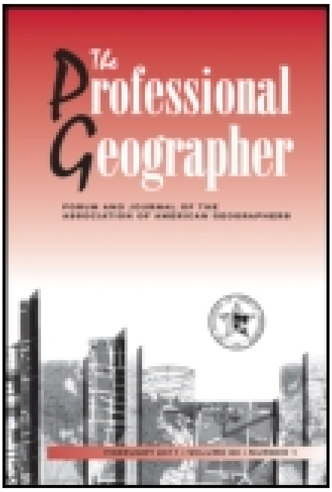

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# Resilience Theory and Thomas Vale's Plants and People: A Partial Consilience of Ecological and Geographic Concepts of Succession

J. Anthony Stallins[a], Joy Nystrom Mast[b] & Albert J. Parker[c]
[a] University of Kentucky
[b] Carthage College
[c] University of Georgia
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# Resilience Theory and Thomas Vale's *Plants and People:* A Partial Consilience of Ecological and Geographic Concepts of Succession*

**J. Anthony Stallins**
*University of Kentucky*

**Joy Nystrom Mast**
*Carthage College*

**Albert J. Parker**
*University of Georgia*



Geography has discovered resilience theory, a body of thought about ecological change that initiated with C.S. Holling in the 1970s. We describe the similarities and differences between resilience theory and a geographical treatise, Thomas Vale's (1982) book *Plants and People*. Vale's work draws more from the tradition of field botany and plant succession than from the theoretical and mathematical ecology that prompted Holling's ideas. Yet like resilience theory, Vale's model of ecological change emphasized multiple states, the threshold transitions between them, and their irreversibility. Each described how forests and rangelands can flip between stability domains in response to altered fire regimes, modified grazing pressures, and climate change. *Plants and People* also recognized the dual nature of stability encapsulated in Holling's formalization of engineering and ecological resilience. Although resilience theory predates Vale's work and retains primacy through its citation record, we show how their partial consilience promotes a more critical understanding of resilience theory and the ways in which models, scale, and human values influence our comprehension of ecological change. **Key Words: biogeography, models, resilience, scale, succession.**

地理学发现了恢復力理论———一个起始于1970年代一位名为候凌 (C.S. Holling) 的学者有关生态变迁的思想体系。我们描绘恢復力理论与维尔 (Thomas Vale) (1982) 的地理学着作 "植物与人类" 之间的异同。维尔的着作运用较多的田野植物园与植物演替传统, 而非促成了候凌的概念的理论与数学生态学。但维尔的生态变迁模式正如恢復力理论一般, 强调多重的状态、其间的临界过渡, 以及它们的不可逆性。他们各自描绘了森林与牧场如何得以在稳定的领域中转换, 以回应改变的火动态、变更后的牧压, 以及气候变迁。"植物与人类" 亦承认候凌在形式化工程与生态恢復力中所纳入的稳定性的双重性。儘管恢復力理论早于维尔的着作, 并因引用纪录而保有优势, 我们仍指出两者的部分吻合, 如何促成我们更批判地理解恢復力理论, 以及模型、尺度与人类价值如何影响我们理解生态变迁的方式。 **关键词: 生物地理学, 模型, 恢復力, 尺度, 演替。**

La geografía ha encontrado la teoría de la resiliencia, un cuerpo de pensamiento relacionado con el cambio ecológico que se inició con C.S. Holling en los años 1970. Describimos las similitudes y diferencias entre la teoría de la resiliencia y un tratado geográfico, el libro *Plantas y gente*, de Thomas Vale (1982). El trabajo de Vale se apoya más en la tradición de la botánica de campo y en la sucesión vegetal que en la ecología teórica y matemática, en las que se basan las ideas de Holling. No obstante, como en la teoría de la resiliencia, el modelo de Vale de cambio ecológico enfatiza múltiples estados, las transiciones de umbral situadas entre aquellos y su irreversibilidad. Cada uno de estos autores describe cómo los bosques y montes pueden voltearse entre diferentes dominios de estabilidad en respuesta a regímenes de incendios alterados, presiones modificadas de pastoreo y cambio climático. En *Plantas y gente* también se reconoció la naturaleza dual de la estabilidad, expresa en las ideas de Holling sobre ingeniería de la formalización y resiliencia ecológica. Aunque la teoría de la resiliencia es anterior al trabajo de Vale y retiene su primacía a través del registro de citaciones, mostramos cómo su consiliencia parcial promueve una comprensión más crítica de la teoría de la resiliencia y del modo como los modelos, la escala y los valores humanos influyen nuestro cabal entendimiento del cambio ecológico. **Palabras clave: biogeografía, modelos, resiliencia, escala, sucesión.**

Geography and ecology have a long history of intellectual exchange. Botanists, including the ecologists Henry Chandler Cowles and Frederic Clements, were among founders of the Association of American Geographers in 1904 (Brigham 1924; Smith 1952; James and Martin 1972). Geographers were also involved in the establishment of the Ecological Society of America in 1915 (Cowell and Parker 2004). For well over a century, both disciplines have maintained a shared interest in succession and vegetation change (Sprugel 1980; Glenn-Lewin, Peet, and Veblen 1992; Barbour et al. 1998). Modern ecological thought

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originated in part with botanists and plant ecologists whose successional models and publications were integrated into geography (Cowles 1911; Gleason 1922). Later, concepts relating to scale and spatial techniques began moving between the two disciplines (Meentemeyer 1989; Levin 1992; Legendre 1993). Despite this trade in ideas, few studies have formally detailed the content and context of any particular intellectual current moving between ecology and geography.

