Pitfalls and Opportunities with Integrating Dissimilar Indicators to Assess Condition

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CALIFORNIA AQUATIC BIOASSESSMENT WORKGROUP

Special Session on Multi-Indicator Integration

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Iara Lacher, Susana Cardenas, & David Waetjen (UC Davis)

with

Abdul Khan, Rich Juricich, & Kamyar Guivetchi (DWR)

Vance Fong & Don Hodge (USEPA)

Council for Watershed Health & SAWPA

Pacific Institute, Sacramento River Watershed Program, Sacramento Regional County Sanitation District, Napa County, and South Yuba River Citizens League

http://indicators.ucdavis.edu

Examining Aquatic Indicators in Watershed Condition/Function Assessment

(*Beyond IBIs*)

CABW, 2007

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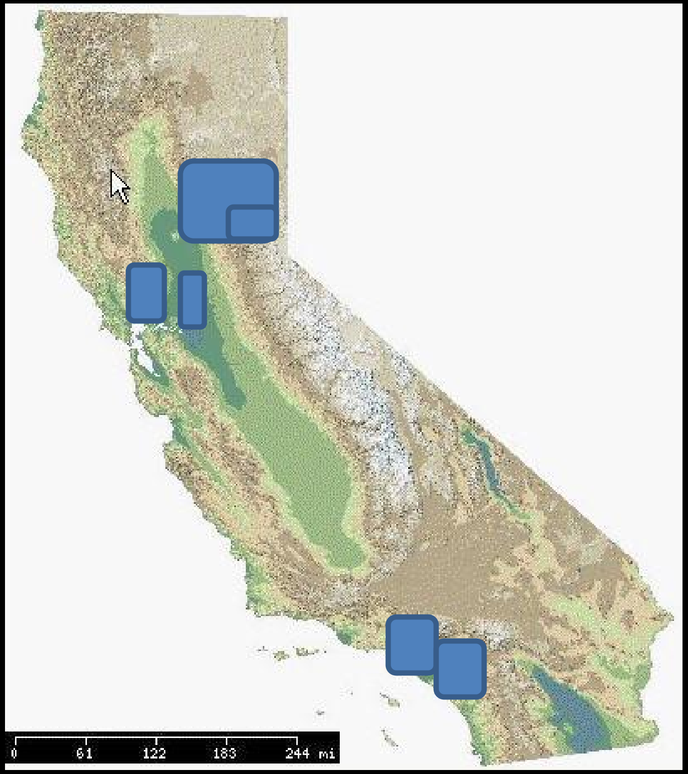
Definitions

- Metrics– things we can measure in “the wild”
- Indicators – often composed of metrics, things we can evaluate around us that can tell us a story about components of a natural or human system
- Performance Measures – similar to indicators, except often confined to management actions and other intentional human actions
- Index – an aggregation of indicators that convey a more complete story about a system

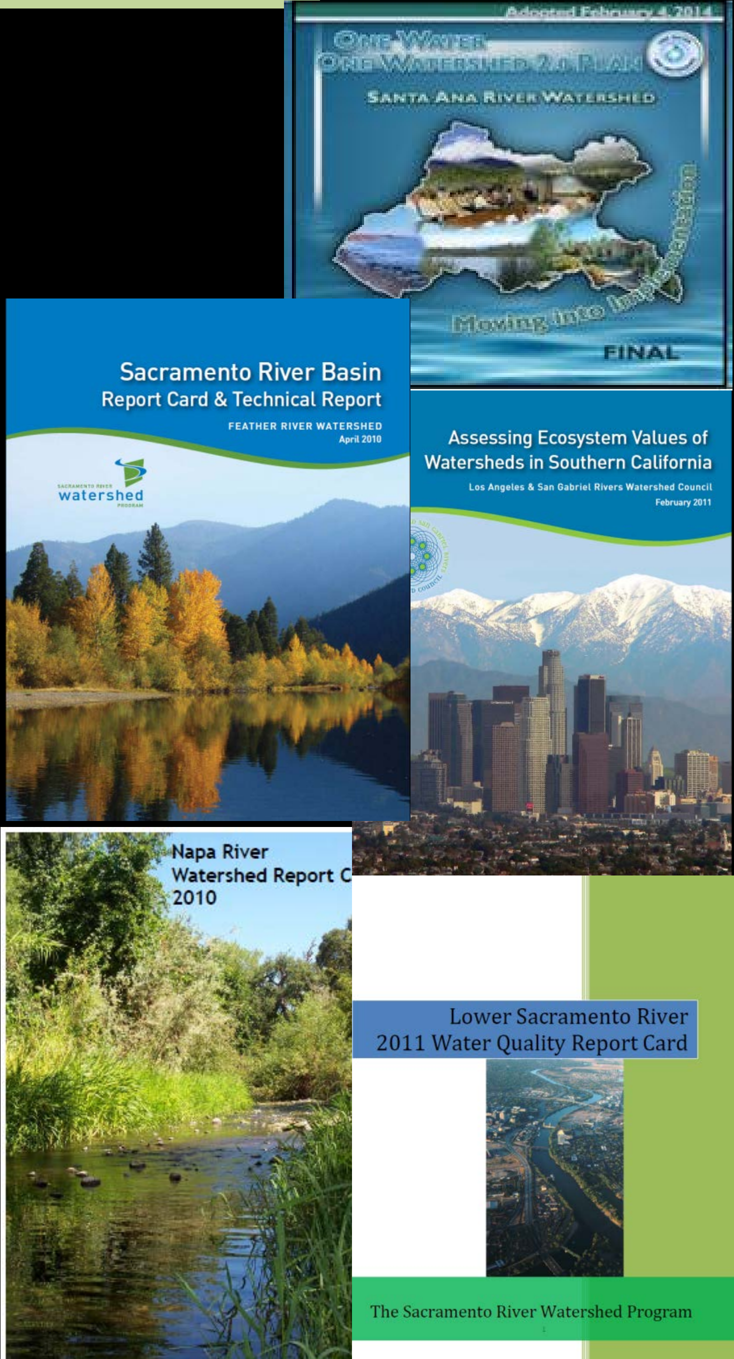
My Previous Work with Sustainability Indicators

- Measuring whole system condition and performance
- Consistent with global literature, while breaking new ground

- Test cases in Lower Sacramento River and Yuba River, Feather River, Napa River, Los Angeles River, Santa Ana River Watersheds + state-scale test (2001-2013)



