University of Wyoming
ZOO 5890-09
Population Modeling in Ecology (3 credits)
Enzi STEM Laboratories 155
Spring 2023
Monday 1:10–4:00 pm; January 17–May 5

Instructor: Dr. Gabriel Barrile, Biological Sciences Building Room 311, gbarrile@uwyo.edu
Office hours: Monday 4:00–5:00 pm; or if my door is open or by appointment.

Course prerequisites: None, but prior courses in statistics and some familiarity with Program R is recommended.

Course description: This course introduces students to key software packages and fundamental models used in fish and wildlife population analysis. Course content includes the parameterization of models used to estimate ecological state variables (occupancy, abundance) and population vital rates (survival, recruitment, dispersal) of both marked and unmarked populations, accounting for imperfect capture/detection probability. The course will cover closed population models, Cormack-Jolly-Seber models, multistate models, reverse-time Pradel models, and Robust Design models with *capture-mark-recapture data*, closed and open *N*-mixture models with *repeated count data*, and site-occupancy models with *detection/nondetection data*. Models will be fit using the 'RMark' and 'unmarked' packages in Program R. Each class will begin with an introduction to the subject material through a brief lecture followed by the application of the concepts through exercises in R (e.g., formatting data, fitting and selecting models, visualizing predicted relationships) using simulated or real datasets. Students will be encouraged to use their own data when possible.

Course objectives: (1) build familiarity with key statistical packages used in fish and wildlife population analysis; (2) improve ability to record and format field data for suitable input into appropriate analytical tools; (3) gain comfort in fitting models to estimate demographic rates and forecast population dynamics; (4) properly interpret model outputs and generate tables and figures for reports and scientific publications; and (5) recognize the types of data needed to model specific population parameters in order to develop better study designs (e.g., number of sites, number of surveys per site, whether to tag or not tag individuals).

Evaluation: The grade will be based on weekly lab reports and a final student project. Each lab report will be worth 8% of your grade, and the student project will be worth 20% of your grade.

Grading Scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), F (0-59%), S (>70%)

Student Project: apply methods of the course to at least one demographic analysis, using your own data or data obtained from colleagues/published archives. The project includes: (1) a written script to read and properly format data from field formats; (2) running at least five alternative models appropriate to the data structure in RMark or unmarked; (3) summary of results with tables and figures; and (4) presentation of the project at the end of the course.

Required materials: laptop computer with Program MARK and Program R installed.

Online references (free): Program MARK – 'a gentle introduction'. Go to http://www.phidot.org/software/mark/docs/book/ and select specific chapters from the dropdown menu.

All other required readings constitute articles from the primary literature that are freely available online—see the 'Readings' section below for a complete list of required readings (pdfs of articles will be provided if students cannot access).

Text (optional):
Williams, B. K., Nichols, J. D., & Conroy, M. J. (2002). *Analysis and management of animal populations*. Academic press.
Amstrup, S. C., McDonald, T. L., & Manly, B. F. (2005). *Handbook of capture-recapture analysis*. Princeton University Press.
Kéry, M., & Royle, J. A. (2015). *Applied Hierarchical Modeling in Ecology: Analysis of distribution, abundance and species richness in R and BUGS: Volume 1: Prelude and Static Models*. Academic Press.
Kéry, M., & Royle, J. A. (2020). *Applied Hierarchical Modeling in Ecology: Analysis of distribution, abundance and species richness in R and BUGS: Volume 2: Dynamic and Advanced Models*. Academic Press.

Classroom Statement on Diversity: The University of Wyoming values an educational environment that is diverse, equitable, and inclusive. The diversity that students and faculty bring to class, including age, country of origin, culture, disability, economic class, ethnicity, gender identity, immigration status, linguistic, political affiliation, race, religion, sexual orientation, veteran status, worldview, and other social and cultural diversity is valued, respected, and considered a resource for learning.

Course Statement on Diversity: All classroom activities, curricula, and assessments will consider issues of diversity as primary importance, with a collective goal of engaging all students in learning that is meaningful and accessible. This course will adhere to the principles of inclusive pedagogy, and all participants will establish a code of conduct to follow, which will help foster a positive classroom climate for all. Through our required readings, we will specifically highlight works that are typically underrepresented in courses on population analysis, including articles written by individuals that self-identify within groups historically and currently marginalized in the field of population ecology.