In this article, we compare and contrast two models of ecological change, one from ecology and one from geography. The first, resilience theory, arose in large part out of the work of C.S. Holling and his 1973 article "Resilience and Stability of Ecological Systems." Although this article formulated its central tenets, resilience theory did not ascend in popularity until the 1990s (see Janssen 2007, Figure 1). Today, scholars from geography, economics, and political science among many other fields identify resilience theory with how socioecological systems can flip from one state to another and how they develop and persist between these transitions (Berkes, Colding, and Folke 2003). The second is a model of ecological change articulated by geographer Thomas Vale (1982) in his book *Plants and People: Vegetation Change in North America*. Several subsequent works by Vale offered additional insights on the assumptions and foundations of his model (Vale 1988, 2001, 2002, 2003). Drawing from geographers (Sauer 1950; Knox 1977; Parsons 1981; Veblen et al. 1981) as well as field-oriented ecologists, Vale's model communicates many of the dynamical behaviors that define resilience theory. It outlined a plurality of successional states that vegetation could organize around through time. Although designed to apply largely to vegetation dynamics, Vale's model was prescient of some of the same broad resource management implications as resilience theory (e.g., Holling and Meffe 1996).

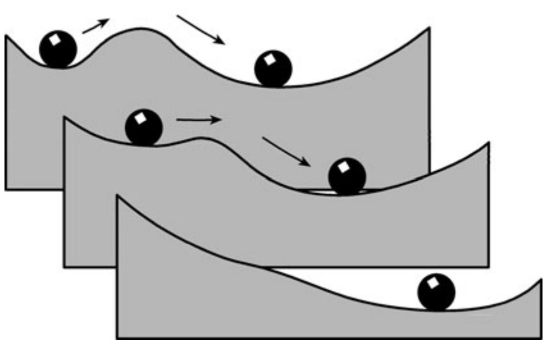


**Figure 1** *An example of the ball and cup heuristic used in resilience theory. The top landscape represents the start of a system flip from one stability domain to another. Engineering resilience is defined by the slope of the sides of an individual valley. It represents return stability. The loss of the intervening hill in the middle and lower landscape represents a loss of ecological resilience. At this point the system can potentially reorganize around a different stability domain. Movement of a ball in the horizontal direction is a measure of the change in ecological resilience. The ball in the final state is in a stability domain with low engineering and ecological resilience. Source: Adapted from Gunderson (2000).*

Because Holling's work predates Vale's by a decade, we are not attempting to resituate primacy of authorship for resilience with *Plants and People*. However, we do consider *Plants and People* a forward-looking articulation of how ecological change unfolds. At the time *Plants and People* was being written, Holling's ideas were just starting to expand beyond their origins in theoretical ecology. They had not coalesced into the version of resilience theory that Vale's work most resembles. Consequently, *Plants and People* does not cite Holling's (1973) publication, nor does it draw from the same ecological literature. Given this intellectual proximity, one of our aims is to convey how the models of Vale and Holling emerged from the same academic context. They share a perspective on succession that was very much a product of its time. Yet even with their overlap in historical context and content, Vale's and Holling's models diverge in how ecological dynamics are recognized and assigned meaning. By characterizing the convergence and divergence of resilience theory with *Plants and People*, we aim to promote recognition of the advantages of a pluralistic view of ideas about ecological change (e.g., Downs et al. 2013).

For those geographers invested in resilience theory, our recognition of Vale's foresight does not mean that we are advocating a revisionist flip in how geographers treat the lineage of resilience ideas. We do intend to renew attention to Vale's work, but we do so only in the service of synthesizing inquiry about succession (Prach and Walker 2011). Many, including Vale (1988), have argued that parallel evolution of scientific ideas is not an uncommon intellectual phenomenon. A range of terms (*alternative stable states*, *multiple stable states*, *state and transition models*) have been coined to describe analogs of resilience dynamics, each with varying levels of indebtedness to Holling's ideas (Westoby, Walker, and Noy-Meir 1989; Laycock 1991; Beisner, Haydon, and Cuddington 2003; Scheffer and Carpenter 2003; Scheffer 2010). Following some of the premises of the philosophy of critical realism, if resilience theory does indeed capture an objective aspect of the world, one could readily expect that investigators across multiple disciplines will observe similar phenomena but describe them in different ways. To illuminate this partial consilience in the sections to follow, we first outline how each model recognized analogous cyclical and threshold-driven ecological dynamics. We then identify how their resemblance to each other arose from the historical conjuncture of several long-standing debates in ecology. Finally, we discuss their differences, most notably those that relate to scale and its role in making knowledge claims.