Report Cards

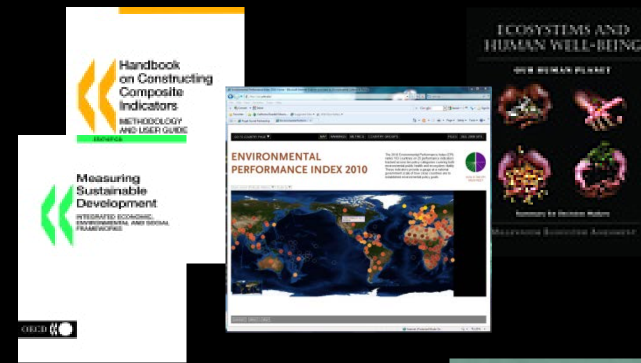


Goals	Icon	Objectives
A. Maintain and improve water quality and supply to sustainably meet the needs of natural and human communities		1) Protect receiving waters from pollution to comply with current and future water quality regulations
		2) Maintain water quality for healthy aquatic systems*
		3) Protect the quality of drinking water supplies
		4) Maintain and restore natural stream flows for aquatic and riparian communities*
		5) Maintain water supplies to meet human needs within the watershed
B. Protect and enhance native aquatic and terrestrial species, especially sensitive and at-risk species and natural communities		1) Protect and enhance native fish populations, including anadromous fish*
		2) Protect and enhance bird populations
		3) Protect and enhance amphibian populations
		4) Protect and enhance mammal populations*
		5) Protect and enhance native invertebrate communities*
		6) Discourage and reduce invasive, non-native species
C. Protect and enhance landscape and habitats structure and processes to benefit ecosystem and watershed functions		1) Protect and enhance riparian habitat quality
		2) Protect and enhance wetland habitat quality
		3) Protect and enhance aquatic habitat connectivity*
		4) Protect and enhance terrestrial habitat connectivity*
		5) Maintain and restore stream geomorphic processes
		6) Optimize primary production and nutrient cycling to support aquatic and terrestrial communities* (for N)
		7) Manage land-uses to reduce impacts on aquatic and terrestrial habitats
D. Maintain and restore natural disturbance processes that balance benefits for natural and human communities		1) Reduce high severity fire frequency; encourage natural fire regimes that support native communities*
		2) Reduce flood risk to human communities; encourage natural flood processes that support native communities*
		3) Reduce greenhouse gas emissions and encourage activities to adapt to climate change
E. Maintain and improve the social and economic conditions, including benefits from healthy watersheds		1) Protect and enhance wildlife friendly agricultural practices*
		2) Improve grazing management
		3) Encourage sustainable land use practices
		4) Improve community economic status in balance with watershed condition*
		5) Improve community relationship with watershed processes
		6) The watershed supports sustainable social practices
		7) Support and improve human uses associated with watershed condition*
		8) To have widespread community awareness and deep civic engagement in the protection and improvement of watersheds*

What are indicators and how are they used?

World

United Nations Environment Programme (2006)
Millenium Ecosystem Assessment (2005)
Environmental Performance Index (2010)
NOAA Arctic Report Card (2010)
New Zealand Ministry of Environment "State of NZ" (2007)
Kingdom of Bhutan Happiness Index
European Commission – OECD

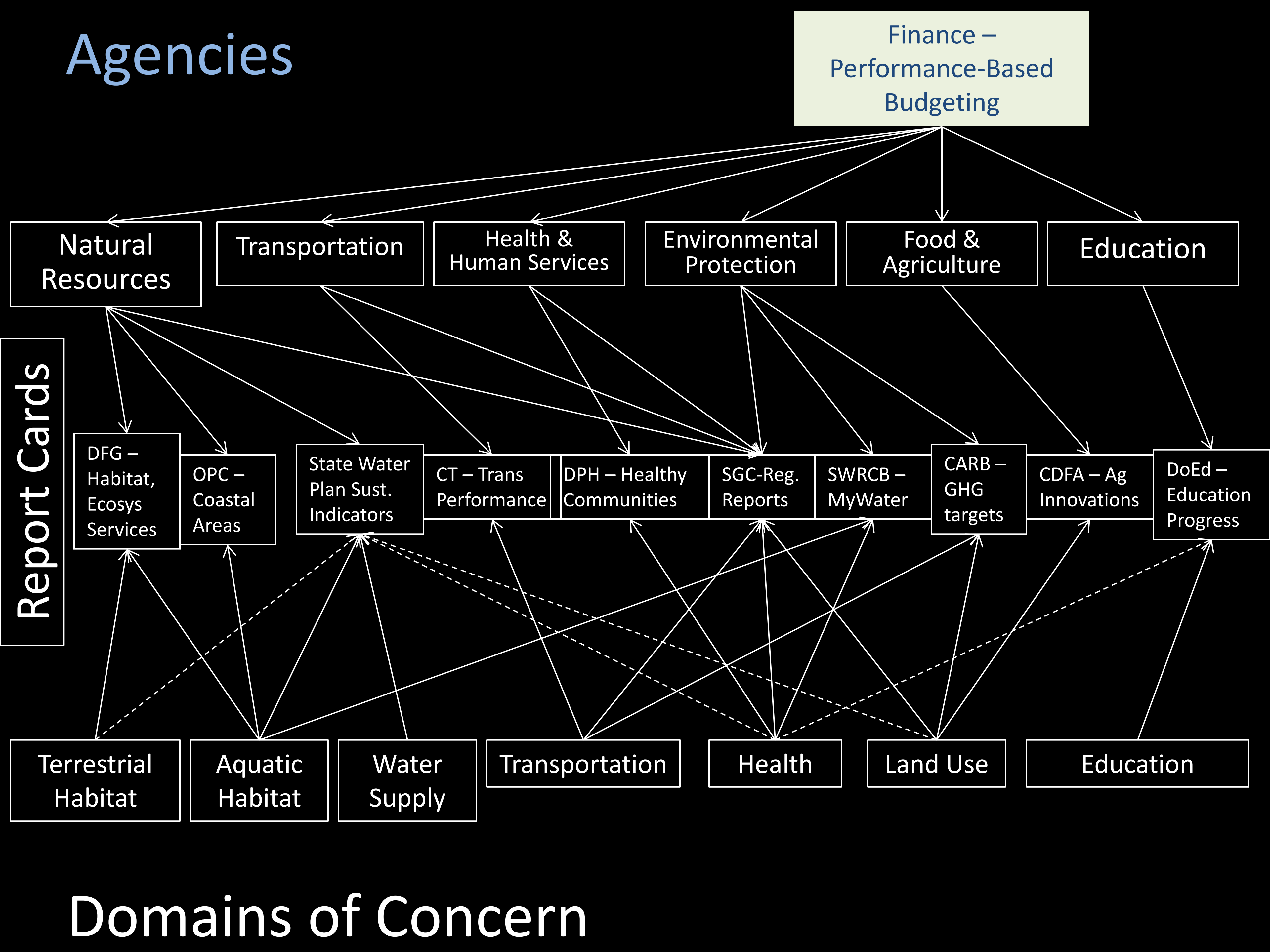


US

US EPA Environmental Indicators & Report on the Environment
Chesapeake Bay Eco-Check
State of the Sound (Puget Sound Partnership)

