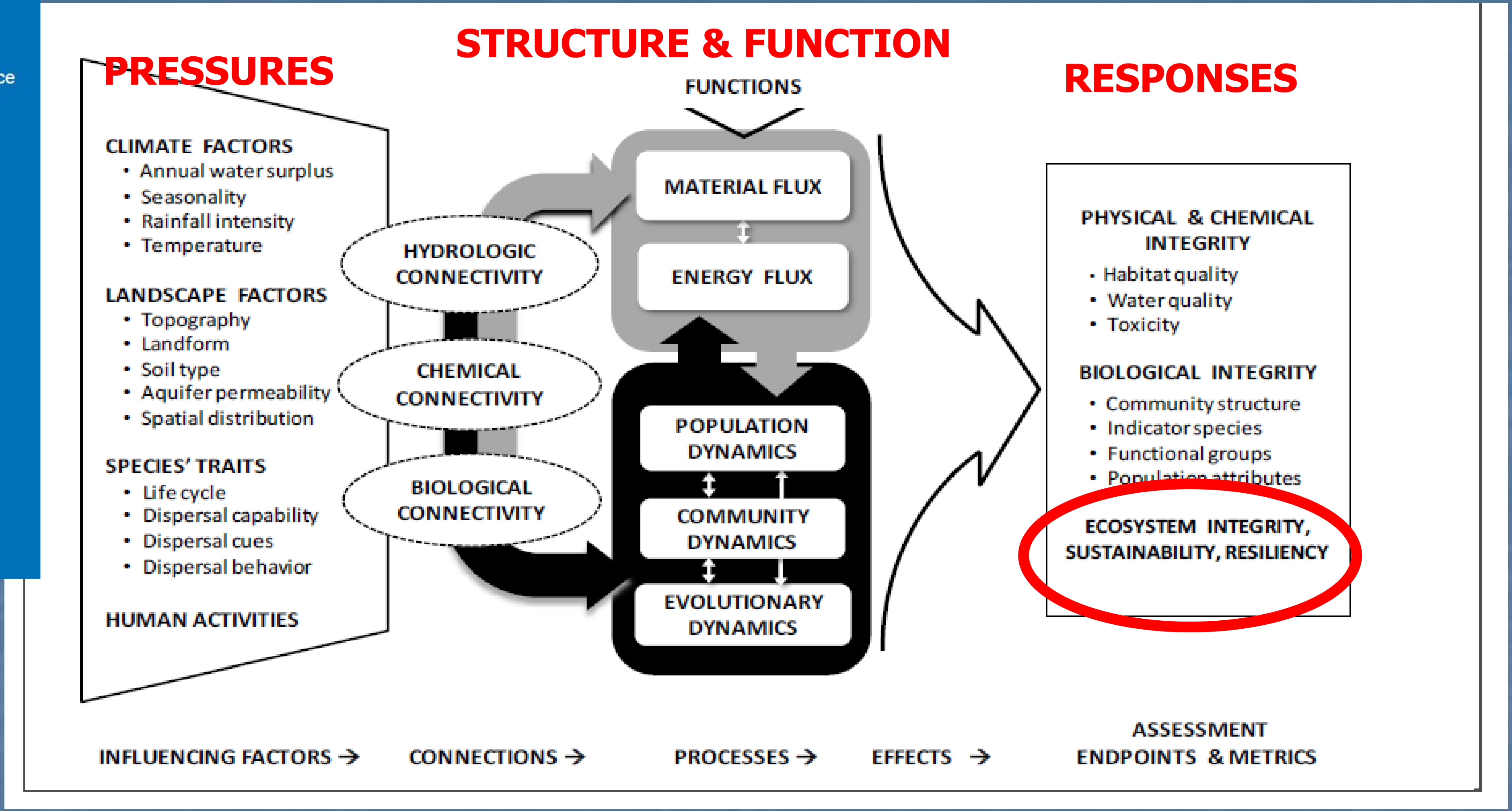
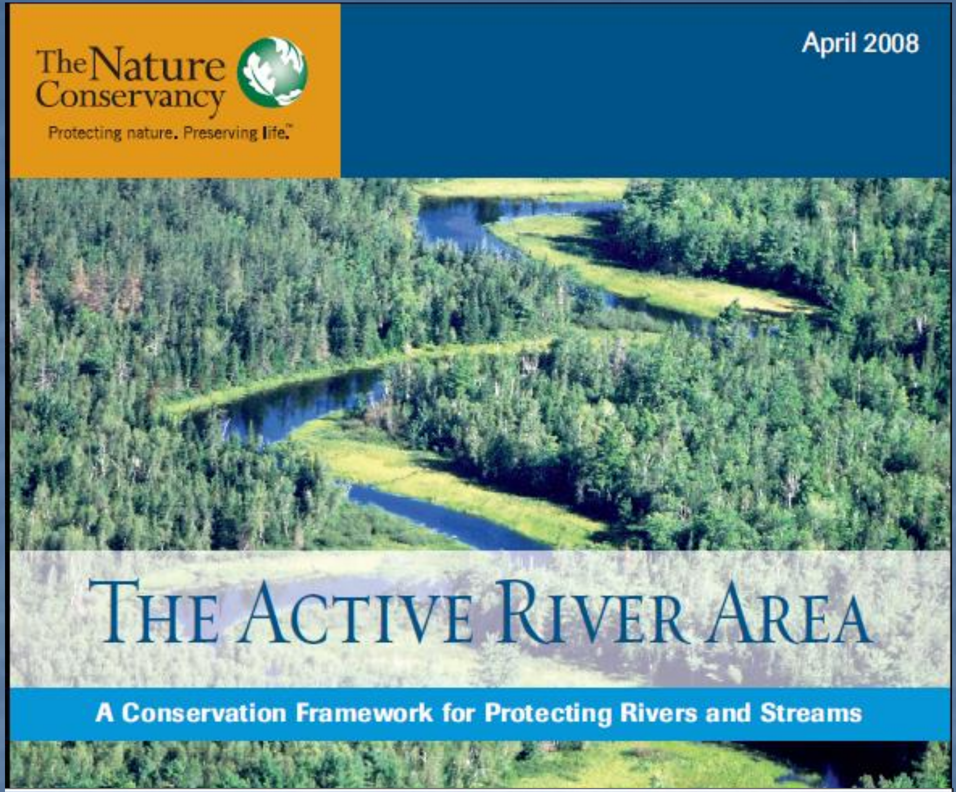
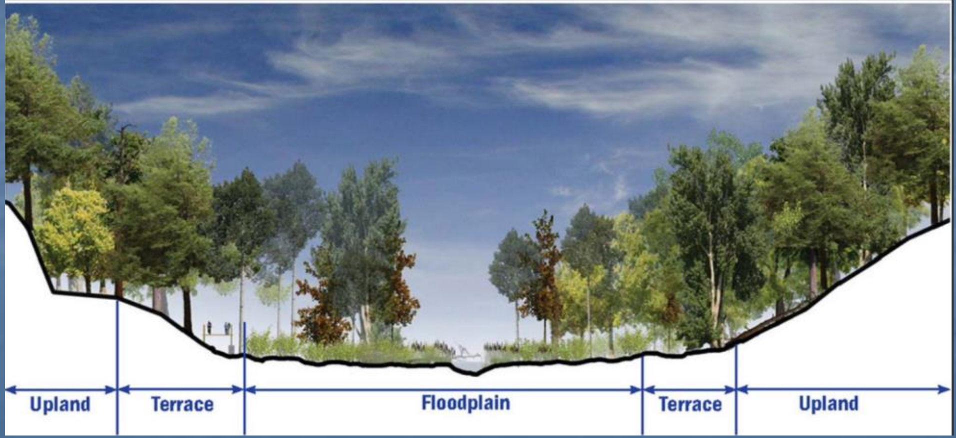


Figure 2-4 Healthy watersheds assessment components


EPA
United States Environmental Protection Agency
EPA/600/R-14/475F | January 2015 | epa.gov/research
Connectivity of Streams & Wetlands to Downstream Waters:
A Review & Synthesis of the Scientific Evidence
Office of Research and Development
NCEA (Washington DC, Cincinnati OH), NERL (Cincinnati OH, Las Vegas NV) and NHEERL (Corvallis OR)


STRUCTURE & FUNCTION
PRESSURES
RESPONSES
FUNCTIONS
CLIMATE FACTORS
• Annual water surplus
• Seasonality
• Rainfall intensity
• Temperature
LANDSCAPE FACTORS
• Topography
• Landform
• Soil type
• Aquifer permeability
• Spatial distribution
SPECIES' TRAITS
• Life cycle
• Dispersal capability
• Dispersal cues
• Dispersal behavior
HUMAN ACTIVITIES
HYDROLOGIC CONNECTIVITY
CHEMICAL CONNECTIVITY
BIOLOGICAL CONNECTIVITY
MATERIAL FLUX
ENERGY FLUX
POPULATION DYNAMICS
COMMUNITY DYNAMICS
EVOLUTIONARY DYNAMICS
PHYSICAL & CHEMICAL INTEGRITY
• Habitat quality
• Water quality
• Toxicity
BIOLOGICAL INTEGRITY
• Community structure
• Indicator species
• Functional groups
• Population attributes
ECOSYSTEM INTEGRITY, SUSTAINABILITY, RESILIENCY
INFLUENCING FACTORS →
CONNECTIONS →
PROCESSES →
EFFECTS →
ASSESSMENT ENDPOINTS & METRICS





What is an Active River Area?