## C.S. Holling's Resiliency Theory

Geographers have recognized the utility of resilience theory, particularly in human–environment geography

(Zimmerer 1994; Scoones 1999; Adger 2000; Adger and Brown 2009; Leichenko 2011; Eakin et al. 2012; Soane et al. 2012). Recent meetings of the Association of American Geographers have held special sessions on applied and critical facets of resilience theory. The origins of resilience, however, began with theoretical debates on the relationship between diversity and stability (MacArthur 1955; Lewontin 1969; May 1972), and Holling's (1973) article laid the groundwork for what was to become resilience theory. Holling began with a mathematical description of a domain of attraction, the space that defines a group of organisms and their reinforcing interactions with each other and with the environment. Holling quantified how these interactions fluctuate within the boundaries of stable limit cycles. Populations oscillate in abundance instead of conforming to a single stable point equilibrium. It is through these oscillations that organisms and their environment derive a degree of persistence. As one of his best known examples, Holling described the linkages among boreal forest tree species in Canada and outbreaks of spruce budworm, a defoliator of balsam fir. Invoking predator–prey cycles, Holling described how the sequence of fir canopy dominance, budworm outbreak, decline of fir, and collapse of budworm populations reinforce one another. After an outbreak, only less susceptible spruce and healthy birch remain, and a dense regeneration of spruce and fir initiates. Fir eventually assumes dominance in the canopy, initiating another budworm outbreak. This sequence of interactions and their mutual dependence demarcates a domain of attraction. The variability in species abundance over time promotes the resilience of the system. The cyclical nature of these dynamics, however, was also contingent on geographic and historical setting (Bouchard, Kneeshaw, and Bergeron 2006). Renewal of a budworm outbreak when fir became dominant again was more likely when climate was dry and predation pressure on the budworm was relaxed.

Holling also postulated how a domain of attraction can flip or switch to a new stability domain through changes in structuring processes. This shift can be accompanied by pronounced changes in species abundances and their interactions with each other and the environment (Figure 1). Using a history of Great Lakes fisheries as an example, Holling related how water pollution and overfishing leading up to the 1970s resulted in a dramatic flip in freshwater fish species composition. These same system dynamics were also invoked by Holling for arid rangelands in the Western United States. Grazing as well as fire suppression can promote the establishment of shrubs and trees at the expense of grass. Once shrubs or trees have attained sufficient size or density, reduction of grazing or introduction of controlled burns will not result in grassland reestablishment. The system has flipped or undergone a regime change from a grassland domain to a shrub-dominated domain. Many of the descriptions of stability domains in resilience theory emphasize human-caused shifts, although these dynamics can also develop in the absence of human perturbations.

From these examples, Holling derived his conceptions of stability and resilience. *Stability* was defined as the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stability it retains. By contrast, *resilience* emphasizes the persistence of relationships within a system. It is a measure of the magnitude of perturbation required to initiate a flip to another domain of attraction. These definitions and their applications gained momentum as the backbone of resilience theory in the 1990s and early 2000s (Holling 1996; Gunderson 2000; Gunderson and Holling 2001; Gunderson and Pritchard 2002). The terminology has also evolved. Holling's original definition of resilience was renamed *ecological resilience*, the magnitude of disturbance that can be absorbed before the system redefines its structure and organization. *Engineering resilience* came to denote Holling's original conception of stability as a measure of return time. Engineering resilience is the propensity to maintain a set of reinforcing or cyclical interactions within the boundaries of single domain of attraction.

Resilience theory also introduced the concept of adaptive cycles (Gunderson and Holling 2001; Holling 2001). Adaptive cycles comprise the set of ecosystem interactions that confer resiliency through oscillatory or cyclical dynamics (Figure 2). Their dynamics are analogous to ecosystem succession within a single stability domain, except that there is a greater

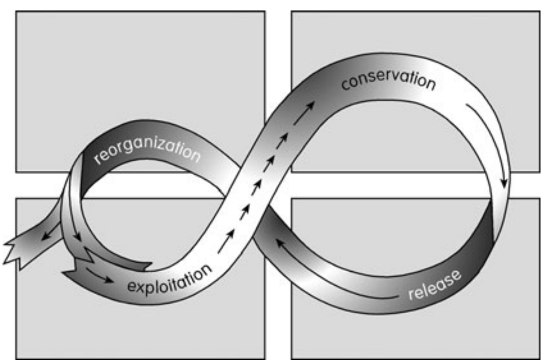
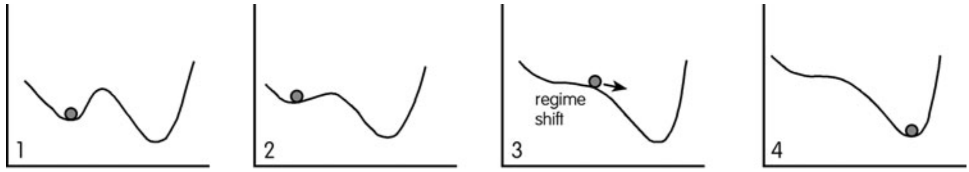



**Figure 2** *An adaptive cycle in resiliency theory. Arrows represent speed of cycle. Shorter, closely spaced arrows indicate slowly changing conditions. Larger, more distant arrows represent faster conditions. The y-axis represents the accumulation of biomass. The x-axis represents the degree of connectedness. Biomass and internal connectedness build slowly in the exploitation through conservation stages. As the system becomes brittle, it might rapidly collapse, undergo a release, and then reorganize. System reorganization might repeat these cyclical dynamics. It also has the propensity to innovate and reorganize into another adaptive cycle and persist in a new stability domain. The exit arrow on the left represents the stage where another state is most likely. The four stages in an adaptive cycle, growth, conservation, release, and reorganization systems confer resilience as well as the potential for novelty. Source: Adapted from Holling (2001).*