California

California's Legislative Report Card (Sierra Club)
Southern California Issue-specific reports (Institute of the Environment, UCLA)
Beach Report Card (Heal the Bay, annual)
Ski Areas Report Card (Sierra Nevada Alliance and others)
Central Valley Economy and Environment (Great Valley Center)


Agencies
Finance – Performance-Based Budgeting
Natural Resources
Transportation
Health & Human Services
Environmental Protection
Food & Agriculture
Education
Report Cards
DFG – Habitat, Ecosys Services
OPC – Coastal Areas
State Water Plan Sust. Indicators
CT – Trans Performance
DPH – Healthy Communities
SGC-Reg. Reports
SWRCB – MyWater
CARB – GHG targets
CDFA – Ag Innovations
DoEd – Education Progress
Terrestrial Habitat
Aquatic Habitat
Water Supply
Transportation
Health
Land Use
Education
Domains of Concern

How do we integrate the parts to say something about watershed or waterway "condition"?

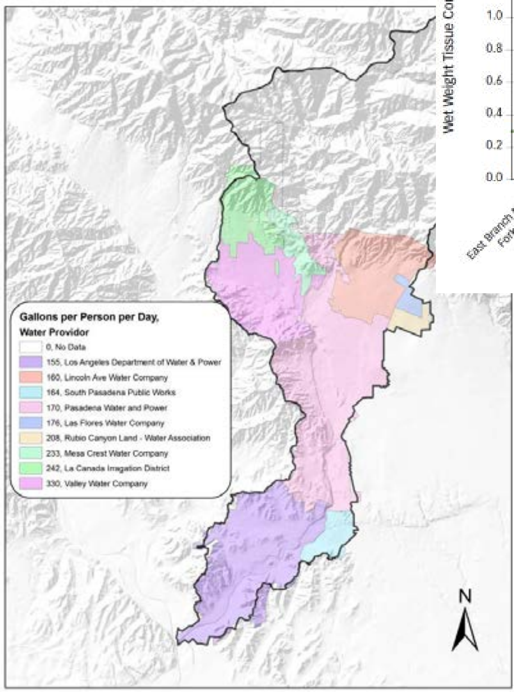
IBI/CSCI

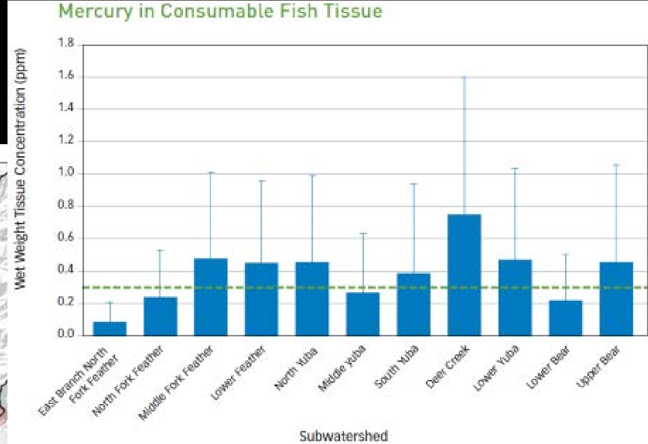
HGM

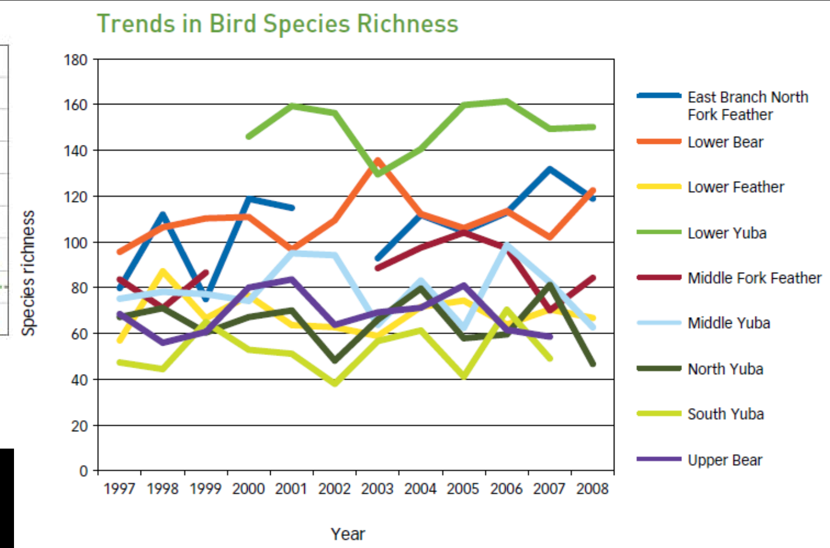
WQI

AQI

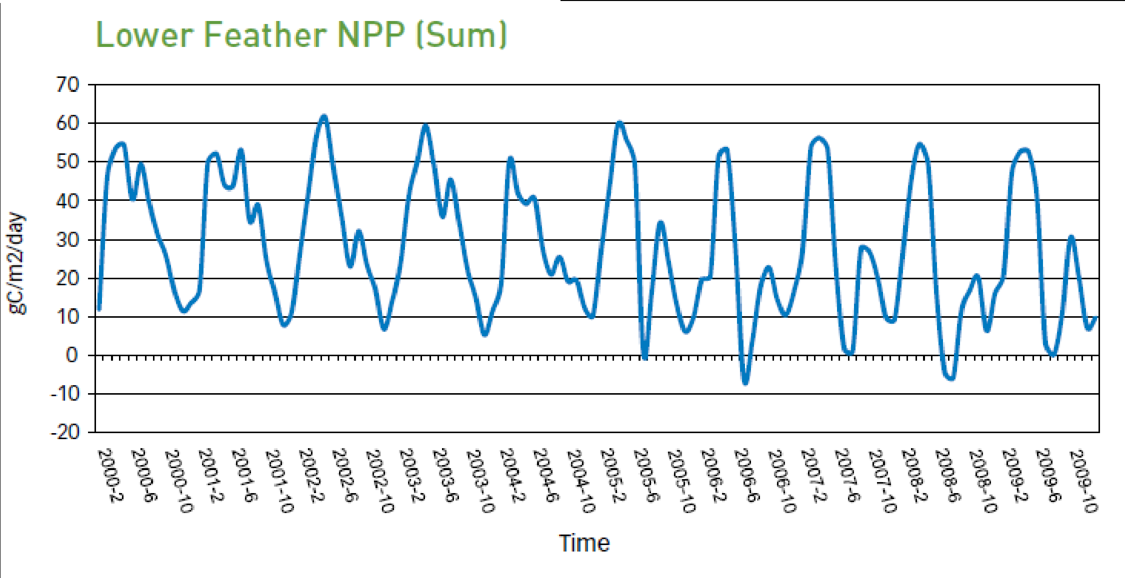
PI

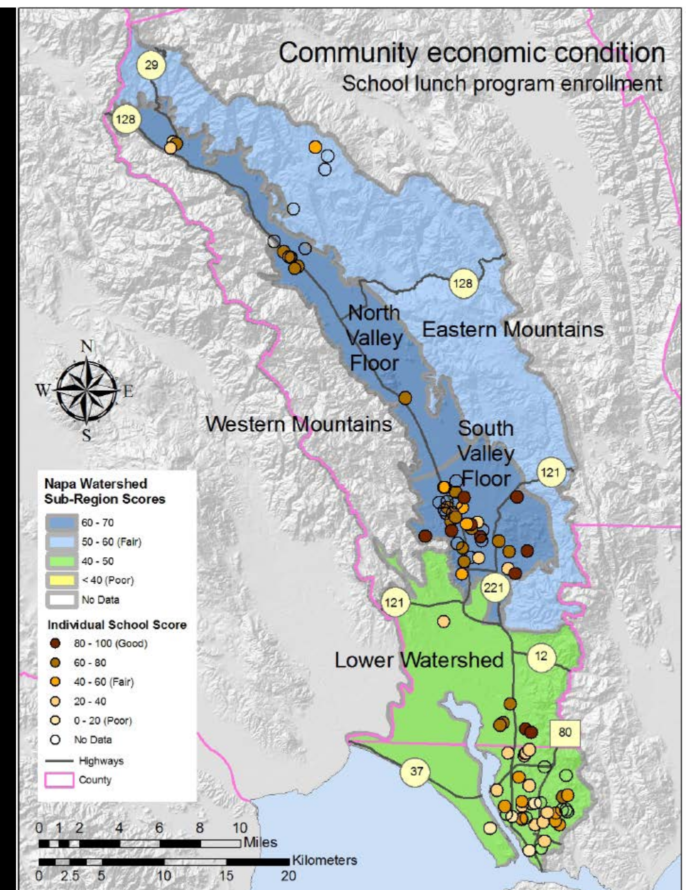

Gallons per Person per Day,
Water Providor
0, No Data
155, Los Angeles Department of Water & Power
160, Lincoln Ave Water Company
164, South Pasadena Public Works
170, Pasadena Water and Power
176, Las Flores Water Company
208, Rubio Canyon Land - Water Association
233, Mesa Crest Water Company
242, La Canada Irrigation District
330, Valley Water Company
N


Mercury in Consumable Fish Tissue
