Conceptual Approaches to Monitoring and Evaluation

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Why are you monitoring?

- To assess the current condition?
- To establish a reference condition?
- To detect change in the system?
- Measure effectiveness of management practices?
- Monitor progress toward an environmental objective?
- Improve understanding of system structure and function?
- Obtain data for model calibration?

Refine Your Objectives

- Why are you monitoring?
- Bad answer:
  - Ummmmm…????
- Fair answer:
  - To protect environmental quality
- Better answers:
  - To map the extent and quality of fish habitat
  - To determine trends in fish populations over time
  - To assess changes in fish community structure and function

Work from the general to the specific

Environmental Values

- Sustainable Fisheries

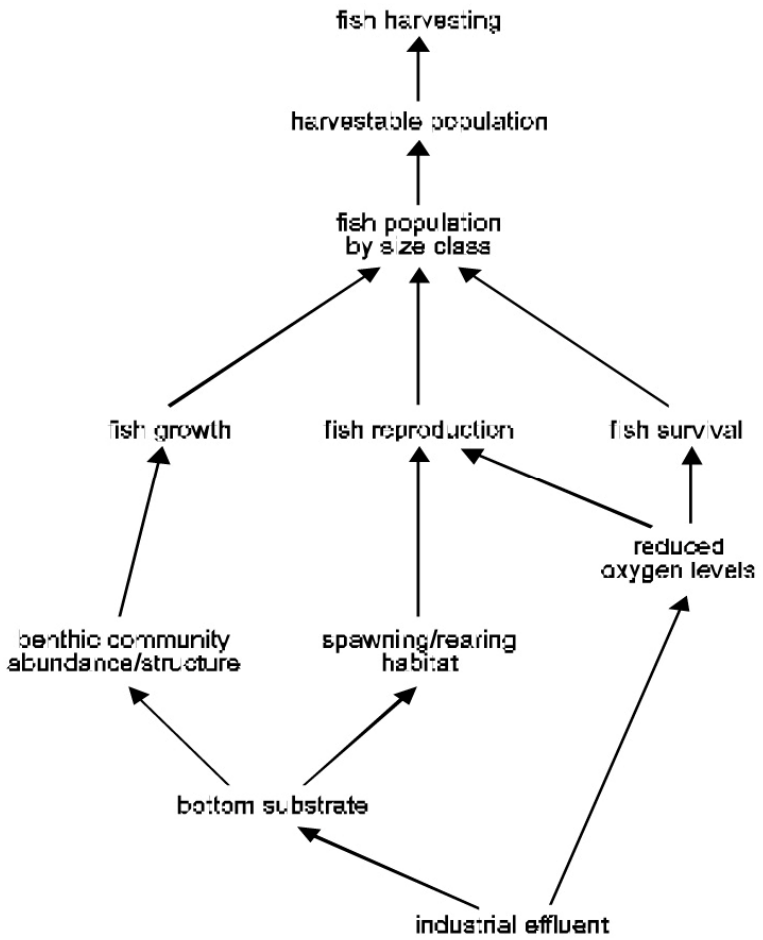
Assessment Endpoint

- Changes in the abundance of sport fish

Ecological Indicators

- Fish populations by size class

Example Impact Analysis (Everitt 1992)



What to monitor, where, and when?

- Clarify the question
- Identify indicators of desired or impaired conditions
- Identify appropriate statistical tests
- Choose frequency and spacing of samples
- Is an annual average enough? Or do you need hour-by-hour information?
  - You probably need hourly information for DO or *E. coli* from stormwater flows, but you probably don't need it for benthic invertebrate or fish population analysis

