Statistical designs and potential indicators for evaluation of restoration success

Katey Driscoll

Middle Rio Grande Collaborative Seminar

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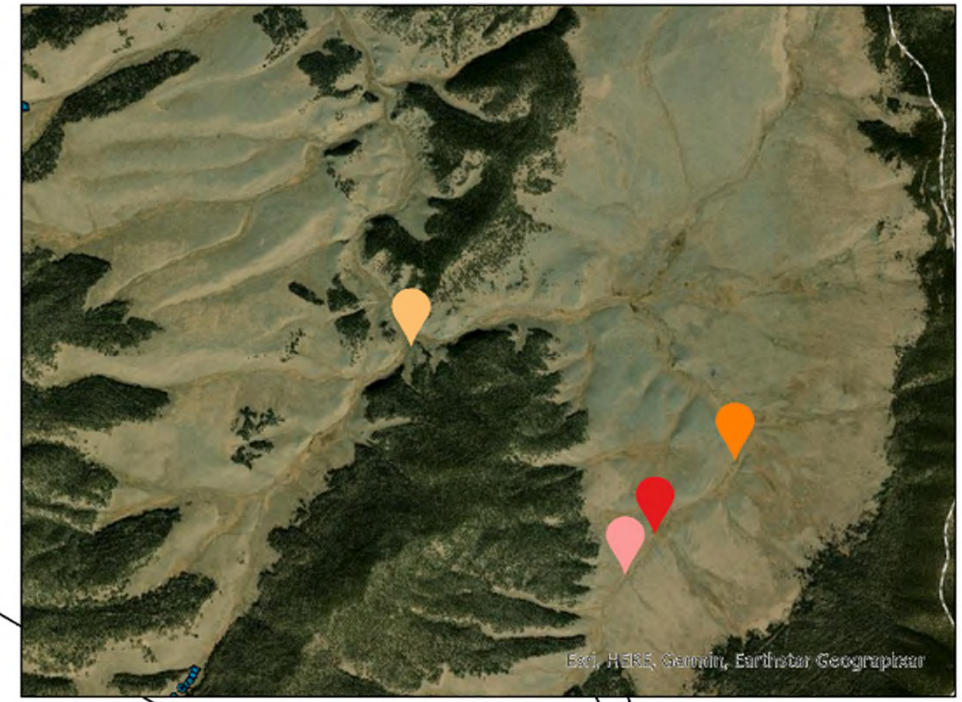
Outline

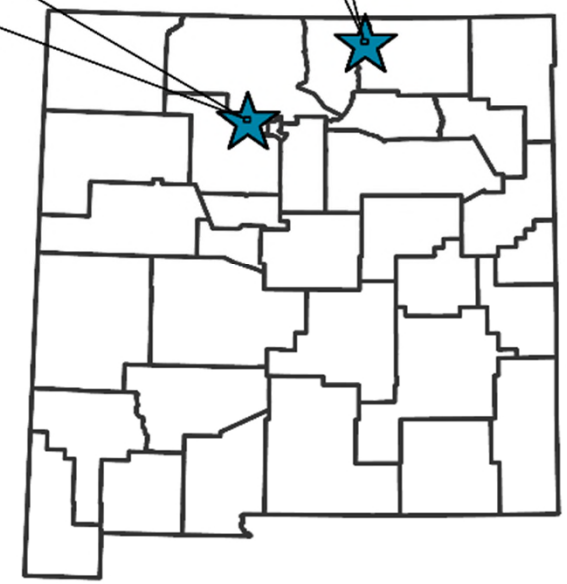
1. Introduce the work I do

2. Discussion of Before-After-Control-Impact (BACI) study designs

3. Discussion of indicators for ecosystem function



Rio Cebolla 1
Rio Cebolla 2
San Antonio 1
San Antonio 2
Valle Vidal - 10C
Valle Vidal - 10I
Valle Vidal - 9C
Valle Vidal - 9I



- Restoration projects are field experiments

- If monitoring is conducted within an appropriate study design, we can draw conclusions regarding treatment effectiveness

- Ongoing debate about the most appropriate study design to draw inferences from field studies involving nonrandom assignment of unreplicated treatments, but general agreement that before-after-control-impact as an underlying framework is best