| | | | |
|---|---|---|---|
| clear-water lakes | phosphorous accumulation | flooding, warming, overexploitation of predators | turbid-water lakes |
| coral-dominated reefs | overfishing, eutrophication | disease, bleaching hurricane | algae-dominated reefs |
| grassland | fire prevention | continuous heavy grazing | shrub-brushland |
| mesotidal barrier island dune | decreased sediment availability or sea level rise | increased overwash disturbance | microtidal barrier island dune |
| kelp forests | elimination of apex predators | thermal event, storm, disease | sea urchin dominance |
| pine forests | microclimate and soil changes, loss of pine regeneration | decreased fire frequency, increased fire intensity | oak forest |
| Earth - 11,000 ya | human population growth | climate change | Earth - post 2045? |
| tropical lake with sub-merged vegetation | nutrient accumulation during dry spells | nutrient release with water table rise | floating-plant dominance |

**Figure 3** *Settings in which resiliency theory has been applied. Revised from Folke et al. (2004). With perturbations in the two middle columns, the system can flip from its original state in the first column to the new state in the fourth column. Vale's* Plants and People *also recognized multiple states in several of these settings. The examples here are detailed in Gunderson (2000), Gunderson and Holling (2001), and Scheffer et al. (2001). Stallins (2005) is the source of the barrier island transition example. Earth critical state transitions are described in Barnosky et al. (2012).*



acknowledgment of the capacity of the system to remember and respond to inputs in a more adaptive or evolutionary way. Adaptive cycles have the potential to reorganize into a new configuration or stability domain if their resilience or adaptive capacity is exceeded (Lopez et al. 2011). They can be nested together to form a panarchy, a variation on the idea of hierarchical linkages but with more self-organizing tendencies across scales.

Resilience theory has also popularized the recognition of hysteresis in ecological systems. Hysteresis, or irreversibility, develops after a stability domain flips to another state. A flipped system can no longer simply reverse and go back to its earlier state. Only when inputs and energy to accomplish this reversal exceed the magnitude required to cross the initial forward threshold can earlier conditions be approximated. Hysteresis also allows for different states to persist under the same environmental conditions. Hysteresis as well as the other terms associated with resilience theory have become widely cited, recognized by funding agencies, and part of a common ecological vocabulary (Figure 3; Moore et al. 2009; National Science Foundation 2009; Benson and Garmestani 2011; Folke et al. 2011).

## Thomas Vale's *Plants and People*

Amid similar tensions about stability that influenced resilience theory, Vale synthesized his descriptive model of vegetation dynamics. Unlike Holling's work, Vale's model was not published as a journal article. Instead, it was disseminated in 1982 as a book in the Association of American Geographers Resource Publication in Geography series. *Plants and People* presented a conceptual framework for plant succession that benefits from the works of geographers and ecologists. Like resilience theory, Vale, citing Watt's (1947) seminal work and more thorough elaborations by Bormann and Likens (1979), emphasized that cyclical change can confer persistence among a group of species and their interaction with the environment around a single equilibrium (Vale 1982, 6–10). Vale, noting Egler (1954) and Henry and Swan (1974) as examples, also described threshold transitions in vegetation structure and composition that were irreversible or, in his terms, "vegetation change with new equilibria" (Vale 1982, 12–16). Like Holling's work, Vale identified with the fluid and multiplicative nature of equilibrium instead of a static, single point conception. Vale's nonmathematical model also described a dual nature of stability, yet his work is rarely cited by geographers using resilience theory.

Echoing the definition of engineering resilience, Vale detailed the propensity for the persistence of a group of species through cyclical replacement and the historically prevalent disturbance regime. During succession, vegetation can organize around growth and release, or replacement, cycles. There are fluctuations in species abundances, yet the overall system stays within boundaries that demarcate a state analogous to a stability domain. Vale provided several examples that convey this particular type of stability. For instance, creosote bush in the North American Southwest can function as a nurse tree for cholla. The nurse effects of the creosote bush on cholla reverse over time, leading to cholla decline, exposure of bare soil, and recolonization by creosote (Figure 4). This cycle is also contingent on the population densities of birds (cholla seed dispersers) and burrowing rodents (bioerosional disturbance agents of cholla). The cyclical interactions among these plant and animal species can reinforce one another, thereby conferring engineering resilience.



