The Water Quality Index: Bringing water quality to the table

Baishali Bakshi (US EPA), Todd Doley (US EPA), Kristen Swedberg (ORISE, EPA)

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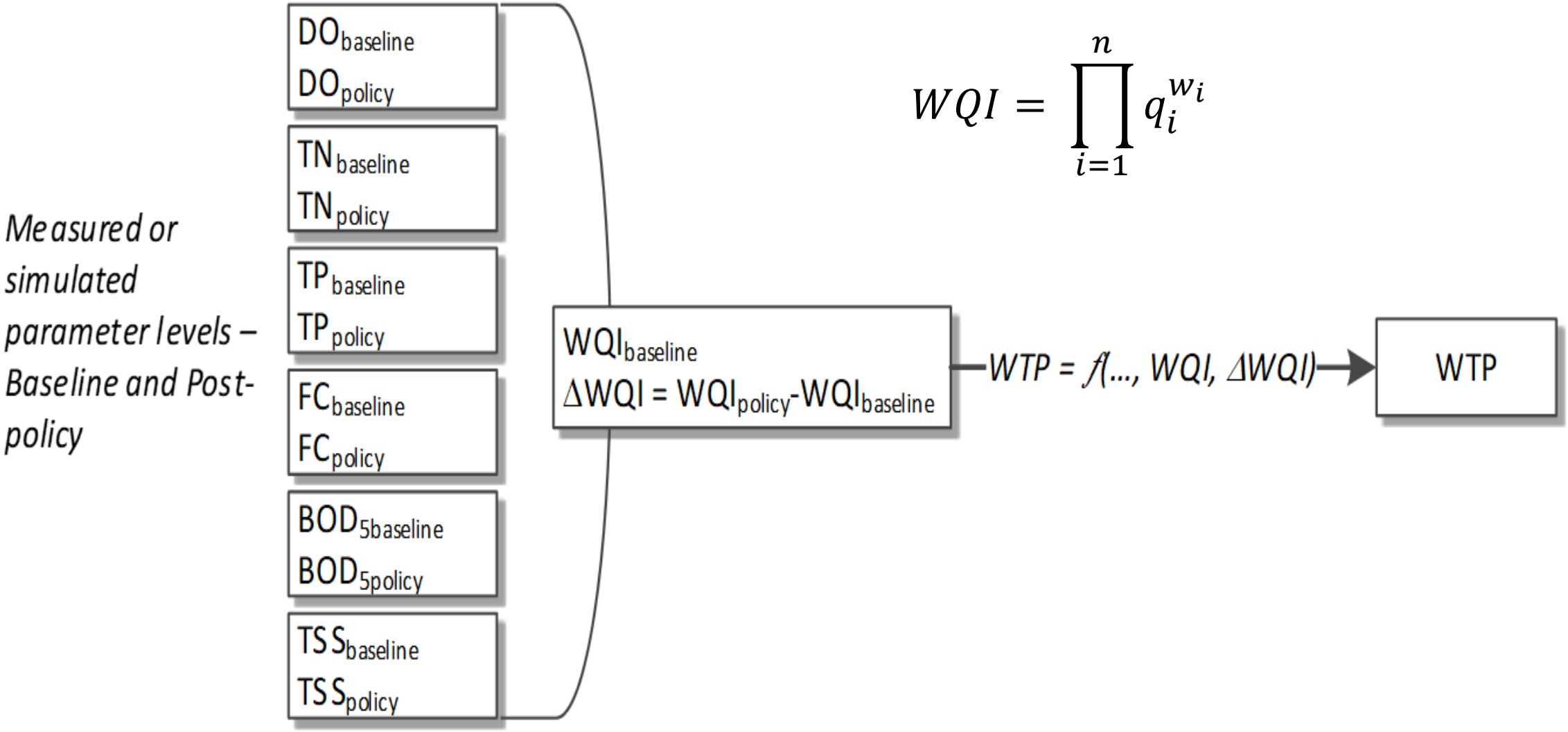
Outline

- WQI
- The EPA WQI
- Links with Ecosystem Services and goals of Clean Water Act
- EPA WQI: Advantages and Limitations
- Project to improve WQI
  - Example of one improvement project: A New Use-Based WQI
- Take aways
- Questions

What is a WQI?