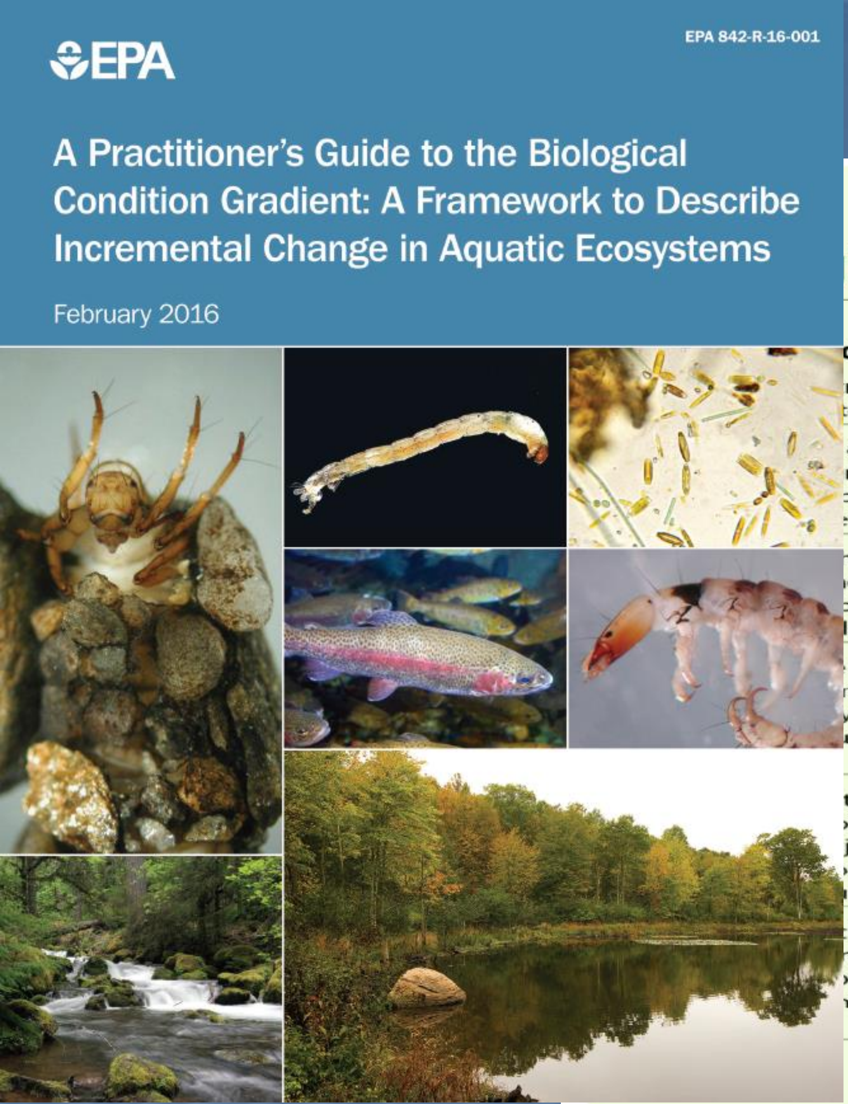
Conserving or restoring stream and river ecosystems requires an approach that *not only focuses on the streams and rivers themselves*, but also *incorporates floodplains and other adjacent upland areas*, and the processes that directly link them.

The Active River Area (ARA) model is a mapping framework. It is *designed to capture the ever-changing nature of streams and rivers by identifying the full range of riparian and floodplain conditions across the landscape.*

ARA mapping results are intended to *support effective freshwater conservation, restoration and management* by ensuring the extent of the *full complement of physical and ecological processes required to maintain freshwater ecological health* is known.

https://storymaps.arcgis.com/stories/87087ecab92f4b36ab47ea7162c59009

The Biological Condition Gradient (BCG)



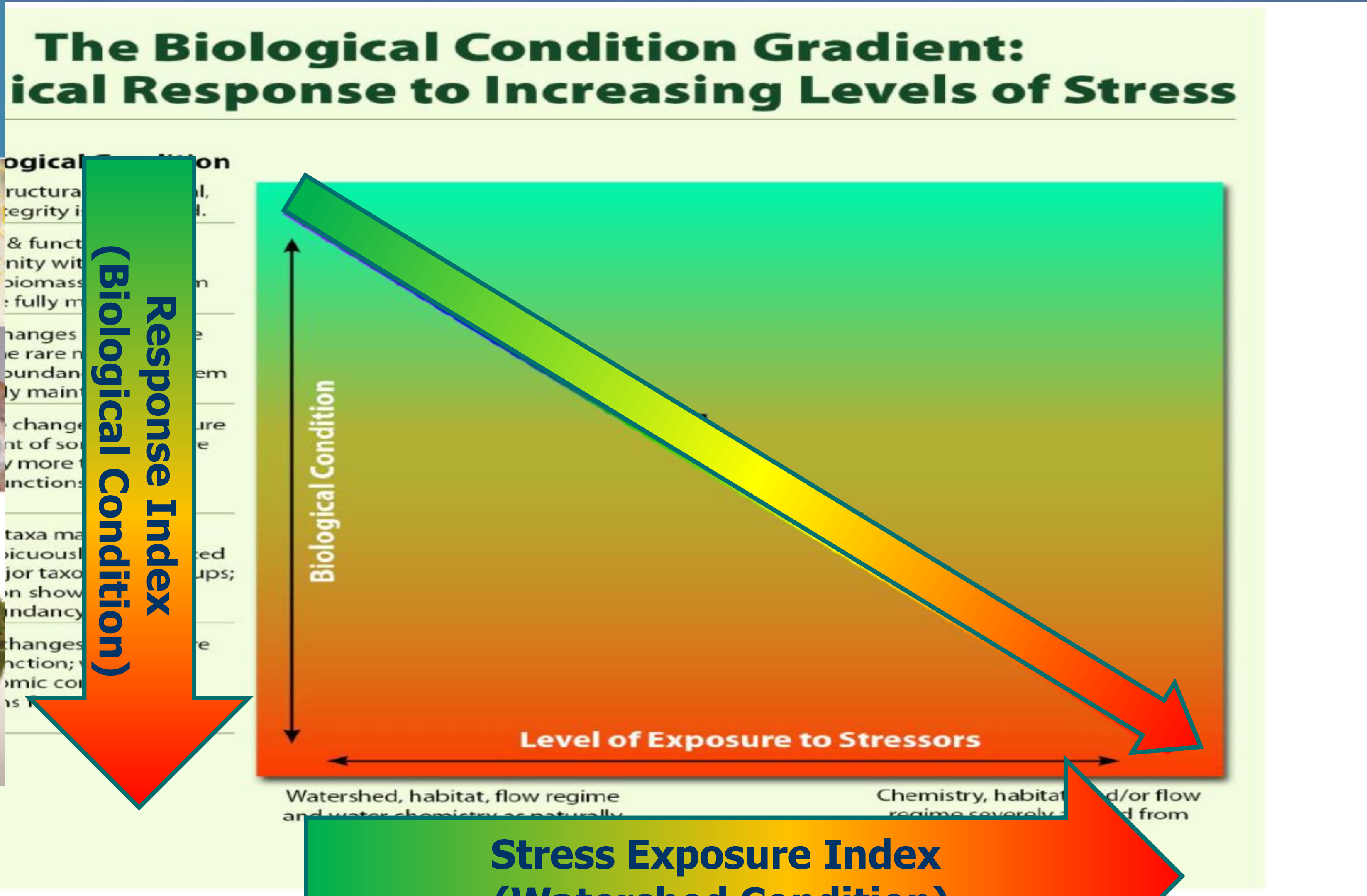


Figure 2. Conceptual model of the BC … their cumulative effects on the biota is likely nonlinear, the relationship is presented as such to ill… ate the concept.

BENCHMARKING

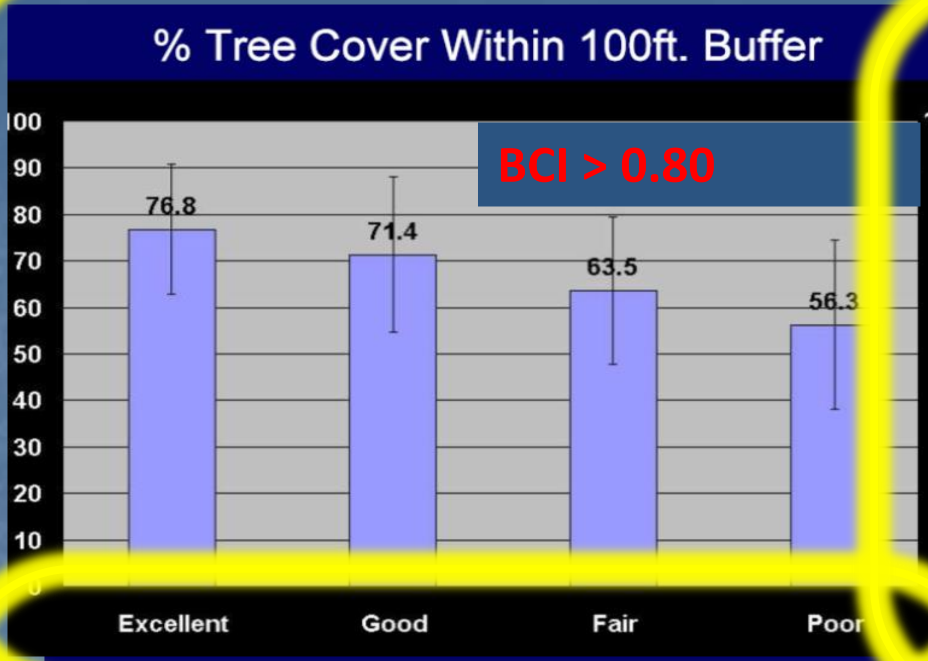
(Goetz et al. 2003)

