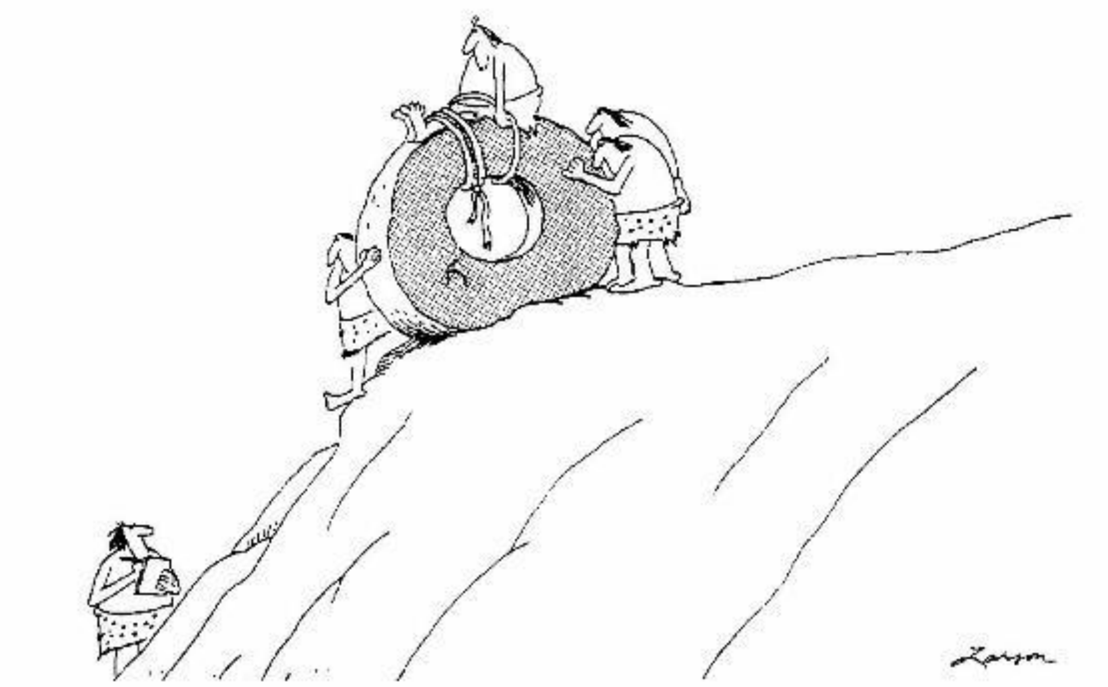
Knowledge is Power: Developing Monitoring Programs that Increase Understanding of Restoration Outcomes



Early Experiments in Transportation

Cara R. Nelson

— Associate Professor & Director, Ecological Restoration Program, UM

— Chair, Society for Ecological Restoration

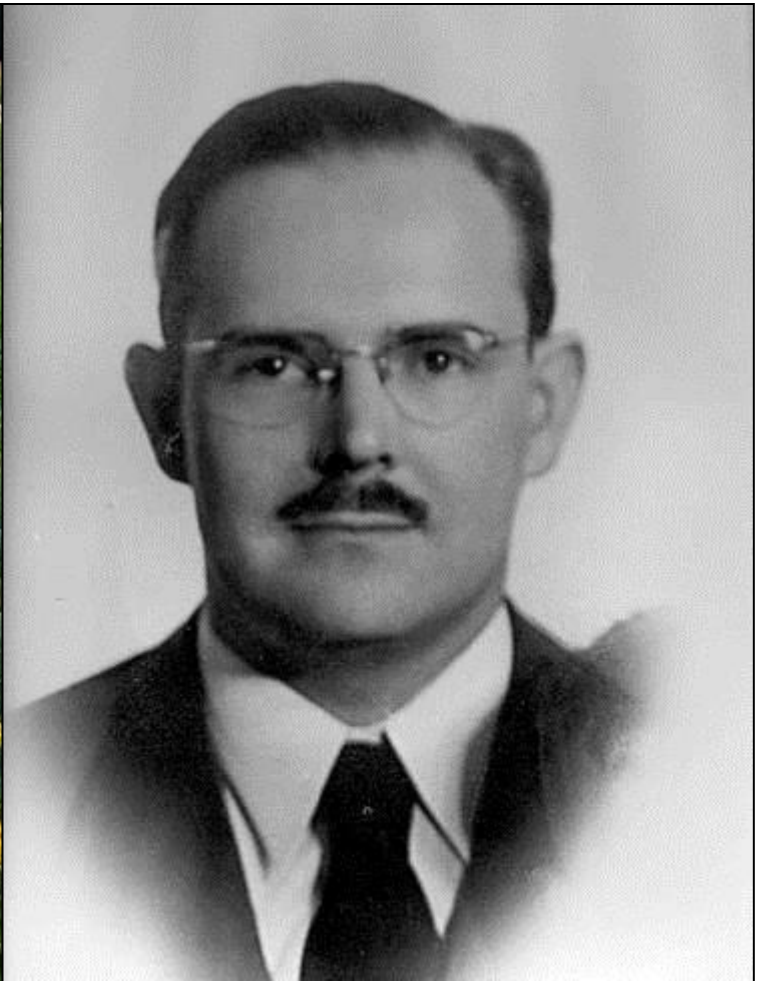
COLLEGE OF FORESTRY AND CONSERVATION

Where Ideas Take Flight

SER
SOCIETY FOR
ECOLOGICAL
RESTORATION

SIACRE
Sociedad Iberoamericana
y del Caribe de
Restauración Ecológica

Roots of Ecological Restoration



John Curtis (1913-1961), Director of Plant Research, UW-Madison Arboretum

The Stakes are Increasing

POLICY FORUM

ECOLOGY

Synthesizing U.S. River Restoration Efforts

E. S. Bernhardt,[1*†] M. A. Palmer,[1] J. D. Allan,[2] G. Alexander,[2] K. Barnas,[3] S. Brooks,[4] J. Carr,[5] S. Clayton,[6] C. Dahm,[7] J. Follstad-Shah,[7] D. Galat,[8,9] S. Gloss,[10] P. Goodwin,[6] D. Hart,[5] B. Hassett,[1] R. Jenkinson,[11] S. Katz,[3] G. M. Kondolf,[12] P. S. Lake,[4] R. Lave,[12] J. L. Meyer,[13] T. K. O'Donnell,[9] L. Pagano,[12] B. Powell,[14] E. Sudduth[13]

The importance of rivers and streams for fresh water, food, and recreation is well known, yet there is increasing evidence that degradation of running waters is at an all-time high (*1*). More than one-third of the rivers in the United States are listed as impaired or polluted (*2*), and freshwater withdrawals in some regions are so extreme that some major rivers no longer flow to the sea year round (*3*). Extinction rates of freshwater fauna are five times that for terrestrial biota (*4*, *5*). Fortunately, stream and river restoration can lead to species recovery, improved inland and coastal water quality, We found that existing restoration databases are highly fragmented and often rely on ad hoc or volunteer data entry. Thus, we developed methods for the unbiased collection and cataloging of river and stream restoration projects. Here, we report a synthesis of information on 37,099 projects in the National River Restoration Science Synthesis (NRRSS) database.

The NRRSS database includes all stream and river restoration projects present in national databases as of July 2004, as well as a large sample of river and stream restoration projects from seven geographic regions (see

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[see table, page 637 a

The number of ri
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below). Data from na
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supports some trac
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majority of projects a
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The most comm
river restoration in th
to enhance water q
riparian zones, (iii)
habitat, (iv) for fish
bank stabilization (
Projects with these g

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CONCLUSIONS

- a comprehensive assessment of restoration progress is not possible with information currently available.
- < 10% of projects included any type of monitoring.


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Monitoring versus Research

Topics for This Morning

I. *A perspective* —the importance of coupling research and monitoring

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II. *Some sampling design theory* — methods for assessing efficacy and effects of restoration treatments

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II. *Some sampling design theory* — methods for assessing efficacy and effects of restoration treatments

III. *Action items* — to ensure monitoring programs succeed

Scientific Method (Baconian Method)

Francis Bacon (1561 – 1626)

Knowledge is power!

Religious Meditations of Heresies (1597)

Scientific Method (Baconian Method)

Definition: A method or procedure that has characterized natural science since the 17th century, consisting in *systematic observation, measurement, and experiment*, and the *formulation, testing, and modification of hypotheses* (Oxford English Dictionary)

Characteristics: 1) objective, 2) repeatable, and 3) sharable.

Monitoring can be Unrelated to Research

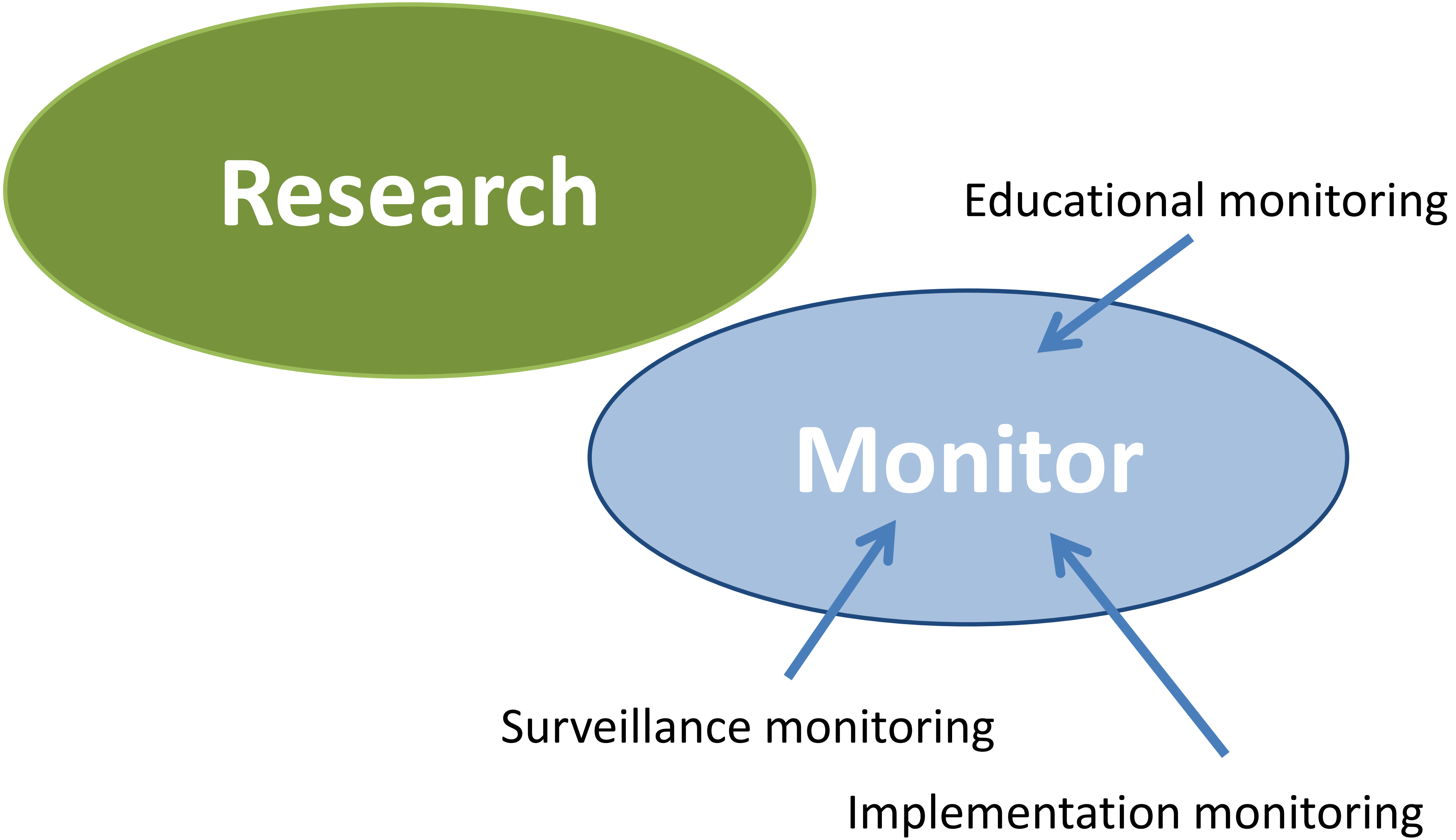
Research = The systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.