Disability Support: The University of Wyoming is committed to providing equitable access to learning opportunities for all students. If you have a disability, including but not limited to physical, learning, sensory or psychological disabilities, and would like to request accommodations in this course due to your disability, please register with and provide documentation of your disability as soon as possible to Disability Support Services (DSS), Room 128 Knight Hall. You may also contact DSS at (307) 766-3073 or udss@uwyo.edu. Visit the DSS website for more information at: www.uwyo.edu/udss.

Academic Dishonesty Policies: Academic dishonesty will not be tolerated in this class. Cases of academic dishonesty will be treated in accordance with UW Regulation 2-114. The penalties for academic dishonesty can include, at my discretion, an "F" on an exam, an "F" on the class component exercise, and/or an “F” in the entire course. Academic dishonesty means anything that represents someone else’s ideas as your own without attribution. It is intellectual theft – stealing - and includes (but is not limited to) unapproved assistance on examinations.

Duty to Report: UW faculty are committed to supporting students and upholding the University’s non-discrimination policy. Under Title IX, discrimination based upon sex and gender is prohibited. If you experience an incident of sex- or gender-based discrimination, we encourage you to report it. While you may talk to a faculty member, understand that as a "Responsible Employee" of the University, the faculty member MUST report information you share about the incident to the university’s Title IX Coordinator (you may choose whether you or anyone involved is identified by name). If you would like to speak with someone who may be able to afford you privacy or confidentiality, there are people who can meet with you.

Course Outline

ZOO 5890-09 Population Modeling in Ecology

Day	Date	Topic	Assessment
Week 1	1/23	Closed Binomial N-mixture Model	Lab Report due Friday (1/27)
Week 2	1/30	Open Binomial N-mixture Model	Lab Report due Friday (2/3)
Week 3	2/6	Closed Population Estimation	Lab Report due Friday (2/10)
Week 4	2/13	Site-Occupancy Model (Single-Season)	Lab Report due Friday (2/17)
Week 5	2/20	Site-Occupancy Model (Multi-Season)	Lab Report due Friday (2/24)
Week 6	2/27	Site-Occupancy Model (Multi-Season)	Lab Report due Friday (3/3)
Week 7	3/6	Cormack-Jolly-Seber Model	Lab Report due Friday (3/10)
Week 8	3/13	**Spring Break**	
Week 9	3/20	Robust Design with Temporary Emigration	Lab Report due Friday (3/24)
Week 10	3/27	Robust Design Pradel Recruitment Model	Lab Report due Friday (3/31)
Week 11	4/3	Robust Design Multi-State Model	Lab Report due Friday (4/7)
Week 12	4/10	Model(s) selected by students	Lab Report due Friday (4/14)
Week 13	4/17	Model(s) selected by students	
Week 14	4/24	Student Projects	
Week 15	5/1	Student Projects	Final Project due Friday (5/5)

*Schedule subject to change depending on student needs

**Students need only submit 10 of 11 lab reports

Readings

Week 1 (1/23) – Closed Binomial N-mixture Model

Royle, J. A. (2004). N-mixture models for estimating population size from spatially replicated counts. *Biometrics*, *60*(1), 108-115. https://doi.org/10.1111/j.0006-341X.2004.00142.x

Kéry, M., Royle, J. A., & Schmid, H. (2005). Modeling avian abundance from replicated counts using binomial mixture models. *Ecological applications*, *15*(4), 1450-1461. https://doi.org/10.1890/04-1120

Fiske, I., & Chandler, R. (2011). Unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. *Journal of statistical software*, *43*, 1-23. https://doi.org/10.18637/jss.v043.i10

McCaffery, R., Nowak, J. J., & Lukacs, P. M. (2016). Improved analysis of lek count data using N-mixture models. *The Journal of Wildlife Management*, *80*(6), 1011-1021. https://doi.org/10.1002/jwmg.21094

Coelho, I. P., Collins, S. J., Santos Junior, E. M., Valença-Montenegro, M. M., Jerusalinsky, L., & Alonso, A. C. (2020). Playback point counts and N-mixture models suggest higher than expected abundance of the critically endangered blond titi monkey in northeastern Brazil. *American Journal of Primatology*, *82*(5), e23126. https://doi.org/10.1002/ajp.23126

