ECOLOGICAL LAWS

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INTRODUCTION

The question of whether there are laws in ecology is important for a number of reasons. If, as some have suggested, there are no ecological laws, this would seem to distinguish ecology from other branches of science, such as physics. It could also make a difference to the methodology of ecology. If there are no laws to be discovered, ecologists would seem to be in the business of merely supplying a suite of useful models. These models would need to be assessed for their empirical adequacy but not for their ability to capture fundamental truths, or the like. If, on the other hand, ecology does have laws, this prompts further questions about what these laws are and why even the best candidates for ecological laws fall short of what might be expected of laws. Such issues lead very naturally to the philosophical question of what laws in science are. There is no straight-forward answer to this question, and there is substantial disagreement amongst those engaging in the relevant debates. A common starting point, at least, is that laws in science are non-accidental, exceptionless generalisations, which make precise, falsifiable predictions. There are good reasons to doubt this account of laws, but still it serves as a useful point of departure. A great deal of the material on this topic focuses on the issue of what laws of nature are and what roles they are supposed to play in scientific theory. The debate about laws in ecology thus crops up in two different guises: directly tackling the question of laws in ecology, and as a debate about the differences and similarities between ecology and physics. The literature on this topic naturally spans both ecology and philosophy of science, and is generally well-informed from both perspectives. Further progress on the topic of laws in ecology will need to take on board insights from both ecology and the broader interdisciplinary perspective offered by philosophy of science.

PHILOSOPHICAL BACKGROUND

Before determining whether there are ecological laws, a clear picture of what laws of nature are and what roles they play in other branches of science is needed. In the service of this goal, some general reading in philosophy of science is essential. Good introductions to the philosophy of science include Chalmers 1999, Godfrey-Smith 2003, and Newton-Smith 2000. Sterelny and Griffiths 1999 provides a philosophical overview of the life sciences, while Colyvan et al. 2009, Cooper 2003 (cited under *Biological Laws*), McIntosh 1987 (cited under *Against Ecological Laws*), Peters 1991, and Shrader-Frechette and McCoy 1993 (cited under *Against Ecological Laws*) focus on philosophical issues in ecology. Other relevant material on general philosophy of science includes Lakatos 1970, Quine and Ullian 1978, and van Fraassen 1980.

Chalmers, Alan. F. 1999. *What is this thing called science?* 3rd edition Brisbane: University of Queensland Press.

A classic introduction to the philosophy of science, including a very good critique of falsification.

Colyvan, Mark, Stephan Linquist, William Grey, Paul E. Griffiths, Jay Odenbaugh, and Hugh P. Possingham. 2009. *Philosophical issues in ecology: Recent trends and future

directions[http://www.ecologyandsociety.org/vol14/iss2/art22/]*. *Ecology and Society*,14(2): article 22.

A survey article, covering some of the current issues in philosophy of ecology, including a discussion of laws in ecology.

Godfrey-Smith, Peter. 2003. *Theory and reality: an introduction to the philosophy of science*. Chicago: University of Chicago Press.

A very good introduction to philosophy of science, covering all the main issues of contemporary interest.

Lakatos, Imre. 1970. Falsification and the methodology of scientific research programmes. In: Lakatos, I. and Musgrave, A. (eds), *Criticism and the growth of knowledge*. Cambridge: Cambridge University Press. Pp. 91–195.

The classic critique of Popperian falsification, suggesting that crucial hypotheses (or laws) can be shielded from disconfirmation by making adjustments elsewhere.

Newton-Smith, W. H. (ed.). 2000. *A companion to the philosophy of science*. Oxford: Blackwell.

A good source book for philosophy of science.

Peters, Robert H. 1991. *A critique for ecology*. Cambridge: Cambridge University Press.

Criticises ecology for its lack of predictive success and its poor data, suggesting that ecology is at best a “soft science”.

Quine, W. V. and Ullian, J. S. 1978. *The web of belief*. New York: Random House.

This short book is a good gentle introduction to post-Popperian philosophy of science and provides a very clear articulation of the holist thesis that hypotheses cannot be confirmed or falsified individually.

Sterelny, Kim and Paul E. Griffiths. 1999. *Sex and death: an introduction to the philosophy of biology*. Chicago: University of Chicago Press.

