Welcome to NRES 701A

Causal Inference and Analysis, Spring 2027 (draft syllabus v5)

Draft, subject to change. This is a preliminary syllabus to help students decide whether to enroll. The readings, schedule and assignment details will probably change before the semester starts.

Instructors: Kevin Shoemaker and Todd Steury, Dept. of Natural Resources & Environmental Science
Offices: Kevin: Fleischmann Agriculture, room 220e; Todd: Fleischmann Agriculture, room 217
Email (preferred contact): kevinshoemaker@unr.edu; tsteury@unr.edu
Office hours: by appointment
Credits: 2 credits, letter grade
Section: 1003 (class number 30643), in person
Course website: https://kevintshoemaker.github.io/Causal-Inference/

Course meeting time

Class meeting: one 2-hour meeting per week, Tuesdays, 1:30 to 3:30 PM, in [room to be announced], January 19 to May 4, 2027

Course description

How do we know that one thing causes another? What would it take to show that a decline in a wildlife population was driven by habitat loss rather than climate, that deer abundance in the past was driven by people rather than by climate, or that more species make an ecosystem more productive or stable? What can we conclude from observational data when an experiment is impossible? And what changes when the system we study has feedback, networks and many interacting parts?

This course introduces the modern tools of causal inference and shows how to apply them to research in ecology, natural resources, anthropology and related fields. We start with the core ideas: the "ladder of causation," counterfactuals, and causal diagrams (directed acyclic graphs, or DAGs). We then work through the main strategies for estimating causal effects: experiments, quasi-experimental designs, structural equation models and time-series methods. Throughout, we read and critique published papers,

both those that use formal causal methods and those that make causal claims without them. The readings are chosen to be accessible to a mixed audience of ecologists, anthropologists and others.

The course is open to graduate students from any department. The centerpiece is an individual project: each student builds and refines a well-reasoned causal diagram of their own study system, one that can guide the design and analysis of their thesis or dissertation research.

Prerequisites

- None required. One regression-level statistics course is recommended.
- No prior training in causal inference, philosophy or R is assumed.

Course format

Each weekly meeting has three parts:

1. **Lecture and discussion (20 to 25 minutes),** led by Kevin or Todd, introducing the week's concepts.
2. **Paper discussion,** centered on the week's readings. Students help lead these discussions (see "Paper discussion leadership" below).
3. **Hands-on exercise,** a short problem set or DAG workshop done in small groups in class. Exercises can be done with pencil and paper; some include optional R extensions.

Student learning outcomes

SLO 1. Distinguish associational, interventional and counterfactual questions (the ladder of causation) and say which one a given study answers.
SLO 2. Draw a causal diagram (DAG) for a question in your own field, and use it to identify confounders, colliders and mediators and to choose an adjustment set.
SLO 3. Explain the assumptions behind experiments, quasi-experimental designs, structural equation models and time-series causal methods, and judge when each is credible for a given study system.
SLO 4. Read a published paper critically for the causal claim it makes, the evidence offered, and the assumptions stated and unstated.
SLO 5. Describe how feedback, network structure and scale complicate causal reasoning,

and where acyclic graphs stop being adequate.
SLO 6. Communicate a causal argument clearly in discussion, in a presentation and in writing.

Texts

- **Required text:** Pearl, J., and D. Mackenzie (2018) *The Book of Why: The New Science of Cause and Effect.* Basic Books. We read four chapters (Introduction and Chapters 1, 4 and 7); the rest is recommended.
- **Also required:** Chapter 6 of McElreath, R. (2020) *Statistical Rethinking*, 2nd ed. (CRC Press), available free online through UNR Libraries.
- **Readings on WebCampus:** most weekly reading consists of journal articles, posted on WebCampus. Each week has at most two required readings, usually one that frames the concepts and one applied paper.
- **Recommended books (not required):** Pearl, Glymour and Jewell, *Causal Inference in Statistics: A Primer* (Wiley, 2016), the technical companion to *The Book of Why*; Huntington-Klein, *The Effect* (free online); Cunningham, *Causal Inference: The Mixtape* (free online); Shipley, *Cause and Correlation in Biology*, 2nd ed. (Cambridge, 2016); Johansson et al., *A Primer to Causal Reasoning About a Complex World* (Springer, 2024; open access); the rest of McElreath's *Statistical Rethinking*.