Della Rocca, F., Milanesi, P., Magna, F., Mola, L., Bezzicheri, T., Deiaco, C., & Bracco, F. (2020). Comparison of two sampling methods to estimate the abundance of Lucanus cervus with application of n-mixture models. *Forests*, *11*(10), 1085. https://doi.org/10.3390/f11101085

Week 2 (1/30) – Open Binomial N-mixture Model

Hostetler, J. A., & Chandler, R. B. (2015). Improved state-space models for inference about spatial and temporal variation in abundance from count data. *Ecology*, *96*(6), 1713-1723. https://doi.org/10.1890/14-1487.1

Zipkin, E. F., Thorson, J. T., See, K., Lynch, H. J., Grant, E. H. C., Kanno, Y., ... & Royle, J. A. (2014). Modeling structured population dynamics using data from unmarked individuals. *Ecology*, *95*(1), 22-29. https://doi.org/10.1890/13-1131.1

Kanno, Y., Letcher, B. H., Hitt, N. P., Boughton, D. A., Wofford, J. E., & Zipkin, E. F. (2015). Seasonal weather patterns drive population vital rates and persistence in a stream fish. *Global Change Biology*, *21*(5), 1856-1870. https://doi.org/10.1111/gcb.12837

Kidwai, Z., Jimenez, J., Louw, C. J., Nel, H. P., & Marshal, J. P. (2019). Using N-mixture models to estimate abundance and temporal trends of black rhinoceros (*Diceros bicornis* L.) populations from aerial counts. *Global Ecology and Conservation*, *19*, e00687. https://doi.org/10.1016/j.gecco.2019.e00687

Week 3 (2/6) – Closed Population Estimation

Program MARK – a 'gentle introduction.' Chapter 14: Closed population capture-recapture models, written by Paul Lukacs. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 14 from the dropdown menu.

Program MARK – a 'gentle introduction.' Appendix C: RMark – an alternative approach to building linear models in MARK, written by Jeff Laake and Eric Rexstad. Go to http://www.phidot.org/software/mark/docs/book/ and select Appendix C from the dropdown menu.

Otis, D. L., Burnham, K. P., White, G. C., & Anderson, D. R. (1978). Statistical Inference from Capture Data on Closed Animal Populations. *Wildlife Monographs*, *62*, 3–135. http://www.jstor.org/stable/3830650

Huggins, R. (1989). On the statistical analysis of capture experiments. *Biometrika*, *76*(1), 133-140. https://doi.org/10.1093/biomet/76.1.133

Week 4 (2/13) – Site-Occupancy Model (Single-Season)

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Andrew Royle, J., & Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, *83*(8), 2248-2255. https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2

Tyre, A. J., Tenhumberg, B., Field, S. A., Niejalke, D., Parris, K., & Possingham, H. P. (2003). Improving precision and reducing bias in biological surveys: estimating false-negative error rates. *Ecological Applications*, *13*(6), 1790-1801. https://doi.org/10.1890/02-5078

Chibesa, M., & Downs, C. T. (2017). Factors determining the occupancy of Trumpeter Hornbills in urban-forest mosaics of KwaZulu-Natal, South Africa. *Urban Ecosystems, 20*(5), 1027-1034. https://doi.org/10.1007/s11252-017-0656-3

Zungu, M. M., Maseko, M. S., Kalle, R., Ramesh, T., & Downs, C. T. (2020). Factors affecting the occupancy of forest mammals in an urban-forest mosaic in EThekwini Municipality, Durban, South Africa. *Urban Forestry & Urban Greening*, *48*, 126562. https://doi.org/10.1016/j.ufug.2019.126562

Abdoulaye, D., Adama, T., & Matthias, W. (2021). Research and tourism affect positively the occupancy pattern of Loxodonta cyclotis (Elephantidae) in Taï National Park, Côte d'Ivoire. *Nature Conservation Research. Заповедная наука*, *6*(1), 68-77.