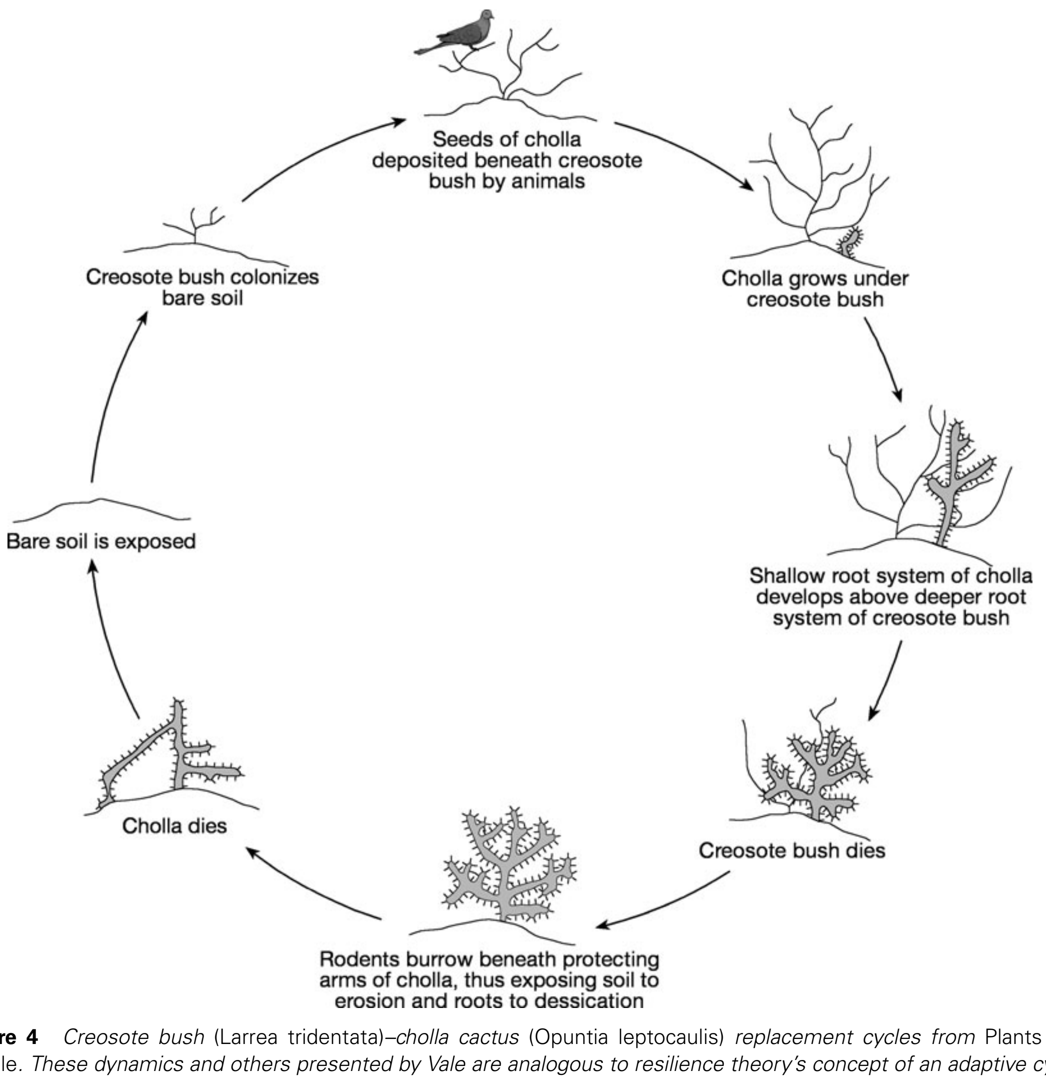



**Figure 4** *Creosote bush* (Larrea tridentata)*–cholla cactus* (Opuntia leptocaulis) *replacement cycles from* Plants and People*. These dynamics and others presented by Vale are analogous to resilience theory's concept of an adaptive cycle. Biomass and internal connectivity increase around the right side of the circle. Release and reorganization are linked to the dynamics on the left side of the circle. In Vale's model, the persistence of these cyclical interactions comprises a stability domain. Source: Adapted from Vale (1982).*