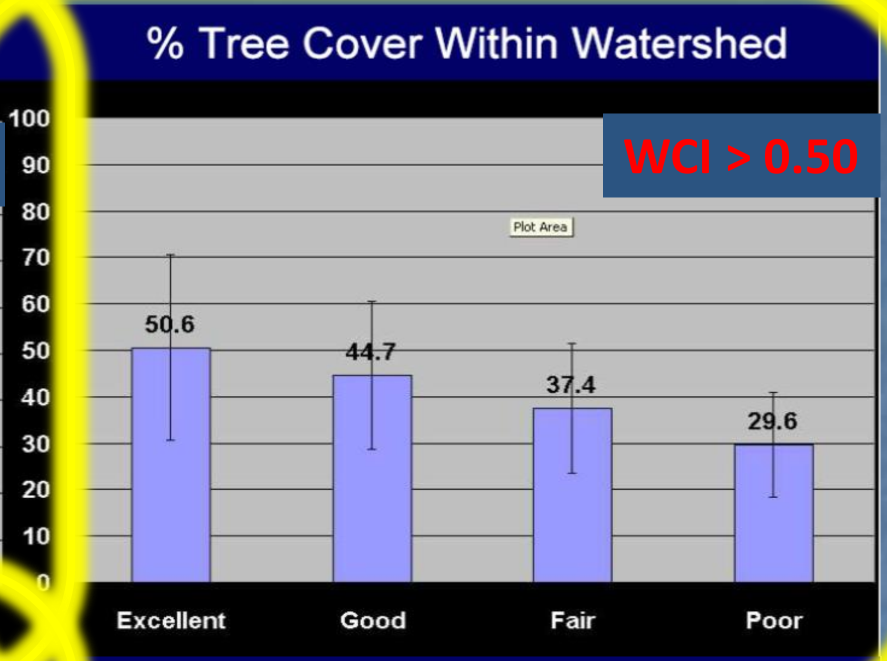
Biointegrity Benchmarks:

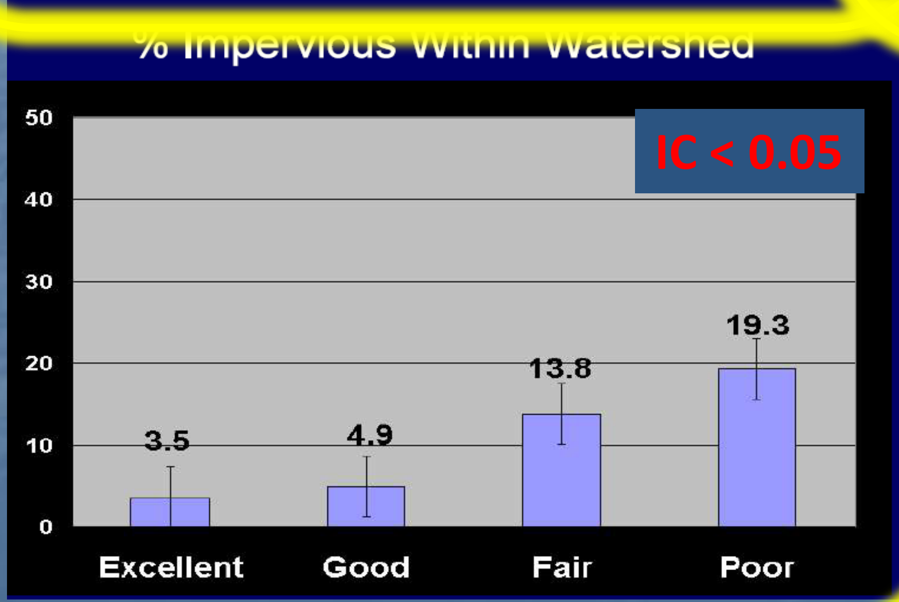
- Buffer Condition
  - >80% Tree Cover

- Watershed Condition
  - >50% Tree Cover

- Impervious Cover
  - <5% Imperv Cover







Across all watersheds there is a significant *decrease* in stream health rating with:

1) more impervious cover

2) fewer trees in buffer

3) less tree cover in watershed

BENCHMARKING

(Goetz et al. 2003)

Biointegrity Benchmarks:

Combined Condition

- **Excellent = <u><</u>6% IC and <u>></u>65% BC**
- **Good = <u><</u>10% IC and <u>></u>60% BC**

Combined Condition Index (CCI_E) = WCI x (1-(WCI-BCI)) = .51 * (1-(.51 - .77)) = 0.64

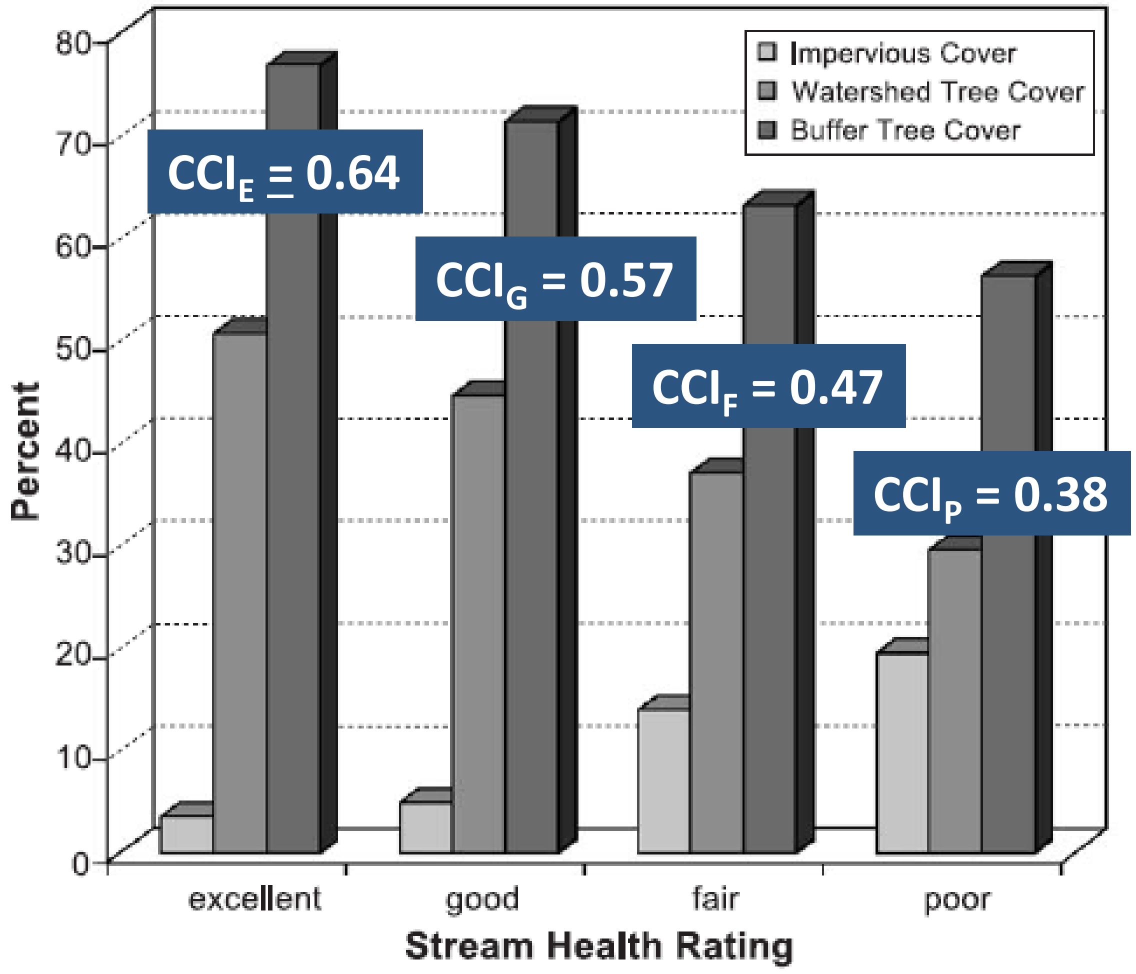
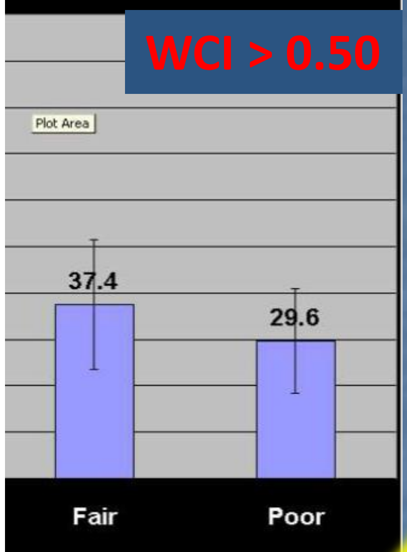


Fig. 7. Stream health rankings in relation to (a) impervious surface cover, (b) watershed tree cover, and (c) riparian buffer tree cover, each derived from the IKONOS image data.

ithin Watershed

WCI > 0.50



sheds there is
ecrease in
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ous cover