- A single metric that translates water quality data into an indicator easily interpreted by decision makers and the public.
- Different types of WQI are used to summarize different types of water quality data
  1. ***Physico-chemical***: based on a set of key water quality parameters.
  2. *Biological*: based on assessments of biological organisms.
  3. *Hydromorphological*: based on structural and functional processes of the waterbody, such as streambed geology, sediment dynamics.
- Background of WQIs:
  - McClelland et al. 1974—Expert solicitation for parameter scoring
  - Cude, 2001—regional thresholds for parameters
  - Vaughan, 1986—Water quality ladder based on broad uses

EPA WQI is Unique: Helps Evaluate WQ Benefits of Policy



$$WQI = \prod_{i=1}^{n} q_i^{w_i}$$

WQI and Ecosystem Services

- The designated '***use***' of a waterbody relates to the purpose the waterbody supports, such as drinking water, aquatic life, recreation.
- The service provided by the use is an ***ecosystem service***, such as the value of drinking water provided by a clean stream complying with drinking water criteria.
- Ecosystem services may have ***use*** (consumptive and non-consumptive), and/or ***non-use*** (existence, option, bequest) values.
- Water quality is affected by pollution, which in turn, affects designated uses, and thereby ecosystem services.

TEEB, Europe

Information about changes in specific ecosystem services is essential

- Ecosystem services are essential for human well-being.
- Underlying ecosystems are essential for biodiversity conservation.
- Ecosystem services are declining from a variety of factors including climate change.
  - Many ecosystems lost, >60% degraded/ unsustainably used—MA2005; IPBES, 2019/22.
- Society has value for ecosystem services —help conserve ecosystems.
- Ecosystem services differ—types of values, regions, groups of people.
- Tradeoffs between ecosystem services maybe present in a WQ change.
- Have implications for environmental justice across space and time.
- Protected by the Clean Water Act.
- Efficient mitigation, adaptation, prioritization of resources.