Wet Weight Tissue Concentration (ppm)
East Branch North Fork Feather
North Fork Feather
Middle Fork Feather
Lower Feather
North Yuba
Middle Yuba
South Yuba
Deer Creek
Lower Yuba
Lower Bear
Upper Bear
Subwatershed


Trends in Bird Species Richness
Species richness
Year
East Branch North Fork Feather
Lower Bear
Lower Feather
Lower Yuba
Middle Fork Feather
Middle Yuba
North Yuba
South Yuba
Upper Bear

- Examples


Lower Feather NPP (Sum)
gC/m2/day
Time


Community economic condition
School lunch program enrollment
North Valley Floor
Eastern Mountains
Western Mountains
South Valley Floor
Lower Watershed
Napa Watershed Sub-Region Scores
60 - 70
50 - 60 (Fair)
40 - 50
< 40 (Poor)
No Data
Individual School Score
80 - 100 (Good)
60 - 80
40 - 60 (Fair)
20 - 40
0 - 20 (Poor)
No Data
Highways
County
Miles
Kilometers

Aggregation into Index

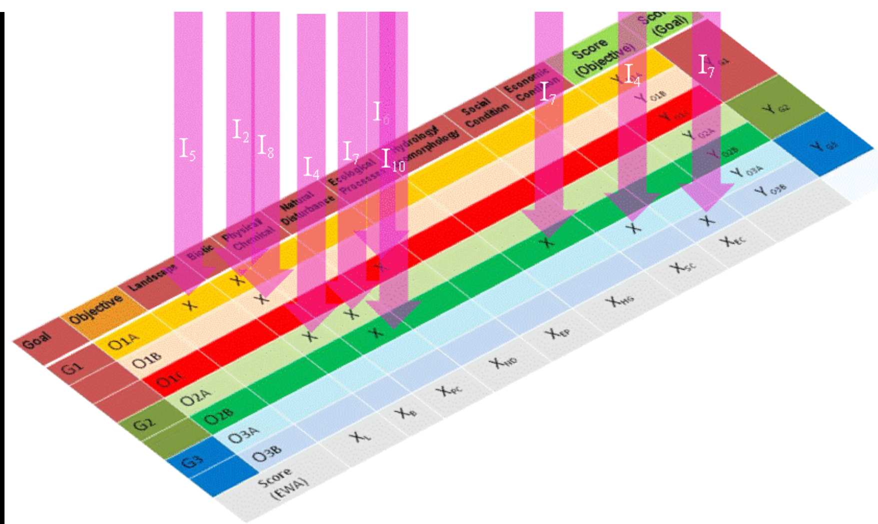
Aggregation of dis-similar indicators into an index of condition depends on definition of a goal for doing so, defined scales of analysis, references, and good application of statistics and logic.

1. Goals and Objectives

Condition

Goal	Objective	Landscape	Biotic	Physical/ Chemical	Natural Disturbance	Ecological Processes	Hydrology/ geomorphology	Social Condition	Economic Condition	Score (Objective)	Score (Goal)
G1	O1A	X	X							Y_{O1A}	Y_{G1}
	O1B		X							Y_{O1B}	
	O1C				X					Y_{O1C}	
G2	O2A		X	X						Y_{O2A}	Y_{G2}
	O2B			X			X			Y_{O2B}	
G3	O3A							X		Y_{O3A}	Y_{G3}
	O3B								X	Y_{O3B}	
Score (EWA)		X_L	X_B	X_{PC}	X_{ND}	X_{EP}	X_{HG}	X_{SC}	X_{EC}		