The standard introduction to the philosophy of biology, and an excellent one, at that. It includes some discussion of issues in philosophy of ecology.

van Fraassen, Bas C. 1980. *The scientific image*. Oxford: Clarendon Press.

A very influential and controversial account of science as being merely in the business of producing theories that are empirically adequate; not producing theories that are true or even approximately true.

Laws of Nature

Useful discussions of what laws might be and the roles they play in science can be found in Armstrong 1983, Harré 2000, Lange 2000, and Lange 2002, with a range of positions defended. Of particular note is the work of Cartwright 1983, Giere 1999 and van Frassen 1989, who are rather deflationary about the role of laws in science. Also of note is Duhem’s 1954 argument that falsifying or confirming hypotheses or laws, one at a time is not possible. The point of departure for much of this work is Hempel’s account of laws playing a central role in scientific explanation. This view is presented in Hempel 1966.

Armstrong, David M. 1983. *What is a law of nature?* Cambridge: Cambridge University Press.

This short monograph offers a good critical overview of some of the traditional philosophical thinking on what laws of nature are and how they feature in scientific theorising.

Cartwright, Nancy. 1983. *How the laws of physics lie*. Oxford: Clarendon Press.
An influential article in which a case is made that laws, even in physics, are false.

Duhem, Pierre. 1954. *The aim and structure of physical theory*. Princeton: Princeton University Press.
This classic book, originally published in French in 1906, presents a compelling case for the thesis that hypotheses are not confirmed or disconfirmed individually, but only systems of hypotheses are confirmed or disconfirmed. If Duhem is right, this would hold for laws as well.

Hempel, Carl G. 1966. *Philosophy of natural science*. Englewood Cliffs, N.J.: Prentice-Hall.
A classic introduction to the philosophy of science, discussing among other things, the role of laws in science, written by one of the major figures in the area.

Giere, Ronald N. 1999. *Science without laws*. Chicago (IL): University of Chicago Press.
A book-length defence of the view that science does not have nor need laws.

Harré, Rom. 2000. Laws of nature. In: Newton-Smith, W. H. (ed.), *A companion to the philosophy of science*. Oxford: Blackwell. Pp. 213–223.
A good overview of philosophical thinking on laws of nature.

Lange, Marc. 2000. *Natural laws in scientific practice*. Oxford: Oxford University Press.
A good book-length discussion of the roles of laws in science, including in the special sciences.

Lange, Marc. 2002. Who's afraid of ceteris-paribus laws? Or: how I learned to stop worrying and love them. *Erkenntnis* 57(3): 407–423.
Discusses the role of ceteris-paribus clauses in laws and argues that ceteris-paribus generalisation is inexact sciences, such as ecology, do indeed qualify as laws.

van Fraassen, Bas C. 1989. *Laws and symmetry*. Oxford: Clarendon Press.
Has a very good discussion of laws in science, what they are supposed to be, and why there may be nothing that lives up to this.

BIOLOGICAL LAWS

It is useful to consider the broader question of biological laws. If biology as a whole fails to have laws, then ecology would be expected to follow suit. Moreover, the lack of laws in ecology would be well understood and would follow from the lack of laws in biology. If, however, biology does have laws and ecology does not, then there would seems to be interesting methodological differences between ecology and the rest of biology. In any case, the issue of laws in biology is important when assessing the cases for and against laws in ecology. Some of the discussion of laws in biology in general can be found in Brandon 1997 (cited under *Ecology and Physics*), Cartwright 1999 (also cited under *Ecology and Physics*), Cooper 1996, Cooper 2003, Rosenberg 1994, Smart 1963, Sober 1998, and Waters 1998. Most of the literature on the topic is sceptical of the existence of biological laws, but there are a few who speak out in favour, such as Ruse 1970 and Elgin 2006.

Cooper, Gregory J. 1996. Theoretical modeling and biological laws. *Philosophy of Science* 63 (Proceedings): S28–S35.

This paper argues that if there are no laws in biology, explanation cannot be easily accommodated. The paper concludes that we need to rethink the relationship between laws and explanation.

Cooper, Gregory J. 2003. *The science of the struggle for existence: On the foundations of ecology*. Cambridge: Cambridge University Press.