How I communicate the benefits of BACI with managers and stakeholders

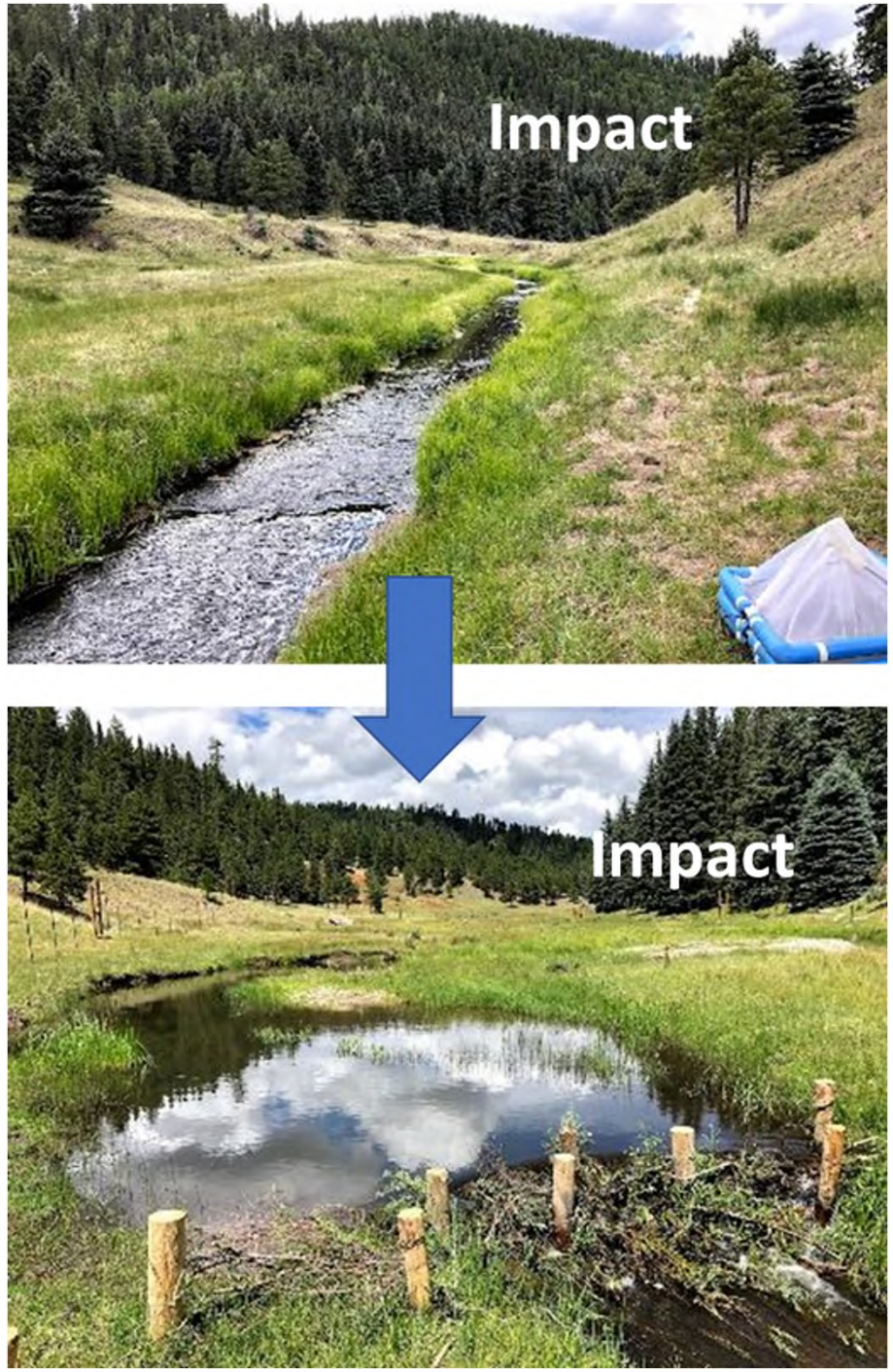
- Early discussions with managers and stakeholders regarding goals and monitoring plans
  - Effective restoration treatments
  - Resource constraints
- Ensure managers and stakeholders are familiar with pros and cons of different monitoring study designs
- Provide examples of what can be done with data collected under BACI approaches

Control-Impact (CI)