Software

- dagitty: free, web-based tool for drawing and analyzing causal diagrams (DAGs); no account needed
- R: software for statistical computing and graphics (free installation); optional, for exercise extensions

Grading

The course grade will be based on the following components:

- Participation and weekly reading responses 20%
- In-class exercises 10%
- Paper discussion leadership 10%
- "Causal claims in the wild" critique 15%

- Causal DAG project: initial DAG (Week 5) 10%
- Causal DAG project: revised DAG and peer review (Week 10) 5%
- Causal DAG project: final presentation (Week 15) 10%
- Causal DAG project: final write-up (finals week) 20%

Grading scale: A (100 to 93), A− (92 to 90), B+ (89 to 87), B (86 to 83), B− (82 to 80), C+ (79 to 77), C (76 to 73), F (below 73). The UNR Graduate School requires a C or better for a course to count toward a graduate degree, so C is the lowest passing grade.

Participation and weekly reading responses (20 points). Come to class having done the reading and ready to discuss it. At least 2 hrs before class each week, post a short response (about 150 words) on WebCampus: one point you found important and one question you want to discuss. Your two lowest response scores are dropped.

In-class exercises (10 points). Each week's hands-on exercise is graded for completion (or good-faith effort to complete!), not on correctness.

Paper discussion leadership (10 points). Each student (or in pairs if enrollment is large) helps lead the discussion of one week's applied paper. Leaders give a short summary of the paper's causal claim and evidence, and bring three discussion questions. Sign-up is in Week 1.

"Causal claims in the wild" critique (15 points; due Week 8). Working individually or in pairs (depending on enrollment), find a published paper in your field(s) that makes a causal claim (for example, "X drives Y" or "X caused the decline") without using formal causal inference methods. In a joint write-up of about 1,000 words: state the claim and which rung of the ladder of causation it reaches; draw the DAG the authors implicitly assume; identify likely confounders, colliders or selection effects; judge whether the conclusion follows; and describe what design or analysis would have supported the claim. Each pair also gives a 10-minute presentation of its paper in class (Weeks 8 and 9). Choose your paper by Week 4.

Causal DAG project (45 points total). Over the semester you will build a well-reasoned causal diagram of your own study system, aimed at a causal question in your thesis or dissertation research. Students without a thesis system yet may choose a well-studied system from the literature, with instructor approval.

- *Initial DAG (Week 5):* a DAG for your system and focal causal question, with one or two sentences justifying each arrow and the adjustment set it implies for the effect you care about.

- *Revised DAG and peer review (Week 10):* an updated DAG that incorporates what you learned in Weeks 6 to 9 (including mediation and design choices), plus a written review of a classmate's DAG.
- *Final presentation (Week 15):* an 8 to 10 minute presentation of your DAG and its implications.
- *Final write-up (due finals week, 1,500 to 2,000 words):* your final DAG; the justification and assumptions behind it; the adjustment set(s) for your focal question; testable implications; a discussion of feedback or unmeasured variables the DAG may miss; and the study design and analysis you would use to estimate your causal effect.

Course schedule

Reading should be completed before the class for which it is listed. Classes meet on Tuesdays; there is no class on March 23 (spring break). Readings marked "BoW" are from *The Book of Why*; all others are on WebCampus or online.

Week	Topic and in-class exercise	Required reading	Due
1 (Jan 19)	**Why causality?** Seeing, doing and imagining: the ladder of causation; causal claims in your own field. *Exercise:* place published claims from your field on the ladder.	BoW Introduction and Ch. 1	Pre-course survey; sign up for discussion week
2 (Jan 26)	**What is a cause?** Counterfactuals, manipulation and how people infer causes; which cause counts as "the" cause, and does that depend on what we can intervene on? *Exercise:* potential-outcomes tables.	Woodward (SEP), selected sections; Cheng 1997	Reading responses begin