Monitoring can be Unrelated to Research

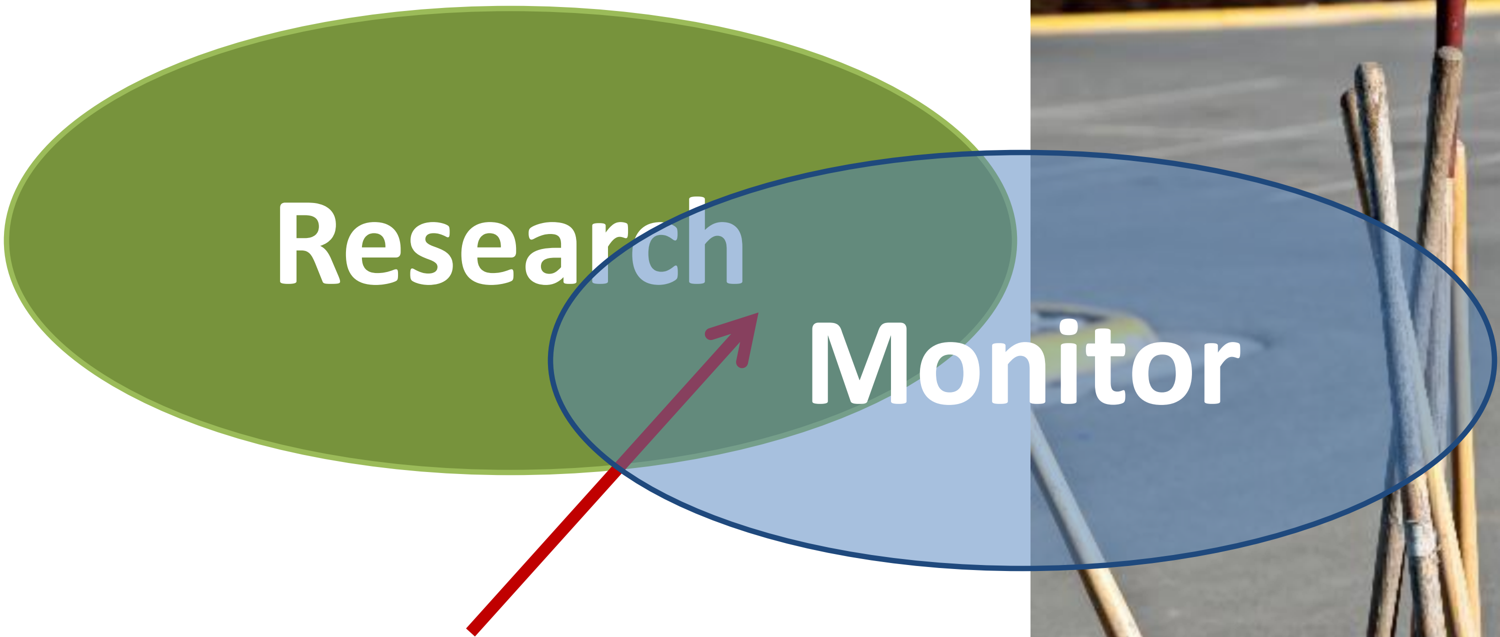
Research = The systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.

Monitor = Watching, keeping track of, or checking usually for a special purpose


Monitoring can be Unrelated to Research



Research or Monitoring?



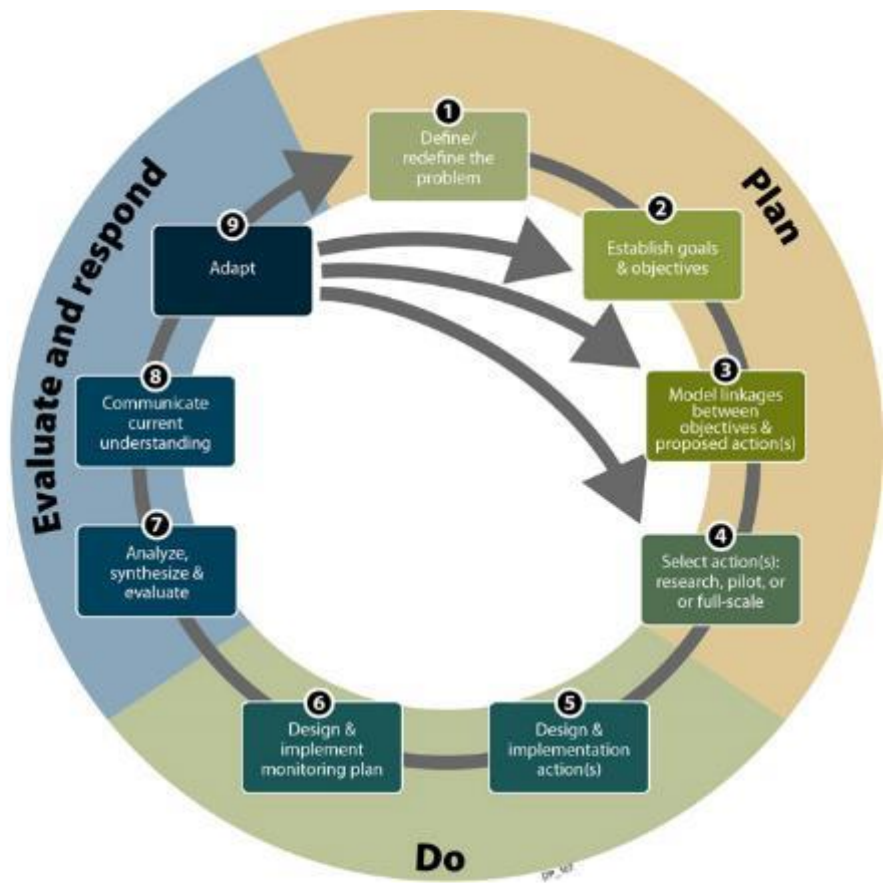
Question-driven monitoring

(efficacy & effects of management activities)

Requires systematic observation, measurement, and experiment

The risk of decoupling monitoring and research….

The risk of decoupling monitoring and research….



II. Some sampling design theory —

Methods for assessing efficacy and effects of restoration treatments

One caveat about monitoring "efficacy"

Management goal: improve riparian habitat

or

What should a goal include?

1. **Attribute:** e.g. riparian habitat
2. **Target:** e.g. density of woody stems
3. **Action:** e.g. increase, decrease, or maintain
4. **Quantity/Status:** e.g. 20%
5. **Time frame:** e.g. 5 Years
6. **Location:** geographical area and extent

Management goals that lack one of these components are unclear !

Modified from Elzinga et al. 2001

Approaches for measuring efficacy: End-point vs. Effect Size Assessment

Approaches for measuring efficacy: End-point Assessment

Question: Did we reach our performance target?

Method: Compare state of the system after treatment with a pre-defined goal

What do you need to get started?

1. Performance target

What do you need to get started?

1. Performance target

What do you need to get started?

1. Performance target
    - Theoretical (e.g., 90% vegetation cover)
    - Empirical (e.g., 90% of a reference condition)

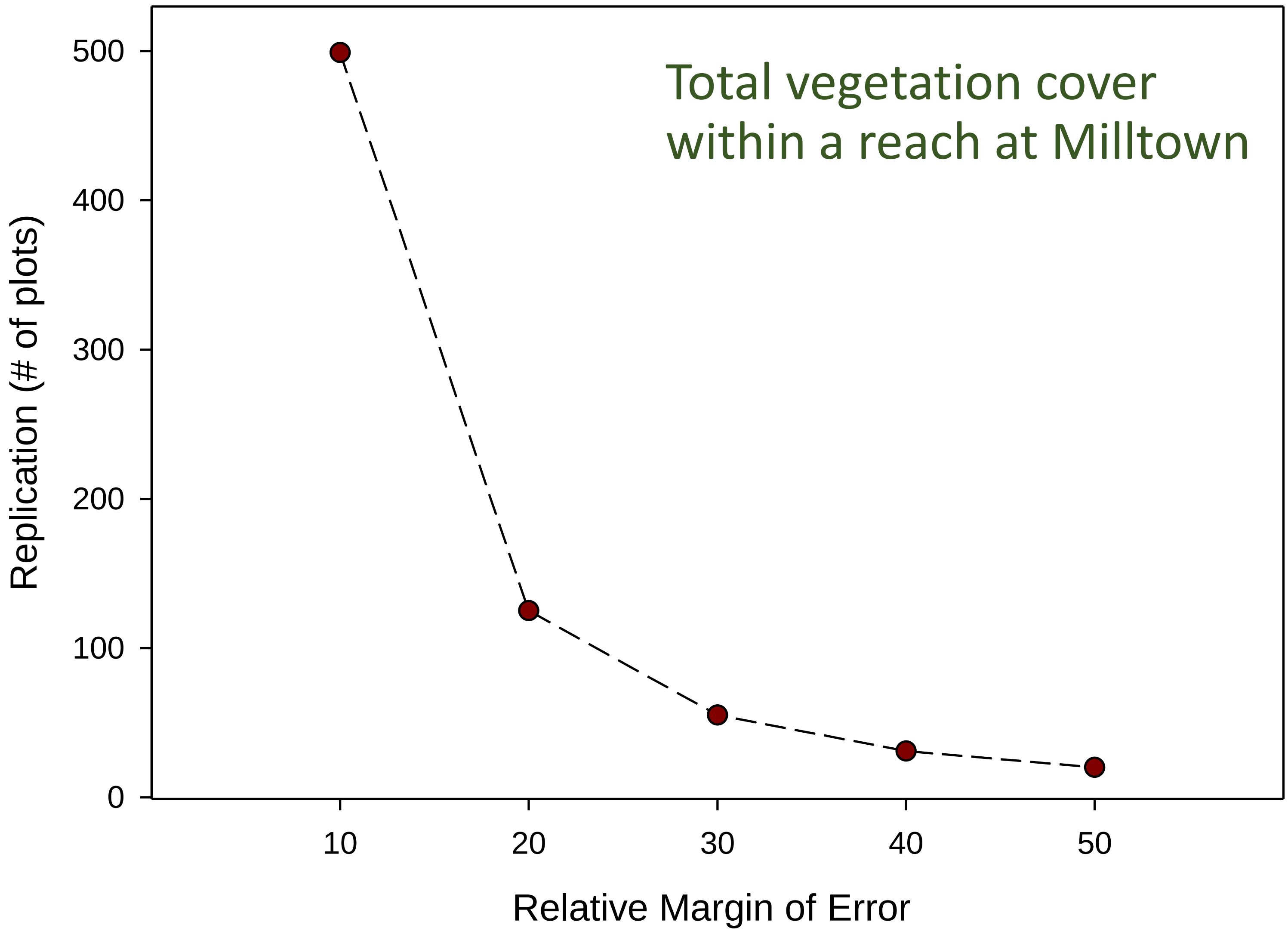
Either way, assessment involves comparing the post-treatment system with the stated goal

What do you need to get started?