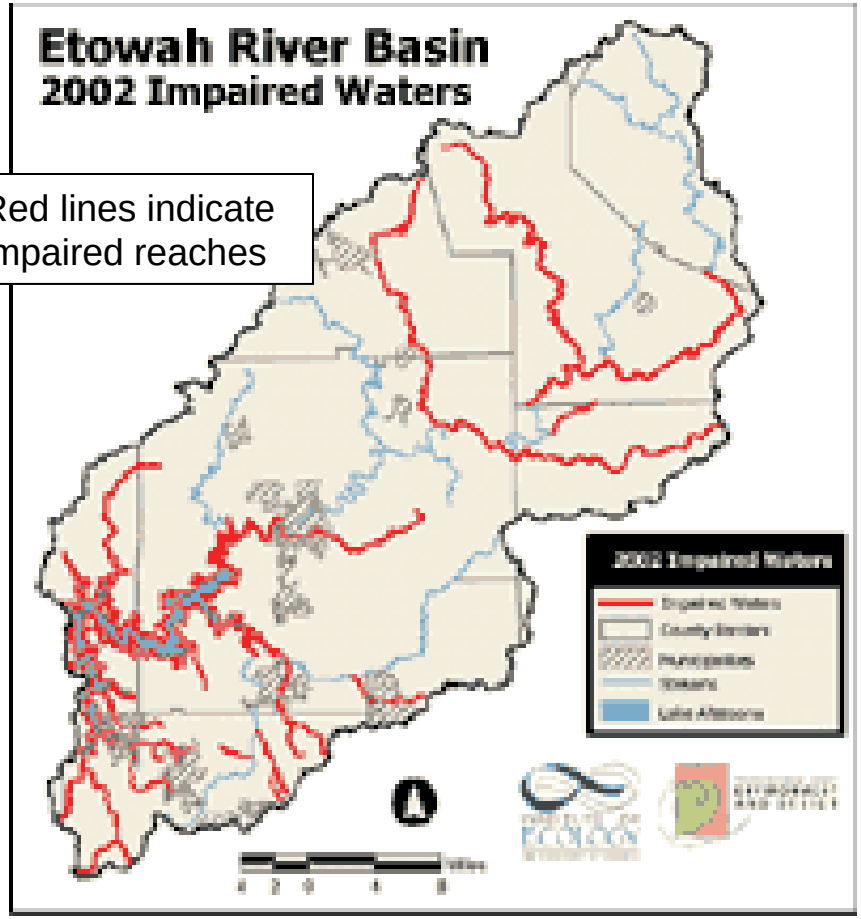
There is no silver bullet

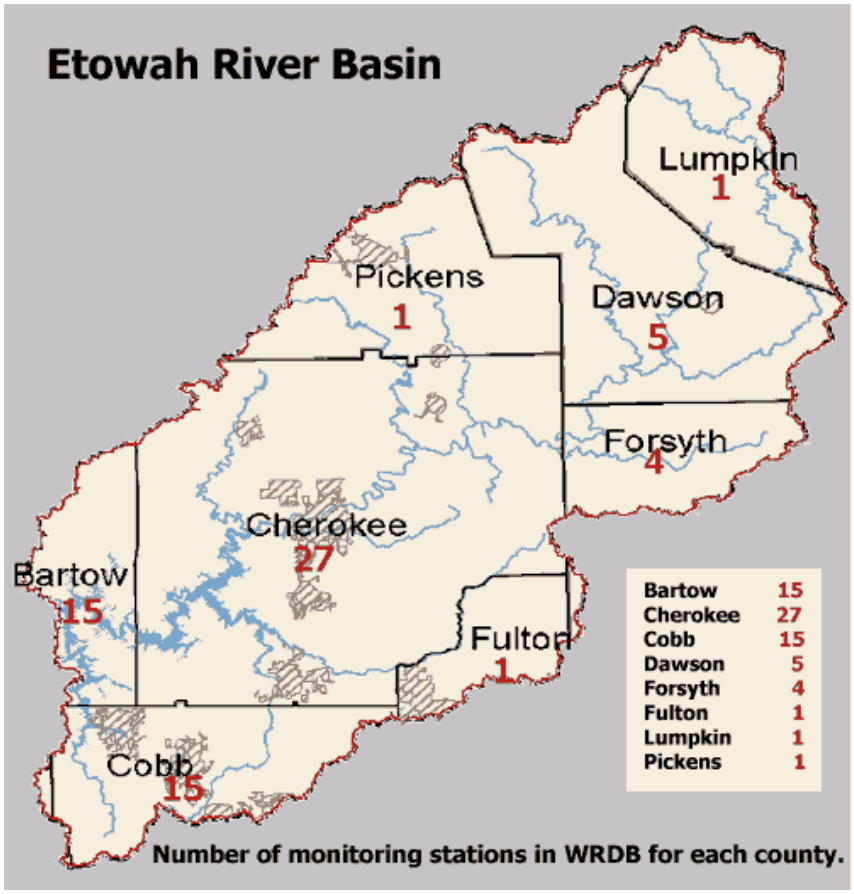
- There is no single right answer
  - Check your preliminary plan: will you be able to answer your questions with the data you will collect?
  - Good idea to have your plan peer-reviewed!
- Sometimes you think you have a good plan, but it doesn't produce the answers you expected
- Learn from your experience and modify the plan for the next round