Week	Topic and in-class exercise	Required reading	Due
3 (Feb 2)	**Causal models and graphs.** From Bayes nets to causal graphs; reading a causal graph; why predictive models are not causal models; probability refresher. *Exercise:* draw DAGs in dagitty and trace open and closed paths.	Arif & MacNeil 2022; Bulbulia 2024 (Part 1)	
4 (Feb 9)	**Confounding and the smoking debate.** Confounders, colliders and mediators; drawing a DAG for a shared class example. *Exercise:* check the adjustment sets reported in Arif & MacNeil 2023; draw the DAG behind Fisher's argument that smoking does not cause lung cancer.	BoW Ch. 4; Arif & MacNeil 2023; Fisher 1958 (one-page letter)	Choose "claims in the wild" partner and paper
5 (Feb 16)	**Back-door criterion, colliders and the do-operator.** Simpson's paradox; adjustment sets; when "controlling for" a variable makes things worse. *Exercise:* simulate confounding and collider bias; explain and review initial DAGs in small groups.	BoW Ch. 7; McElreath 2020, Ch. 6	**Initial DAG**

Week	Topic and in-class exercise	Required reading	Due
6 (Feb 23)	**Two frameworks and mediation.** Potential outcomes vs. structural causal models; mechanism vs. covariation; direct and indirect effects. *Exercise:* separate direct and indirect effects in a DAG.	Hernán et al. 2019; Bulbulia 2024 (Part 2)	
7 (Mar 2)	**Experiments and quasi-experiments.** What randomization and BACI designs do and do not guarantee; matching, difference-in-differences, regression discontinuity and instrumental variables. *Exercise:* find the hidden assumptions in a field experiment; difference-in-differences with a toy dataset.	Arif & Massey 2023; Butsic et al. 2017	
8 (Mar 9)	**Observational data and unmeasured confounders.** Selection bias and natural experiments; testing for and addressing confounders you cannot measure; fixed effects and panel data. *Exercise:* simulate omitted-variable bias.	Byrnes & Dee 2025; plus one of Watson et al. 2025 or Cardillo & Carranza 2025	**"Claims in the wild" critique**; pair presentations

Week	Topic and in-class exercise	Required reading	Due
9 (Mar 16)	**Path analysis and structural equation models.** Testing a causal model against data; d-separation in practice. *Exercise:* fit and test a simple path model.	Grace & Irvine 2020; Cole et al. 2024	Pair presentations (continued)
(Mar 23)	*Spring break: no class.*		
10 (Mar 30)	**Time series and dynamical systems.** Granger causality and convergent cross mapping: what does each test? *Exercise:* apply both to simulated predator–prey data.	Sugihara et al. 2012; Barraquand et al. 2021	**Revised DAG and peer review**
11 (Apr 6)	**Complexity and stability: cause or statistical artifact?** The diversity–stability debate. *Exercise:* structured debate.	Tilman et al. 1998; Doak et al. 1998	
12 (Apr 13)	**Feedback, networks and systems thinking.** Why DAGs are acyclic, and what to do about feedback. *Exercise:* unroll a feedback loop through time.	M. Salmon 1978	
13 (Apr 20)	**Synthesis: from DAG to study design.** Choosing an approach for your own question. *Exercise:* draft an analysis plan for your DAG.	Siegel & Dee 2025	
14 (Apr 27)	**Project workshop.**	None	

Week	Topic and in-class exercise	Required reading	Due
15 (May 4)	**Final presentations.**	None	**Presentation**; write-up due finals week

Readings by week

Week 1. Pearl, J., and D. Mackenzie (2018) *The Book of Why: The New Science of Cause and Effect.* Basic Books. Introduction and Ch. 1.

Week 2. Woodward, J. Causation and manipulability. *Stanford Encyclopedia of Philosophy.* (Free online.) — Cheng, P. W. (1997) From covariation to causation: A causal power theory. *Psychological Review* 104(2): 367–405.