Kamjing, A., Ngoprasert, D., Steinmetz, R., Chutipong, W., Savini, T., & Gale, G. A. (2017). Determinants of smooth-coated otter occupancy in a rapidly urbanizing coastal landscape in Southeast Asia. *Mammalian Biology*, *87*(1), 168-175. https://doi.org/10.1016/j.mambio.2017.08.006

Week 5 (2/20) – Site-Occupancy Model (Multi-Season)

MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., & Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology*, *84*(8), 2200-2207. https://doi.org/10.1890/02-3090

Kéry, M., & Chandler, R. (2016). Dynamic occupancy models in unmarked. http://cran.nexr.com/web/packages/unmarked/vignettes/colext.pdf

Broms, K. M., Hooten, M. B., Johnson, D. S., Altwegg, R., & Conquest, L. L. (2016). Dynamic occupancy models for explicit colonization processes. *Ecology*, *97*(1), 194-204. https://doi.org/10.1890/15-0416.1

Week 6 (2/27) – Site-Occupancy Model (Multi-Season)

Program MARK – a 'gentle introduction.' Chapter 21: Occupancy models – single-species, written by Brian Gerber, Daniel Martin, Larissa Bailey, Thierry Chambert, and Brittany Mosher. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 21 from the dropdown menu.

Maphisa, D. H., Smit-Robinson, H., & Altwegg, R. (2019). Dynamic multi-species occupancy models reveal individualistic habitat preferences in a high-altitude grassland bird community. *PeerJ*, *7*, e6276. https://doi.org/10.7717/peerj.6276

Ruiz-Gutiérrez, V., Zipkin, E. F., & Dhondt, A. A. (2010). Occupancy dynamics in a tropical bird community: unexpectedly high forest use by birds classified as non-forest species. *Journal of Applied Ecology*, *47*(3), 621-630. https://doi.org/10.1111/j.1365-2664.2010.01811.x

Week 7 (3/6) – Cormack-Jolly-Seber Model

Program MARK – a 'gentle introduction.' Chapter 4: Building & comparing models. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 4 from the dropdown menu.

Program MARK – a 'gentle introduction.' Chapter 7: 'Age' and cohort models. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 7 from the dropdown menu.

Lebreton, J. D., Burnham, K. P., Clobert, J., & Anderson, D. R. (1992). Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecological Monographs*, *62*(1), 67-118. https://doi.org/10.2307/2937171

Muñoz, A. P., Kéry, M., Martins, P. V., & Ferraz, G. (2018). Age effects on survival of Amazon forest birds and the latitudinal gradient in bird survival. *The Auk: Ornithological Advances*, *135*(2), 299-313. https://doi.org/10.1642/AUK-17-91.1

Kanyamibwa, S., Bairlein, F., & Schierer, A. (1993). Comparison of survival rates between populations of the White Stork Ciconia 6iconia in Central Europe. *Ornis Scandinavica*, 297-302. https://doi.org/10.2307/3676791

Wei, L., Wenqin, Z., & Wang, D. (2020). Seasonal dynamic of population survival and its mechanism in Mongolian gerbils (*Meriones unguiculatus*) in the Inner Mongolia agro-pastoral ecotone. *ACTA Theriologica Sinica*, *40*(6), 571. https://doi.org/10.16829/j.slxb.150431

Week 8 (3/13) – Spring Break

Week 9 (3/20) – Robust Design with Temporary Emigration

Program MARK – a 'gentle introduction.' Chapter 15: The 'robust design', written by William Kendall. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 15 from the dropdown menu.

Kendall, W. L., Nichols, J. D., & Hines, J. E. (1997). Estimating temporary emigration using capture–recapture data with Pollock's robust design. *Ecology*, *78*(2), 563-578. https://doi.org/10.1890/0012-9658(1997)078[0563:ETEUCR]2.0.CO;2

Muths, E., Scherer, R. D., Corn, P. S., & Lambert, B. A. (2006). Estimation of temporary emigration in male toads. *Ecology*, *87*(4), 1048-1056. https://doi.org/10.1890/0012-9658(2006)87[1048:EOTEIM]2.0.CO;2

Fujiwara, M., & Caswell, H. (2002). A general approach to temporary emigration in mark–recapture analysis. *Ecology*, *83*(12), 3266-3275. https://doi.org/10.1890/0012-9658(2002)083[3266:AGATTE]2.0.CO;2

Bailey, L. L., Simons, T. R., & Pollock, K. H. (2004). Estimating detection probability parameters for plethodon salamanders using the robust capture-recapture design. The Journal of Wildlife Management, 68(1), 1-13. https://doi.org/10.2193/0022-541X(2004)068[0001:EDPPFP]2.0.CO;2

Week 10 (3/27) – Robust Design Pradel Recruitment Model

Program MARK – a 'gentle introduction.' Chapter 13: Time-symmetric open models: recruitment, survival, and population growth rate. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 13 from the dropdown menu.