Example 1: Upper Etowah River
(Atlanta, Georgia; Stribling and Davie 2005)

- Close proximity to “vast urban and urbanizing area”
  - Critical need to balance water and wastewater demands against ecological objectives
- Need a multi-objective, multi-scale monitoring program that will stand up to scientific and regulatory scrutiny

Etowah River Stations





H2Ontario

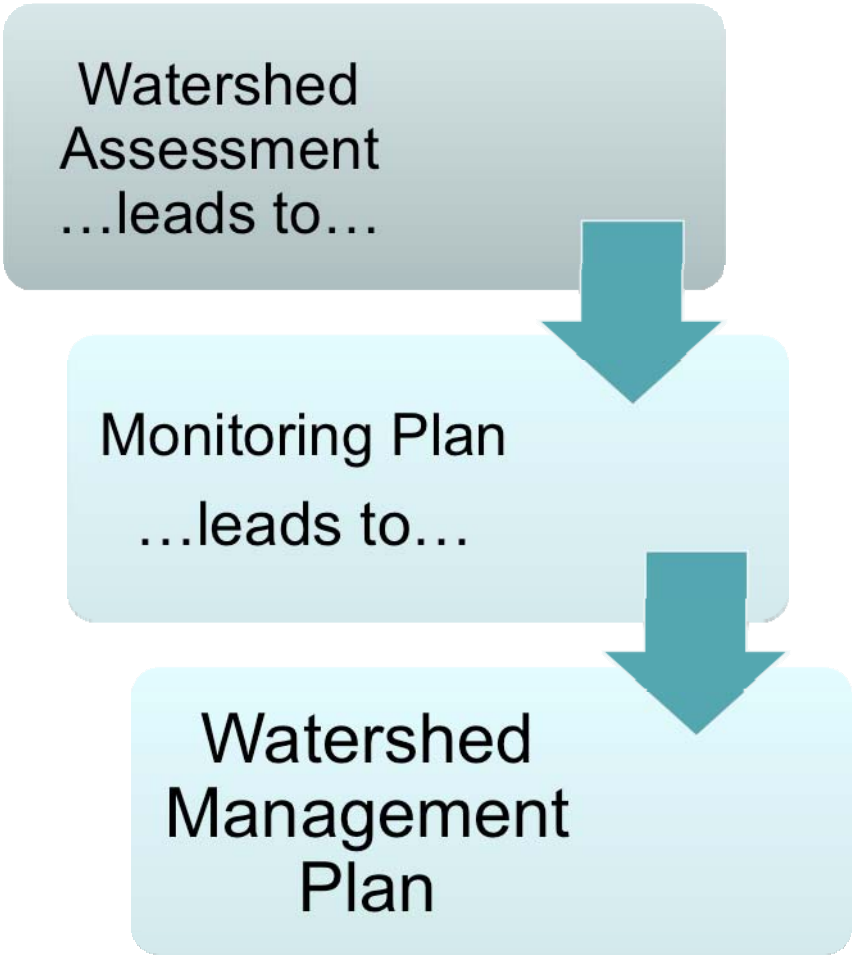
Integrated Watershed Management: Navigating Ontario's Future

Conceptual Design

- Two kinds of sampling locations
  - Targeted sites geared to known issues, and
  - A network of other sites for a regional picture
- Three sampling frequencies:
  - Annual
  - Intermittent
  - Regular, rotating basin schedule
- Parameters: water chemistry, flows, physical habitat, benthic macroinvertebrates, and fish

Monitoring Goals

- Ultimate goal: to produce a watershed plan to guide management decisions
- Monitoring must provide credible data and valid, defensible results
- Three planning stages