Week 3. Arif, S., and M. A. MacNeil (2022) Predictive models aren't for causal inference. *Ecology Letters* 25(8): 1741–1745. doi:10.1111/ele.14033 — Bulbulia, J. A. (2024) Methods in causal inference. Part 1: Causal diagrams and confounding. *Evolutionary Human Sciences* 6: e40. doi:10.1017/ehs.2024.35

Week 4. Pearl and Mackenzie (2018), Ch. 4. — Arif, S., and M. A. MacNeil (2023) Applying the structural causal model framework for observational causal inference in ecology. *Ecological Monographs* 93(1): e1554. doi:10.1002/ecm.1554 — Fisher, R. A. (1958) Lung cancer and cigarettes? *Nature* 182: 108. doi:10.1038/182108a0 (a one-page letter; free online)

Week 5. Pearl and Mackenzie (2018), Ch. 7. — McElreath, R. (2020) *Statistical Rethinking*, 2nd ed. CRC Press. Ch. 6. Free online through UNR Libraries.

Week 6. Hernán, M. A., J. Hsu, and B. Healy (2019) A second chance to get causal inference right: A classification of data science tasks. *Chance* 32(1). — Bulbulia, J. A. (2024) Methods in causal inference. Part 2: Interaction, mediation, and time-varying treatments. *Evolutionary Human Sciences* 6. doi:10.1017/ehs.2024.32

Week 7. Arif, S., and M. D. B. Massey (2023) Reducing bias in experimental ecology through directed acyclic graphs. *Ecology and Evolution* 13. doi:10.1002/ece3.9947 (open access) — Butsic, V., D. J. Lewis, V. C. Radeloff, M. Baumann, and T. Kuemmerle (2017) Quasi-experimental methods enable stronger inferences from observational data in ecology. *Basic and Applied Ecology* 19: 1–10.

Week 8. Byrnes, J. E. K., and L. E. Dee (2025) Causal inference with observational data and unobserved confounding variables. *Ecology Letters* 28: e70023. doi:10.1111/ele.70023 (open access) — Plus one of: Watson, E. J., D. J. Glass, and L. C. Petito (2025) Toward new directions in human biology: A roadmap for anthropological causal inference with observational data. *American Journal of Human Biology.* doi:10.1002/ajhb.70149; or Cardillo, M., and E. Carranza (2025) Applying statistical and causal modeling to interpret thermal alteration in observational lithic data. *Peer Community Journal* 5: e88.

Week 9. Grace, J. B., and K. M. Irvine (2020) Scientist's guide to developing explanatory statistical models using causal analysis principles. *Ecology* 101(4): e02962. doi:10.1002/ecy.2962 — Cole, K. E., M. Moffatt, B. F. Codding, and J. M. Broughton (2024) Human settlement density, not late Holocene climate change, influenced Artiodactyla species abundance in northeastern California faunal assemblages. *Quaternary International* 689–690: 43–54. doi:10.1016/j.quaint.2023.10.006

Week 10. Sugihara, G., R. May, H. Ye, C. Hsieh, E. Deyle, M. Fogarty, and S. Munch (2012) Detecting causality in complex ecosystems. *Science* 338. — Barraquand, F., C. Picoche, M. Detto, and F. Hartig (2021) Inferring species interactions using Granger causality and convergent cross mapping. *Theoretical Ecology* 14(1): 87–105.

Week 11. Tilman, D., C. L. Lehman, and C. E. Bristow (1998) Diversity-stability relationships: Statistical inevitability or ecological consequence? *American Naturalist* 151. — Doak, D. F., et al. (1998) The statistical inevitability of stability-diversity relationships in community ecology. *American Naturalist* 151.

Week 12. Salmon, M. H. (1978) What can systems theory do for archaeology? *American Antiquity* 43: 174–183.