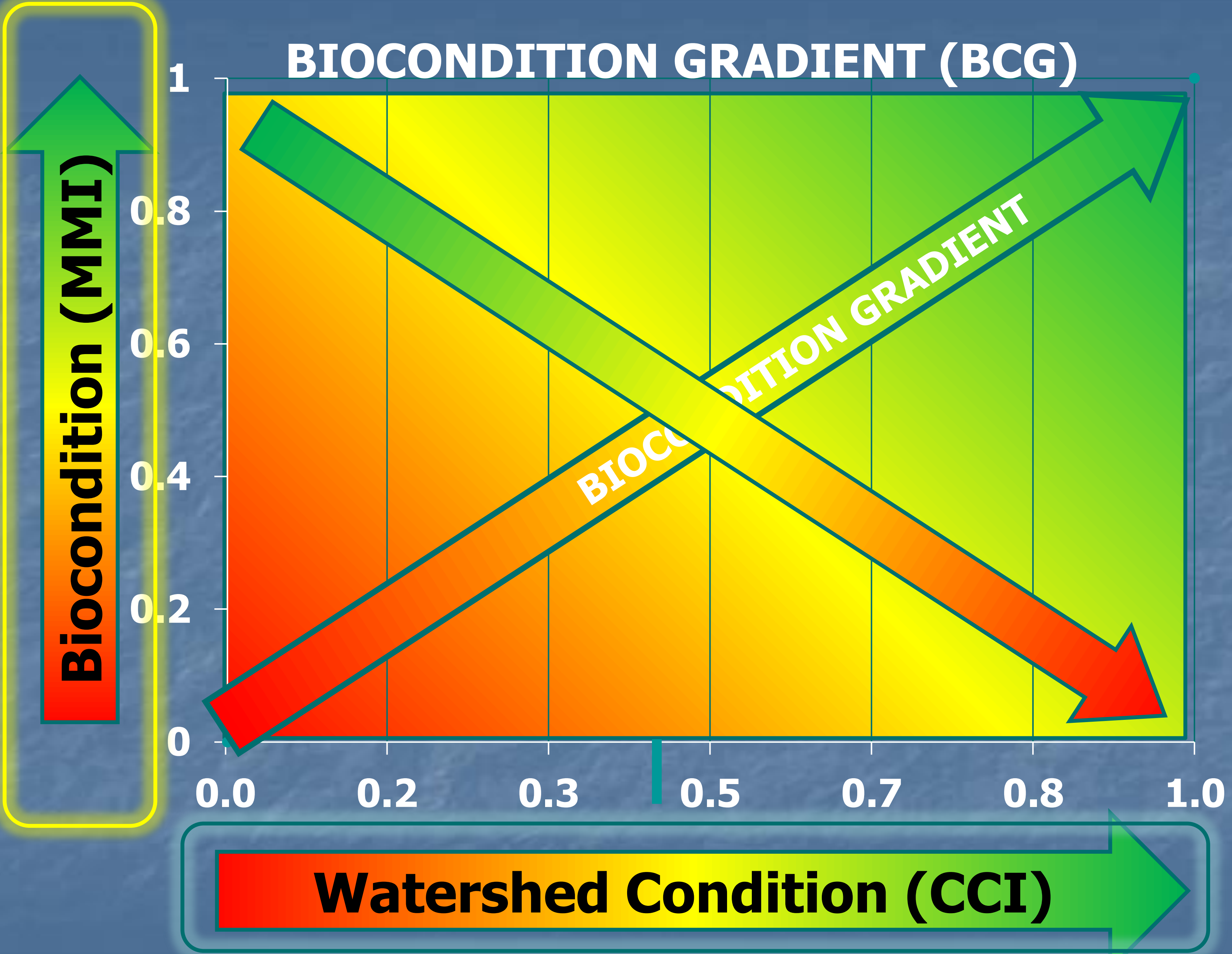
buffer

r in watershed

Ecosystem Approach

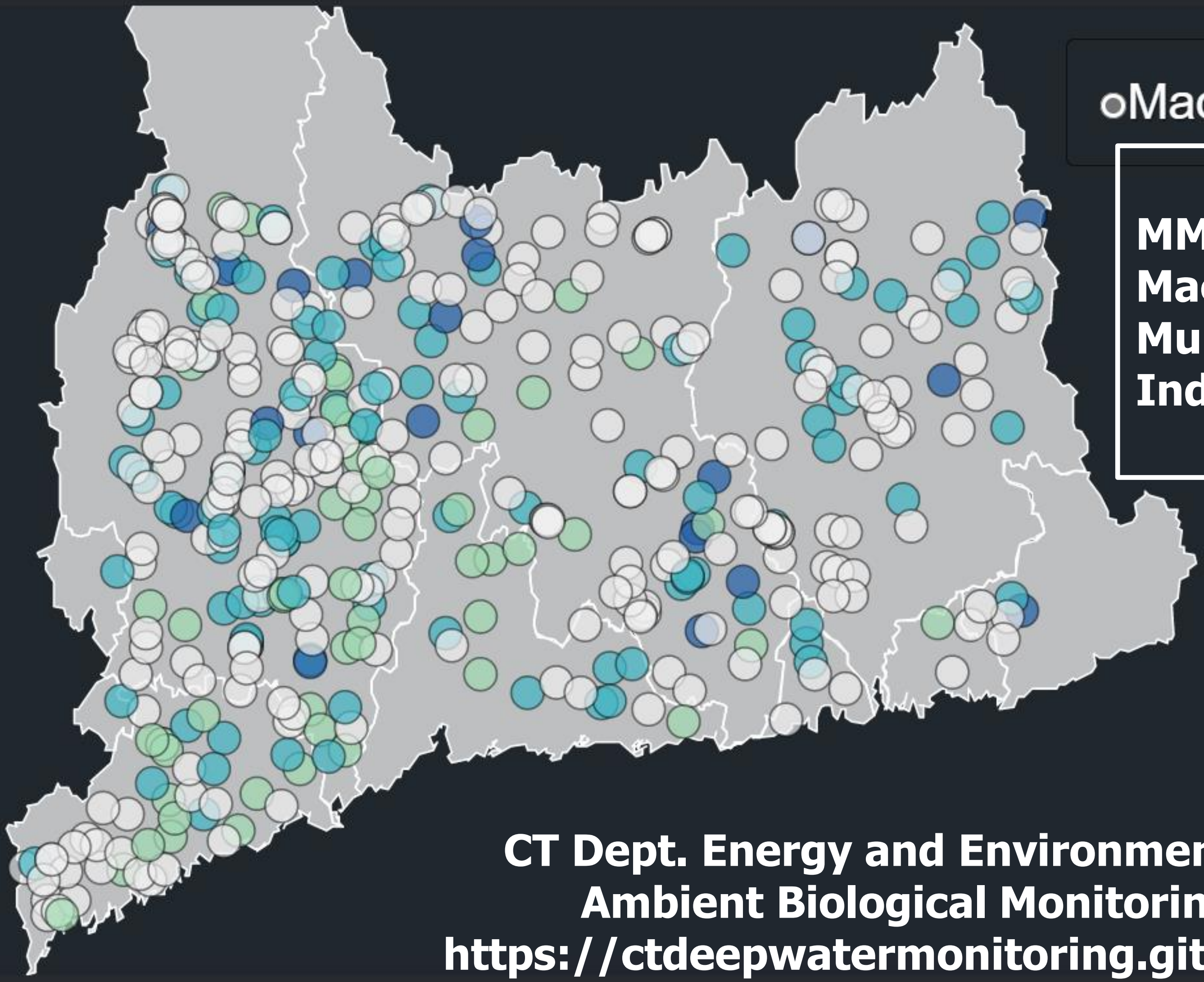
CCI = Combined Watershed Condition Index

MMI = Macroinvertebrate Multimetric Index (Biocondition)



Biological Condition Gradient (BCG) Data 2020 Assessments

BCG Value
- 1 to 2 (Low Stress)
- 3 to 4 (Moderate Stress)
- 5 to 6 (High Stress)
- No data for selected taxa



oMacroinvertebrates

MMI = Macroinvertebrate Multimetric Index

160 Samples

From 144
1st – 3rd Order Streams

CT Dept. Energy and Environmental Protection
Ambient Biological Monitoring Network
https://ctdeepwatermonitoring.github.io/BCGMap/

Model My Watershed

STROUD
WATER RESEARCH CENTER

Analyze Monitor Model

Continental US Medium Resolution 32 km²

Streams Land Soil Terrain Climate Pt Sources Animals Water Qual

Land cover distribution

Land cover distribution

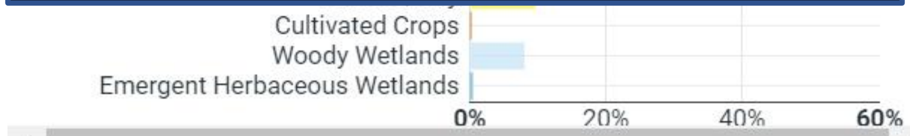
Related Layer: National Land Cover Database ✖ Turn off

Source: National Land Cover Database (NLCD 2011)

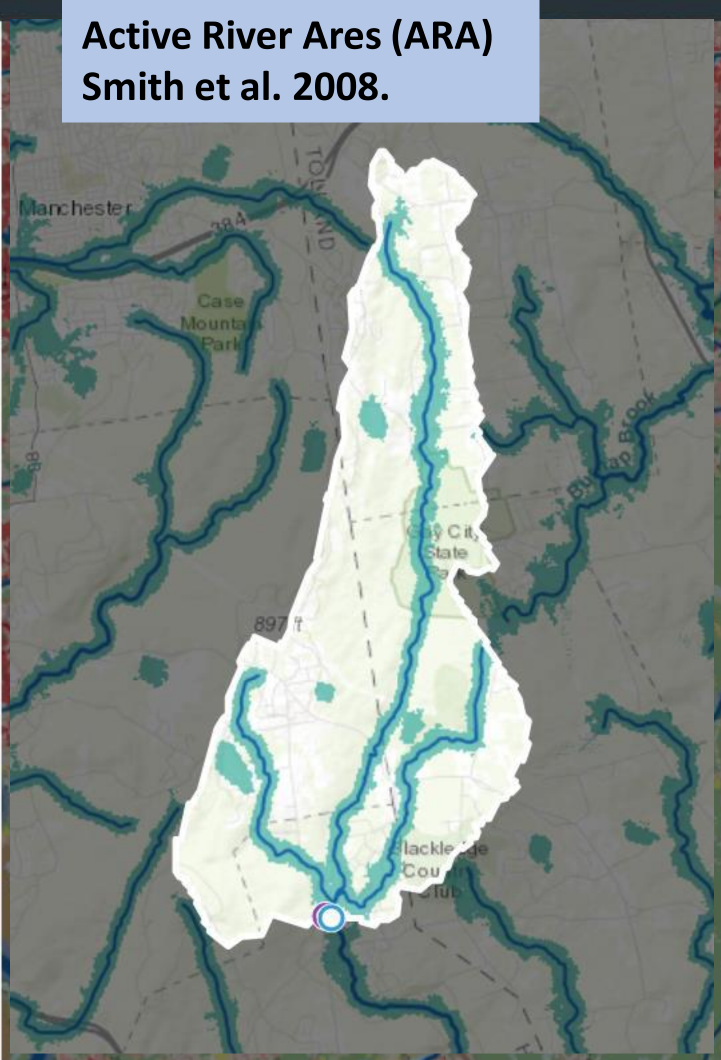
Combined Condition Index (CCI)