Specific Program Goals

- Water quantity monitoring:
  - Goal is to measure volume and timing of water flow
  - Assessed current gauge distribution, added 3 sites
  - Continuous monitoring of surface elevation and flow
- Water quality monitoring
  - Continuous monitoring of pH, temperature, DO, conductivity, and turbidity
  - Monthly (or more frequent) grab samples for nutrients, BOD, metals, sediment; FC and *E.coli* quarterly
  - Includes 3 wet weather sites (forest, ag, urban)

Specific Program Goals, cont'd

- Ecological condition monitoring
  - Determined by sampling/analysis of the aquatic community and comparison to similar pristine and stressed systems
  - Need to assess biotic interactions, energy sources, and influence of chemical variables, habitat structure, and flow regime
  - Include both **Receptors** (benthic macroinvertebrates; fish) and **Stressors (**physical habitat quality, geomorphology, selected field chemistry)

Summary of Etowah R. Sampling Stations
(Stribling and Davie 2005)

Table 1 Summary of the number of sites to be sampled in the watershed over a 6-year period.

	Number of Locations					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Water Quantity [a]	12	12	12	12	12	12
Water Quality [b]	68	75	65	65	70	65
Water Chemistry [c]	72	19	19	19	19	19
Ecological Condition [d]						
Stratified random	53	60	50	50	55	50
Targeted	11	-	11	-	11	-
Total No. Sites	72	79	69	69	74	69

a - flow and volume; b - DO, pH, temperature, conductivity, turbidity; c - nutrients, BOD, metals, sediment; d - biology, physical habitat, geomorphology

