**BIOE 149 Disease Ecology**
**Instructor:** Dr. Marm Kilpatrick, Associate Professor, Ecology and Evolutionary Biology
**Office:** CBB 252
**Email:** akilpatr@ucsc.edu
**Phone:** (831) 459-5070
**Office Hours:** M 11:45am-12:45pm and by appt.

**TA:** Luz de Wit
**Email:** ldewit@ucsc.edu
**Office Hours:** COH 249; Tu 2-3pm, Th 2-3pm

**Lecture:** CBB 110 M,W 10-11:35am
**Discussions:** All in CBB 203
M 8:30am-9:35am
M 12-1:05pm
W 1:25-2:30pm

**Course Description:** This is a class on problem solving and critical thinking focusing on problems related to the ecological and evolutionary processes that drive the transmission of pathogens between hosts; the impact of disease on host populations; and what causes the emergence of an infectious disease. The course content includes a theoretical framework, hands-on experience with field techniques, and a discussion of wildlife and human diseases including Zika, Ebola, influenza (swine flu, bird flu), malaria, West Nile virus, Lyme disease, HIV, Chikungunya, tuberculosis, chytridiomycosis, and many others.

**Course Readings:** There is no book. See schedule of readings below.

**Attendance:** Attendance at lectures and discussion is mandatory and attendance will be taken. If you miss a class you need to find a fellow student who will share their notes.

**Daily Assignments:** There are short assignments on the reading for each day. There will be questions on the two papers in columns I and II (see below), with questions on papers in column II providing extra credit.

**Grades:** Daily assignments 15%; Poster Project 15%; Midterm 25%; Discussion Activities: 15% Final exam: 30%.

**Weekly Schedule.** Everyone should read the papers in column I; the papers in column II are for extra credit. Papers in column III are additional readings for those especially interested in the topic.

| Wk | Day | Date | Topic | Readings I | II | III |
|---|---|---|---|---|---|---|
| 1 | Mon | Apr 2 | What is disease ecology, and what is it good for? | 1 | 2 | 3 |
| 1 | Wed | Apr 4 | Foundations of disease ecology: SIR models, $R_0$, Frequency and density dependent transmission, Nth | 4 | 5 | 6, 7 |
| 2 | Mon | Apr 9 | Directly transmitted human pathogens | 8 | 9 | 10 |
| 2 | Wed | Apr 11 | Disease impacts on populations and ecosystems | 11 | 12 | 13 |
| 3 | Mon | Apr 16 | Livestock, wildlife, zoonotic pathogens | 14 | 15 | |
| 3 | Wed | Apr 18 | Disease control: Vaccination, Behavioral changes, culling | 16 | 17 | 18 |
| 4 | Mon | Apr 23 | Problem solving: Controlling influenza | 16,19 | | |
| 4 | Wed | Apr 25 | Problem solving: Herpes dynamics | 20 | 22 | |
| 5 | Mon | Apr 30 | Problem solving: Evolution of virulence | 23 | 24 | 25-27 |
| 5 | Wed | May 2 | Mid-term | | | |
| 6 | Mon | May 7 | Case Study: White nose syndrome | | | |
| 6 | Wed | May 9 | Vector borne disease ecology I. | 30 | 31 | |
| 7 | Mon | May 14 | Vector borne disease ecology II. | 32 | 33 | |
| 7 | Wed | May 16 | Seasonality, climate change and transmission dynamics | 34 | 35 | 36 |
| 8 | Mon | May 21 | Antibiotic resistance | 37 | 38 | 39 |
| 8 | Wed | May 23 | Multi-host pathogens, biodiversity and disease: the "dilution effect" | 40 | 41 | 42 |
| 9 | Mon | May 28 | Holiday | | | |
| 9 | Wed | May 30 | ON-CAMPUS – Outside Communications Building near Baskin circle! Plant pathogens w Greg Gilbert | 45 | 46 | 47 |
| 10 | Mon | Jun 4 | Disease and conservation | 48 | 49 | |
| 10 | Wed | Jun 6 | Poster session | | | |
| 11 | Thu | May 14 | Final Exam 12-3pm | | | |

Readings


1 Kilpatrick, A. M. and Altizer, S., Disease Ecology. *Nature Education Knowledge* 1 (11), 13 (2010). Link to Article

2 Smith, K. F., Dobson, A. P., McKenzie, F. E., Real, L. A., Smith, D. L., and Wilson, M. L., Ecological theory to enhance infectious disease control and public health policy *Frontiers in Ecology and the Environment* 3 (1), 29 (2005). PDF

3 Plowright, R. K., Sokolow, S. H., Gorman, M. E., Daszak, P., and Foley, J. E., Causal inference in disease ecology: investigating ecological drivers of disease emergence *Frontiers in Ecology and the Environment* 6 (8), 420 (2008). PDF