1. Performance target

2. Confidence interval (precision of estimation)

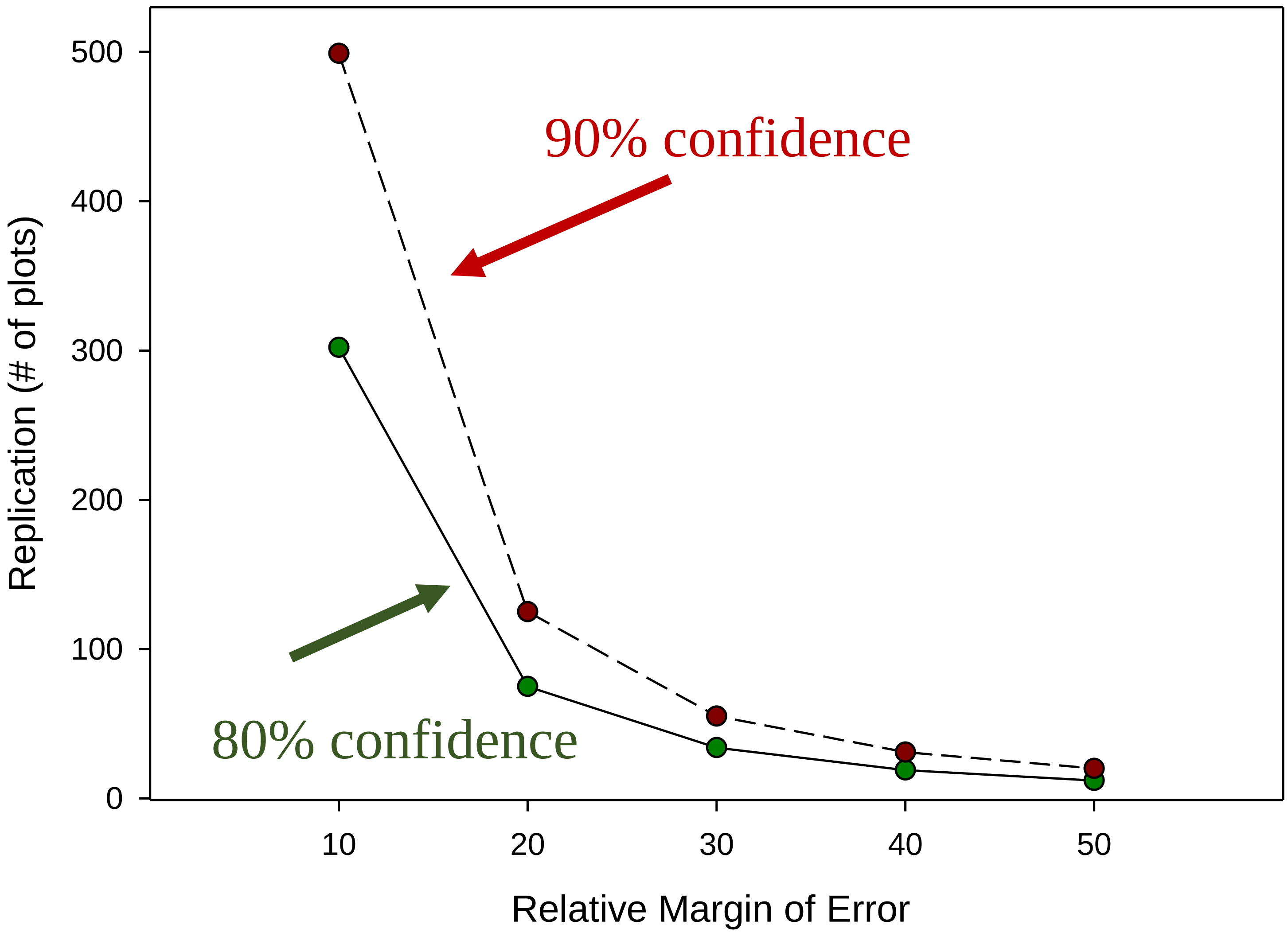
Precision of Estimation



What do you need to get started?

1. Performance target
2. Confidence interval (precision of estimation)
3. Confidence level

Precision of Estimation



Recent Examples of Empirical End-point Assessments

OPEN ACCESS Freely available online PLoS BIOLOGY

Structural and Functional Loss in Restored Wetland Ecosystems

David Moreno-Mateos[1,2*], Mary E. Power[1], Francisco A. Comín[3], Roxana Yockteng[4]

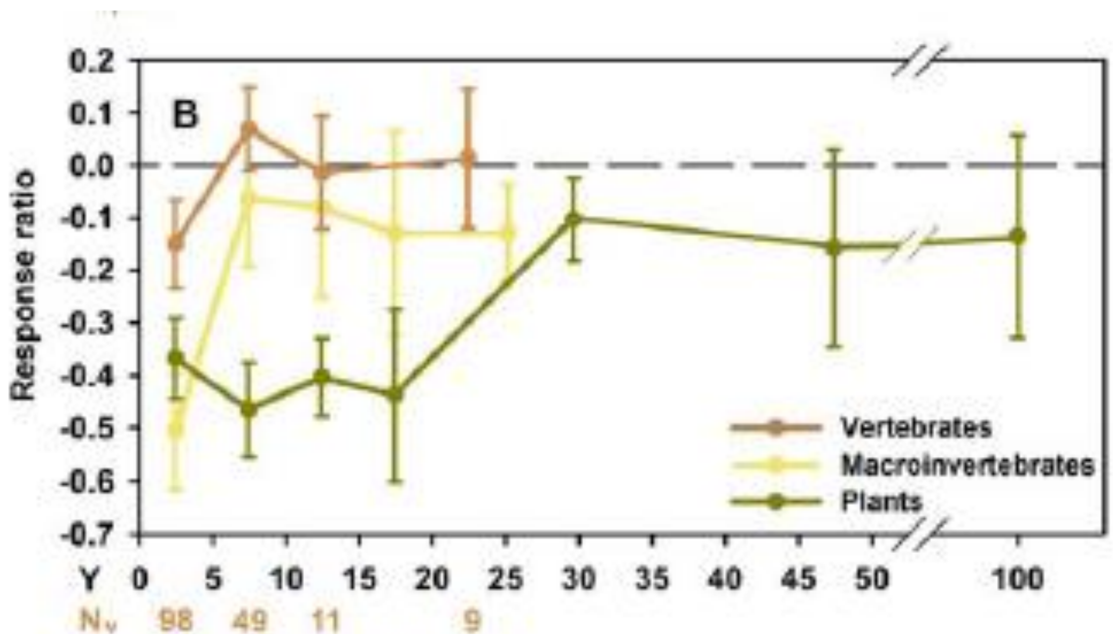
1 Integrative Biology Department, University of California at Berkeley, Berkeley, California, United States of America, 2 Jasper Ridge Biological Preserve, Stanford University, Woodside, California, United States of America, 3 Department of Conservation of Biodiversity and Ecosystem Restoration, Pyrenean Institute of Ecology – CSIC, Zaragoza, Spain, 4 UMR CNRS 7205, Muséum National d'Histoire Naturelle, Paris, France

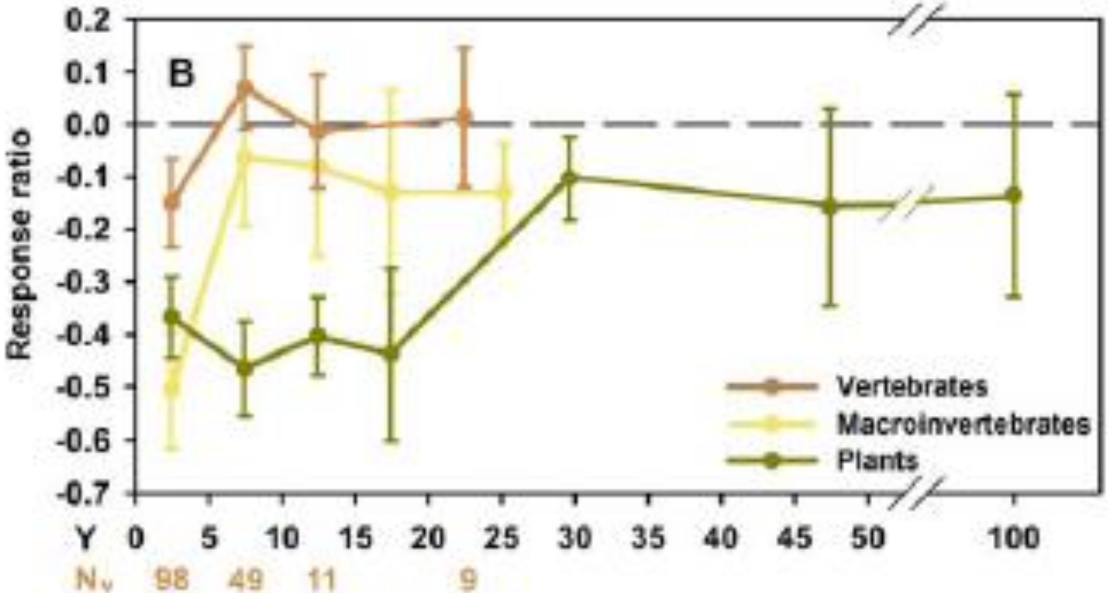
Abstract

Wetlands are among the most productive and economically valuable ecosystems in the world. However, because of human activities, over half of the wetland ecosystems existing in North America, Europe, Australia, and China in the early 20th century have been lost. Ecological restoration to recover critical ecosystem services has been widely attempted, but the degree of actual recovery of ecosystem functioning and structure from these efforts remains uncertain. Our results from a meta-analysis of 621 wetland sites from throughout the world show that even a century after restoration efforts, biological structure (driven mostly by plant assemblages), and biogeochemical functioning (driven primarily by the storage of carbon in wetland soils), remained on average 26% and 23% lower, respectively, than in reference sites. Either recovery has been very slow, or postdisturbance systems have moved towards alternative states that differ from reference conditions. We also found significant effects of environmental settings on the rate and degree of recovery. Large wetland areas (>100 ha) and wetlands restored in warm (temperate and tropical) climates recovered more rapidly than smaller wetlands and wetlands restored in cold climates. Also, wetlands experiencing more (riverine and tidal) hydrologic exchange recovered more rapidly than depressional wetlands. Restoration performance is limited: current restoration practice fails to recover original levels of wetland ecosystem functions, even after many decades. If restoration as currently practiced is used to justify further degradation, global loss of wetland ecosystem function and structure will spread.