A very good book on the philosophy of ecology that explicitly addresses the issue of laws in ecology and biology more generally.

Elgin, Mehmet. 2006. There may be strict empirical laws in biology, after all. *Biology and Philosophy* 21(1): 119–134.

Argues against the sceptics about biological laws. Makes the case that there are laws in biology, giving specific examples. Much of the case against the sceptical view holds for scepticism about ecological laws as well.

Rosenberg Alex. 1994. *Instrumental biology, or the disunity of science*. Chicago: University of Chicago Press.

Argues against the existence of strict biological laws.

Ruse Michael. 1970. Are there laws in biology. *Australasian Journal of Philosophy* 48(2): 234–246.

Takes issue with Smart's 1963 argument that biology does not have laws.

Smart J. J. C. 1963. *Philosophy and scientific realism*. London: Routledge & Kegan Paul.

This classic account of realism in science, argues, in passing, that biology does not have laws.

Sober, Elliott. 1998. Two outbreaks of lawlessness in recent philosophy of biology. *Philosophy of Science* 64 (Proceedings): S458–S467.

Makes a case for biology having problems with identifying laws.

Waters, C. Kenneth. 1998. Causal regularities in the biological world of contingent distributions. *Biology and Philosophy* 13(1): 5–36.

Analyses the role of biological generalisations and argues that, once these are properly understood, they play very similar roles to laws.

AGAINST ECOLOGICAL LAWS

A number of authors have suggested that ecology is not law governed (Lockwood 2008, Roughgarden 1997, Shrader-Frechette 2001) or that ecology is better construed as a science where laws do not play a central role (Hansson 2003, Sarkar 1996, Shrader-Frechette and McCoy 1993). Such views give rise to a range of conclusions, from ecology lacks laws and thus is not rightfully thought of as a science (Murray 1999), to ecology does not have laws but nor does it need them in order to justify as a legitimate branch of science (Cooper 1998, cited under *Ecology and Physics*, and O'Hara 2005). McIntosh 1987 suggests that ecology cannot be treated as one science in this regard: different branches of ecology have different methods and goals. Lange 2005 (cited under *Ecology and Physics*) provides a good discussion of what is at issue in the debate over ecological laws.

Hansson, L. 2003. Why ecology fails at application: should we consider variability more than regularity? *Oikos* 100(3): 624–662.

Suggests that ecology has been poorly served by searching for laws and that it might be more fruitful to focus on variability.

Lockwood, Dale R. 2008. When logic fails ecology. *Quarterly Review of Biology* 83(1): 57–64.
Takes issue with Colyvan and Ginzburg 2003 (cited under *For Ecological Laws*) and argues that ecology does not have laws, and in this sense is different from physics.

McIntosh, Robert P. 1987. Pluralism in ecology. *Annual Review of Ecology and Systematics* 18: 321–341
Review article looking at claims that ecology is not monolithic, but rather pluralistic, with different methodologies and agendas in different parts of ecology. Includes some discussion of disagreement about laws in ecology.

Murray, Bertram M. Jr. 1999. Is theoretical ecology a science? *Oikos* 87(3): 594–600.
Adopts a broadly Popperian approach to science and suggests that ecology may be at best a kind of primitive science.

O'Hara, R. B. 2005. The anarchist's guide to ecological theory. Or, we don't need no stinkin' laws. *Oikos* 110(2): 390–393.
An interesting and provocative article suggesting that ecology has no need for laws.

Roughgarden, Jonathan. 1997. *Primer of ecological theory.* San Francisco: Benjamin Cummings.
Expresses considerable pessimism that ecology will ever have anything deserving of the name "laws".

Sarkar, Sahotra. 1996. Ecological theory and anuran declines. *BioScience* 46(3): 199–207.
Suggests that ecology is a science of case studies rather than being law governed.

Shrader-Frechette, Kristin S. 2001. Non-indigenous species and ecological explanation. *Biology and Philosophy* 16(4): 507–519.
Makes a case against laws in ecology.

Shrader-Frechette, Kristin and Earl D. McCoy. 1993. *Method in ecology: strategies for conservation*. Cambridge: Cambridge University Press.
Argues that ecology is a discipline of individual cases studies rather than a law governed discipline.