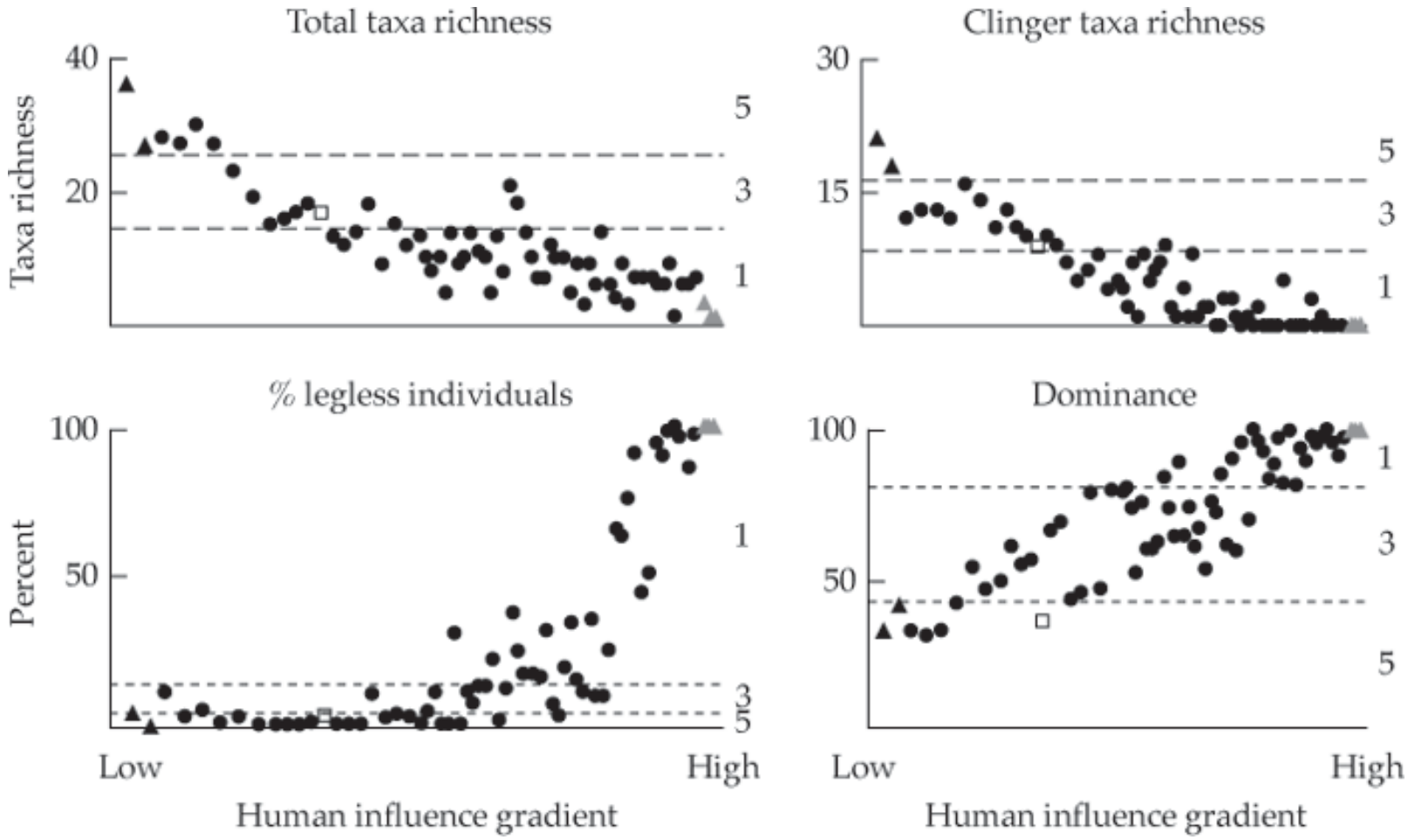
Example 2: Hypothetical

- Concern about potential impact of rapid urbanization in a largely rural basin
- How much development is too much?
  - Goal is to detect change and diagnose cause; halt or change development if change exceeds allowable threshold
- But resources are scarce! What to do?
- Consider a two-tier approach

Example Two-Tier Approach

- **Tier 1**:
  - Continuous monitoring of DO, conductivity, turbidity throughout basin
  - Consider use of satellite or air photo imagery to track sediment transport patterns, land cover
  - Annual or biennial fish and invertebrate surveys
- When non-trivial change detected, begin **Tier 2** (intensive, diagnostic) monitoring in selected reaches
  - Specialized hypothesis-testing surveys and studies

Hypothetical Stream Response to Disturbance (James Karr, UW)



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Choosing Indicators

- Good indicators for environmental monitoring should be:
  - Measurable
  - Reflective of and sensitive to target conditions
  - Appropriate to the nature of impact and time/space scale of affected processes
  - Diagnostic of potential cause
  - Ideally have existing data available

Examples

- Need an indicator of coldwater fish spp. potential
- What about…?
  - Average annual flows?
  - Total phosphorus?
  - Hourly stormwater flows?
  - Average low flows?
  - Daily low flows?
  - Benthic macroinvertebrate fauna?
  - Temperature? DO?
- Peer review can be helpful!

Ten steps to successful monitoring

1. State your problem or objective clearly; include a statement of when you will believe the objective to have been met.
2. Develop a conceptual model of the system
3. Establish system boundaries
   - Geographic boundaries
   - Time boundaries
   - Spatial scale
4. Identify appropriate indicators
5. Develop testable hypotheses if appropriate

Ten steps (continued)

6. Identify additional data sources and determine compatibility with the data you will collect
7. Identify statistical tests appropriate for the questions you are asking; check test assumptions
8. Identify and if possible quantify potential sources of variability in the data
9. Determine appropriate number and spacing of samples
10. Ensure appropriate sample collection/preservation techniques are in place; calibrate equipment as necessary

The Importance of Evaluation

- Ideally, monitoring results should be used to inform periodic review and revision of the monitoring plan and management actions (adaptive management)
- While this takes time and money, it avoids errors and results in a better plan
  - Evaluation is especially critical when the system has undergone massive change or natural disturbance
  - Will be critically important for managing under climate change!