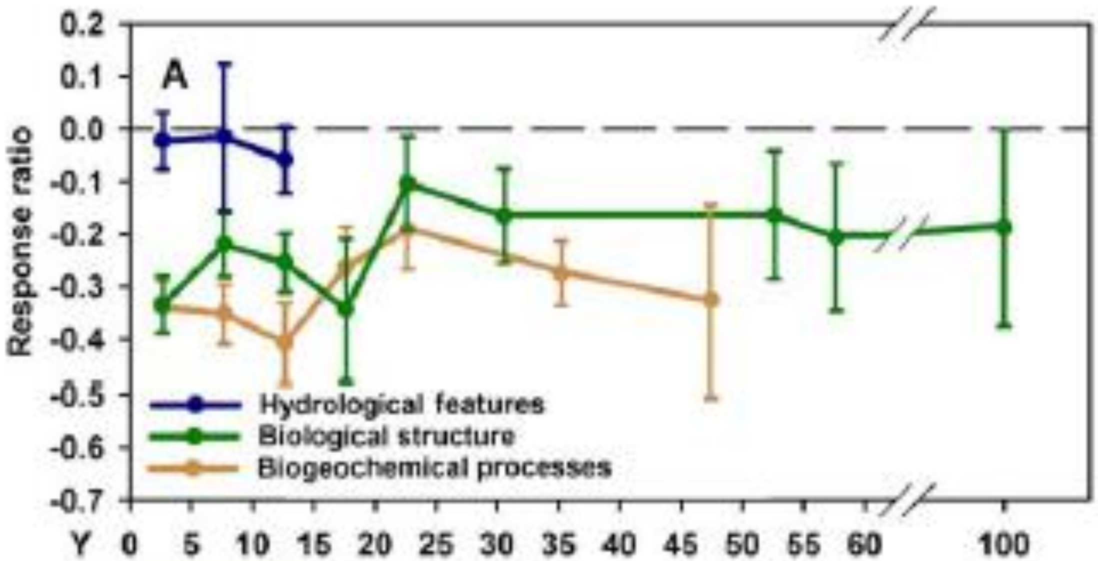
Citation: Moreno-Mateos D, Power ME, Comín FA, Yockteng R (2012) Structural and Functional Loss in Restored Wetland Ecosystems. PLoS Biol 10(1): e1001247. doi:10.1371/journal.pbio.1001247

Academic Editor: Michel Loreau, McGill University, Canada


B
Response ratio
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
Vertebrates
Macroinvertebrates
Plants
Y 0 5 10 15 20 25 30 35 40 45 50 100
Nv 98 49 11 9



B
Response ratio
Vertebrates
Macroinvertebrates
Plants
Y
Nv 98 49 11 9



A
Response ratio
Hydrological features
Biological structure
Biogeochemical processes
Y

they highly correlate (table S3). We selected Maurer's rather than Foote's rates because the later cannot be calculated for three of the four Early Triassic time bins, that is, when ammonoids actually recovered (table S2).

Model comparison using evidence ratios calculated from corrected Akaike information criterion values favors the hierarchical diversification model over the logistic one (table S5). Indeed, even if both models converge toward the same steady-state richness values (~70 sampled genera) (Fig. 4), the logistic model clearly fails to capture the Early Triassic nondelayed recovery dynamics, contrary to the hierarchical one. In addition, the empirical (log) richness-rates relationships (table S4) illustrate a possible niche incumbency effect (*30*). This hypothesis, which predicts that richness and extinction rates are independent, allows the estimate of an average steady-state generic niche saturation level of ~85% under the hierarchical model, compatible with species niche saturation levels previously published for various clades of marine organisms (*30*).

Numerous Lazarus taxa among benthic and pelagic mollusks reappear during the Smithian (e.g., *6*, *31*). Coupled with the Triassic ammonoid

Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis

José M. Rey Benayas,[1,2]* Adrian C. Newton,[3] Anita Diaz,[3] James M. Bullock[4]

Ecological restoration is widely used to reverse the environmental degradation caused by human activities. However, the effectiveness of restoration actions in increasing provision of both biodiversity and ecosystem services has not been evaluated systematically. A meta-analysis of 89 restoration assessments in a wide range of ecosystem types across the globe indicates that ecological restoration increased provision of biodiversity and ecosystem services by 44 and 25%, respectively. However, values of both remained lower in restored versus intact reference ecosystems. Increases in biodiversity and ecosystem service measures after restoration were positively correlated. Results indicate that restoration actions focused on enhancing biodiversity should support increased provision of ecosystem services, particularly in tropical terrestrial biomes.

Ecological restoration involves assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed, typically as a result of human activities (*1*). Restoration actions are increasingly being implemented throughout the world (*2*), supported by global policy commitments such as the Convention on Biological Diversity [article 8(f), (*3*)]. A major they highly correlate (table S3). We selected Maurer's rather than Foote's rates because the later cannot be calculated for three of the four Early Triassic time bins, that is, when ammonoids actually recovered (table S2).

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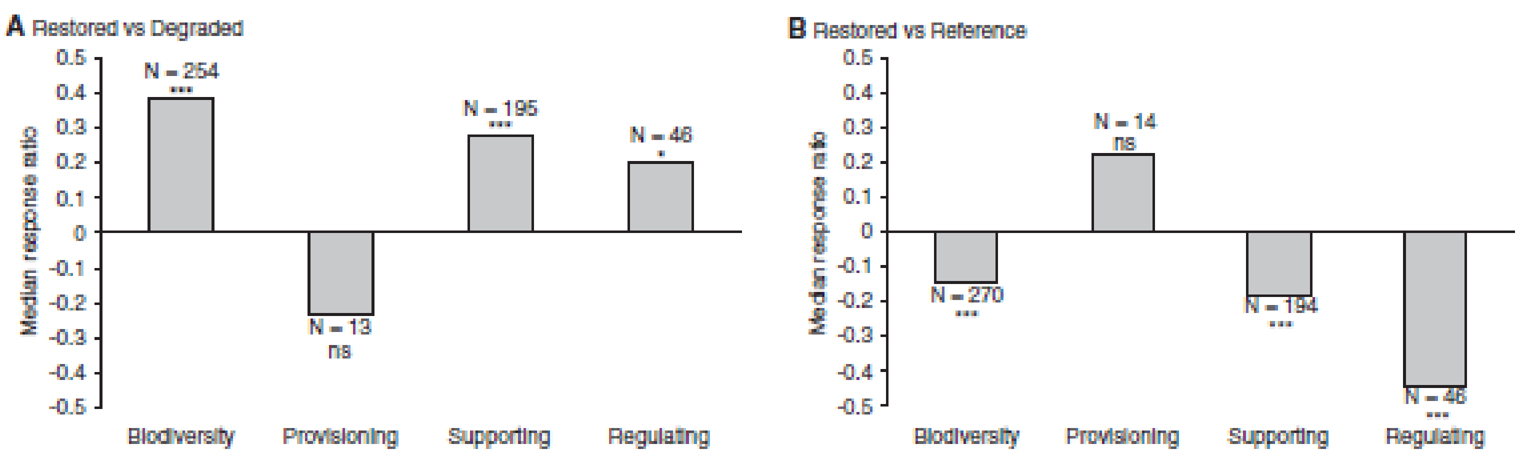


Fig. 1. Response ratios of biodiversity and ecosystem services in (**A**) restored compared with degraded ecosystems and (**B**) restored compared with reference ecosystems. All response ratios differed significantly from zero (Wilcoxon signed rank tests, ***$P < 0.001$, *$P < 0.05$), except those for provisioning services [not significant (ns) $P > 0.05$]. Significant differences were found between the response ratios for biodiversity and the three ecosystem service categories with the use of Kruskal-Wallis tests [restored versus degraded: H (the K-W test statistic) = 11, N (sample size) = 508, $P < 0.05$; restored versus reference: $H = 15$, $N = 524$, $P < 0.01$].

Can an end-point assessment determine if your treatment was effective?

Another approach for measuring efficacy and effects: Effect-size Assessment

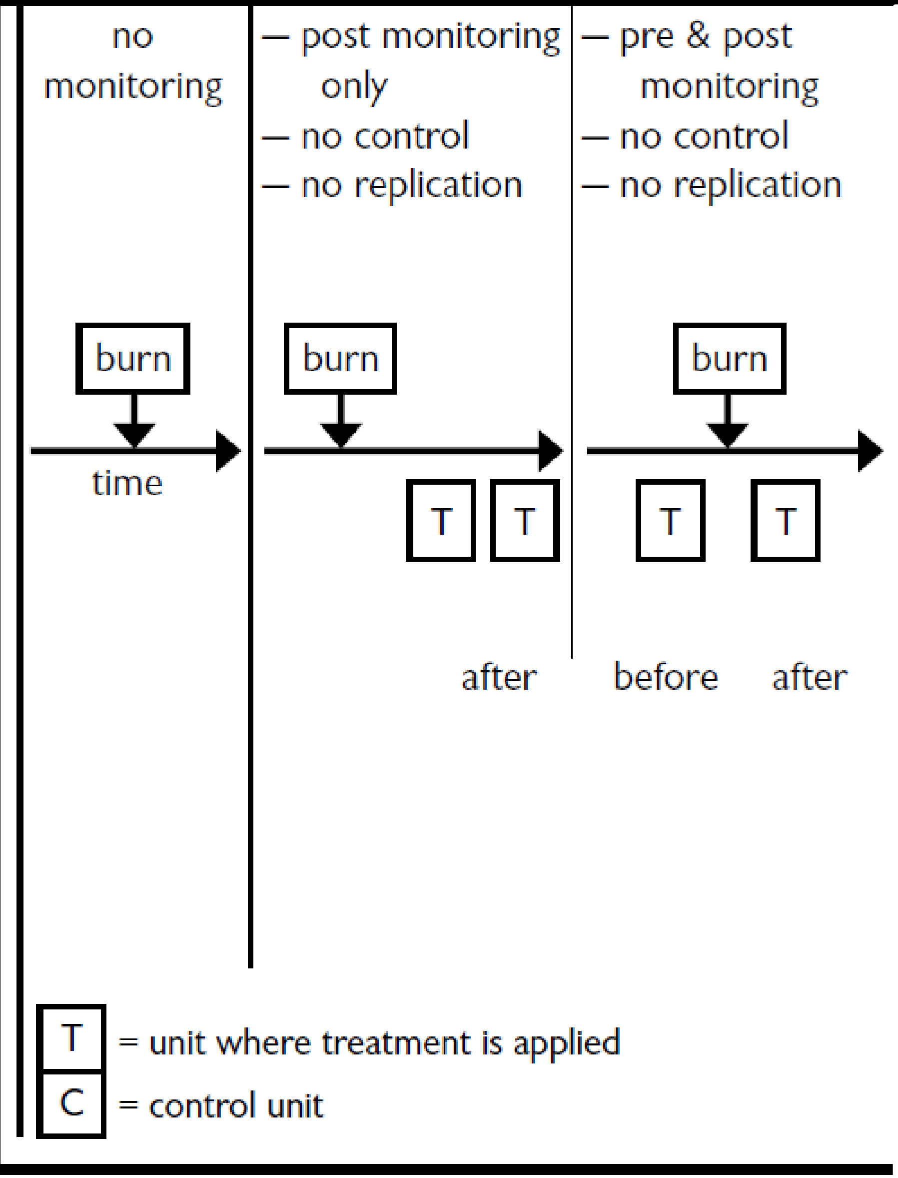
Another approach for measuring efficacy and effects: Effect-size Assessment

- End point assessments – did we reach our goal?
- Effect-size assessments – what was the effect of the treatment (i.e. causal relationship)?