CCI =

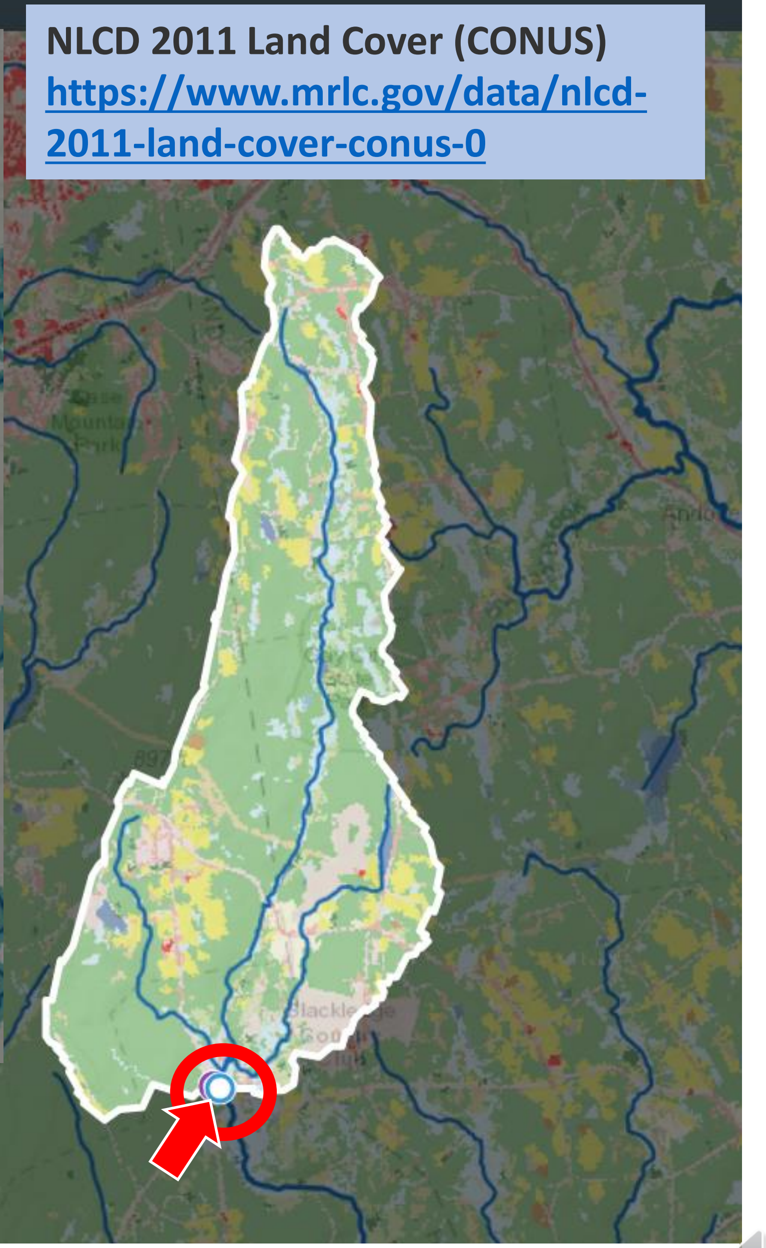
WCI x (1-(WCI-BCI))



Active River Ares (ARA)
Smith et al. 2008.



NLCD 2011 Land Cover (CONUS)
https://www.mrlc.gov/data/nlcd-2011-land-cover-conus-0

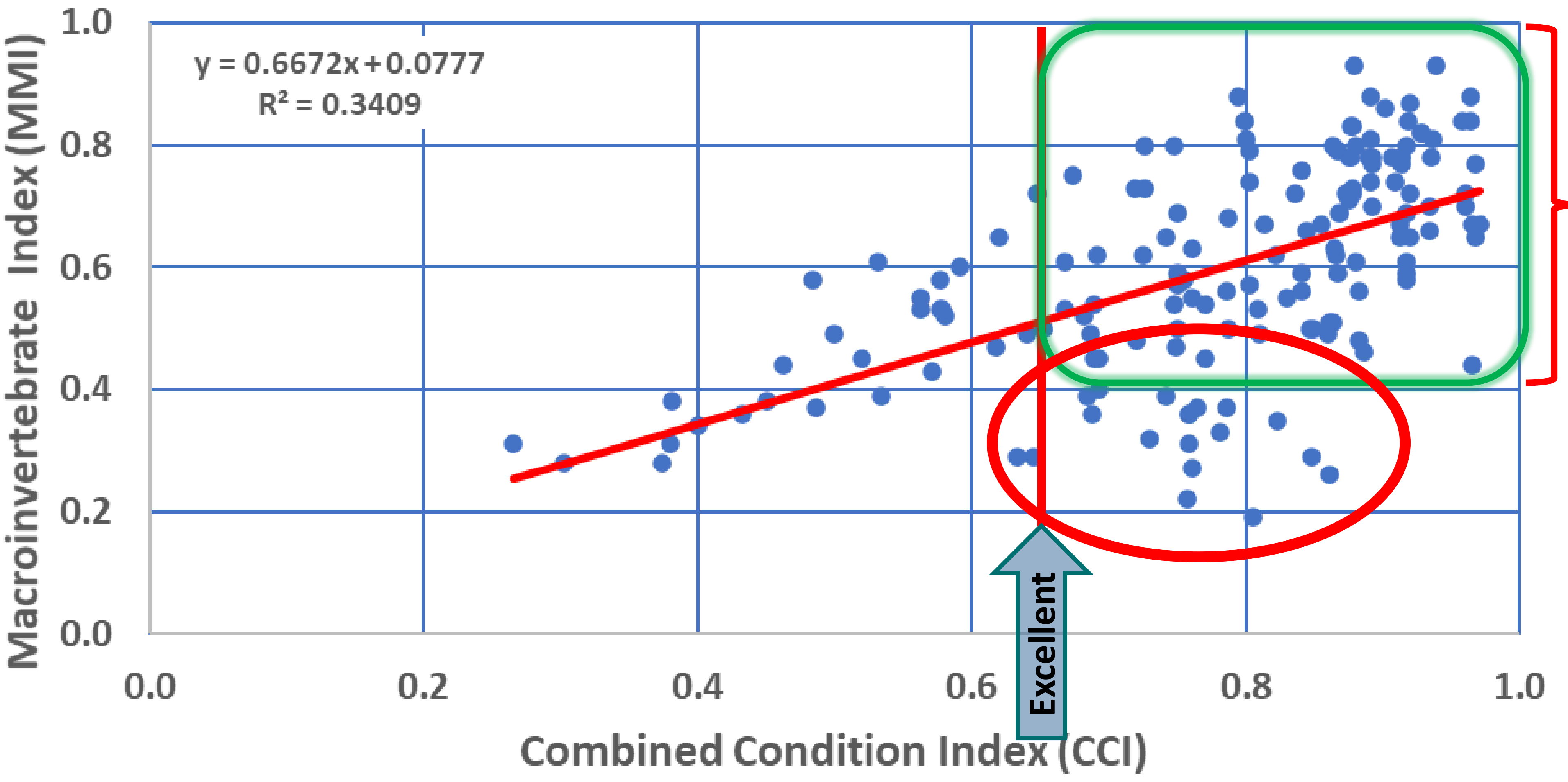


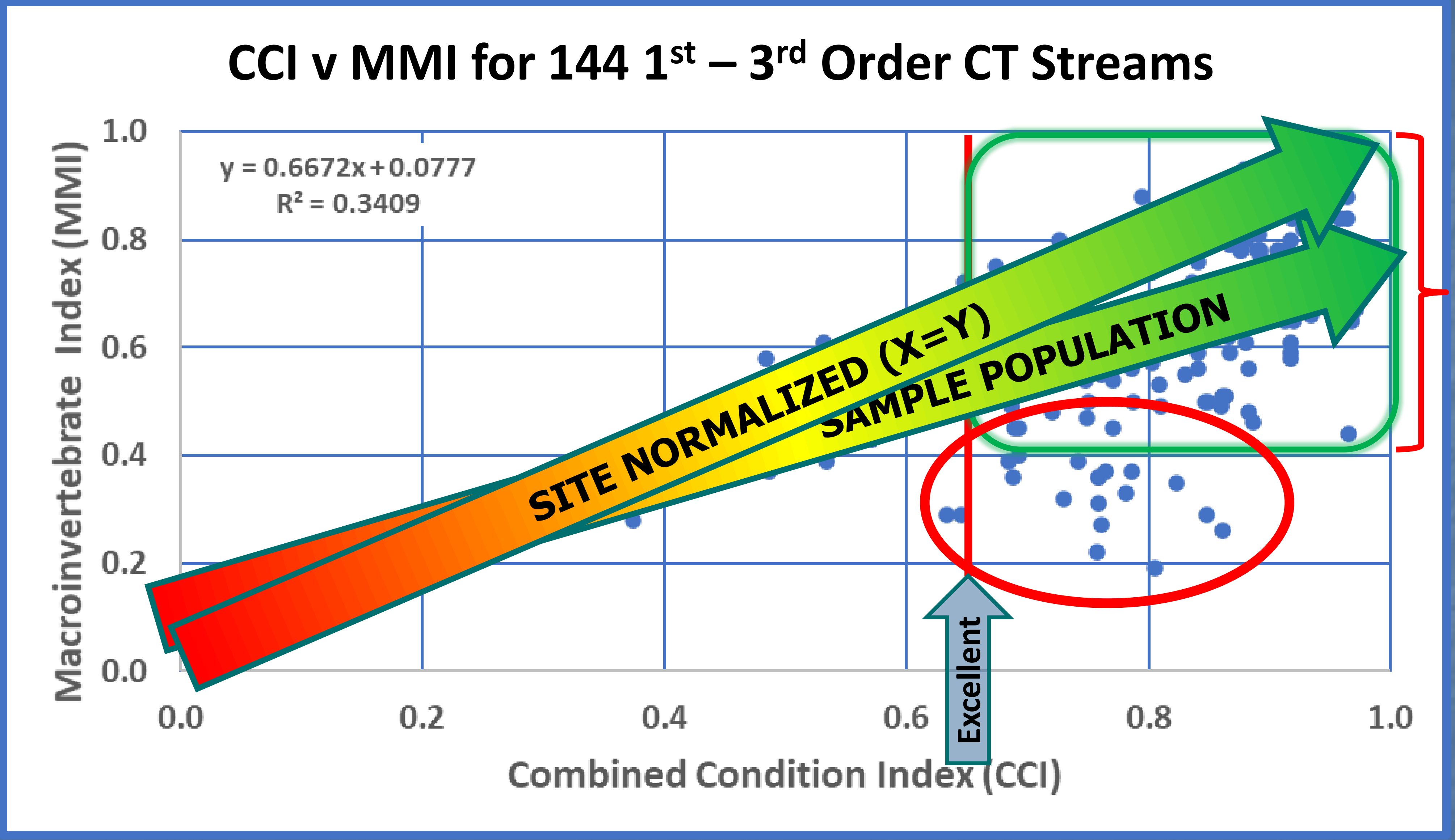
Layers

Note: ARA w/ variable buffer widths used for BCI

https://modelmywatershed.org/

CCI v MMI for 144 1st – 3rd Order CT Streams




CCI v MMI for 144 1st – 3rd Order CT Streams
y = 0.6672x + 0.0777
R² = 0.3409
Macroinvertebrate Index (MMI)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Combined Condition Index (CCI)
SITE NORMALIZED (X=Y)
SAMPLE POPULATION
Excellent