Influences on Condition



Inter-Regional Goals Comparison

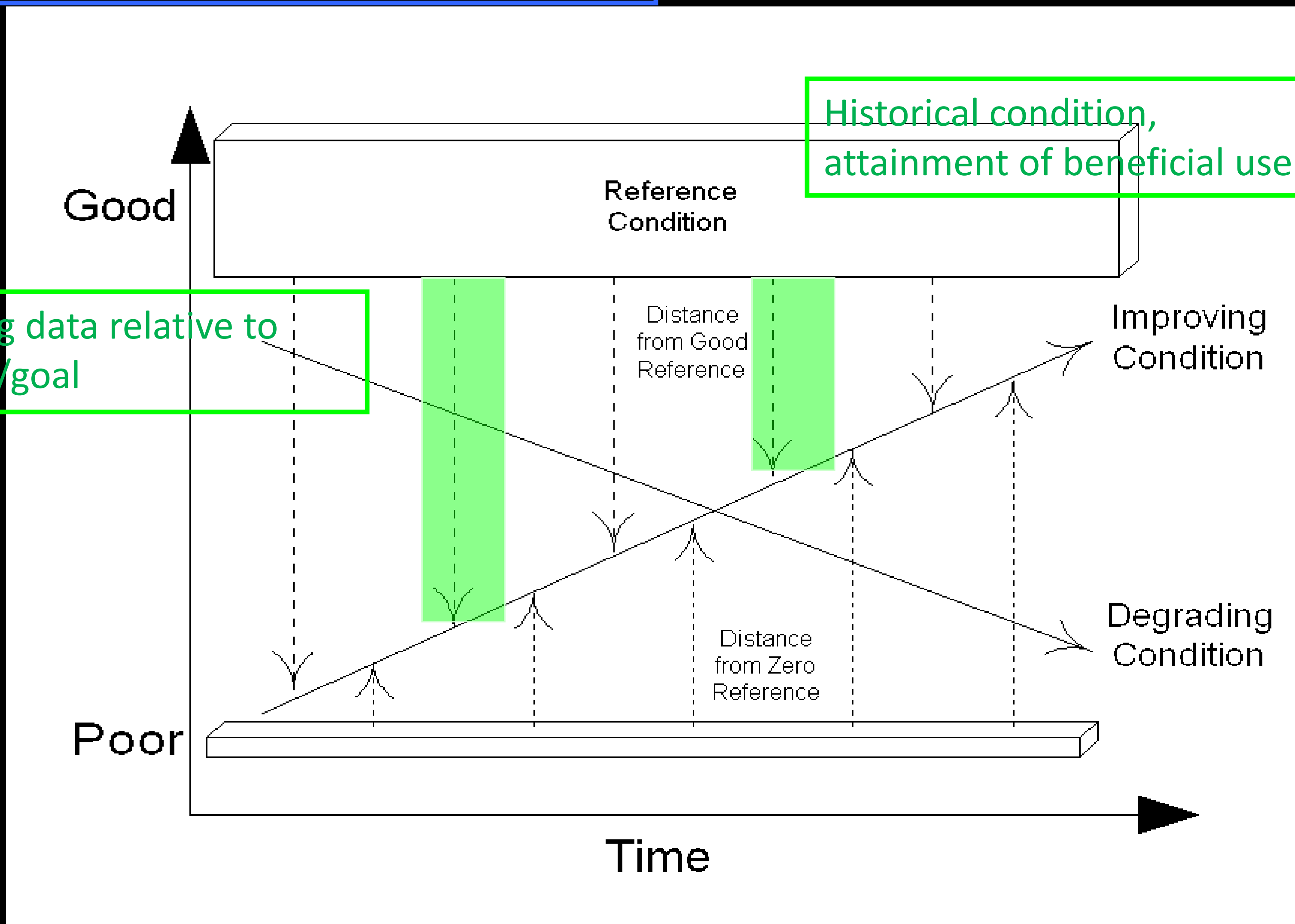
Southern California Whole System Report Card	Sacramento River Watershed Watershed Health Indicator Program	North Bay Transect Report Card
To sustainably manage local water supplies for human and natural communities.	Maintain and improve water quality and supply to sustainably meet the needs of natural and human communities	Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity
To meet human needs and enhance the quality of life by improving the conditions of watersheds and their ecosystems.	Protect and enhance landscape and habitats structure and processes to benefit ecosystem and watershed functions	Support community planning and management actions that further the goal of a healthy, happy, and economically just community
To conserve and restore a diversity of native habitats to support fish and wildlife.	Protect and enhance native aquatic and terrestrial species, especially sensitive and at-risk species and natural communities	Conserve, protect and improve native plant, wildlife and fish habitats and their communities
To restore or simulate natural disturbance processes that balance benefits for human and natural communities	Maintain and restore natural disturbance processes to benefit natural and human communities	Improve and protect geomorphic and hydrologic processes
To have widespread community awareness and deep civic engagement in the protection and improvement of watersheds	Maintain and improve the social and economic conditions, including benefits from healthy watersheds	Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making
		Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change

2. Measuring Performance

We are almost always measuring condition against some standard. It is unlikely that indicators would be as useful without this comparison. What approach allows inter-indicator and inter-regional comparison?

Some Issues & Examples

What is the condition and trend in condition?



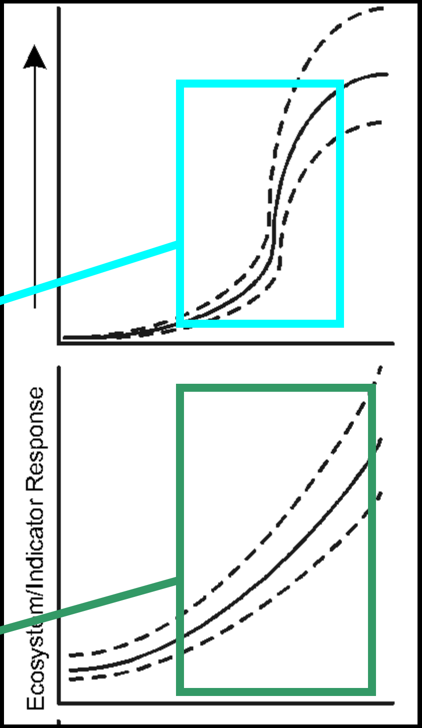
Historical condition, attainment of beneficial use

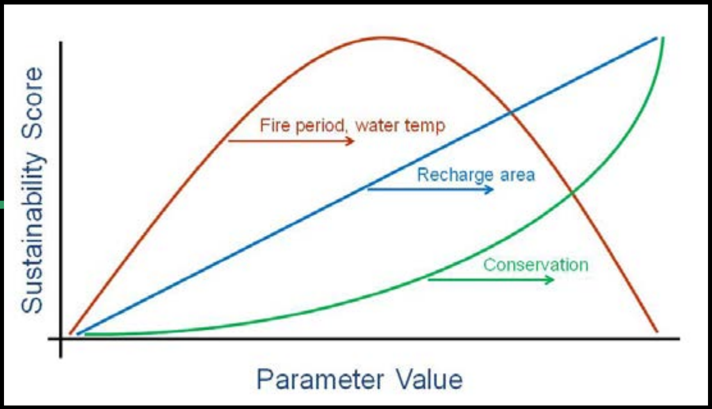
Re-scaling data relative to standard/goal

