

Introduction to Research Methods in

Introduction to Research Methods in Environmental Science

Environmental Science

Designed as a quick-reference guide for students and early-career researchers

1. Why Research Methods Matter

Reason	What It Means for Your Work
Credibility	Rigorous methods let others trust your findings.
Reproducibility	Others can repeat the study and verify results.
Policy Relevance	Sound evidence is the basis for environmental regulations and management plans.
Interdisciplinary Integration	Combines ecology, chemistry, geology, social science, and more.

2. The Scientific Process – A Step-by-Step Flow

1. Identify a Problem / Question

- Example: “How does urban runoff affect river macroinvertebrate diversity?”

2. Literature Review

- Systematic search (Web of Science, Google Scholar, Scopus).
- Summarize gaps, hypotheses, and methodological precedents.

3. Formulate Hypotheses / Objectives

- *Null hypothesis (H_0) and alternative hypothesis (H_a).*
- Clear, testable, and measurable.

4. Select a Study Design

- Observational, experimental, modelling, or mixed.

5. Develop a Sampling Plan

- Define *population, sampling unit, sample size, spatial & temporal resolution.*

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6. Collect Data

- Follow standard operating procedures (SOPs).
- Record metadata (date, GPS, weather, equipment).

7. Data Management

- Raw data ? cleaned data ? analysis?ready dataset.
- Use version?controlled repositories (Git, OSF) and metadata standards (e.g., EML).

8. Statistical / Analytical Methods

- Choose appropriate tests (ANOVA, GLM, NMDS, Bayesian).
- Verify assumptions (normality, homoscedasticity, independence).

9. Interpret Results

- Relate findings back to hypotheses, theory, and real?world implications.

10. Communicate

- Write reports, peer?reviewed papers, policy briefs, or public outreach materials.

11. Reflect & Iterate

- Identify limitations, propose future work, refine methods.

3. Core Research Designs in Environmental Science

Design	When to Use	Key Features	Typical Analyses
Descriptive (Survey)	Baseline inventories, status assessments	Systematic sampling, no manipulation	Species richness, diversity indices, GIS mapping
Comparative (Cross ?sectional)	Compare sites or conditions at a single time	Paired or independent groups	t?tests, ANOVA, PERMANOVA

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Design	When to Use	Key Features	Typical Analyses
Longitudinal (Repeated Measures)	Detect trends, seasonal cycles	Same sites sampled repeatedly	Mixed-effects models, time-series analysis
Experimental (Manipulative)	Test causal relationships	Control vs. treatment, randomization	ANCOVA, GLM, dose- response curves
Before-After? Control-Impact (BACI)	Assess impact of a disturbance or management action	Pre- and post-impact data at impact & control sites	Two-way ANOVA, interaction terms
Model-Based (Simulation)	Predict future scenarios, fill data gaps	Process-based or statistical models	Sensitivity analysis, Monte Carlo, Bayesian inference

4. Sampling Strategies

Strategy Strengths Weaknesses Typical Applications