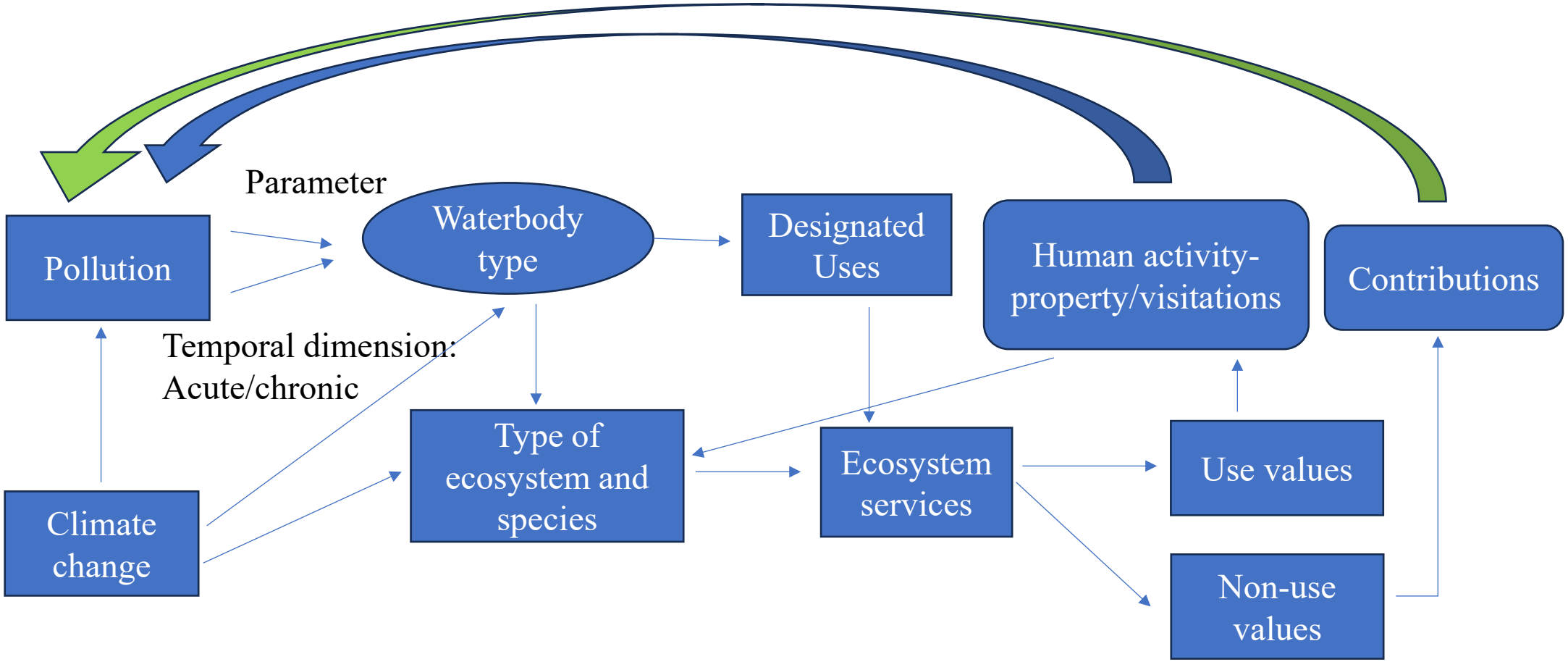
EPA WQI: Advantages

- The EPA WQI uses a water quality ladder to relate water quality to broad water uses: boatable, swimmable, drinkable etc
- ***The EPA WQI provides a broad understanding of water quality in a region in a single, easily interpretable metric.***
- It is used to evaluate the benefit of a water quality change through an empirical benefit transfer approach.
- Water quality is a compound ecosystem service comprising
  - Drinking water
  - Recreation
  - Filtration
  - Wildlife habitat
  - ….
- ***The EPA WQI facilitates a broad understanding of the value of a given change in water quality (a compound ecosystem service).***