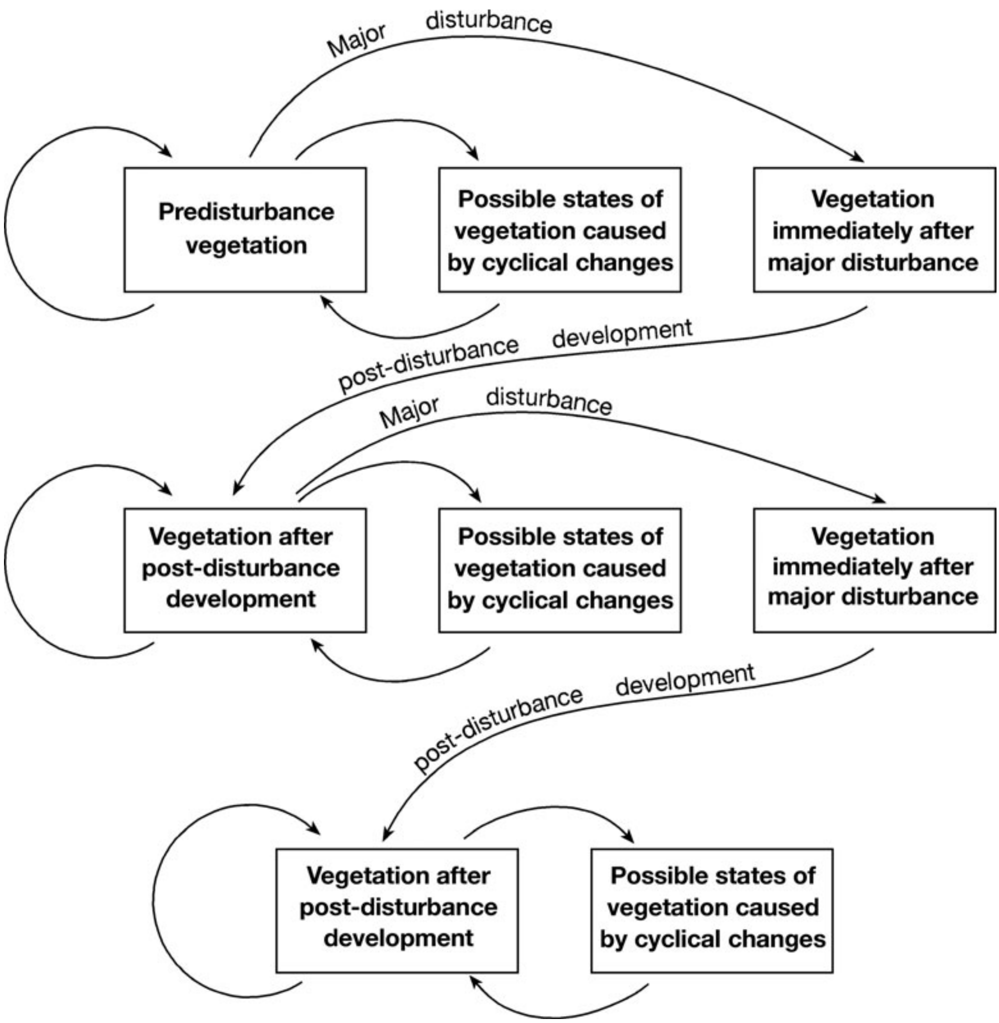



**Figure 5** *Vale's model of vegetation dynamics. Vegetation states have the potential to persist through cyclical dynamics. As represented by the circular arrows to the left, these cycles approximate engineering resilience and adaptive cycling. With a major disturbance, these cyclical dynamics can potentially undergo a flip to a new state. The sequence of flips from top to bottom is analogous to changes in ecological resilience and flips to new stability domains.*



Vale's cholla–creosote bush example is an analog of an adaptive cycle from resilience theory. In the cholla–creosote cycle there is a growth and accumulation stage, followed by a release and reorganization stage. There are periods in these cyclical dynamics where the system stores biomass and increases in connectivity. These are followed by periods of change in which the system becomes brittle and susceptible to reorganization around another set of interactions. Vale's description of yellow birch–sugar maple–beech forest dynamics, as based on Bormann and Likens (1979), also conveyed the dynamic of adaptive cycling and how it generates engineering resilience. Gap phase canopy dynamics in these forest settings played out in a way to reinforce oscillatory abundances of tree species based on their life history characteristics.

Vale's model also expressed the idea of ecological resilience. Vegetation, according to Vale, exhibits the capacity to jump or flip to a new state composed of different species and interactions (Figure 5). These sets of alternative states are analogous to resilience theory's stability domains, attractors around which vegetation can organize. Disturbance outside the range of historic variability can lead to the removal of species and the disruption of a replacement cycle. A novel state could then emerge, develop along a unique successional trajectory, and evolve its own adaptive cycling and potential for persistence. To support this second conception of stability, Vale described successional dynamics in vegetation undergoing alteration of fire regime, changes in grazing pressure, and logging. Fire suppression can drive a flip from a vegetation state maintained by frequent fire to a state that tends to resist fire and reinforce the persistence of plant species less tolerant of burning. Rangelands can similarly flip between a grassland-dominated state and a woody

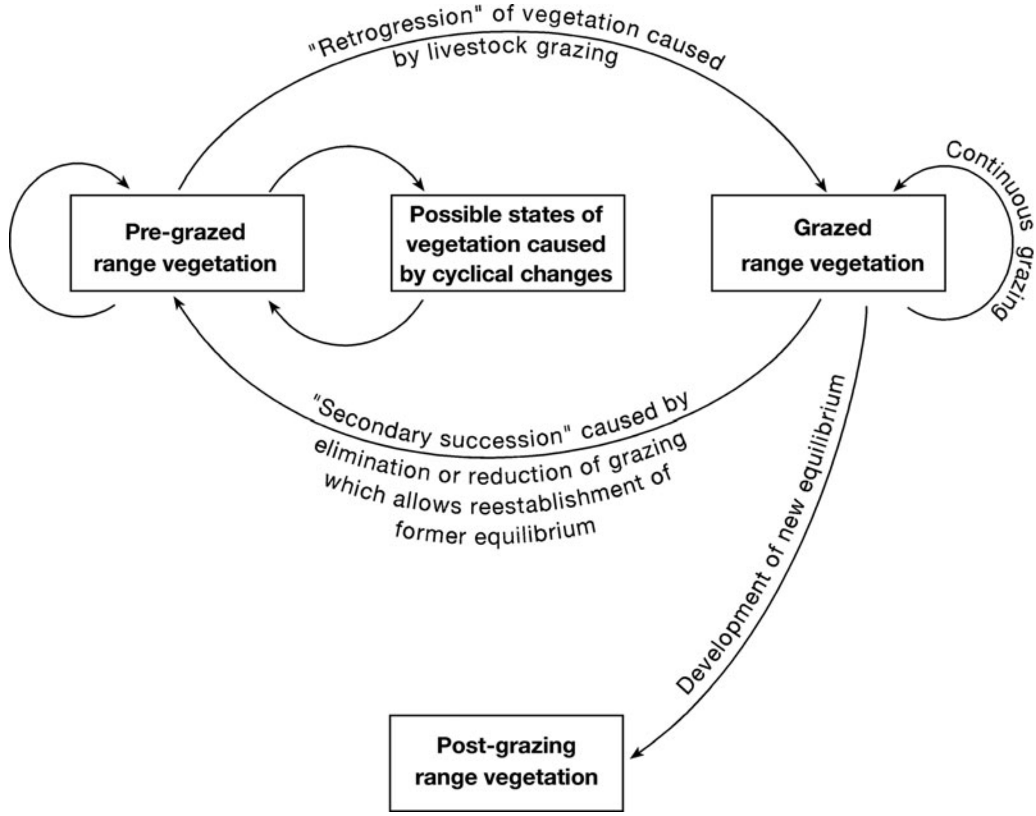



**Figure 6** *Vale's model of vegetation dynamics illustrating its multiple state potential for rangelands. Depending on the intensity of grazing, a state might persist through replacement cycles or flip to another state or stability domain.*