- Compares control & impact sites
- Concludes impact of restoration if sites significantly differ
- No two sites are identical, C&I likely differ prior to restoration
- Confounds effect of restoration with processes that produce spatial variation
- High rate of type I error (conclude effect when there isn't one)

Before-After (BA)

- Compares state of impact site before and after restoration
- Concludes effect of restoration if periods significantly differ
- Confounds restoration effect with processes that produce temporal variation
- High rate of type I error
- Good alternative to BACI if:
  - Long and dense time series
  - Well-behaved temporal dynamics

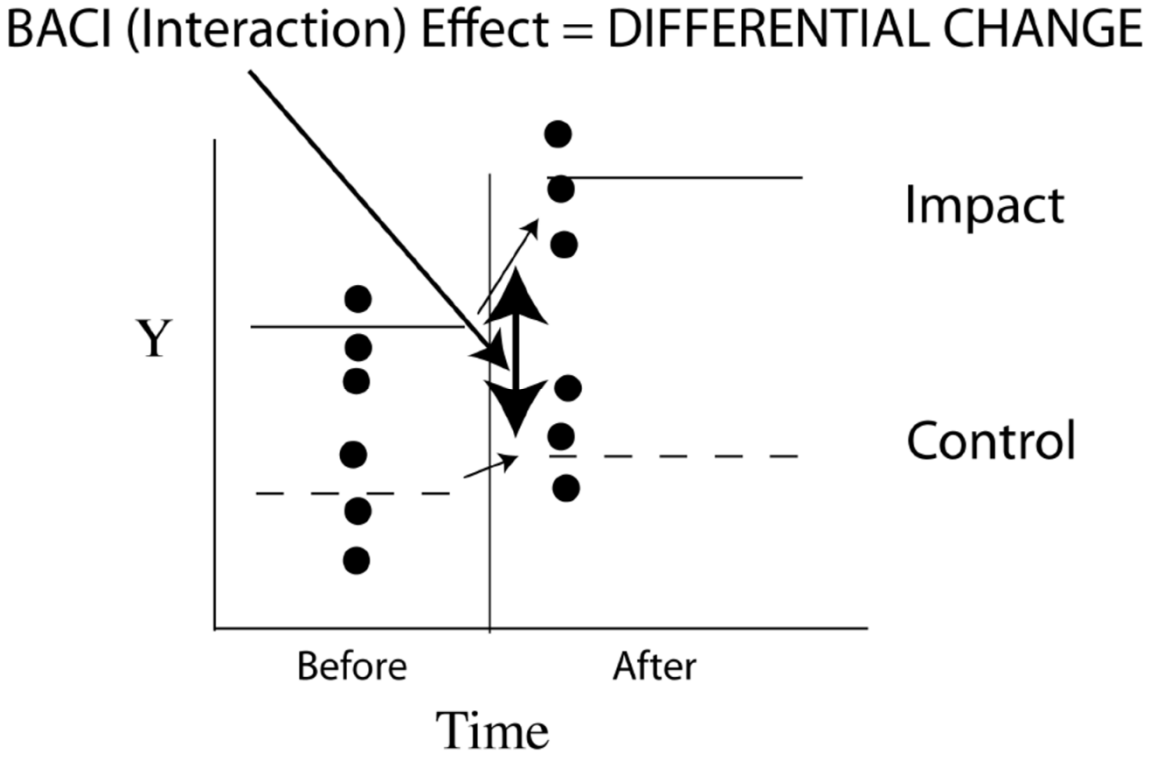


BACI

Before

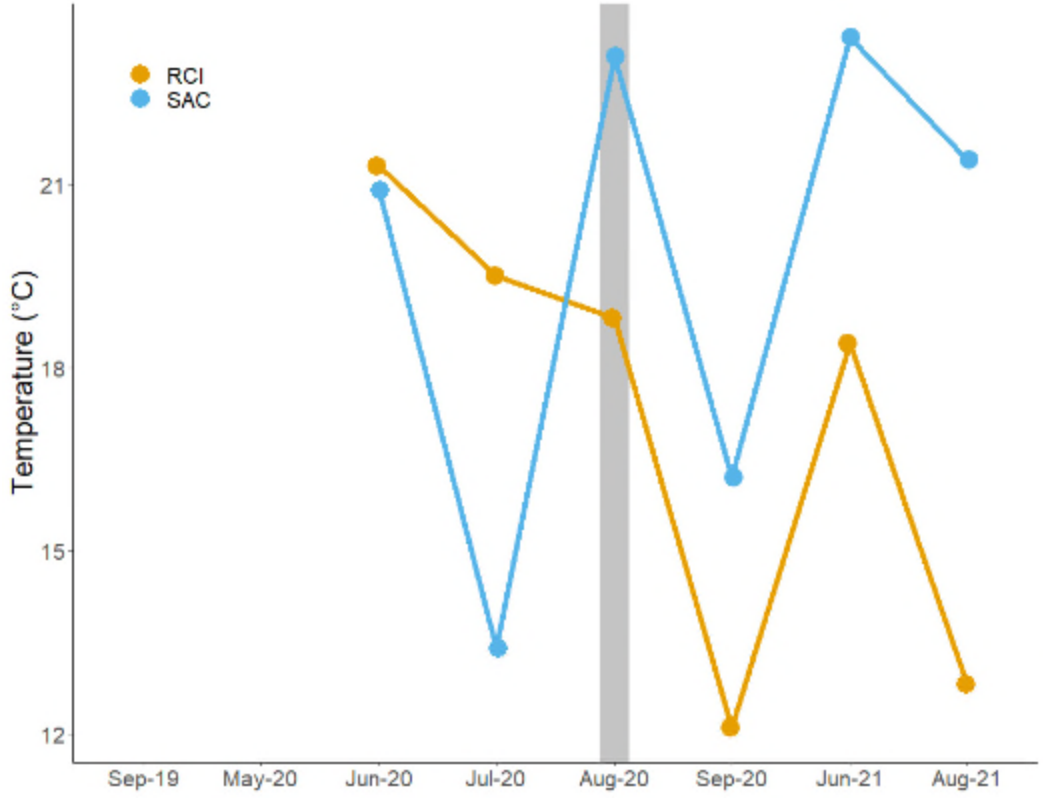
After

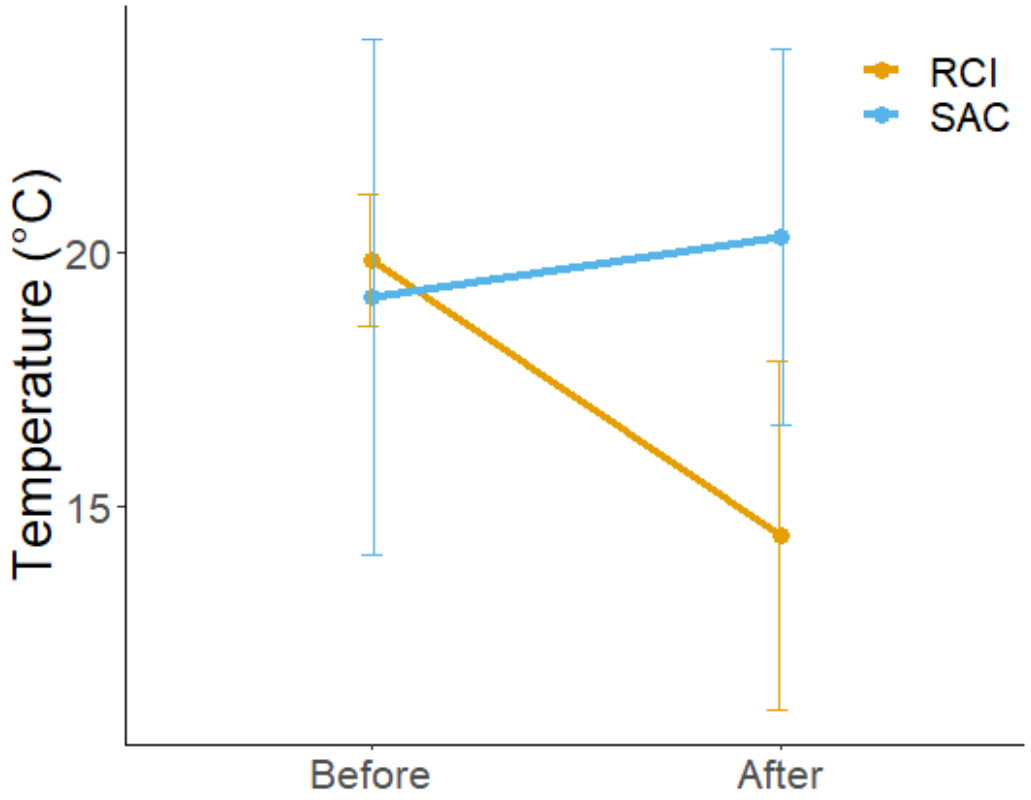
$$(\overline{X_{impact} - X_{control}})_{after} - (\overline{X_{impact} - X_{control}})_{before}$$