Week 13. Siegel, K., and L. E. Dee (2025) Foundations and future directions for causal inference in ecological research. *Ecology Letters* 28. doi:10.1111/ele.70053

Suggested readings (not required)

- Pearl and Mackenzie (2018), the remaining chapters (especially Ch. 5, the smoking debate; Ch. 6, paradoxes; Ch. 8, counterfactuals; and Ch. 9, mediation).
- Bateson, G. (1972) 'Form, substance, and difference' and 'Cybernetic explanation.' In *Steps to an Ecology of Mind.* University of Chicago Press.
- Dee, L. E., et al. (2023) Clarifying the effect of biodiversity on productivity in natural ecosystems with longitudinal data and methods for causal inference. *Nature Communications* 14: 2607. doi:10.1038/s41467-023-37194-5 (open access)

- Deffner, D., J. M. Rohrer, and R. McElreath (2022) A causal framework for cross-cultural generalizability. *Advances in Methods and Practices in Psychological Science* 5(3).
- Ferraro, P. J., and M. M. Hanauer (2014) Advances in measuring the environmental and social impacts of environmental programs. *Annual Review of Environment and Resources* 39.
- Glymour, C. (2003) Learning, prediction and causal Bayes nets. *Trends in Cognitive Sciences* 7.
- Grace, J. B., et al. (2016) Integrative modelling reveals mechanisms linking productivity and plant species richness. *Nature* 529.
- Holland, P. W. (1986) Statistics and causal inference. *Journal of the American Statistical Association* 81.
- Johansson, L.-G., et al. (2024) *A Primer to Causal Reasoning About a Complex World.* Springer. doi:10.1007/978-3-031-59135-8 (open access)
- Kimmel, K., L. E. Dee, M. L. Avolio, and P. J. Ferraro (2021) Causal assumptions and causal inference in ecological experiments. *Trends in Ecology & Evolution* 36(12). doi:10.1016/j.tree.2021.08.008
- Laubach, Z. M., E. J. Murray, K. L. Hoke, R. J. Safran, and W. Perng (2021) A biologist's guide to model selection and causal inference. *Proceedings of the Royal Society B* 288(1943): 20202815. doi:10.1098/rspb.2020.2815
- May, R. M. (1972) Will a large complex system be stable? *Nature* 238.
- Pearl, J., M. Glymour, and N. P. Jewell (2016) *Causal Inference in Statistics: A Primer.* Wiley. Ch. 3.
- Salmon, W. (1982) Causality in archaeological explanation. In C. Renfrew, M. J. Rowlands, and B. A. Segraves (eds.), *Theory and Explanation in Archaeology*, pp. 45–56. Academic Press.
- Stolley, P. D. (1991) When genius errs: R. A. Fisher and the lung cancer controversy. *American Journal of Epidemiology* 133(5).
- Tainter, J. A. (1988) *The Collapse of Complex Societies.* Cambridge University Press. Ch. 4.

Classroom policies

Attendance. Attendance is expected. Because the course depends on discussion and in-class exercises, please tell us in advance if you must miss a meeting. Participation is evaluated through weekly reading responses and contributions to discussion (see Grading).

Late work and make-up policy. Submit assignments on WebCampus by the start of class on the due date. If you know you will miss a class, you may turn work in early. Contact us before the due date if you need an extension. If you are sick, please do not come to class. If you must miss class due to illness, please contact your instructor immediately to make arrangements for any missed work or lecture materials.

Communication. Course announcements (cancellations, room changes, schedule updates) will be posted on WebCampus and sent by email. You should expect a response to email within 24 hours on weekdays; emails sent after 5 PM on Friday will usually be answered on Monday.

Use of generative artificial intelligence (AI). This course assumes that all work submitted by students - which includes all process work, drafts, brainstorming artifacts, final works – will be generated by the students themselves, working individually or in groups as directed by course assignment instructions. This policy indicates the following constitute violations of academic honesty and “cheating”: any unauthorized use of generative AI tools (such as ChatGPT), as outlined in UNR Academic Standards (UAM 6,502).

Some assignments may allow for the use of the authorized use of such tools, but will be expressly described in the assignment instructions. For the purposes of those assignments, specific instructions will be provided on the use of generative AI tools regarding the type of work being allowed (i.e. brainstorming, drafts, final works, etc.). Please email the instructor for any questions or concerns.

University policies

The statements below use the exact wording of UNR's Fall 2026 syllabus template from the Office of the Provost, as required by UAM 6,501.

Statement on Academic Standards

The University Academic Standards Policy defines academic dishonesty, and mandates specific sanctions for violations. See the University Academic Standards policy: UAM 6,502.