The only way to determine if the treatment caused the effect is to use a BACI design

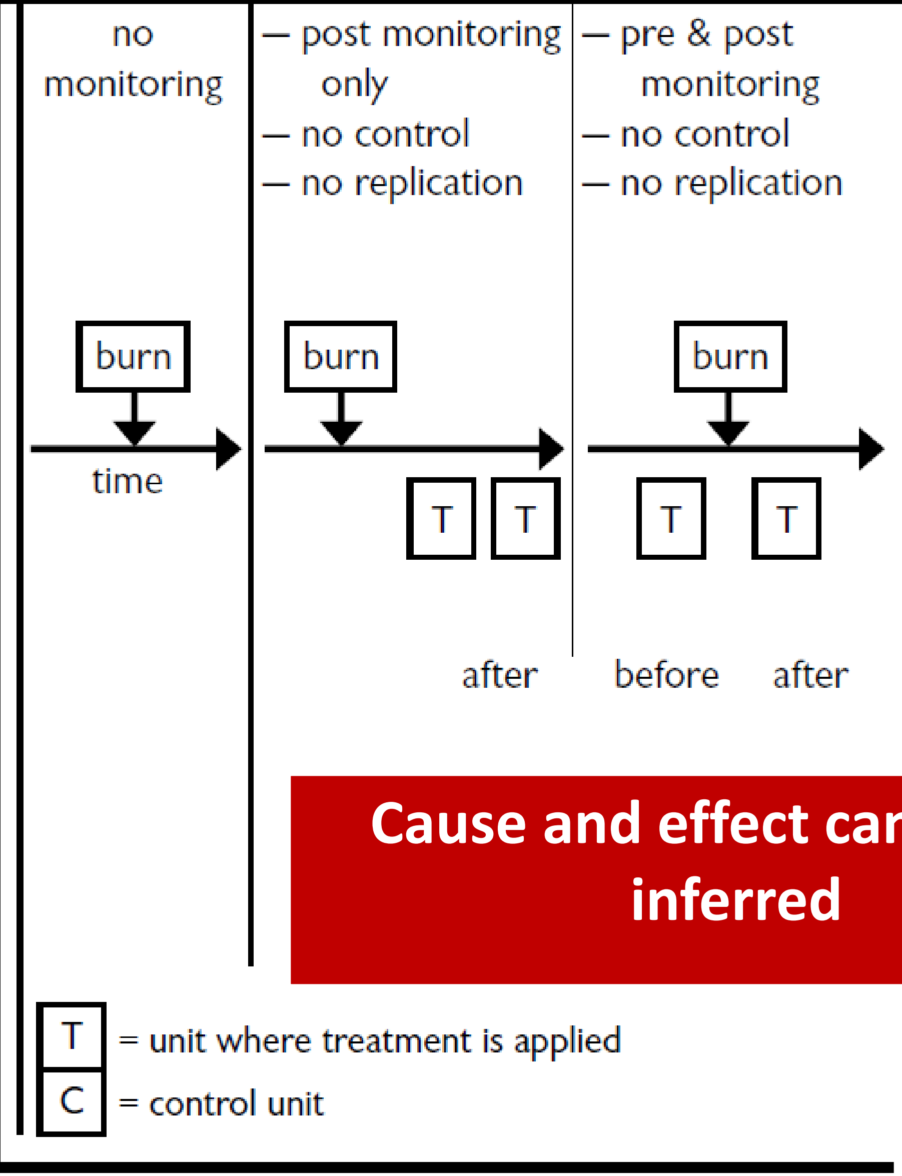
Before-After-Control-Impact

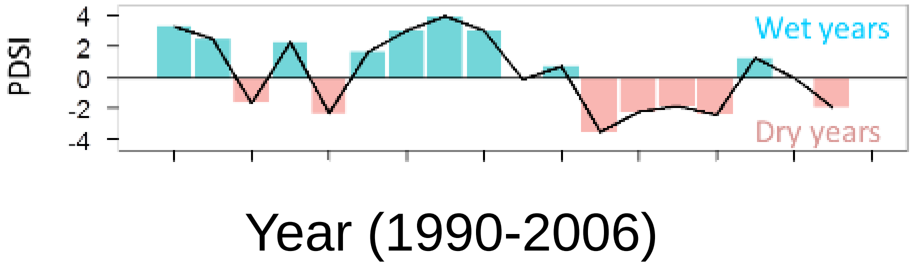
Common Monitoring Designs



Elzinga et al. 2001

Common Monitoring Designs

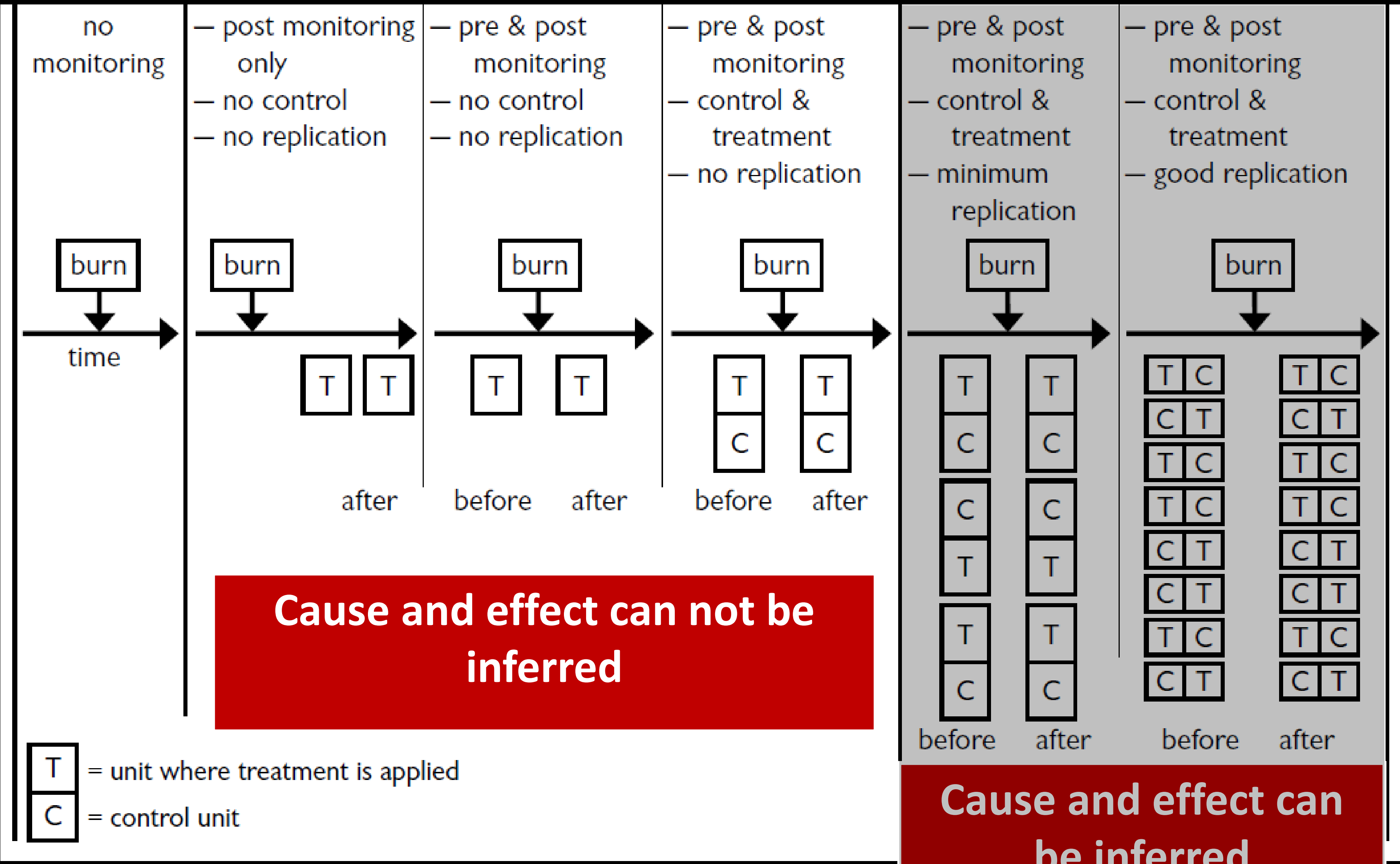




Cause and effect can not be inferred

Elzinga et al. 2001

Common Experimental Design

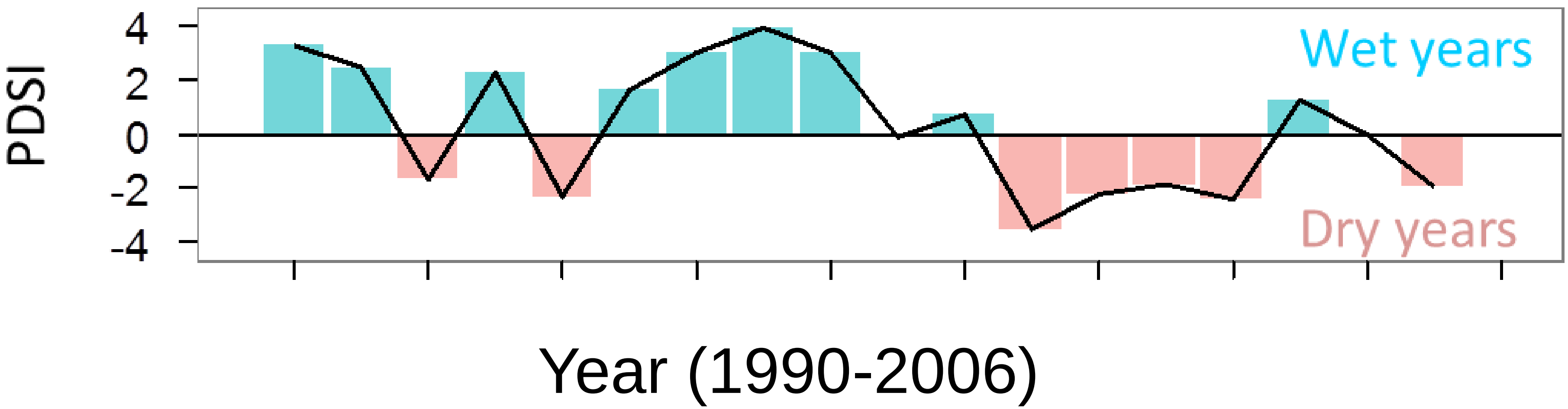


Cause and effect can not be inferred

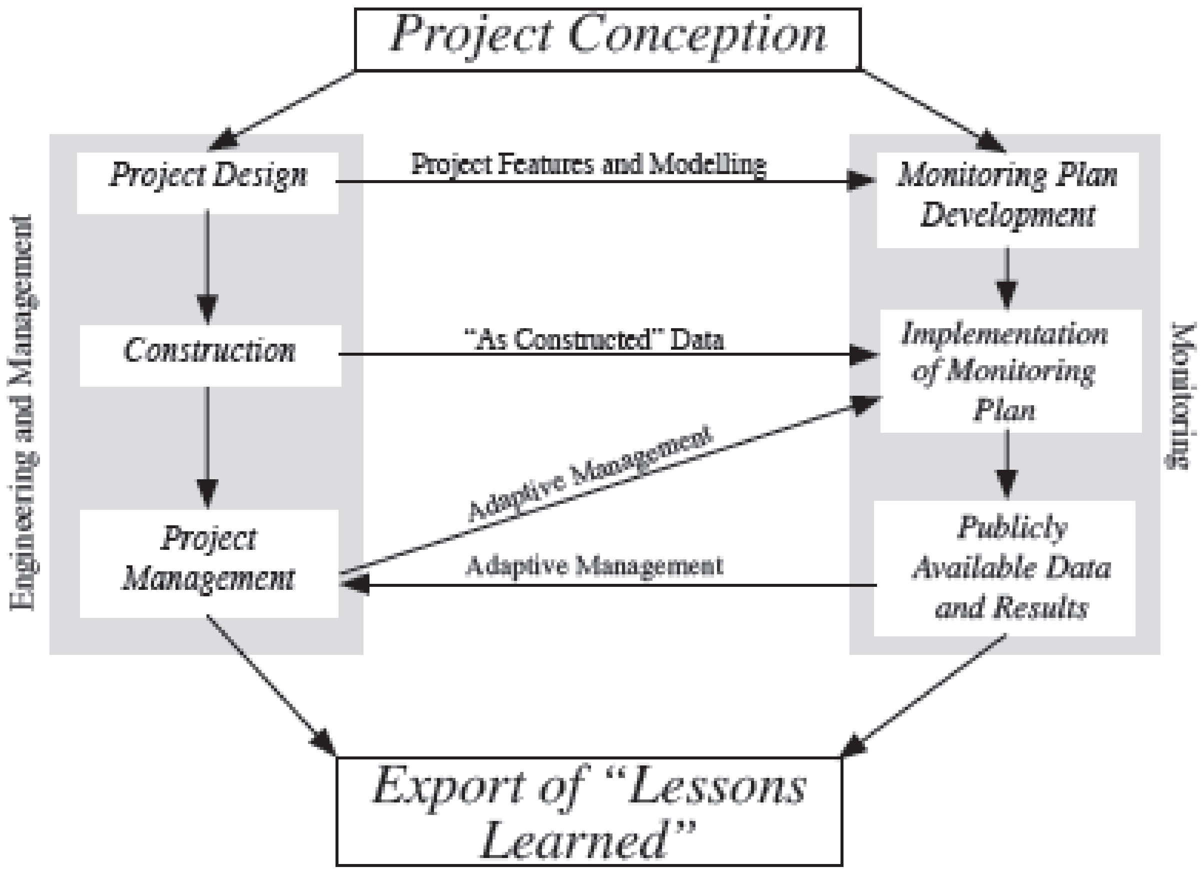
Cause and effect can be inferred

Elzinga et al. 2001

Replication over Time



To assess treatment effects, monitoring must start at the project design phase



Review: Data Requirements

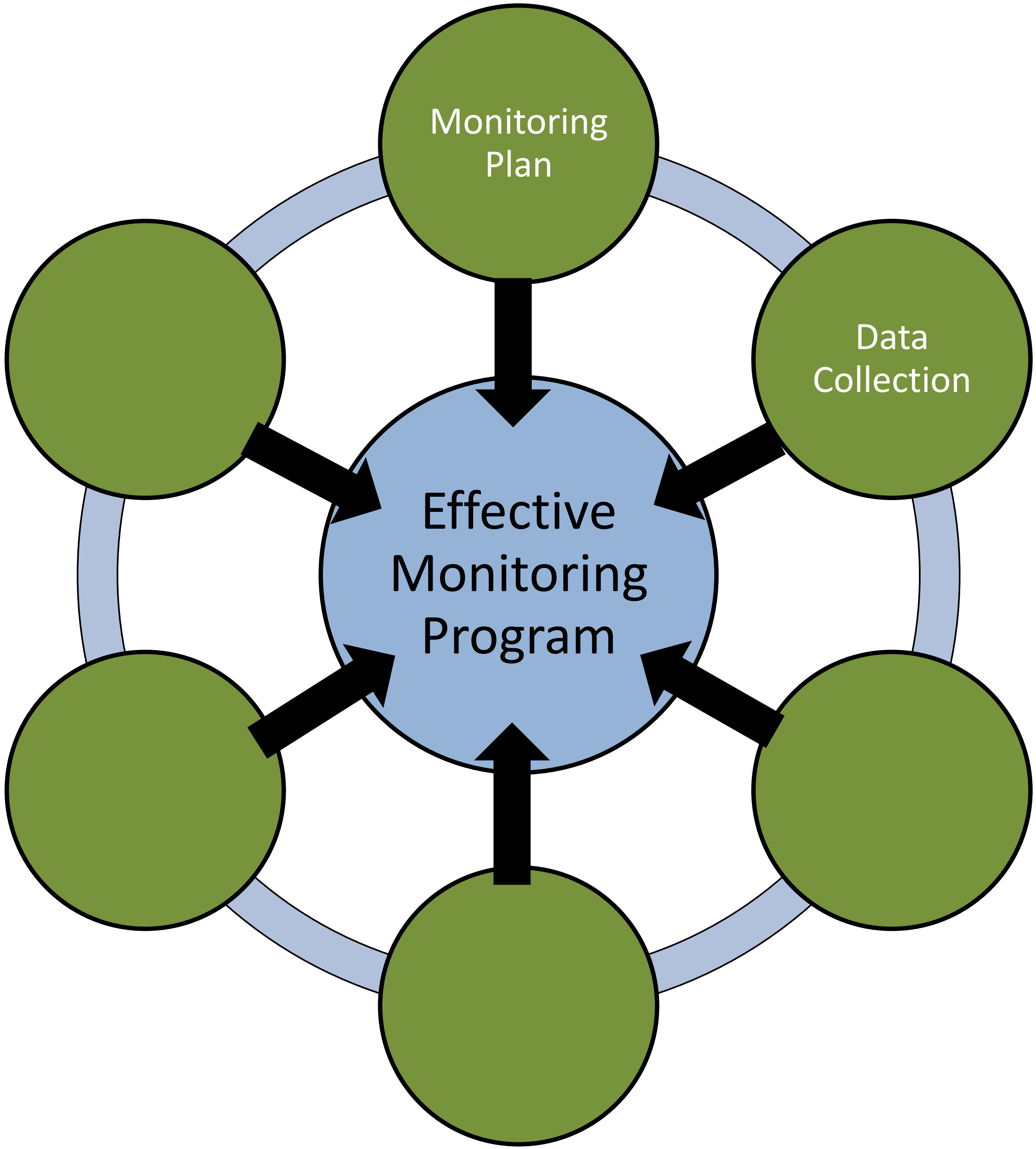
Requirements	**Does the treated area meet the performance target ? (End-point theoretical)**	**To what extent is the treated area restored ? (End-point empirical)**	**Were the treatments effective at achieving target conditions ? (Effect size)**