shrubland (Figure 6). These same landscape-specific examples were also formalized in resilience theory. New states in Vale's model also exhibit hysteresis, a dependency on history and pathways of development that prohibits simple reversals to previous states.

## Similarities in Historical Context

During the ascent of nonequilibrium ecology in the 1970s and early 1980s, some scholars began to consider middle-ground positions on ecological change (Odum 1969; Callicott 2003). They sought to reconcile some of the polarizing views on the nature of community organization that had churned in ecology. On one side, there were the integrated community concepts introduced by Clements decades earlier but now in a form absent their organismic and teleological tone. On the other side were the individualistic community concepts initiated by Gleason. Although these poles of thought offered opportunity for debate for many as well as the construction of academic identify for some, they were also a chance for innovation.

Vale's model of vegetation change and Holling's resilience theory can be seen as synthesizing, conciliatory reinterpretations of the Clements–Gleason debate. They bridge the academic rift between contingent, individualistic, nonequilibrium ideas of ecological change and those that were aggregate, deterministic, and stabilizing. Each identified with chance and contingency—perhaps Vale more so—but they also recognized nature's agency to form boundaries of its own and in response to human impacts. Both offered perspectives that did not throw out the work of the balance-of-nature scholars like Clements. They were also cognizant that one could go too far with an embrace of the individualistic paradigm. The implication of anarchy, or lack of any order, is a common misrepresentation of Gleason's individualistic concept and nonequilibrium concepts in general (McIntosh 1998).

The Clements–Gleason debate is usually told (and taught) as a struggle for academic dominance. In this narrative, individualistic, nonequilibrium views of plant succession trumped Clementsian determinism in the academic marketplace. Resilience theory and Vale's model communicate, however, that Clements and Gleason each captured a fundamental tension about how nature works. Scholars continue to advertise the mutualism of Clements and Gleason rather than their opposition (Anand 2000; Lortie et al. 2004; Callaway 2007). The Clements–Gleason debate is best viewed as a heuristic, a tool for organizing our thoughts, with neither side fully holding true (Brooker et al. 2009; Eliot 2011). Organisms interact, organize, and shape their environment and promote its persistence. Yet there is also the potential for novelty, for contingent events to redirect succession and give rise to different organizational states.

But what motivated Holling and Vale to articulate compromise and move beyond the historical and ongoing reification of the Clements–Gleason dichotomy? Perhaps the individualistic models of succession that began their rise to prominence in the 1950s (Barbour 1996) eventually (and inadvertently) reinserted the necessity of a coaccompanying determinism. In this account, the enchantment with contingency and chance fueled an outpouring of nonequilibrium viewpoints in ecology. This led to successional models that were very open ended, stressing multiple trajectories and divergence in outcomes. This reinserted the question of directionality into successional models, however. What trajectories and convergences are more likely or favorable than others? In response to the rise of a Gleasonian ecology of chaos, questions arose as to how there might be order within chaos. Vale's model and resilience theory can be taken as responses to the need to conceptualize and give texture to the larger state space of ecological succession. They remediated determinism within the contingencies of multiple successional pathways (Stallins 2012). Although nonequilibrium ecology recognized divergent results and multiple pathways of change, some states might be more probable than others. There are near-term outcomes that can emerge without resorting to oversimplified stepwise balance of nature models (Grabbatin and Rossi 2012).

Vale's and Holling's models can also be seen as a reaction against prevailing epistemological and methodological fashion. Successional models in ecology in the 1970s were becoming increasingly dominated by experimental, reductionist approaches that tended to prioritize controlled studies and proximate causes of vegetation change (Connell and Slatyer 1977; Glenn-Lewin, Peet, and Veblen 1992). Rigor in these kinds of successional studies necessitated mechanistic verification and a predilection for Newtonian cause and effect. The assumptions of closure and prediction that these causal narratives depended on, however, were not entirely in agreement with the creativity of nonequilibrium ecological systems. In a world seen as constant flux, proximate closure offered localized clarity on pattern and process, but there remained the diversity of interactions, collectivities, and path dependencies that could emerge (Peet and Christensen 1980). Vale and resilience theory worked this fertile middle ground, eschewing wholesale commitments to either holism or reductionism.

Resilience theory was forthright in its skepticism over any necessity for unwavering fine-grained reductionism (Holling 1998). One of the tenets of resilience theory is that only a few key processes can entrain the elements of a system and contribute disproportionately to its persistence (Holling 1992; Allen and Holling 2002). Knowledge of all of the details might not even be necessary to ascertain ecosystem structure and function. Vale also communicated a resistance to reductionist finitude. Vale's model recognized that the initial conditions driving vegetation change were highly variable, difficult to establish, and thwarted systematic prediction of the outcomes of succession. Like resilience theory, Vale's model emphasized a likelihood—perhaps less so than resilience theory—for these interactions to entrain each other, to become mutually reinforcing or, as later articulated, centripetal (Ulanowicz 2009). Interactions evolve or ascend to reinforce a cyclical-like persistence within a particular state or domain. In this way, Vale and Holling revised reductionist expectations of their time so they could account for novelty and the emergence of structure but without the telos and determinism of earlier holistic views.