4 Anderson, R. M. and May, R. M., A framework for discussing the population biology of infectious diseases in *Infectious diseases of humans. Dynamics and control.* (Oxford University Press, London, 1991), pp. 13. PDF

5 Lloyd-Smith, J. O., Cross, P. C., Briggs, C. J., Daugherty, M., Getz, W. M., Latto, J., Sanchez, M. S., Smith, A. B., and Swei, A., Should we expect population thresholds for wildlife disease?*Trends in Ecology & Evolution* 20 (9), 511 (2005).PDF

6 Anderson, R. M. and May, R. M., Population biology of infectious diseases I *Nature* 280 (5721), 361 (1979). PDF
7 May, R. M. and Anderson, R. M., Population Biology of Infectious-Diseases II *Nature* 280 (5722), 455 (1979).PDF
8 Woolhouse, M. E. J., Dye, C., Etard, J. F., Smith, T., Charlwood, J. D., Garnett, G. P., Hagan, P., Hii, J. L. K., Ndhlovu, P. D., Quinnell, R. J., Watts, C. H., Chandiwana, S. K., and Anderson, R. M., Heterogeneities in the transmission of infectious agents: Implications for the design of control programs *Proceedings of the National Academy of Sciences* 94 (1), 338 (1997).PDF
9. Aylward B, Barboza P, Bawo L, et al. Ebola Virus Disease in West Africa - The First 9 Months of the Epidemic and Forward Projections. *N Engl J Med* 2014; 371(16): 1481-95. PDF
10 Ferguson, N. M., Cummings, D. A. T., Fraser, C., Cajka, J. C., Cooley, P. C., and Burke, D. S., Strategies for mitigating an influenza pandemic *Nature* 442 (7101), 448 (2006). PDF
11 Hudson, P. J., Dobson, A. P., and Newborn, D., Prevention of population cycles by parasite removal *Science* 282 (5397), 2256 (1998).PDF
12 Holdo, R. M., Sinclair, A. R. E., Dobson, A. P., Metzger, K. L., Bolker, B. M., Ritchie, M. E., and Holt, R. D., A Disease-Mediated Trophic Cascade in the Serengeti and its Implications for Ecosystem C *Plos Biology* 7 (9), e1000210 (2009).PDF
13 LaDeau, S. L., Kilpatrick, A. M., and Marra, P. P., West Nile virus emergence and large-scale declines of North American bird populations *Nature* 447 (7145), 710 (2007). PDF
14 Hochachka WM, Dhondt AA. Density-dependent decline of host abundance resulting from a new infectious disease. *Proc Natl Acad Sci U S A* 2000; 97(10): 5303-6. PDF
15 Dobson, A. and Meagher, M., The population dynamics of brucellosis in the Yellowstone National Park *Ecology* 77 (4), 1026 (1996). PDF
16 Fraser, C., Riley, S., Anderson, R. M., and Ferguson, N. M., Factors that make an infectious disease outbreak controllable *Proceedings of the National Academy of Sciences of the United States of America* 101 (16), 6146 (2004). PDF
17 Donnelly, C. A., Woodroffe, R., Cox, D. R., Bourne, J., Gettinby, G., Le Fevre, A. M., McInerney, J. P., and Morrison, W. I., Impact of localized badger culling on tuberculosis incidence in British cattle *Nature* 426 (6968), 834 (2003). PDF
18 Galvani, A. P., Reluga, T. C., and Chapman, G. B., Long-standing influenza vaccination policy is in accord with individual self-interest but not with the utilitarian optimum *Proceedings of the National Academy of Sciences of the United States of America* 104 (13), 5692 (2007). PDF
19 Harris, J. B., R. C. LaRocque, F. Qadri, E. T. Ryan, and S. B. Calderwood. 2012. Cholera. Lancet 379:2466-2476. PDF
20 Cholera Model Homework assignment
21 Graham, A. L., Ecological rules governing helminth-microparasite coinfection *Proceedings of the National Academy of Sciences of the United States of America* 105 (2), 566 (2008). PDF
22 Mina, M. J., C. J. E. Metcalf, R. L. de Swart, A. Osterhaus, and B. T. Grenfell. 2015. Long-term measles-induced immunomodulation increases overall childhood infectious disease mortality. Science 348:694-699. PDF
23 Myxoma virus evolution of virulence homework