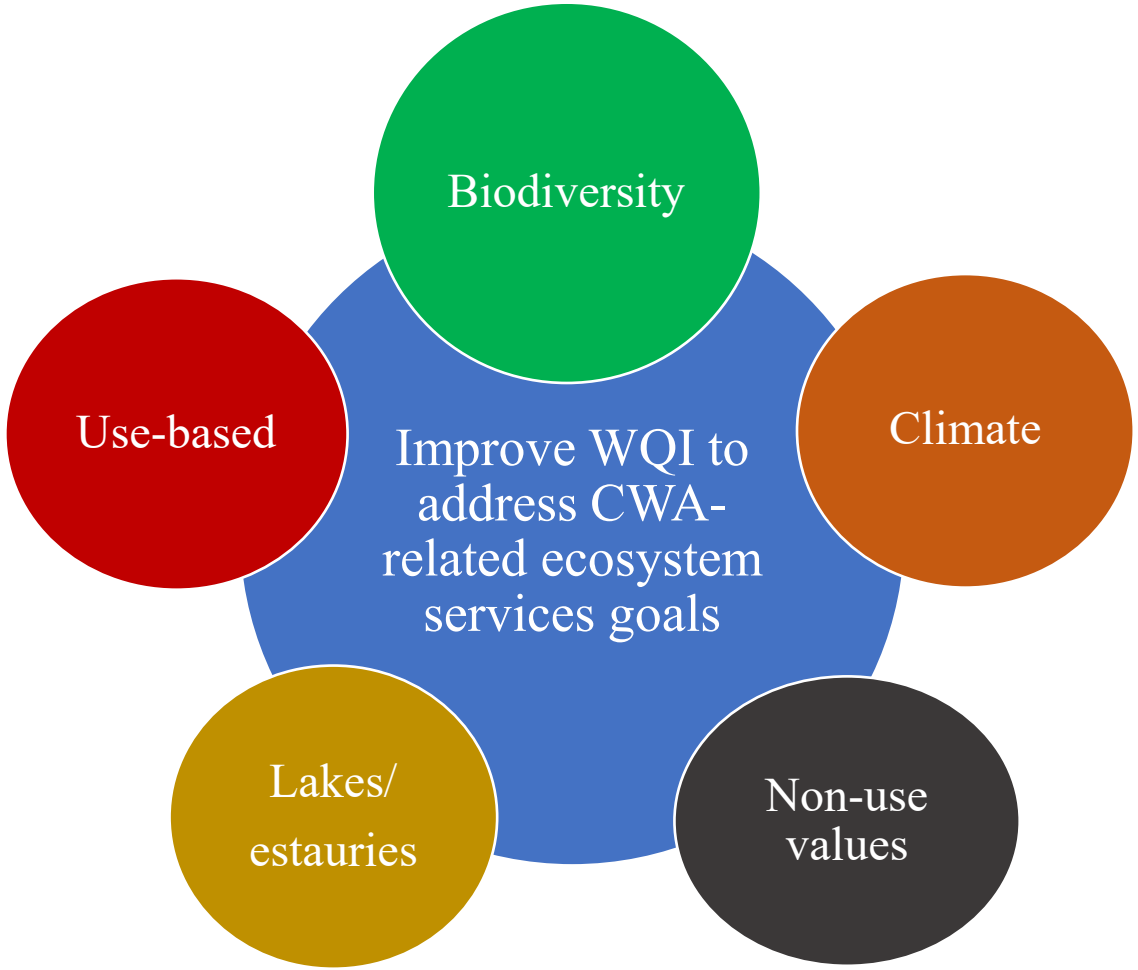
EPA WQI: Limitations

- EPA WQI is general, cannot distinguish between different uses, and cannot inform about changes in specific ecosystem services.
  - The WQ ladder does not provide precise information on specific designated uses
  - Recent valuation studies move toward targeted WQIs—Lupi et al., 2023, PNAS.
- Which parameters should be included?
  - Specific uses may be affected by multiple parameters (EPA 6 parameters)
- Does not show differences based on waterbody type.
- Does not capture temporal dimension of water quality impacts.
- Does not account explicitly for non-use values.
- Does not consider species that are indicators of water quality such as mayflies and freshwater mussels—should there be a separate ecological index tied to sentinel aquatic species?