Benchmarking

(Goetz et al. 2003)

***CCI* = Combined Condition Index**

***MMI* = Macroinvertebrate Multimetric Index (Biocondition)**

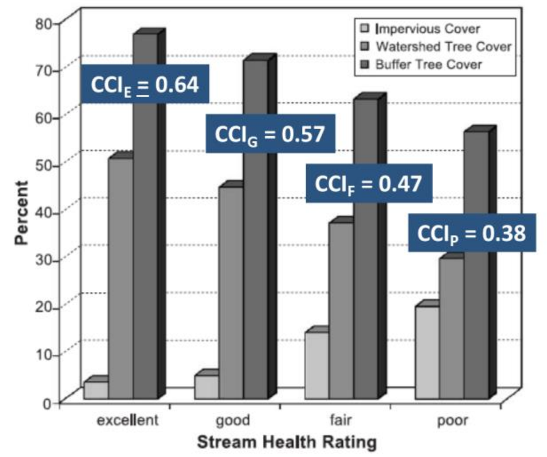
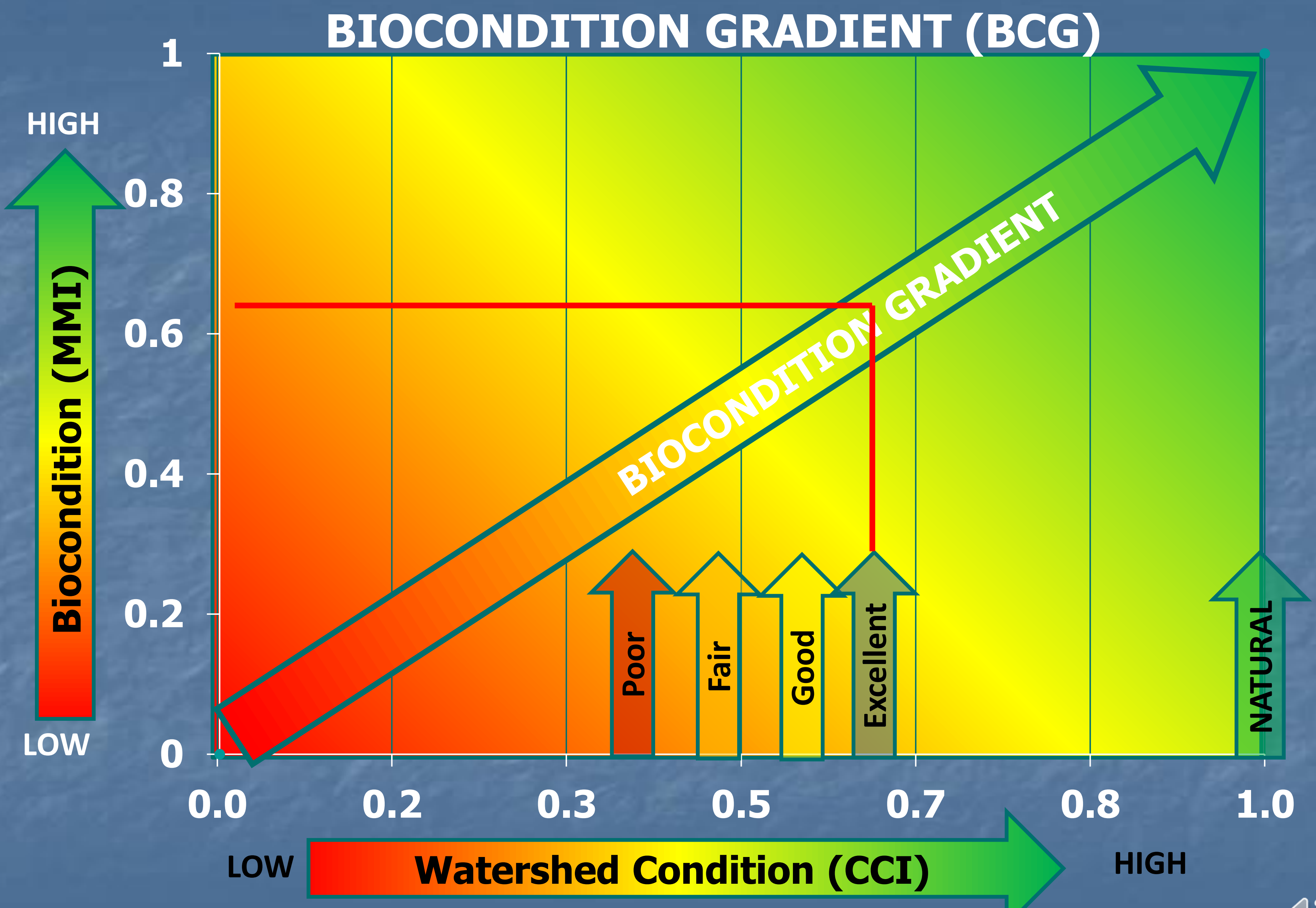
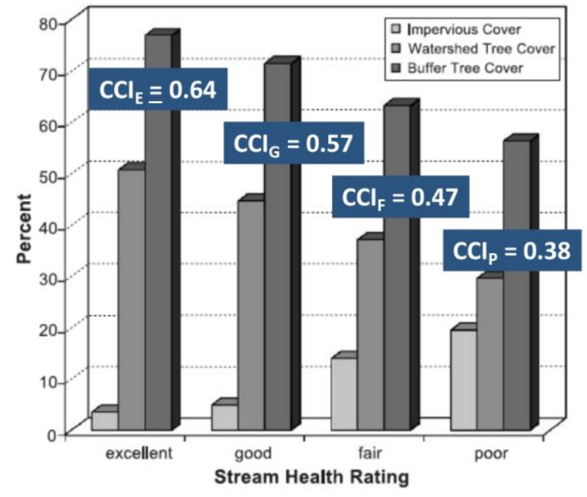


Fig. 7. Stream health rankings in relation to (a) impervious surface cover, (b) watershed tree cover, and (c) riparian buffer tree cover, each derived from the IKONOS image data.



Benchmarking
(Goetz et al. 2003)



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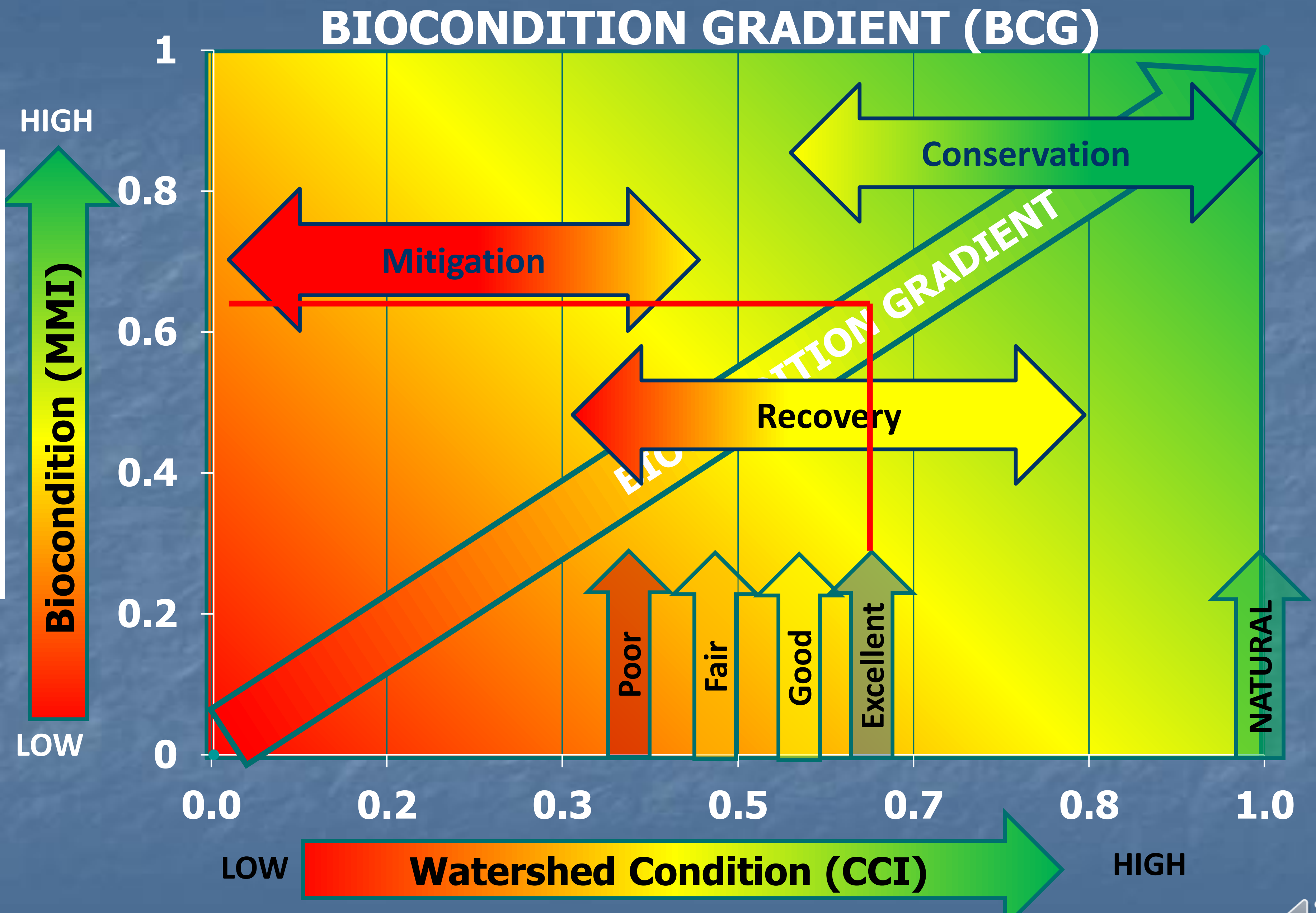


*After Bellucci, Beauchene and Becker (2008) *Streams of Hope* concept.