24 Grenfell, B. T., Pybus, O. G., Gog, J. R., Wood, J. L. N., Daly, J. M., Mumford, J. A., and Holmes, E. C., Unifying the epidemiological and evolutionary dynamics of pathogens *Science* 303(5656), 327 (2004). PDF
25 Woolhouse, M. E. J., Webster, J. P., Domingo, E., Charlesworth, B., and Levin, B. R., Biological and biomedical implications of the co-evolution of pathogens and their hosts *Nature Genetics*32 (4), 569 (2002). PDF
26 Mackinnon, M. J., Gandon, S., and Read, A. F., Virulence evolution in response to vaccination: The case of malaria *Vaccine* 26, C42 (2008). PDF
27 Ewald, P. W., *Evolution of infectious disease*. (Oxford University Press, Oxford, 1994).
28 Metcalf, C. J. E., M. Ferrari, A. L. Graham, and B. T. Grenfell. 2015. Understanding Herd Immunity. Trends in Immunology 36:753-755. PDF
30 Wonham, M. J., de-Camino-Beck, T., and Lewis, M. A., An epidemiological model for West Nile virus: invasion analysis and control applications *Proceedings of the Royal Society of London Series B-Biological Sciences* 271 (1538), 501 (2004). PDF
31. Sachs, J. and Malaney, P., The economic and social burden of malaria *Nature* 415 (6872), 680 (2002). PDF
32 Ostfeld, R. S., Canham, C. D., Oggenfuss, K., Winchcombe, R. J., and Keesing, F., Climate, deer, rodents, and acorns as determinants of variation in Lyme-disease risk *Plos Biology* 4 (6), 1058 (2006). PDF
33. Alonso PL, Brown G, Arevalo-Herrera M, et al. A Research Agenda to Underpin Malaria Eradication. *PLoS Med* 2011; 8(1) e1000400.PDF
34. Mordecai EA, Paaijmans KP, Johnson LR, et al. Optimal temperature for malaria transmission is dramatically lower than previously predicted. *Ecol Lett* 2013; **16**(1): 22-30. PDF
35. Gething, P. W., D. L. Smith, A. P. Patil, A. J. Tatem, R. W. Snow, and S. I. Hay. 2010. Climate change and the global malaria recession. Nature 465:342-346. PDF
36. Rohr, J. R., Raffel, T. R., Romansic, J. M., McCallum, H., and Hudson, P. J., Evaluating the links between climate, disease spread, and amphibian declines *Proceedings of the National Academy of Sciences of the United States of America* 105 (45), 17436 (2008). PDF
37. Levy SB, Marshall B. Antibacterial resistance worldwide: causes, challenges and responses. *Nat Med* 2004; **10**(12): S122-S9.PDF
38. Read AF, Day T, Huijben S. The evolution of drug resistance and the curious orthodoxy of aggressive chemotherapy. *Proc Natl Acad Sci U S A* 2011; **108**: 10871-7. PDF
39. Read AF, Lynch PA, Thomas MB. How to Make Evolution-Proof Insecticides for Malaria Control. *PLoS Biol* 2009; **7**(4): e1000058. PDF
40. Keesing F, Holt RD, Ostfeld RS. Effects of species diversity on disease risk. *Ecol Lett* 2006; **9**(4): 485-98. PDF
41. Kilpatrick, A. M., D. J. Salkeld, G. Titcomb, and M. B. Hahn. 2017. Conservation of biodiversity as a strategy for improving human health and well-being. Philosophical Transactions of the Royal Society B-Biological Sciences 372:20160131. PDF
42. Civitello, D. J., J. Cohen, H. Fatima, N. T. Halstead, J. Liriano, T. A. McMahon, C. N. Ortega, E. L. Sauer, T. Sehgal, S. Young, and J. R. Rohr. 2015. Biodiversity inhibits parasites: Broad evidence for the dilution effect. Proceedings of the National Academy of Sciences of the United States of America 112:8667-8671. PDF
43. Wolfe ND, Dunavan CP, Diamond J. Origins of major human infectious diseases. *Nature* 2007; **447**(7142): 279-83. PDF

44. Faria NR, Rambaut A, Suchard MA, et al. The early spread and epidemic ignition of HIV-1 in human populations. *Science* 2014; **346**(6205): 56-61. PDF
45. Parker IM, Saunders M, Bontrager M, et al. Phylogenetic structure and host abundance drive disease pressure in communities. *Nature* 2015; **520**(7548): 542-4 PDF
46. Gilbert GS, Webb CO. Phylogenetic signal in plant pathogen-host range. *Proc Natl Acad Sci U S A* 2007; 104(12): 4979-83.PDF
47. Parker IM, Gilbert GS. The evolutionary ecology of novel plant-pathogen interactions. *Annu Rev Ecol Evol Syst* 2004; **35**: 675-700.PDF
48. Langwig, K. E., J. Voyles, M. Q. Wilber, W. F. Frick, K. A. Murray, B. M. Bolker, J. P. Collins, T. L. Cheng, M. C. Fisher, J. R. Hoyt, D. L. Lindner, H. I. McCallum, R. Puschendorf, E. B. Rosenblum, M. Toothman, C. K. R. Willis, C. J. Briggs, and A. M. Kilpatrick. 2015. Context dependent conservation responses to emerging wildlife diseases. Frontiers in Ecology and the Environment 13:195–202. PDF
49. McCallum H. Disease and the dynamics of extinction. *Philos Trans R Soc B-Biol Sci* 2012; **367**(1604): 2828-39. PDF