- BACI/Interaction term
- Represents potential environmental impact
- Test for interaction

Stream Temperature Data





Effect Size = 6.6°C

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
Period	32.583	32.583	1	7.5416	3.0344	0.1220
Treatment	10.364	10.364	1	7.0000	0.9652	0.3586
Period:Treatment	33.001	33.001	1	7.0000	3.0734	0.1230

Environ Monit Assess (2016) 188: 555
DOI 10.1007/s10661-016-5526-6

Evaluating impacts using a BACI design, ratios, and a Bayesian approach with a focus on restoration

Mary M. Conner · W. Carl Saunders · Nicolaas Bouwes · Chris Jordan

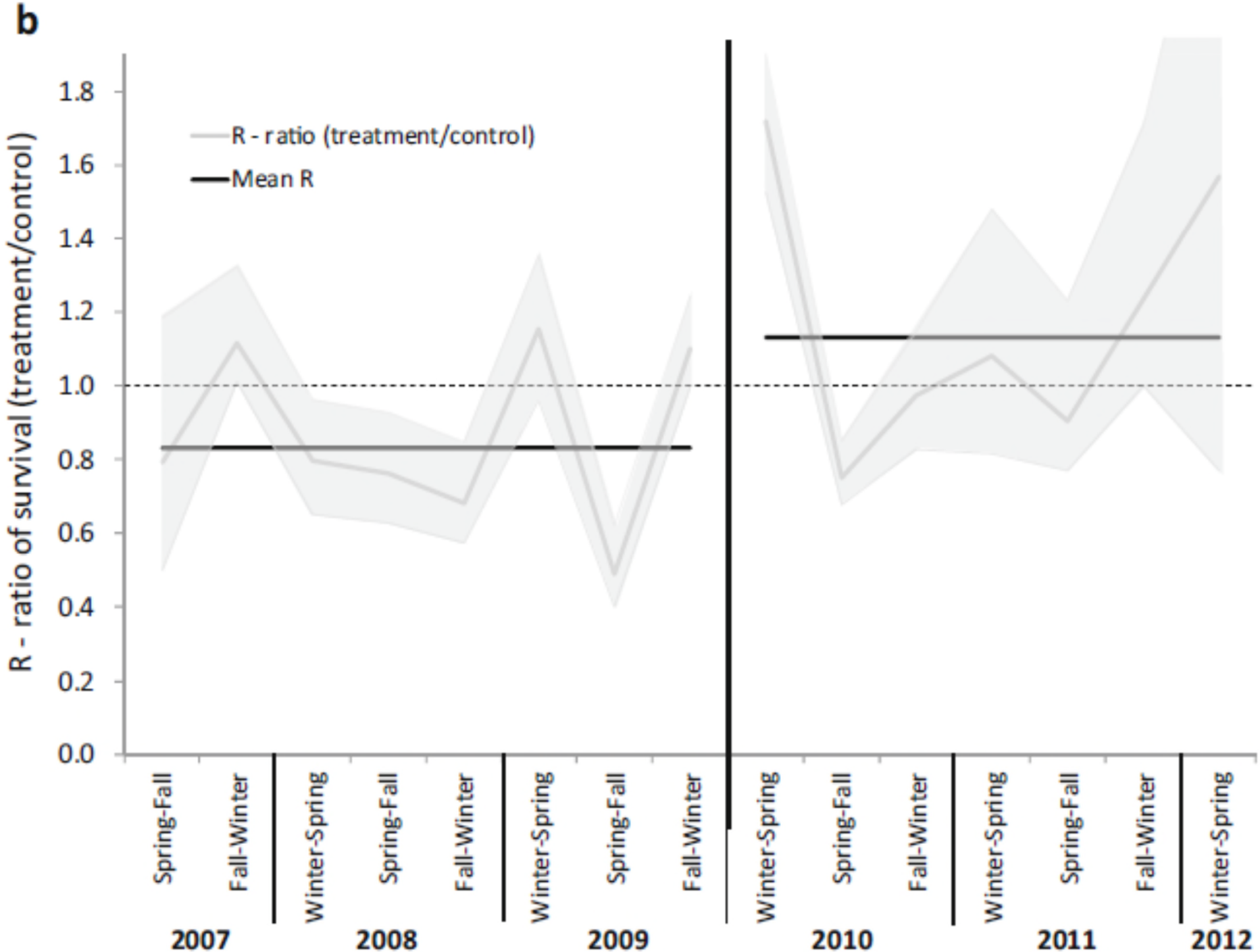


Fig. 2 The **a** 3-month juvenile survival probability of steelhead and **b** the ratio of survival on treatment sites to control sites for each period (*gray line*), and the geometric mean of the ratios (*black line*) before and after BDAs were installed in Bridge Creek, OR, 2007–2012. For **b**, the *shaded area* represents the 95 % credible interval and the *dashed line* represents no treatment effect between control and treatment sites during the before or after periods; *values above the dashed line* indicate survival was higher on treatment sites relative to control sites, and *values below* indicate survival was lower on treatment sites relative to control sites

Conner et al. 2016