Decision Support for Watershed Management

Station_Name	Watershed Area (acres)	Watershed Natural Area (acres)	Watershed Natural Area Fraction (WCI)	Buffer Natural Area Fraction (BCI)	Combined Condition Index (CCI)	Monitored MMI	Linear MMI	Management Emphasis
Harbor Brook	7578	2011	0.26	0.28	0.27	0.31	0.20	Mitigate
Trout Brook	8534	3132	0.35	0.44	0.38	0.31	0.29	Mitigate
Spoonshop Brook	2016	823	0.43	0.36	0.40	0.34	0.31	Mitigate
Muddy River	11488	5903	0.47	0.61	0.53	0.39	0.41	Recovery/Conservation
Coginchaug River	24549	15358	0.61		0.64	0.29	0.49	Investigate
Tankerhoosen River	5896	4090	0.68	0.75	0.73	0.73	0.55	Recovery/Conservation
Bunnell Brook	2613	1870	0.69	0.85	0.80	0.79	0.61	Recovery/Conservation
Latimer Brook	10347	8694	0.83		0.85	0.50	0.65	Investigate
Green Fall River	4777	4448	0.93	0.93	0.93	0.82	0.71	Conservation
Freeman Hill Brook	1181	1102	0.93	0.94	0.94	0.81	0.72	Conservation
Shady Oak School Brook	479	445	0.90		0.97	0.44	0.74	Investigate

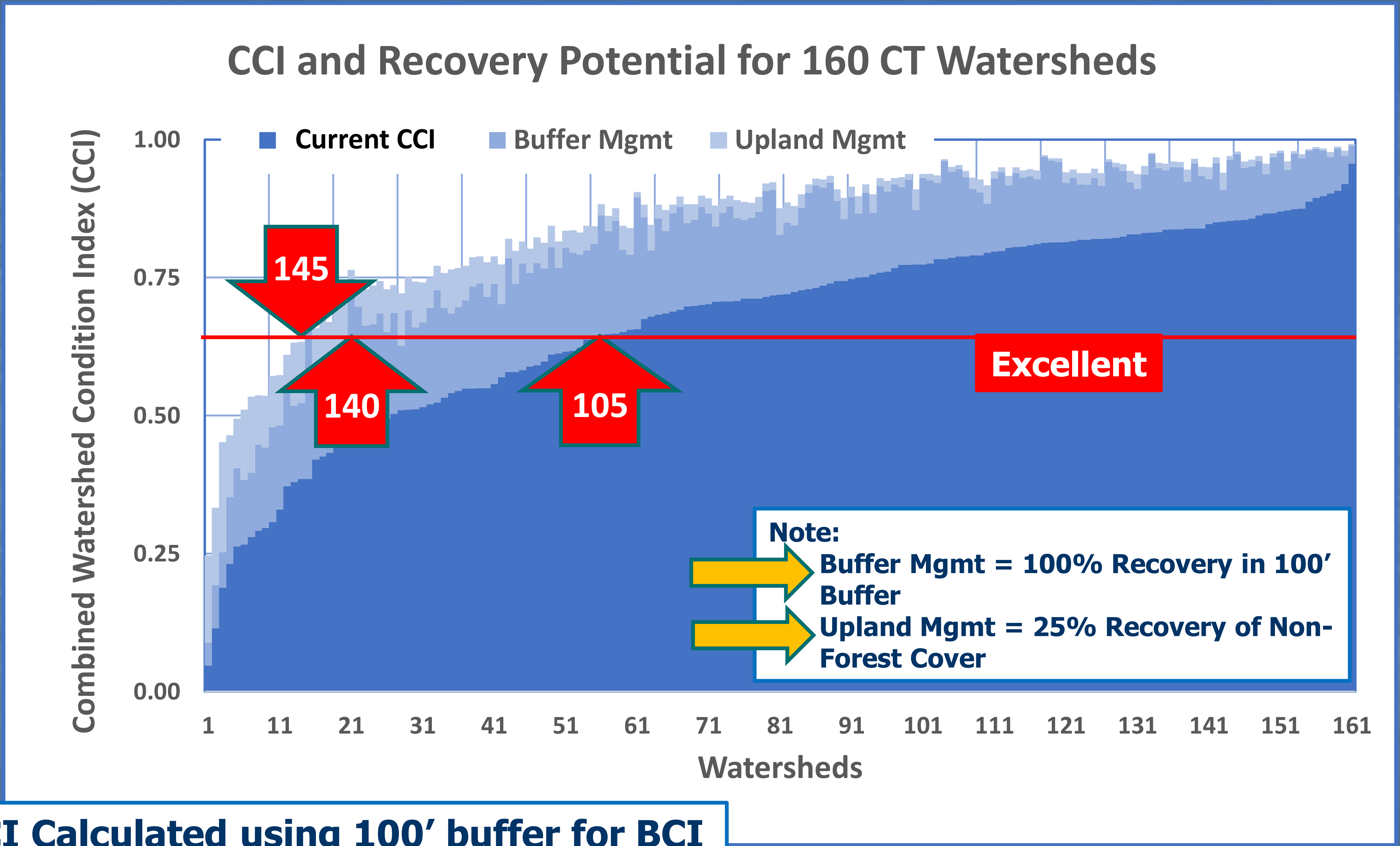
UConn CLEAR | Connecticut's Changing

https://clear3.uconn.edu/viewers/ctstory/

Connecticut's Changing Landscape
a study of land cover change in Connecticut, 1985-2010

UCONN | College of Agriculture and Natural Resources
Center for Land Use Education and Research | CLEAR