Some Issues & Examples

Suitability of Indicator/Index

- Should we use the most sensitive (and potentially noisiest)?
- An index may be less noisy, but also less sensitive to change
- Different indicators have different response patterns & sensitivity





3. Transformation/re-scaling of indicators

- Ranking, empirical, axiological, mathematical, statistical

- Axiological normalization = relative distance between “good” and “bad” conditions (defined by user). This approach was termed the “distance to target” method in the California Water Plan, Update 2013

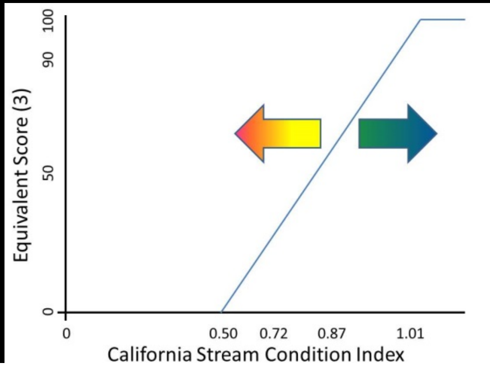
Axiological normalization (CSCI)

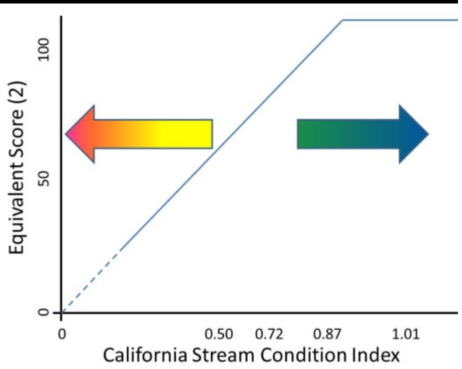
1.01 – mean reference

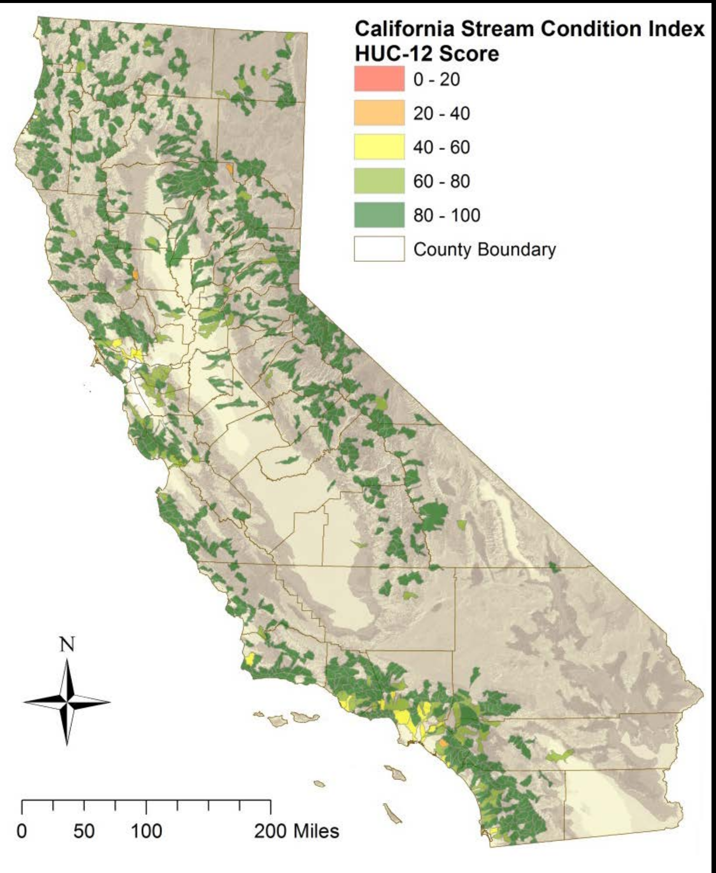
0.87 – low end reference

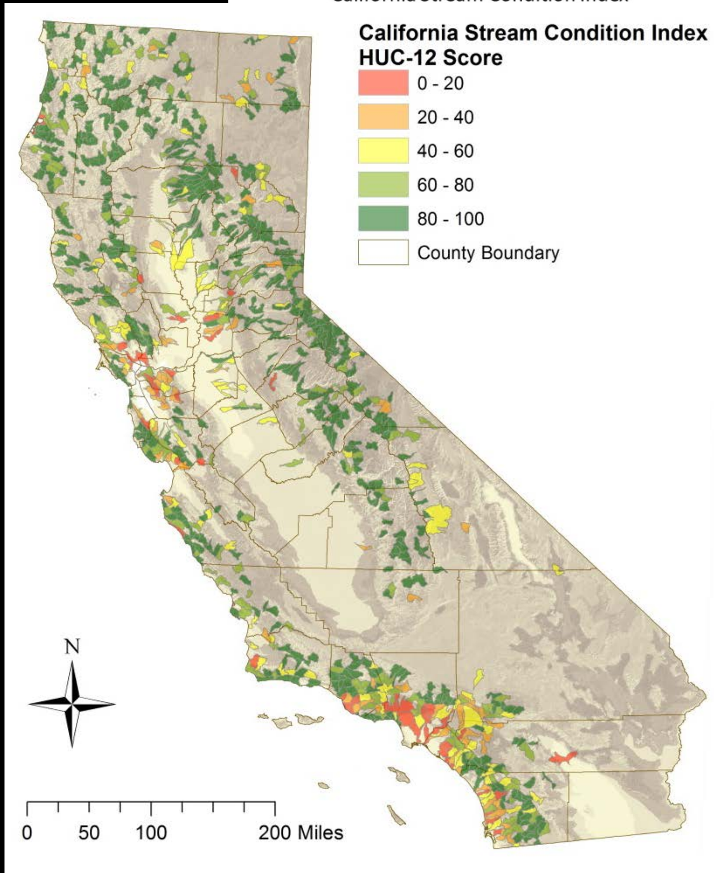
0.50 – stressed site mean minus variance