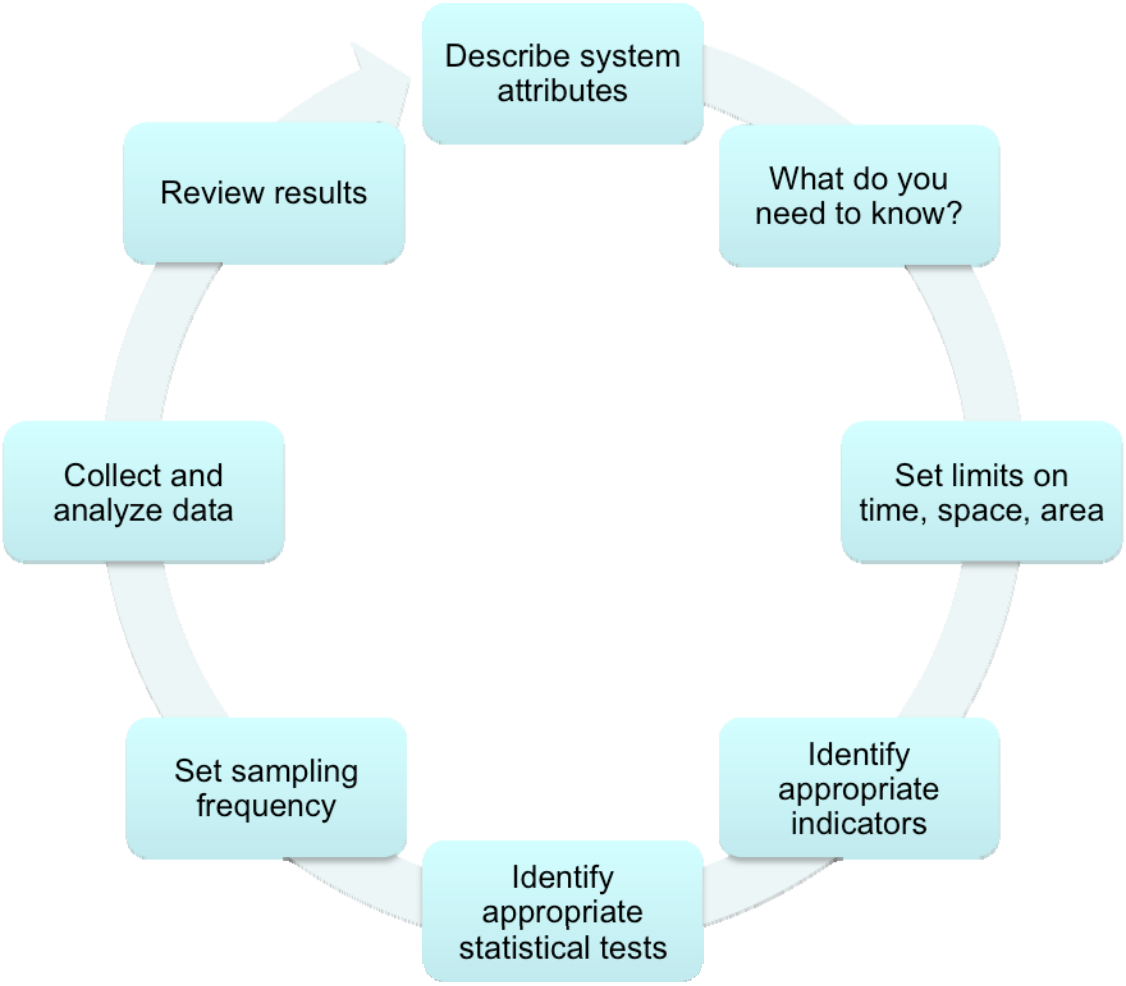
Examples

- Glen Canyon Dam, CO (Grand Canyon Monitoring and Research Center)
  - Long term monitoring plan established in 1997
  - Weaknesses in the plan, and science/information gaps, are periodically reviewed on a five year cycle through a public strategic planning process
  - This process leads to a revised set of management objectives and information needs linked to testable hypotheses.
    - Peer review used for project proposals, reports, and the adaptive management program overall.
    - Center uses a Science Advisory Board for regular advice.

Examples

- River Murray, Australia
  - Adaptive management of flows for protection of biodiversity assets
  - Comprehensive information management system; careful characterization of key system components and processes
    - Asset values and requirements, risk exposures, and management objectives clearly articulated
  - Water managers then make informed judgements about flow manipulation based on strategic objectives, system and resource constraints, modelled scenarios, and real-time information

An iterative, adaptive process



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Conclusion

- There is no magic bullet
- There is no standard approach
- Start with a conceptual model
- Think your way through it
  - Common sense will take you a long way!