Pre-treatment data			
Post-treatment data			
Control data			
Performance target			

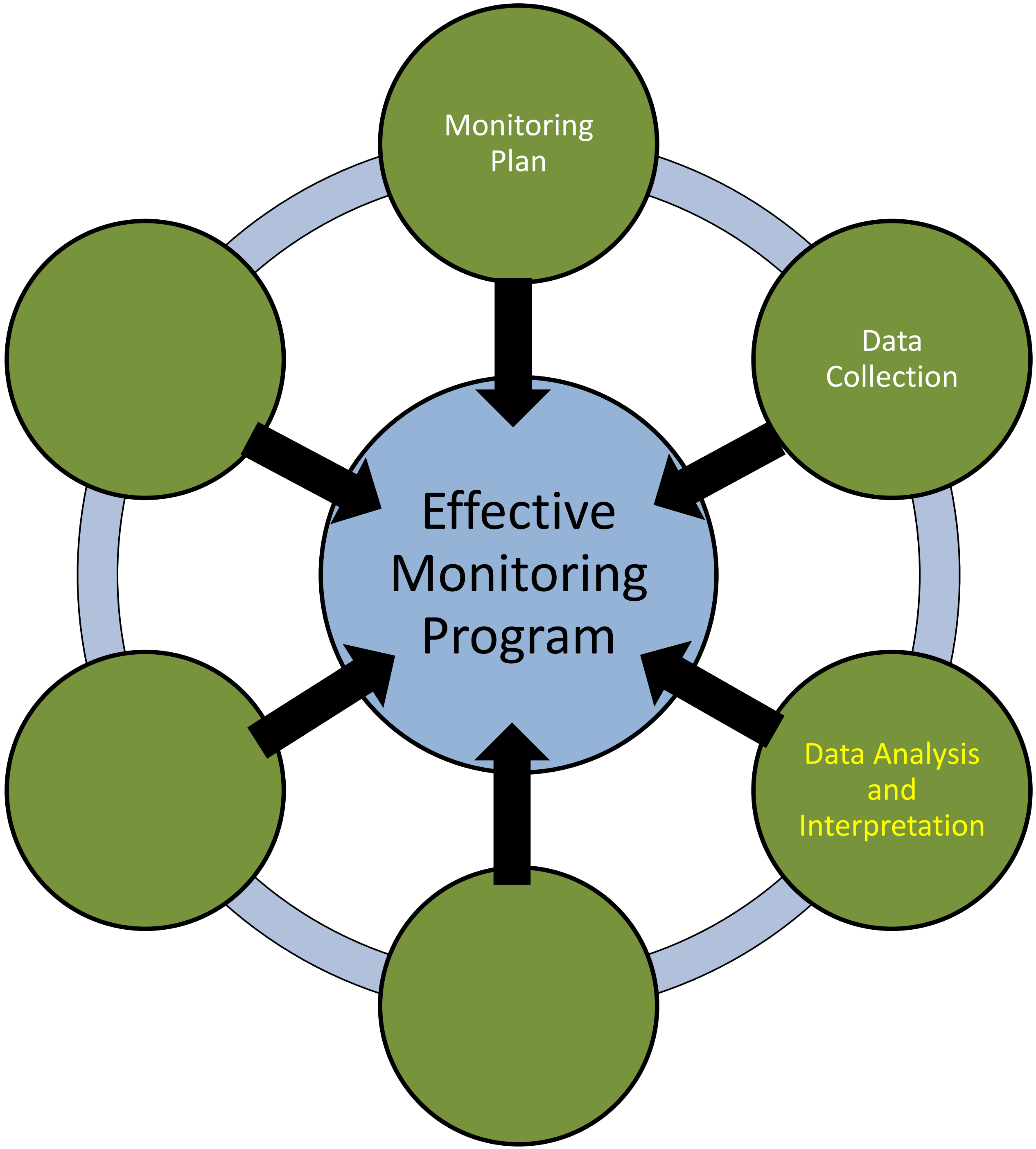
Review: Data Requirements

Requirements	**Does the treated area meet the performance target ? (End-point theoretical)**	**To what extent is the treated area restored ? (End-point empirical)**	**Were the treatments effective at achieving target conditions ? (Effect size)**
Pre-treatment data	No	No	Yes
Post-treatment data	Yes	Yes	Yes
Control data	No	No	Yes
Performance target	Yes: theoretical	Yes: reference data	No

III. Action items — to ensure monitoring programs succeed


Ribbongrass / Yellow Flag Iris
NOXIOUS
WEED SITE
Site # 15-032 Metolius River Area
Date: Sept 23-27, 2013
Aquatic Glyphosate Applied w/wand
Treatment Aquatic Imazepyr
For more information: Maret Pajutee, US Forest Service
(541) 549-7727


Monitoring Plan
Data Collection
Effective Monitoring Program


Monitoring Plan
Data Collection
Effective Monitoring Program
Data Analysis and Interpretation