Conceptual Diagram of Water Quality and Ecosystem Services



Project for improving the WQI

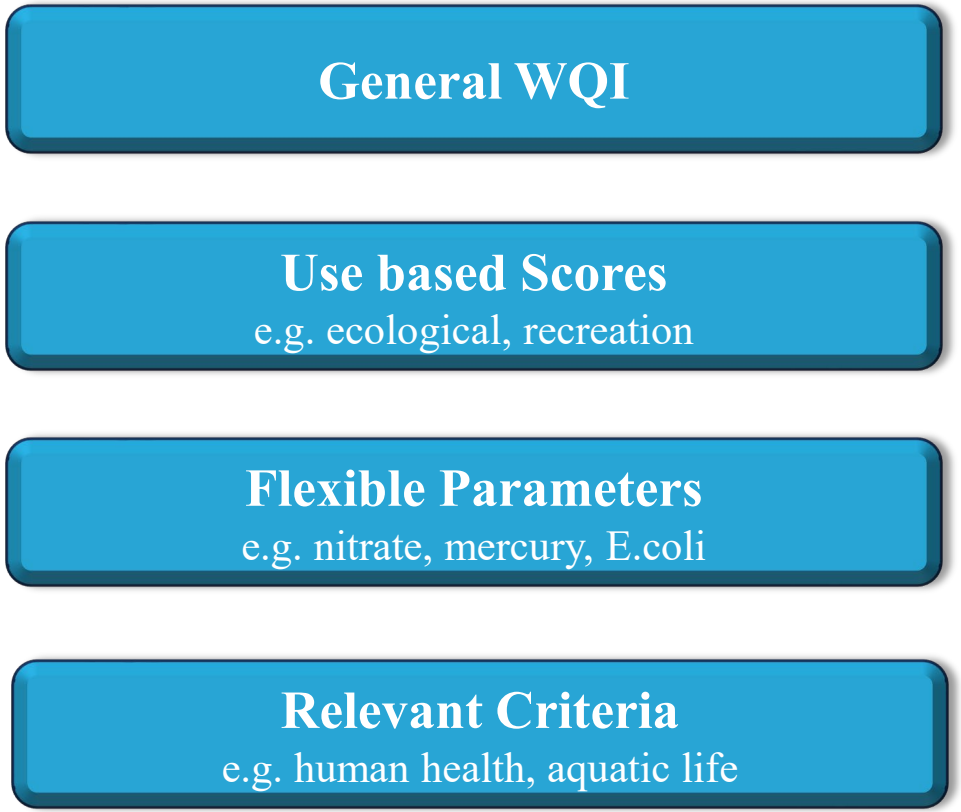


A New Use-based WQI: Conceptual Framework

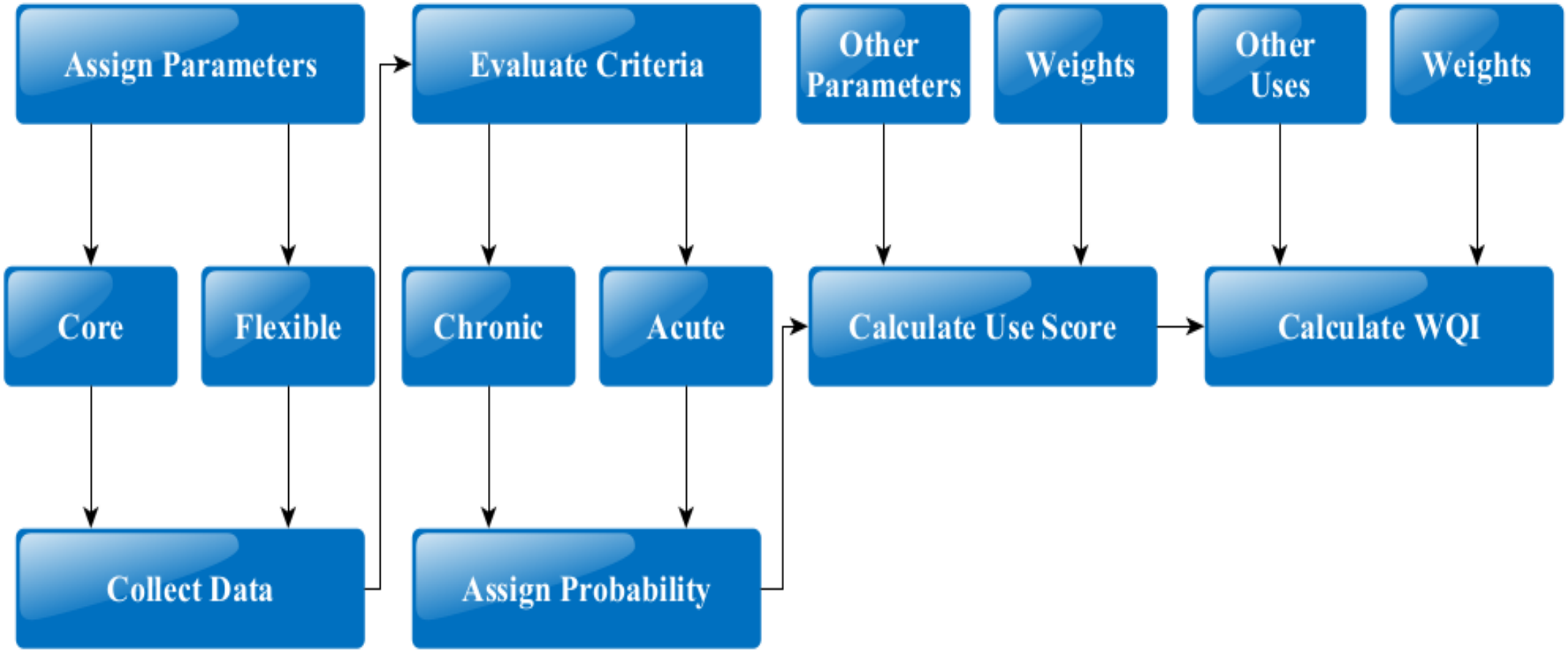
Kristen Swedberg (ORISE @ EPA), Joel Corona (US EPA), Baishali Bakshi (US EPA), Ahmed Rachid El-khattabi (UNC Chapel Hill)

- WQI comprised of different use scores that represent designated uses
  - All on 1-100 point scales
- Flexible set of parameters related to use assessment by states
  - Can contain single parameter (e.g. E.coli) or many pollutants (e.g. metals, nutrients, toxics)
  - Can vary location to location based on available monitoring data
- Each parameter evaluated relative to chronic and/or acute criteria for indicated use