Statement on Student Compliance with University Policies

In accordance with section 6,502 of the University Administrative Manual, a student may receive academic and disciplinary sanctions for failure to comply with policy, including this syllabus, for failure to comply with the directions of a University Official, for disruptive behavior in the classroom, or any other prohibited action. “Disruptive behavior" is defined in part as behavior, including but not limited to failure to follow course, laboratory or safety rules, or endangering the health of others. A student may be dropped from class at any time for misconduct or disruptive behavior in the classroom upon recommendation of the instructor and with approval of the college dean. A student may also receive disciplinary sanctions through the Office of Student Conduct for misconduct or disruptive behavior, including endangering the health of others, in the classroom. The student shall not receive a refund for course fees or tuition.

Statement of Disability Services

Any student with a disability needing academic adjustments or accommodations is requested to speak with me or the Disability Resource Center (Pennington Achievement Center Suite 230) as soon as possible to arrange for appropriate accommodations.

This course may leverage 3rd party web/multimedia content, if you experience any issues accessing this content, please notify your instructor.

Statement on Audio and Video Recording

Student-created Recordings. Surreptitious or covert video-taping of class or unauthorized audio recording of class is prohibited by law and by Board of Regents policy. This class may be videotaped, or audio recorded only with the written permission of the instructor. In order to accommodate students with disabilities, some students may have been given permission to record class lectures and discussions. Therefore, students should understand that their comments during class may be recorded.

Instructor-created Recordings. Class sessions may be audio-visually recorded for students in the class to review and for enrolled students who are unable to attend live to view. Students who participate with their camera on or who use a profile image are consenting to have their video or image recorded. If you do not consent to have your profile or video image recorded, keep your camera off and do not use a profile image. Students who un-mute during class and participate orally are consenting to have their

voices recorded. If you do not consent to have your voice recorded during class, keep your mute button activated and only communicate by using the "chat" feature, which allows you to type questions and comments live.

Statement on Maintaining a Safe Learning and Work Environment

The University of Nevada, Reno is committed to providing a safe learning and work environment for all. If you believe you have experienced discrimination, sexual harassment, sexual assault, domestic/dating violence, or stalking, whether on or off campus, or need information related to immigration concerns, please contact the University's Center for Civil Rights and Equal Access at 775-784-1547. Resources and interim measures are available to assist you. For more information, please visit the Center for Civil Rights & Equal Access page.

Statement on Campus Closures or Delays

In the event of class cancelations or delays caused by inclement weather conditions, fire/smoke conditions, or other unforeseen emergencies, the safety and well-being of students are the University's top priority. Official notifications will be disseminated through the University website and other official channels with details related to any campus delays or closures.

In the event of a campus closure, you will be informed as to whether the class will be offered remotely or if it will be canceled. If the class is cancelled, you will receive information on how to address any missed course content.

Students facing significant impacts due to these events are encouraged to communicate with their instructor for potential accommodations.

Statement for Academic Success Services

Your student fees cover usage of the University Math Center, (775) 784-4433; University Tutoring Center, (775) 784-6801; and University Writing & Speaking Center, (775) 784-6030. These centers support your classroom learning; it is your responsibility to take advantage of their services. Keep in mind that seeking help outside of class is the sign of a responsible and successful student.

Mental Health Support Statement

There are times when you may experience difficulties in life, and you may benefit from seeking help. Mental health services are available to you as a student at no additional cost through Counseling Services at the Pennington Student Achievement Center. This includes same-day in-person and tele mental health initial consultations, brief individual counseling, and group counseling sessions. Limited same-day appointments can be scheduled online via Counseling Services or by calling 775-784-4648. Additional brief drop-in "Let's Talk" student consultations are also available in the Counseling Services Annex located at the southwest corner of Great Basin Hall.

Veteran Statement

Veterans, Reservists, National Guard and military connected family members may wish to check the office of Veteran Services for benefits and support. Besides processing VA educational benefits, the department offers a variety of programs year-round to support student academic and personal success while transitioning to higher education and throughout your educational experience. They welcome inquiries regarding VA benefits and assist in navigating resources, the campus, and in the Reno community.