Personnel	yyyy	mm	dd	reach	x section	plot #	tr az	N/S of river	belt tr az	A subplot dist fr 0	B subplot dist fr 0	lifeform	sp code	coverA	#stmsA	coverB	#stmsB
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	G	BARE	100.0		100.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	B	BRYOP	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	H	HERB	0.3		1.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	G	LOG	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	H	POLLAP	0.2		0.8	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	G	STONE	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	G	TREEBASE	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	H	TRITIC	0.1		0.2	
BILLINGSLE	2010	08	04	CFR2	T128.5	1	22	S	112	2.0	5.0	W	WOODY	0.0	0	0.0	0
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	G	BARE	10.0		45.0	
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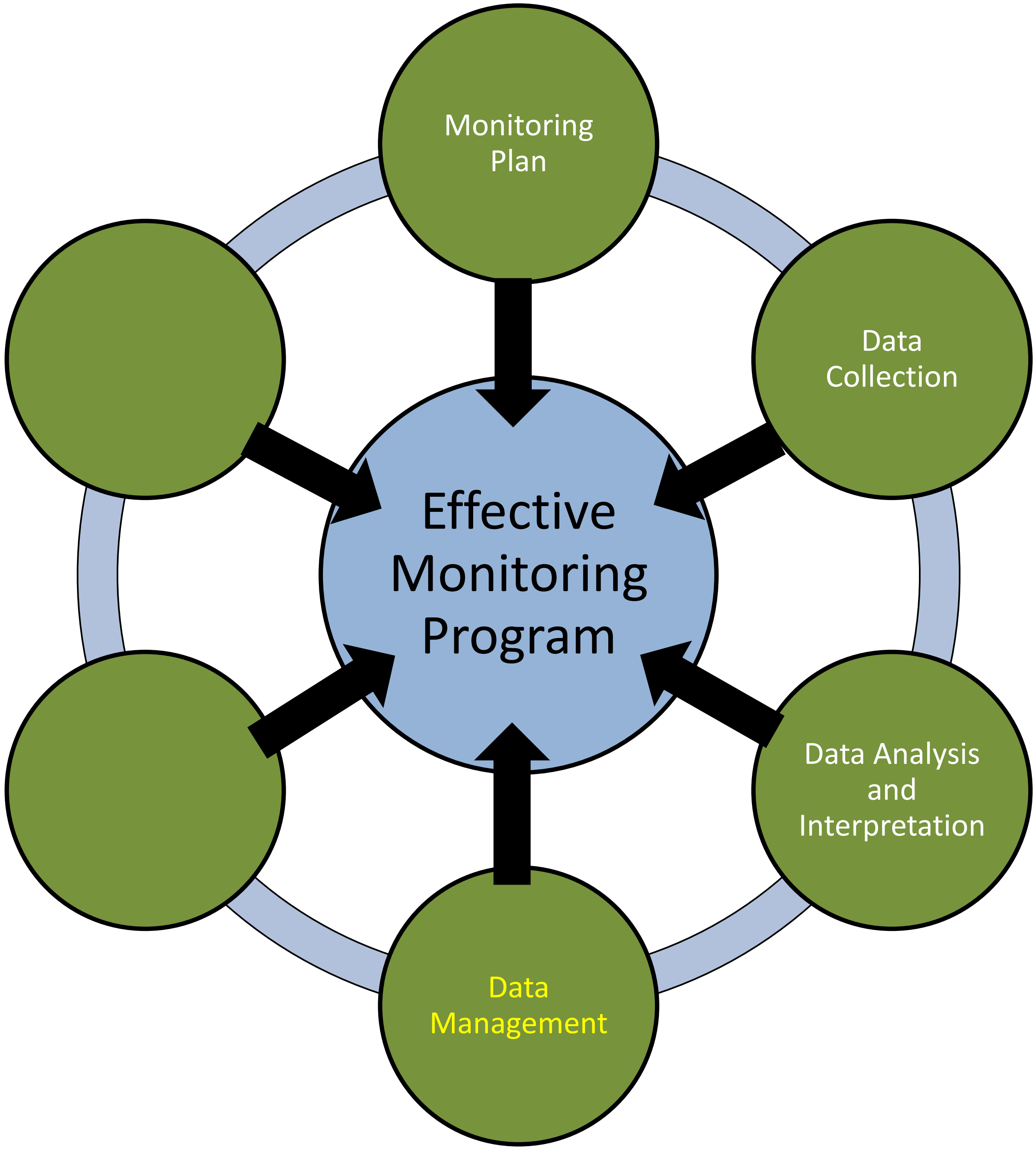
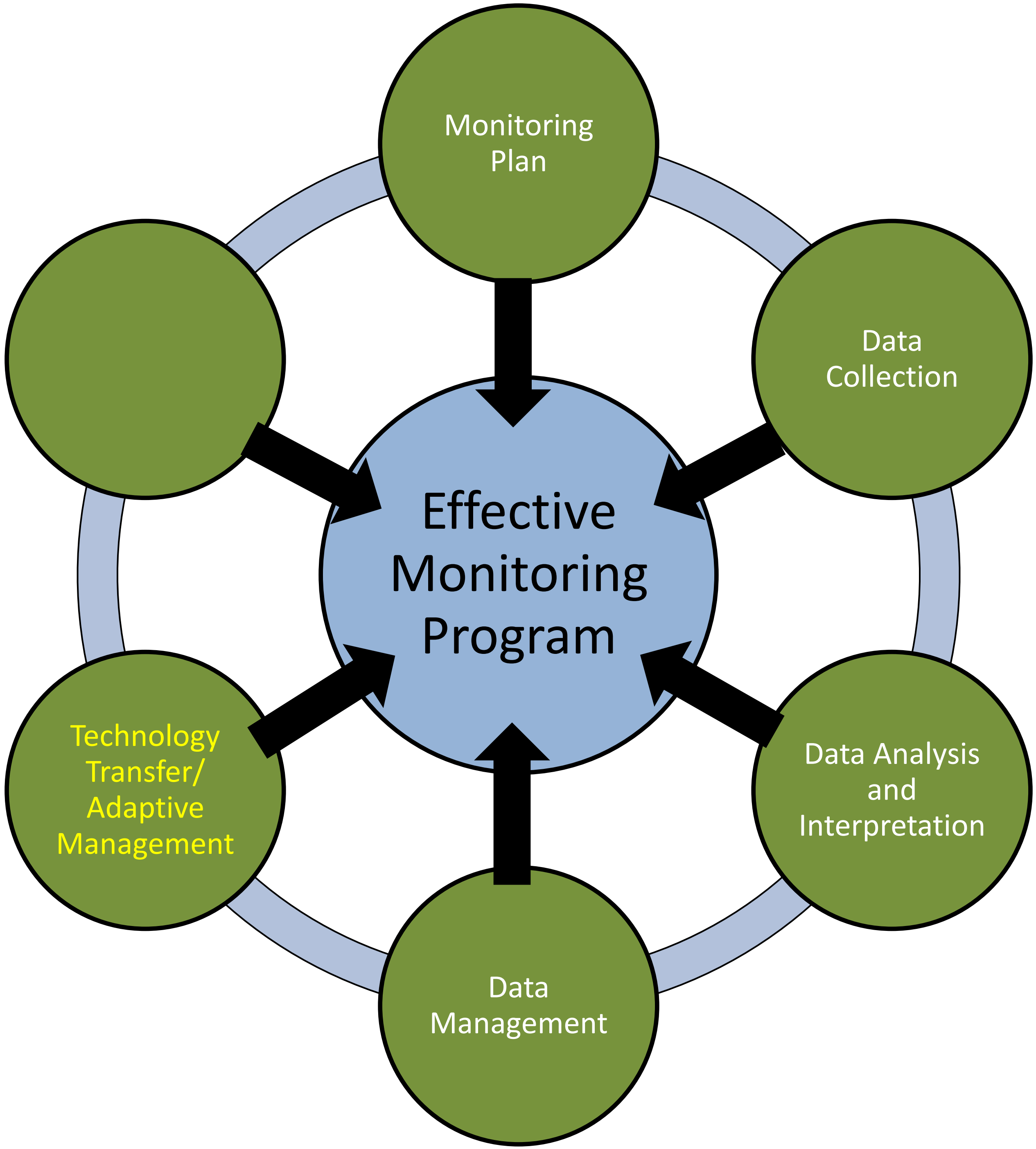
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	H	HERB	90.0		55.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	H	LACSER			1.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	G	LOG	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	H	POACOM	0.3			
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	H	POLLAP	35.0		20.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	H	RUMMAR	15.0		10.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	G	STONE	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	G	TREEBASE	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	H	TYPLAT	55.0		20.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	2	22	S	112	2.0	5.0	W	WOODY	0.0	0	0.0	0
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	G	BARE	50.0		85.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	B	BRYOP	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	CAREX	0.3		2.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	ELEPAI	6.0		0.3	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	EPIGLA	0.3			
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	HERB	50.0		15.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	G	LOG	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	POAPRA	25.0		5.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	POLLAP	3.0		8.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	RORISL	10.0			
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	H	RUMMAR	1.0			
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	G	STONE	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	G	TREEBASE	0.0		0.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	3	22	S	112	2.0	5.0	W	WOODY	0.0	0	0.0	0
BILLINGSLE	2010	08	04	CFR2	T128.5	4	22	S	112	1.0	2.0	H	ACHMIL			4.0	
BILLINGSLE	2010	08	04	CFR2	T128.5	4	22	S	112	1.0	2.0	G	BARE	30.0		45.0	