ECOLOGY AND PHYSICS

Much of the debate over laws in ecology focuses on the alleged differences between ecology and apparently law-governed branches of science such as physics. Most of the work on this issue highlights the differences in methodology between ecology and physics (Cooper 1998, Brandon 1997, Lockwood 2007, Murray 1992, Quenette and Gerard 1993). Lange 2005 argues for the autonomy of ecology from physics. Others such as Cartwright 1999 and Dupré 1993 argue that methodological differences in science are widespread and it is a mistake to think of science as a unified method of enquiry. Fagerström 1987 tackles the related question of the relationship between theory and data in ecology.

Brandon, Robert N. 1997. Does biology have laws? The experimental evidence. *Philosophy of Science* 64 (Proceedings): S444–S457.
Argues that experimental practice in biology differs from physics in important ways and this suggests that biology does not have laws.

Cartwright, Nancy. 1999. *The dappled world: a study of the boundaries of science*. Cambridge: Cambridge University Press.

This book makes the case that there are significant differences between the different branches of science and that they function more or less autonomously.

Cooper, Gregory J. 1998. Generalizations in ecology: a philosophical taxonomy. *Biology and Philosophy* 13(4): 555–586.

Takes something of the middle ground on the laws in ecology issue, suggesting that while there probably aren't any laws in ecology, it is possible to achieve general knowledge in ecology.

Dupré, John. 1993. *The disorder of things: metaphysical foundations of the disunity of science*. Cambridge MA: Harvard University Press.

Argues against there being any unity to science, leaning heavily on biology as a prime example of a disorderly science.

Fagerström, Torbjörn. 1987. On theory data and mathematics in ecology. *Oikos* 50(2): 258–261.

Argues against the priority of data over theory. This is important in the present context because, most of the laws in ecology appear to have conflicting evidence.

Lange, Marc. 2005. Ecological laws: what would they be and why would they matter? *Oikos* 110(2): 394–403.

Clears away some confusion about what laws are supposed to be and why they matter, then makes a case for what ecological laws would look like and argues that the existence of such ecological laws would render ecology autonomous from physics.

Lockwood, Dale R. 2007. Ecology is not rocket science. *Emergence: Complexity and Organization* 9(2): 49–58.

Argues against there being relevant similarities between physics and ecology.

Murray, Bertram M. Jr. 1992. Research methods in physics and biology. *Oikos* 64(3): 594–596.

Suggest that ecologists think quite differently from physicists and ecology is thus rather different from physics.

Quenette, P. Y. and J. F. Gerard. 1993. Why biologists do not think like physicists. *Oikos* 68(2): 361–363.

Makes the case for there being significant methodological differences between ecology and physics, for example, with regard to the existence and role of laws.

FOR ECOLOGICAL LAWS

Other authors defend the view that there are laws in ecology. Some interesting cases are made, often appealing to the similarities with physics. The case for there being laws in ecology is thus closely related to the question of the similarities and differences between the methodologies of ecology and physics. Examples of some of those sympathetic to the idea that ecology has laws are Berryman 1999, Colyvan 2004, Colyvan 2008, Colyvan and Ginzburg 2003, Ginzburg and Colyvan 2004, Mikkelson 2003, Turchin 2001, and Weber 1999. Those explicitly making the case that there are important similarities between physics and ecology include Ginzburg 1986 (cited under *Candidate Laws*) and Colyvan and Ginzburg 2010.

Berryman, Alan A. 1999. *Principles of population dynamics and their application*. Cheltenham, UK: Nelson Thornes.

Makes a case that ecology has laws.

Colyvan, Mark. 2004. Models and explanation in ecology. *Metascience* 13(3): 334–337.

Takes Cooper 2003 (cited under *Biological Laws*) to task on the issue of whether there are laws in ecology.

Colyvan, Mark. 2008. Population ecology. In S. Sarkar and A. Plutynski (eds.), *A Companion to the Philosophy of Biology*, Oxford: Blackwell, pp. 301–320.

A survey article, on philosophical issues in population ecology in which there is a section tentatively defending that view that ecology has laws.

Colyvan, Mark and Lev R. Ginzburg. 2003. Laws of nature and laws of ecology. *Oikos* 101(3): 649–653.