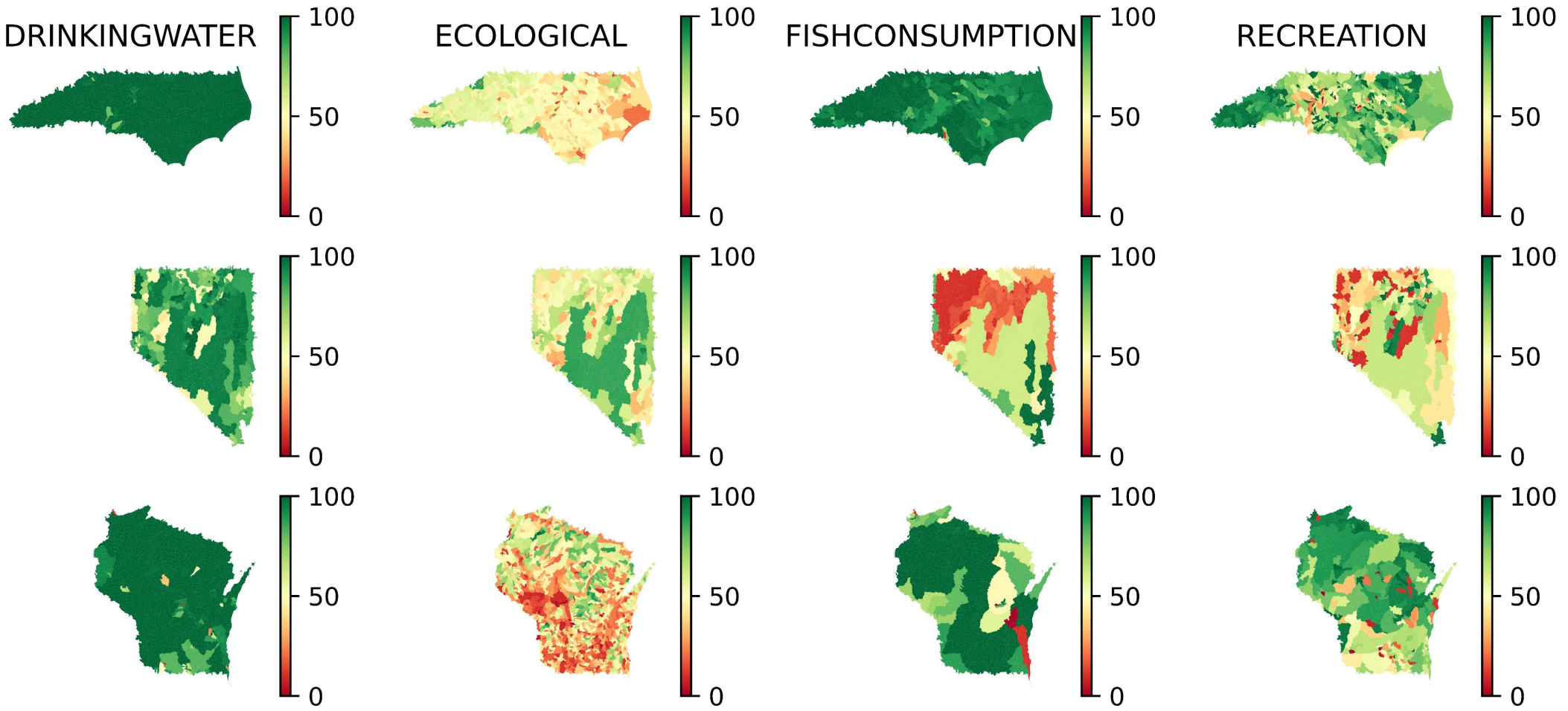
$$Prob(Param|Use, Criteria) = [0,1]$$



Methods: Construct Use Scores and WQI



Results: Use Scores Vary by State and Uses



Correlation with Impairment

Use Group	State	Use score	EPA WQI
DRINKINGWATER	NV	0.02	0.06
ECOLOGICAL	NC	0.10	0.22
ECOLOGICAL	NV	0.15	0.17
ECOLOGICAL	WI	0.23	0.03
FISHCONSUMPTION	NC	**0.37**	0.12
FISHCONSUMPTION	NV	**0.45**	**0.34**
FISHCONSUMPTION	WI	0.02	-0.07
RECREATION	NC	0.14	-0.01
RECREATION	NV	0.11	0.16
RECREATION	WI	**0.30**	-0.15

- Match ATTAINS assessment units to HUC12s
  - 1 = unit fully meets designated use
  - 0 = unit does not meet designated use
- Key Findings
  - Use-based WQI outperforms EPA WQIs, but results are mixed
  - EPA WQIs perform best for ecological use
- Potential Limitations
  - Matching assessment units to HUC12s via catchment correspondence
  - Missing parameters and criteria
  - Unknown sources of impairment

Take Aways

- The EPA WQI is unique in its use in evaluating water quality benefits of policy
- It has scope of major improvement in being able to inform about ecosystem services
- The Use-based WQI addresses key limitations
  - It is flexible and informs WQ benefits by uses
  - It is dependent on water quality monitoring data across regions
  - Can be improved: refine methods for evaluating parameters
- Future directions: WQI for lakes and estuaries, WQI for non-use values.

Questions

- What should be in a WQI?
- Could the WQI help us understand changes in ecosystem services that are meaningful at the field level?
- Should there be a different WQI for biodiversity?