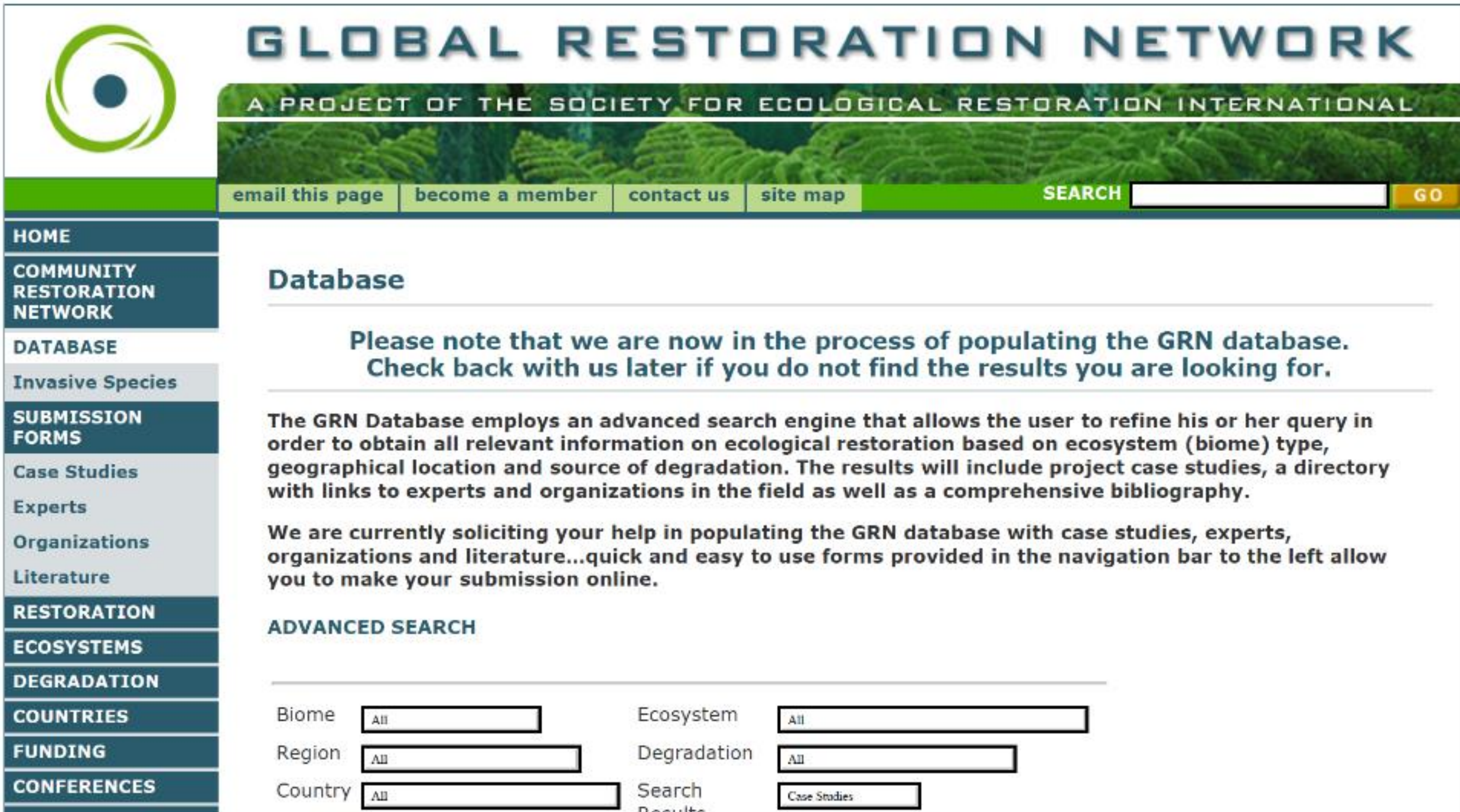


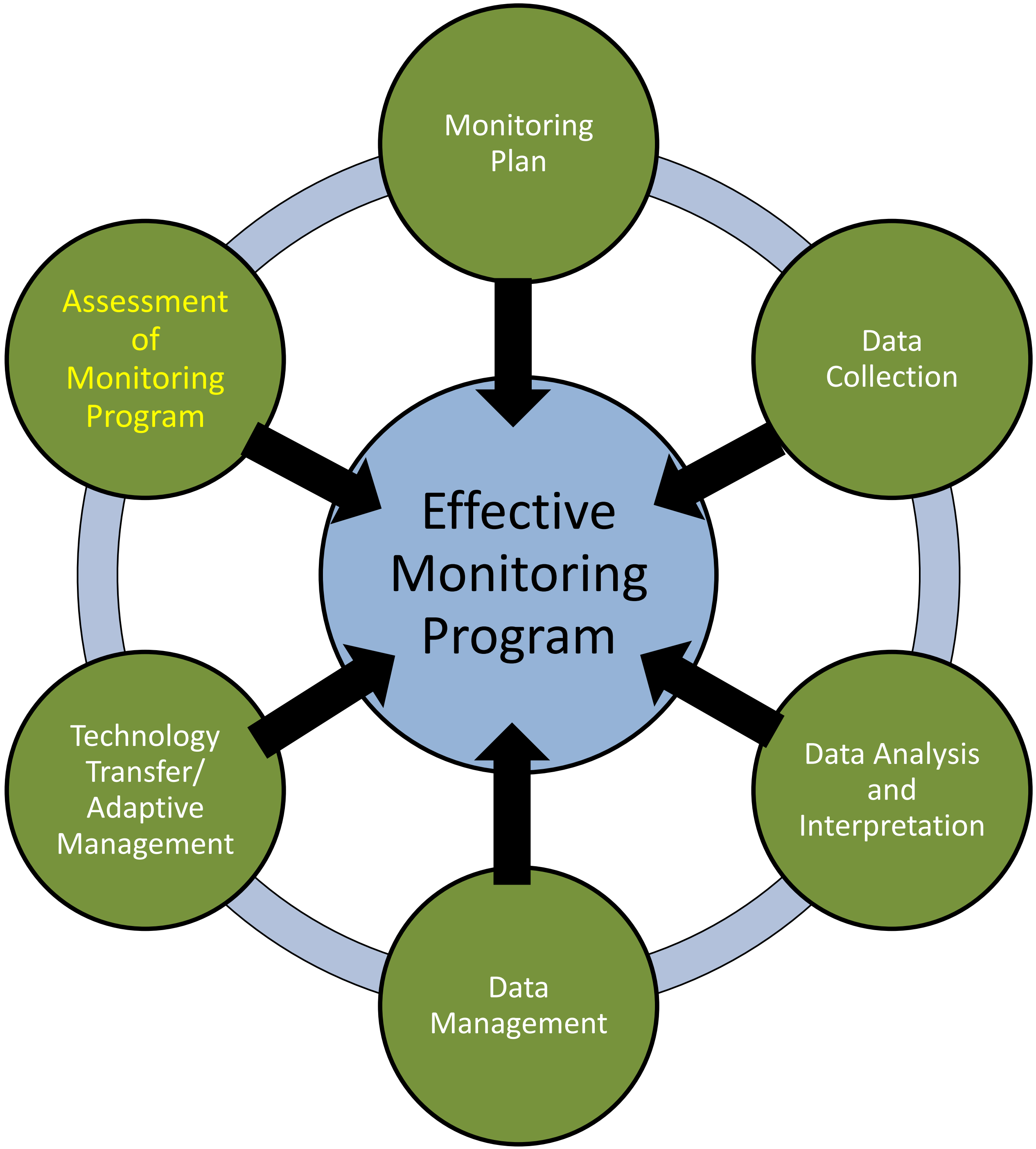
Monitoring Plan
Data Collection
Effective Monitoring Program
Data Analysis and Interpretation
Data Management

Form	Variable	Description	Text or Numeric	Allowable Codes or Values
VEG-B HEADER	Personnel	Last names of the people who collected data	Text	AMBERSON, ABRAHAMSON, BILLINGSLEY, LESICA, NELSON, THELEN
	yyyy	Four digit code for the year that data were collected	Numeric	2010
	mm	Two digit code for the month that data were collected	Numeric	07, 08, 09
	dd	Two digit code for the day that data were collected	Numeric	01-31
	reach	Reach of the Clarkfork River where the plot is located	Text	CFR2 or CFR3B
	x section	Cross section where plot is located	Text	T128.5, T132, T136, T138, T125, T142, T145, T151, T11 + 50, T 14 + 50, T27, T40, T44, T47, T50, T52, T55 + 50, T57, T59, T63, T67, T50 + 11
	plot #	The number of the plot for which data is being entered	Numeric	1-23
	tr az	Azimuth (in degrees) of the transect	Numeric	0-360
	N/S of river	Indicates whether plot was located on the North or South side of the main channel	Text	N or S
	belt tr az	Azimuth (in degrees) of the belt transect, from the 0 meter mark to the 7 meter mark	Numeric	0-360
VEG-B	A subplot dist from 0	Record the distance to the nearest 0.01m	Numeric	usually 2.0, but varies
	B subplot dist from 0	Record the distance to the nearest 0.01m	Numeric	usually 5.0, but varies
	lifeform	Enter the code for the lifeform being measured as B=bryophyte, G=ground cover; H=herbaceous plant; W=woody plant	Text	G, B, H, W
	sp code	Enter five or six letter species acronym or ground substrate code	Text	see "species & substrate codes" worksheet for a list of allowable codes
	coverA	Record values between 0 and 1% to the nearest 0.1 %, between 1 and 10% to the nearest 1%; and those >10% to the nearest 5%. Do not record the % symbol	Numeric	0-100
	coverB	Record values between 0 and 1% to the nearest 0.1 %, between 1 and 10% to the nearest 1%; and those >10% to the nearest 5%. Do not record the % symbol	Numeric	0-100
	#stmsB	Record as the number of stems for each species listed, regardless of lifeform	Numeric	any integer


Monitoring Plan
Data Collection
Data Analysis and Interpretation
Data Management
Technology Transfer/ Adaptive Management
Effective Monitoring Program

Are we being effective at communicating lessons learned?




Monitoring Plan
Data Collection
Data Analysis and Interpretation
Data Management
Technology Transfer/ Adaptive Management
Assessment of Monitoring Program
Effective Monitoring Program

PLOTS CFR2

			Relative Margin of Error = 10			Relative Margin of Error = 20		
				80% Confidence Level	90% Confidence Level		80% Confidence Level	90% Confidence Level
	Mean	SD	Confidence Interval	# Plots	# Plots	Confidence Interval	# Plots	# Plots
Total Species Richness	3.66	3.26	3.47-3.84	130	215	3.29-4.02	**33**	54
Exotic Species Richness	0.73	1.02	0.69-0.77	321	531	0.66-0.80	**80**	133
Noxious Species Richness	0.07	0.30	0.07-0.08	2736	4524	0.07-0.08	**684**	1131
Total Cover	20.60	27.95	19.57-21.63	302	499	18.54-22.66	**75**	125
Total Exotic Cover	4.74	12.84	4.51-4.98	1202	1987	4.27-5.22	**300**	497
Total Noxious Cover	0.03	0.17	0.03-0.03	5833	9646	0.03-0.03	**1458**	2412
Total Native Cover	15.79	23.60	15.00-16.58	366	605	14.21-17.37	**91**	151
Woody Density	1.09	6.21	1.04-1.15	5301	8766	0.98-1.20	**1325**	2192
Woody Cover	2.79	10.32	2.65-2.93	2235	3695	2.51-3.07	**559**	924

PLOTS CFR3B

			Relative Margin of Error = 10			Relative Margin of Error = 20		
				80% Confidence Level	90% Confidence Level		80% Confidence Level	90% Confidence Level
	Mean	SD	Confidence Interval	# Plots	# Plots	Confidence Interval	# Plots	# Plots
Total Species Richness	9.27	5.80	8.81-9.73	64	106	8.34-10.20	**16**	26
Exotic Species Richness	2.56	2.08	2.43-2.69	108	179	2.30-2.82	**27**	45
Noxious Species Richness	0.90	1.00	0.86-0.95	200	331	0.81-0.99	**50**	83
Total Cover	38.13	41.19	36.22-40.04	191	316	34.32-41.94	**48**	79
Total Exotic Cover	12.49	21.65	11.86-13.11	492	814	11.24-13.74	**123**	204
Total Noxious Cover	2.22	5.87	2.11-2.33	1145	1893	2.00-2.44	**286**	473
Total Native Cover	22.85	26.31	21.71-24.00	217	359	20.57-25.14	**54**	90
Woody Density	1.74	3.34	1.66-1.83	601	994	1.57-1.92	**150**	248
Woody Cover	7.82	20.74	7.43-8.21	1153	1907	7.03-8.60	**288**	477

Take-home Messages

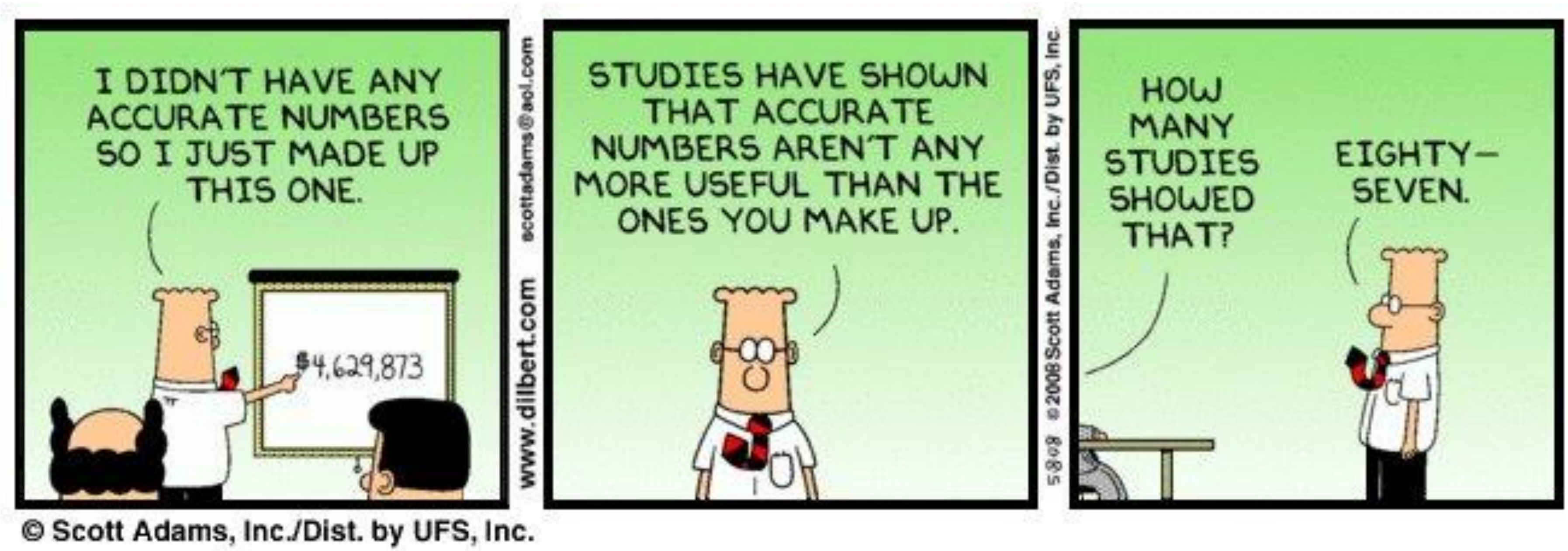
- If you are monitoring in order to ask and answer questions, choose a strong experimental design.
  - *do not confound effects with site-to-site or annual variability*

- Different monitoring approaches are required at the basin, tributary, and project scale.

- Consider building a monitoring program rather than a data-collection plan.


CHANGE
AHEAD

Thanks!



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— Chair, Society for Ecological Restoration

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