0 – theoretically worst condition





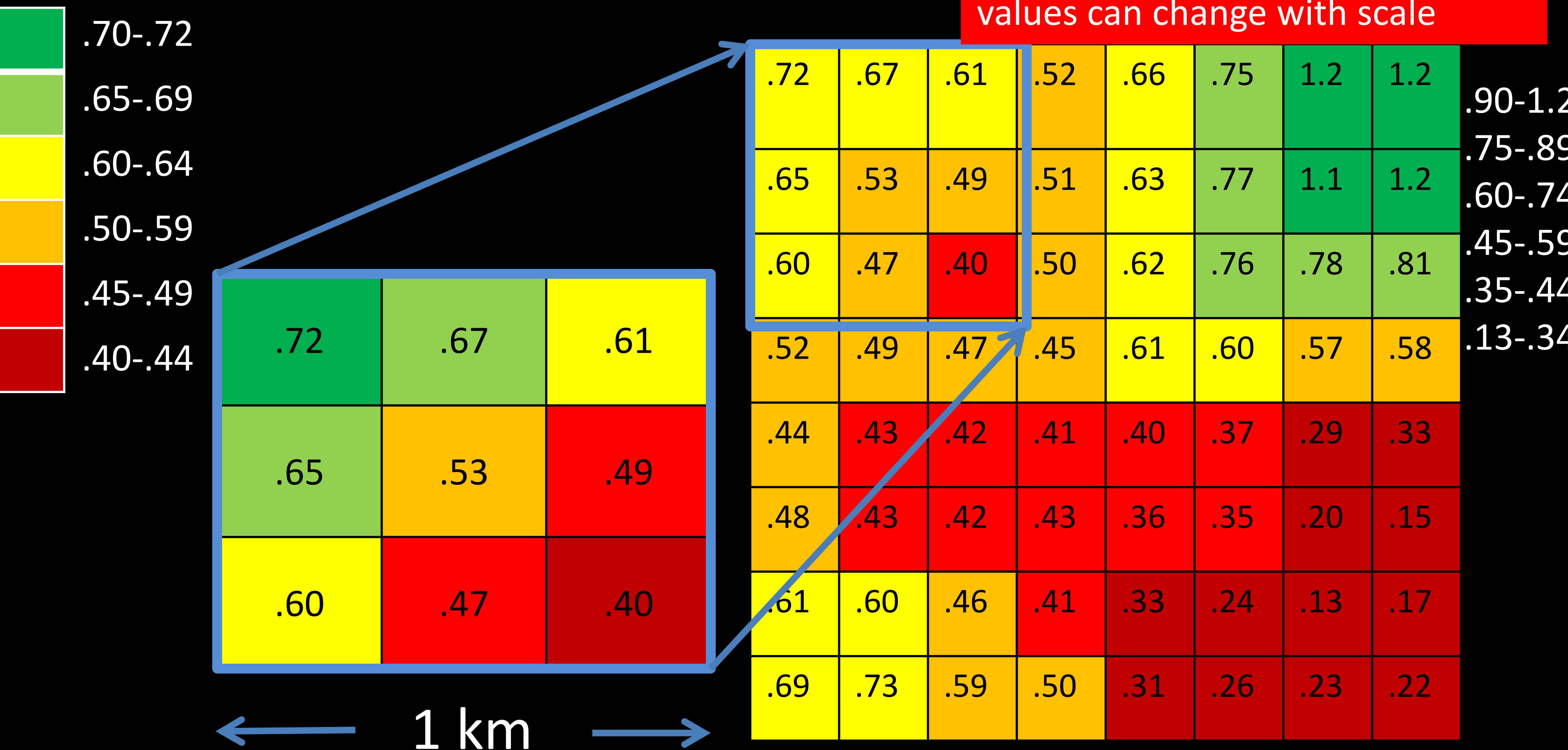




Problematic approaches (and why)

- “Empirical” re-scaling compared to minimum and maximum value in an area

“Scores” equivalent to metric values can change with scale



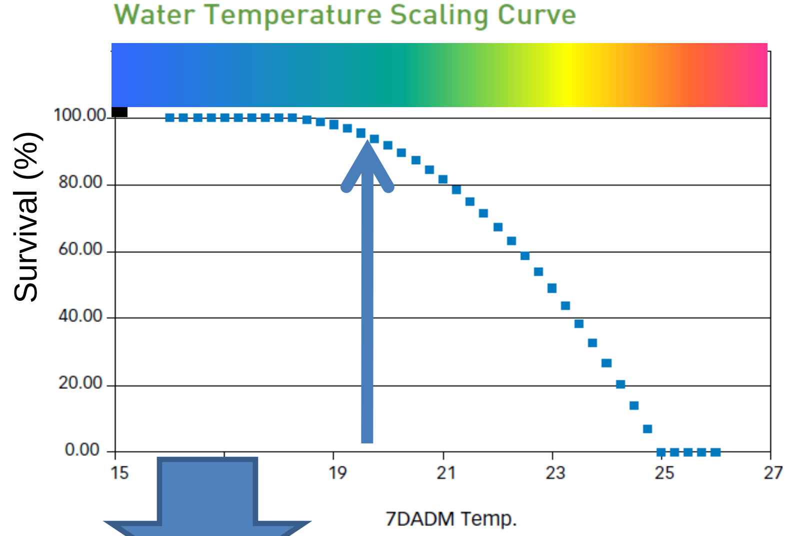
Problematic approaches (and why)

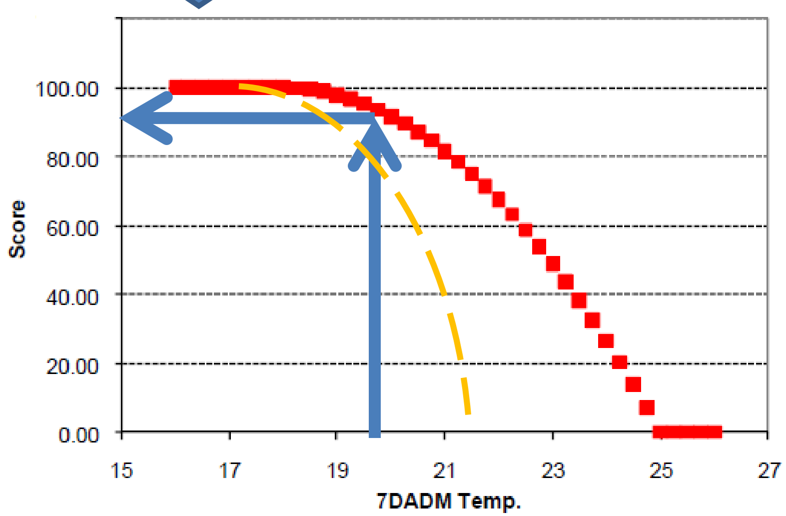
- "Statistical" re-scaling compared to 1,2 SD around a mean value