A critique of much of the preceding literature against laws in ecology.

Colyvan, Mark and Lev R. Ginzburg. 2010. Analogical thinking in ecology: looking beyond disciplinary boundaries, *The Quarterly Review of Biology* 85(2): 171–182.

Makes the case for underlying similarities between ecology and physics, and, in passing, argues against Lockwood 2008 (cited under *Against Ecological Laws*).

Ginzburg, Lev R. and Mark Colyvan. 2004. *Ecological orbits: how planets move and populations grow.* New York: Oxford University Press.

A sustained case for close connections between physics and ecology and that both are plausibly law governed.

Mikkelson, Greg M. 2003. Ecological kinds and ecological laws, *Philosophy of Science* 70(5): 1390–1400.

Argues, via cases studies, that ecology is a law-oriented discipline.

Turchin, Peter. 2001. Does population ecology have general laws? *Oikos* 94(1): 17–26.

Takes issue with some of the Popperian baggage underwriting much of the case for ecology lacking laws.

Weber, Marcel. 1999. The aim and structure of ecological theory. *Philosophy of Science* 66(1): 71–93.

Makes a case for ecology having laws.

CANDIDATE LAWS

If one accepts that there are laws in ecology, it is very natural to ask what these laws are. Several of the authors in the previous section make suggestions for candidate laws (e.g. Colyvan and Ginzburg 2003 and Turchin 2001, both cited under “For Ecological Laws”). Others making cases for specific candidate laws are Arditi and Ginzburg 2012 and Berryman 2003. A popular candidate for an ecological law is Malthusian growth (Ginzburg 1986; Colyvan and Ginzburg 2003; Turchin 2003). The various metabolic allometries are further examples advanced as candidate laws (e.g. Atkinson 1994). See Calder 1984 for a good overview of the allometries, Lawton 1999 for a case that these qualify as laws, and Ginzburg and Damuth 2008 for an attempt to unify them. There are many other candidate laws but in the context of the debate over whether there are laws in ecology, th focus of the discussion

has been on Malthusian growth and the metabolic allometries. The following works are just a sample of representative material on this issue.

Arditi, Roger and Lev R. Ginzburg, 2012. *How species interact: altering the standard view on trophic ecology*, New York: Oxford University Press.

Defends a new candidate law of consumer-resource interaction in ecology.

Atkinson, D. 1994. Temperature and organism size—a biological law for ectotherms? *Advances in Ecological Research* 25: 1–58.

Defends a law relating rearing temperature and organism size.

Berryman, Alan A. 2003. On principles, laws and theory in population ecology. *Oikos* 103(3): 695–701.

Continues the argument from Berryman 1999 (cited under *For Ecological Laws*) that ecology does have laws and provides examples from population ecology.

Calder, William. A. III. 1984. *Size, function, and life history*. Cambridge MA: Harvard University Press.

A classic summary of the various allometries in ecology. These are important in the present context because some have suggested that the allometries are candidates for laws of ecology, although this claim is not made by Calder.

Colyvan, Mark and Lev R. Ginzburg. 2003. The Galilean turn in population ecology. *Biology and Philosophy* 18(3): 401–414.

Suggests that physics and ecology are not so different and suggests that ecology has analogues of specific laws found in physics.

Ginzburg, Lev R. 1986. The theory of population dynamics: I. back to first principles. *Journal of Theoretical Biology* 122(4): 385–399.

An accessible early presentation of the view that Malthus's law in ecology is analogous to Newton's first law in physics and is therefore a genuine law.

Ginzburg, Lev R. and Damuth, John 2008. The space-lifetime hypothesis: viewing organisms in four dimensions, literally. *American Naturalist* 171(1): 125–131.

Assumes that the various allometries are laws and seeks a unification of them.

Lawton, John H. 1999. Are there general laws in biology? *Oikos* 84(2): 177–192.

Argues that there are laws in ecology and that to discover them less attention should be directed to community ecology, where complexity makes it very difficult to find laws, and more attention directed to macro-ecology.

Turchin, Peter. 2003. *Complex population dynamics: a theoretical/empirical synthesis*. Princeton N.J.: Princeton University Press.

A large and rather technical book that, early on, clears the way for ecology having laws. It goes on to suggest what some of these laws might be.