Pradel, R. (1996). Utilization of capture-mark-recapture for the study of recruitment and population growth rate. *Biometrics*, 703-709. https://doi.org/10.2307/2532908

Muths, E., Scherer, R. D., & Pilliod, D. S. (2011). Compensatory effects of recruitment and survival when amphibian populations are perturbed by disease. *Journal of Applied Ecology*, *48*(4), 873-879. https://doi.org/10.1111/j.1365-2664.2011.02005.x

Sanderlin, J. S., Waser, P. M., Hines, J. E., & Nichols, J. D. (2012). On valuing patches: estimating contributions to metapopulation growth with reverse-time capture–recapture modelling. *Proceedings of the Royal Society B: Biological Sciences*, *279*(1728), 480-488. https://doi.org/10.1098/rspb.2011.0885

Korfanta, N. M., Newmark, W. D., & Kauffman, M. J. (2012). Long-term demographic consequences of habitat fragmentation to a tropical understory bird community. *Ecology*, *93*(12), 2548-2559. https://doi.org/10.1890/11-1345.1

Week 11 (4/3) – Robust Design Multi-State Model

Program MARK – a 'gentle introduction.' Chapter 10: Multi-state models. Go to http://www.phidot.org/software/mark/docs/book/ and select Chapter 10 from the dropdown menu.

Chabanne, D. B., Pollock, K. H., Finn, H., & Bejder, L. (2017). Applying the multistate capture–recapture robust design to characterize metapopulation structure. *Methods in Ecology and Evolution*, *8*(11), 1547-1557. https://doi.org/10.1111/2041-210X.12792

Converse, S. J., Kendall, W. L., Doherty Jr, P. F., & Ryan, P. G. (2009). Multistate models for estimation of survival and reproduction in the grey-headed albatross (Thalassarche chrysostoma). *The Auk*, *126*(1), 77-88. https://doi.org/10.1525/auk.2009.07189

Muths, E., Bailey, L. L., Lambert, B. A., & Schneider, S. C. (2018). Estimating the probability of movement and partitioning seasonal survival in an amphibian metapopulation. *Ecosphere*, *9*(10), e02480. https://doi.org/10.1002/ecs2.2480

Week 12 (4/10) – Model(s) voted on by students

TBD

Week 13 (4/17) – Model(s) voted on by students

TBD

Week 14 (4/24) and Week 15 (5/1) – Student projects

No readings, just work on final projects

Details of each model covered in this course

Response	System	Marked	Data	Package	Model
Abundance	Static	No	Repeated Counts	unmarked	Closed Binomial N-mixture Model
Trend in Abundance	Dynamic	No	Repeated Counts	unmarked	Open Binomial N-mixture Model
Abundance	Static	Yes	Capture-Recapture	RMark	Closed Population Estimation
Distribution	Static	No	Detection/Nondetection	unmarked	Site-Occupancy Model (Single-Season)
Change in Distribution	Dynamic	No	Detection/Nondetection	unmarked	Site-Occupancy Model (Multi-Season)
Change in Distribution	Dynamic	No	Detection/Nondetection	RMark	Site-Occupancy Model (Multi-Season)
Survival	Dynamic	Yes	Capture-Recapture	RMark	Cormack-Jolly-Seber Model
Survival	Both	Yes	Capture-Recapture	RMark	Robust Design with Temporary Emigration
Recruitment and Growth	Both	Yes	Capture-Recapture	RMark	Robust Design Pradel Recruitment Model
Dispersal	Both	Yes	Capture-Recapture	RMark	Robust Design Multi-State Model

*In the **Response** column, *Abundance* may be used interchangeably with *Density*, and *Distribution* may be used interchangeably with *Occurrence*

In the **System column, *Static* may be used interchangeably with *Closed*, and *Dynamic* may be used interchangeably with *Open*