Table 2 Estimates of the probability juvenile survival and density increased or decreased a given percentage after BDAs were installed on study sites in Bridge Creek, OR, 2007–2012

Parameter	≥0 %	≥20 %	≥30 %	≥50 %	≥100 %
Increase					
Survival	1.00[a]	0.99	0.88	0.17	0.00
Density	1.00	1.00	0.99	0.82	0.00
Decrease					
Survival	0.00	0.00	0.00	0.00	0.00
Density	0.00	0.00	0.00	0.00	0.00

[a] Probabilities are based on a posterior distribution of relative change (R_{BACI}), which is the geometric mean of the ratios (for each period) of survival and density on the treatment watershed (Bridge Creek) relative to the control watershed (Murderers Creek), with the ratio after divided by the ratio before BDAs were installed

Conner et al. 2016

Lessons learned – how to do BACI successfully

- Collaboration
  - Include researchers at early stages – can help ensure best study design possible given constraints of specific project
- Communication
  - A clear plan outlining goals, treatment types, locations of control and impact sites, and timeline that is shared and agreed to by all parties involved, especially the funding source, the land manager, the contractor or party installing the treatment, and the monitoring group
- Flexibility and Back-up plans
  - Establishment of multiple control & impact sites
  - Potential to transition from BACIPS to BACI to BA
  - Potential ways to incorporate existing long-term datasets