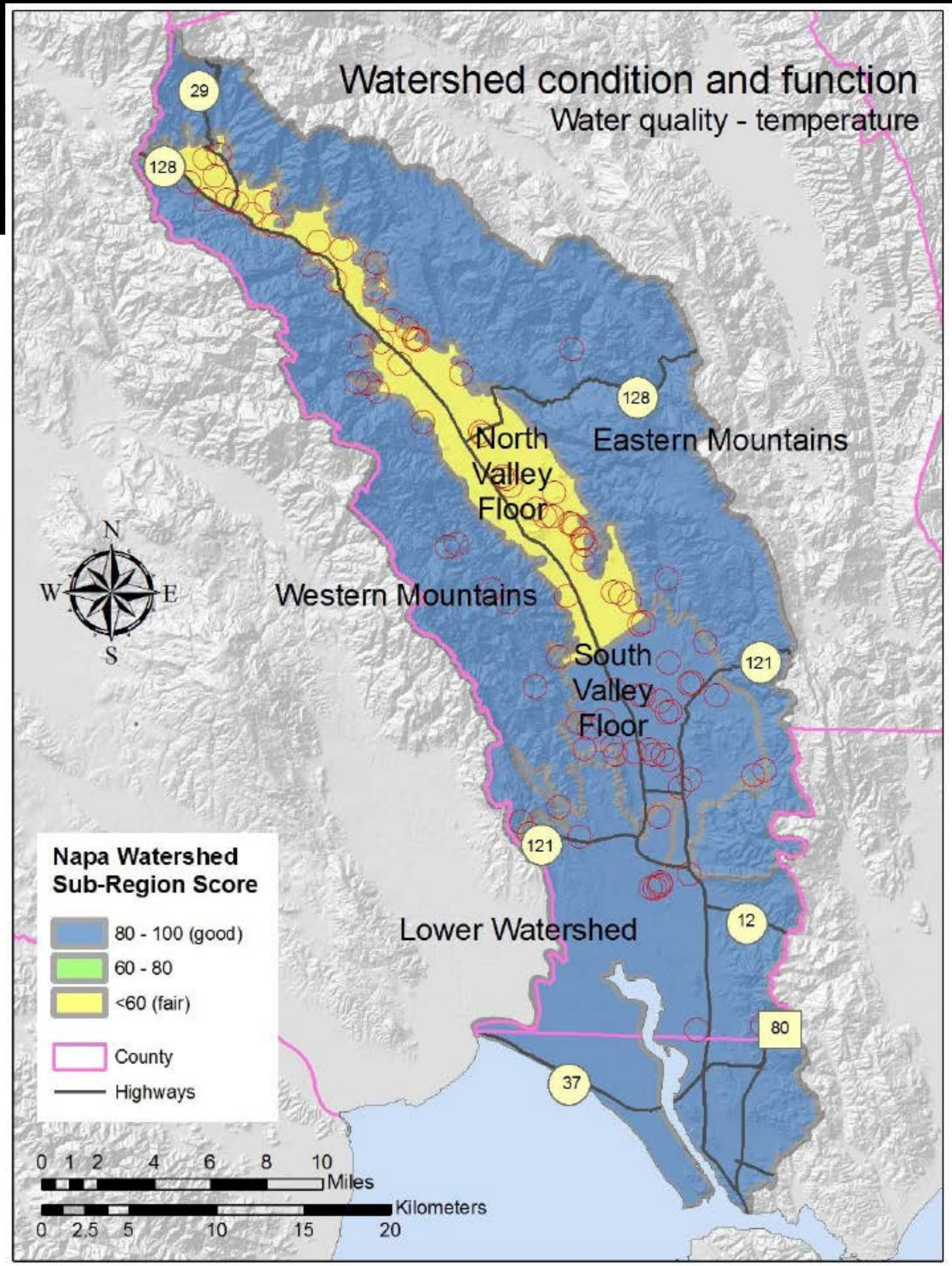
.72	.67	.61	.52	.66	.75	1.2	1.2
.65	.53	.49	.51	.63	.77	1.1	1.2
.60	.47	.40	.50	.62	.76	.78	.81
.52	.49	.47	.45	.61	.60	.57	.58
.44	.43	.42	.41	.40	.37	.29	.33
.48	.43	.42	.43	.36	.35	.20	.15
.61	.60	.46	.41	.33	.24	.13	.17
.69	.73	.59	.50	.31	.26	.23	.22

.72	.67	.61	.52	.66	.75	1.2	1.2
.65	.53	.49	.51	.63	.77	1.1	1.2
.60	.47	.40	.50	.62	.76	.78	.81
.52	.49	.47	.45	.61	.60	.57	.58
.44	.43	.42	.41	.40	.37	.29	.33
.48	.43	.42	.43	.36	.35	.20	.15
.61	.60	.46	.41	.33	.24	.13	.17
.69	.73	.59	.50	.31	.26	.23	.22

Axiological normalization







Aggregation into Index

Axiological normalization allows combination of dis-similar indicators into an index because now all indicators are on the same conceptual and mathematical scale "how far away are conditions from where we want them and don't want them to be?"

4a. Summing Indicator Scores

$Index = I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 + I_{10}$

A	Index = 5 + 10 + ND + 7 + 2 + 1 + ND + 8 + 3 + 6 = 42
B	Index = 9 + 10 + 8 + 7 + ND + 8 + ND + ND + ND + ND = 42
C	Index = 5 + 10 + 8 + 7 + 2 + 1 + 4 + 8 + 3 + 6 = 54
D	Index = 5 + ND + ND + 7 + ND + 8 + ND + ND + 3 + ND = 16

Problem: Missing values affect final index score
Solution: Only sum when all values present

4b. Averaging Indicator Scores

$\text{Index} = (I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 + I_{10})/n$

A Index = (5 + 10 + ND + 7 + 2 + 1 + ND + 8 + 3 + 6)/8 = 5.3

B Index = (5 + 10 + 8 + 7 + ND + 8 + 4 + ND + ND + ND)/6 = 7

C Index = (5 + 10 + 8 + 7 + 2 + 1 + 4 + 8 + 3 + 6)/10 = 5.4

D Index = (5 + ND + ND + 7 + ND + 1 + ND + ND + 3 + ND)/4 = 4

Problem: Missing values affect final index score
Solution: Use average when most values present are the same across conditions/places; determine influence of individual indicators

5. Weighting indicators

- Index = $a(I_1) + b(I_2) + c(I_3) + d(I_4) + e(I_5) + f(I_6) + g(I_7) + h(I_8) + i(I_9) + j(I_{10})$

- Index = $[a(I_1) + b(I_2) + c(I_3) + d(I_4) + e(I_5) + f(I_6) + g(I_7) + h(I_8) + i(I_9) + j(I_{10})]/n$

Problem: Weighting is always present, e.g., 1,2,3…etc = 1
Solution: Test different weighting strategies a priori with users/stakeholders, not after the fact

6. Opposing and co-varying indicators

- (-) co-varying: temperature and dissolved oxygen
- (+) co-varying: low fish, low algae, low BMI (IBI)

- Causing or inhibiting: One system component may directly stop or cause change in another

- Both causation and correlation (with and without direct causation) can affect conducting and interpreting index calculation

Contact

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