160 Coastal Sub-Regional Watersheds

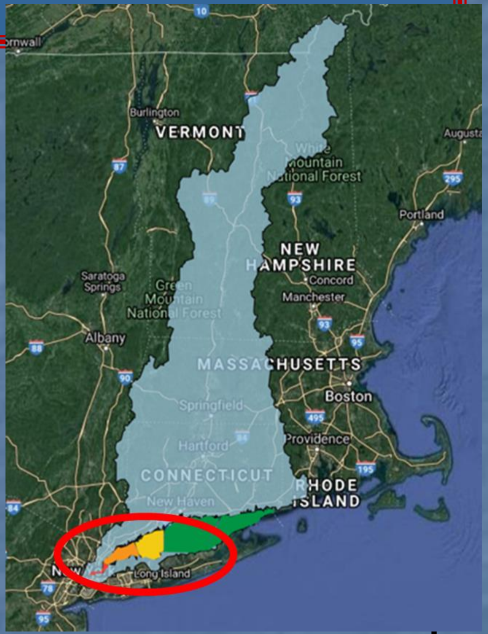


Note: CCI Calculated using 100’ buffer for BCI

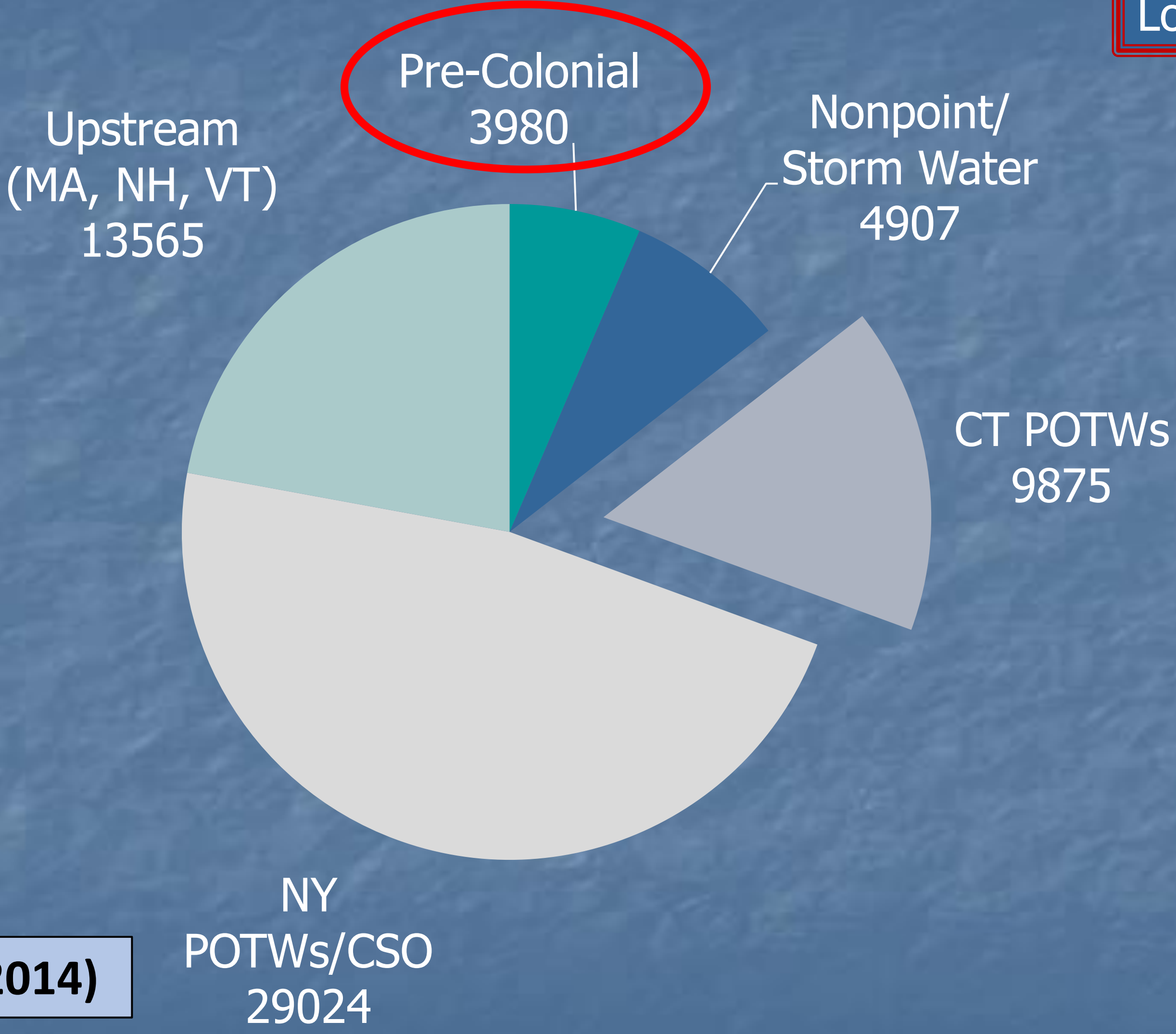
Baseline Load =
61,351 tons N/Year

58.5% Reduction =
24,570 tons N/Year

TMDL Load =
36,781 tons N/Year



Nitrogen Loads (Tons N/Year) by Source
Delivered to Long Island Sound

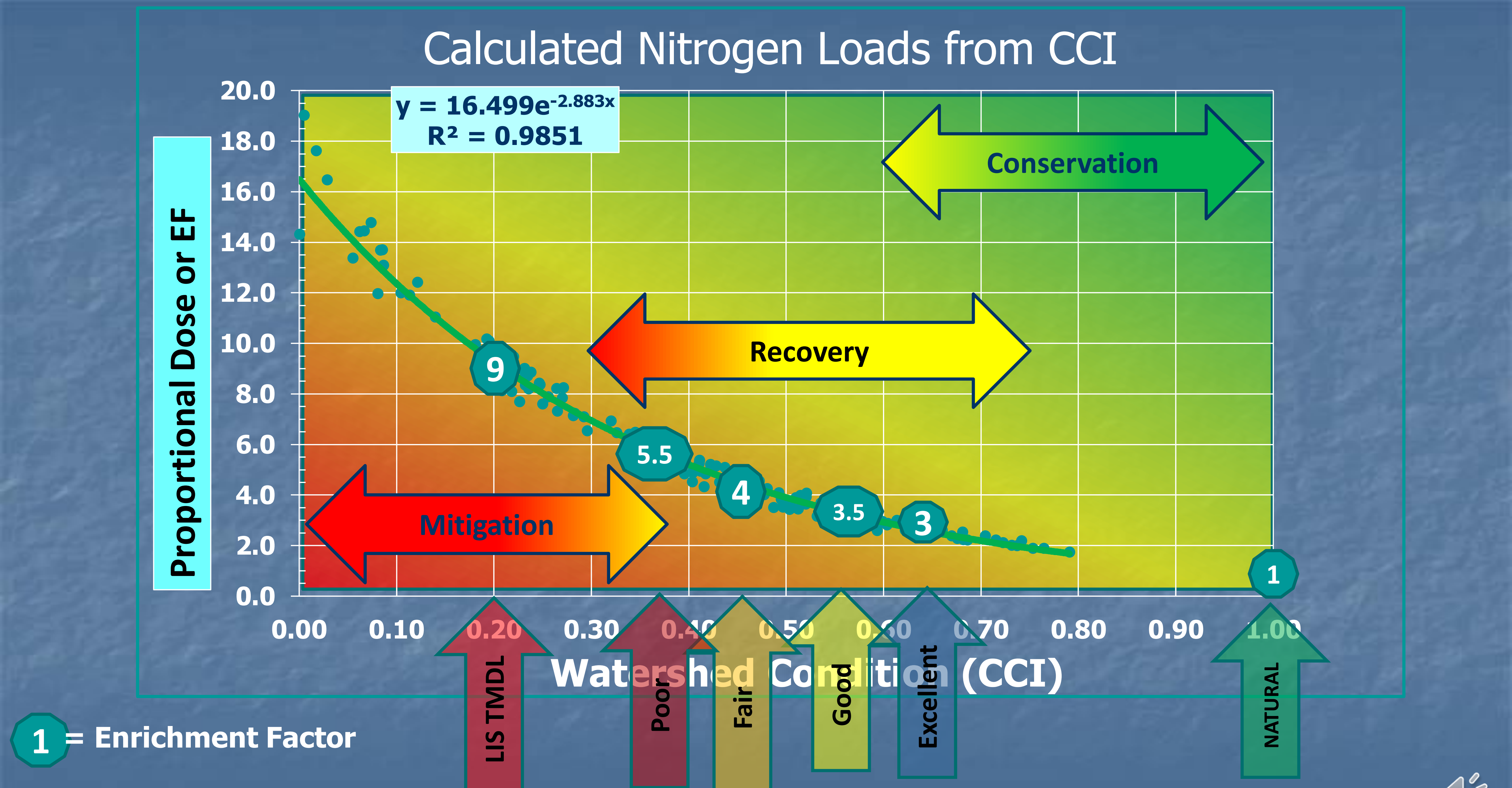


Enrichment Factor =
Load/Natural Load

<u>Baseline</u>
Enrichment Factor =
Total Load/
Pre-Colonial Load =
~ 15!

<u>TMDL</u>
Enrichment Factor=
TMDL Load/
Pre-Colonial Load =
~ 9!

EF = Enrichment Factor (Becker, 2014)



Calculated Nitrogen Loads from CCI
$y = 16.499e^{-2.883x}$
$R^2 = 0.9851$
Proportional Dose or EF
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Watershed Condition (CCI)
Conservation
Recovery
Mitigation
9
5.5
4
3.5
3
1
LIS TMDL
Poor
Fair
Good
Excellent
NATURAL
1 = Enrichment Factor

CT Subregional Watershed Total Nitrogen Loading and Attainment

Subregional WS Data	Condition Indices		TN Loading					
Watershed Name	Combined Watershed Condition Index (CCI)	Combined Recovery Condition Index (CCI_R)	TMDL Target (tons/yr) (EF = 4)	Current Watershed Load (tons/yr)	Point Source Load (tons/yr)	Currently Under/Over TMDL Target	Best Attainable Condition (tons/yr)	BAC Under/Over TMDL Target
YELLOW MILL CHANNEL	0.23	0.54	6	12	0	7	5	-1
WINTERGREEN BROOK	0.43	0.73	13	16	0	3	7	-6
WILLOW BROOK	0.55	0.80	13	12	0	-2	5	-8
SILVERMINE RIVER	0.64	0.86	28	19	0	-9	10	-18
LITTLE RIVER	0.72	0.94	19	10	0	-9	6	-14
COPPS BROOK	0.80	0.94	9	4	0	-5	3	-7
DICKINSON CREEK	0.86	0.98	19	7	0	-12	5	-14
EIGHTMILE RIVER	0.90	0.99	39	13	0	-27	10	-30

CT Subregional Watershed Total Nitrogen Loading and Attainment

Subregional WS Data	Condition Indices		TN Loading					
Watershed Name	Combined Watershed Condition Index (CCI)	Combined Recovery Condition Index (CCI_R)	TMDL Target (tons/yr) (EF = 4)	Current Watershed Load (tons/yr)	Point Source Load (tons/yr)	Currently Under/Over TMDL Target	Best Attainable Condition (tons/yr)	BAC Under/Over TMDL Target
YELLOW MILL CHANNEL	0.23	0.54	6	12	3	10	5	2
WINTERGREEN BROOK	0.43	0.73	13	16	3	6	7	-3
WILLOW BROOK	0.55	0.80	13	12	3	1	5	-5
SILVERMINE RIVER	0.64	0.86	28	19	3	-6	10	-15
LITTLE RIVER	0.72	0.94	19	10	3	-6	6	-11
COPPS BROOK	0.80	0.94	9	4	3	-2	3	-4
DICKINSON CREEK	0.86	0.98	19	7	3	-9	5	-11
EIGHTMILE RIVER	0.90	0.99	39	13	3	-24	10	-27

CT Subregional Watershed Total Nitrogen Loading and Attainment

Subregional WS Data	Condition Indices		TN Loading					
Watershed Name	Combined Watershed Condition Index (CCI)	Combined Recovery Condition Index (CCIR)	TMDL Target (tons/yr) (EF = 4)	Current Watershed Load (tons/yr)	Point Source Load (tons/yr)	Currently Under/Over TMDL Target	Best Attainable Condition (tons/yr)	BAC Under/Over TMDL Target
YELLOW MILL CHANNEL	0.23	0.54	6	12	10	17	5	9
WINTERGREEN BROOK	0.43	0.73	13	16	10	13	7	4
WILLOW BROOK	0.55	0.80	13	12	10	8	5	2
SILVERMINE RIVER	0.64	0.86	28	19	10	1	10	-8
LITTLE RIVER	0.72	0.94	19	10	10	1	6	-4
COPPS BROOK	0.80	0.94	9	4	10	5	3	3
DICKINSON CREEK	0.86	0.98	19	7	10	-2	5	-4
EIGHTMILE RIVER	0.90	0.99	39	13	10	-17	10	-20

In Summary:

Making Nature Great Again

(*Occam's Razor* – the rationality of simple explanations)

A Viable Method!

- Decision Support for:
  - Assessment
  - Management Planning
  - Biointegrity Endpoints
  - WS Condition Targets
  - Buffer Sizing
  - Recovery Potential
  - Nutrient Targets and TMDLs

In an Ecosystem Context!

An Ecosystem Application!

- Natural Recovery is:
  - Functional
  - Adaptive
  - Transitional
  - Resilient
  - Low Cost
  - Aimed at Well-being Outcomes

In a Changing World!

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FRIENDS AND SUPPORTERS

Thank you!

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Long Island Sound Study
A Partnership to Restore and Protect the Sound

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