Potential metrics for evaluating ecosystem function

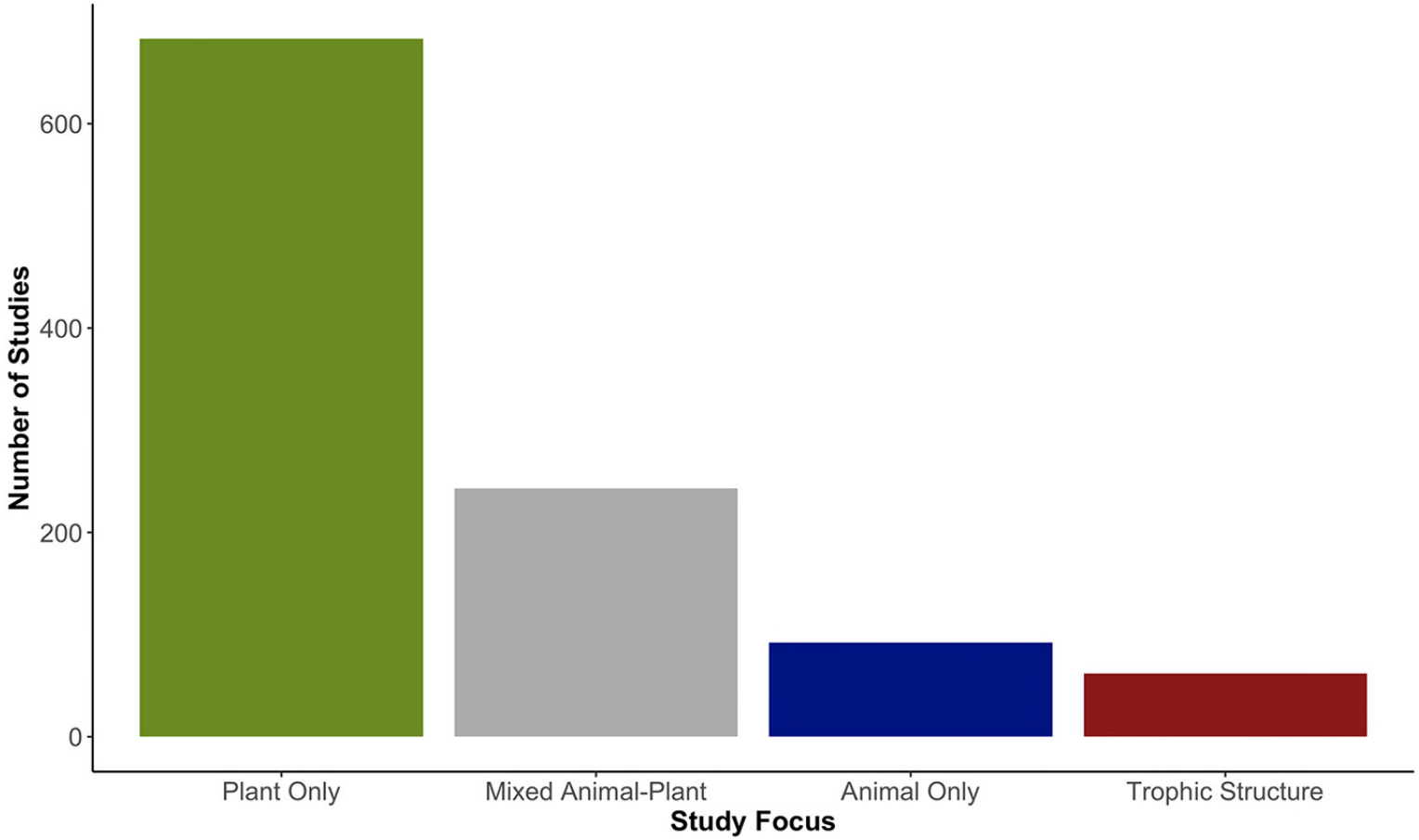
- Restoration targets are often compositional or structural in nature
- Research has shown that achieving these goals does not necessarily result in recovery of ecosystem function
- Metrics for evaluating ecosystem function are rarely included in monitoring plans
- Impacts of restoration on function are not well understood
- Potential Indicators of Ecosystem Function:
  - Rates of decomposition, primary production, respiration, nutrient uptake
  - Community-level functional traits & functional diversity
  - Food web dynamics
  - Trophic transfers

Functional Traits

- Measurable characteristics of individual organisms that describe the response of a species to the environment and/or its effect on ecosystem processes
- Can use community-level traits and functional diversity metrics to evaluate how restoration changes environmental filters and the effects of changes in the community on ecosystem function
- Functional trait databases exist for plants, fish, aquatic macroinvertebrates, etc.
- Relies on community composition data that is already collected for many restoration projects

Food Webs

- Restoration may increase the number of trophic pathways by reestablishing natural disturbance regimes, increasing habitat diversity, and altering community composition
- Recovery of food webs is frequently suggested as restoration target, but has been applied in few studies
- Stable isotope analysis offers a tool to evaluate changes in trophic structure



Loch et al. 2020

Trophic Transfers

- Subsidy: organism, nutrient, energy that cross ecosystem boundaries
  - Highly variable
  - Significant impacts on ecosystem function, consumer-resource dynamics
- Magnitude, quality, and extent of subsidies depend on boundary permeability, mobility of organisms, and the size, shape, similarity, distance between, and relative productivity of habitats
  - Potentially impacted by degradation & restoration
- Can be evaluated using stable isotopes or other methods for studying diet


Questions?

- Can increase the likelihood of detecting a restoration impact when there is one to detect by:
  - Sampling multiple times in before and after periods
  - Using multiple control sites
  - Using a pristine and degraded control site
  - Having long before and after periods
- Constraints
  - Existence of suitable reference sites
  - Ability to collect data at control and impact sites both before and after a restoration occurs for a long enough time to have statistical power to detect a change at impact sites.
  - Can result in high rates of rejecting a null hypothesis when there was no impact or accepting a null hypothesis when there was in impact