## Differences

Holling and Vale articulated their ideas about ecological organization based on readings of different literatures. For Vale, the coexistence of novelty and cyclical persistence was reflected in his synthesis of two historical perspectives from plant ecology: Egler's (1954) emphasis on contingency in succession and Watt's (1947) conceptualization of endogenous and exogenous forest disturbance. Taken together, the ideas of Watt and Egler allow for the coexistence of openness with structure. Disturbance events can reinforce the persistence of species–species and species–environment interactions through gap phase dynamics. But when outside the range of historic variability, disturbance can lead to flips to novel states due to differing initial conditions or the vagaries of dispersal. By contrast, Holling's analogous fusion of chance and order likely originated from debates in theoretical and mathematical ecology over the nature of stability. How high diversity could be stable as well as unstable motivated the development of compromise positions like resilience theory (McCann 2000). Less prominent in resilience theory was the fusion of successional theories developed by Egler, Watt, and Bormann and Likens even though they, too, collectively accommodate a dual nature of ecological causality.

The more prominent contrasts between *Plants and People* and resilience theory, though, reside in how they defined and incorporated scale. Scaling was explicitly developed in Vale's work and in resilience theory. Yet each emphasized certain facets of scale over others. Embedded in *Plants and People* and Vale's later work are early qualitative critiques of how positionality derived from scale shapes epistemology (Vale 1982, 1988, 2001, 2003, 2005). For Vale, human goals and the scalar context of our observations were a basis for conceptualizing and evaluating ecological change. What constitutes a threshold flip will likely depend on human purpose, values, and experience. Vale also details how spatiotemporal extent and the resolution over which observations are made determine what kinds of dynamics and outcomes can be recognized or chosen. Variability in the scales of our observations complicates any unambiguous identification of domain dynamics.

Thus, Vale's model is more sensitive to the epistemological implications of scale. The modeler has more positionality relative to how knowledge or outcomes are produced.

In contrast, resilience theory more resolutely highlights how organisms shape the scales of their boundaries. Organisms give form to the scale breaks that define the phenomena of resilience theory. Two explanatory frameworks have been used to communicate this scalar perspective, cross-scale resiliency (Peterson, Allen, and Holling 1998) and the textural discontinuity hypothesis (Holling 1992; Gagné, Proulx, and Fahrig 2008). Each aims to account for how resilience materializes and how it gives structure to ecosystems and the distribution of organisms within them. In this sense, scale and scaling in resilience theory was more of an ontological tool, a lens for identifying structure and attaching labels and categories to the objects of study.

Neither model expresses entirely one type of scaling or the other, but resilience theory conveys a far more uncritical bird's-eye perspective on ecological change. The position and intent of human observers are down weighted. Entities in resilience theory are objectively given by nature and thus inferred to be universally apparent irrespective of the values, goals, and scales of the observer and their observations. Although seemingly neutral, resilience theory's ecological management approaches are infused with cultural ideas and thus values (Kirchhoff et al. 2010; Kuhlicke 2013). Within resilience theory there are unrecognized assumptions about power and intent not just related to the social and ecological systems under study but to the theorizers themselves (Nadasdy 2007; Hornborg 2009; Cote and Nightingale 2012; Hatt 2013). Resilience theory might also place too much emphasis on threshold transitions (Davidson 2000; Suding and Hobbs 2009; Qian and Cuffney 2012), when other dynamical behaviors are likely in earth surface systems (Phillips 2003; Huggett 2005; Kéfi et al. 2013).

Vale, on the other hand, was more cognizant of this subjectivity in defining thresholds and alternative states. His model was more thoughtful about ontological flexibility. The entities and processes defined reflect the positionality and intent of the observer as well as the world and its inherent materiality. Given its emphasis on ontological certainty, it is not surprising that the more pressing questions in resilience theory today are how commonly threshold responses manifest and what the best ways to identify and label them are (Andersen et al. 2009; Scheffer et al. 2009; Bestelmeyer et al. 2011; Bagchi et al. 2012; Bel, Hagberg, and Meron 2012). Significant quantitative improvements have been made in how thresholds are recognized and anticipated (Carpenter et al. 2011; Scheffer et al. 2012). Recent criticisms of resilience theory coming out of ecology, however, echo Vale's recognition of how scale and human values can lead to different designations of ecological entities. Bestelmeyer (2006) referred to the potential for the "insidious use" of threshold concepts. Threshold delineation can have the effect of reifying particular states. The act of boundary detection attaches labels irrespective of the degree of difference between one state and another. Once identified as a new state, assumptions of its best use change. In this way, uncritical use of threshold concepts might lead to the abandonment of management efforts on land that has tipped when it might otherwise benefit from intervention. Thus, supposedly neutral or objective methods to identify thresholds and irreversible degradation might result in the categorization of land areas that might have been recoverable or could have served other important societal functions but were unrecognized and neglected. Ecologists have also recognized like Vale that the identification of thresholds might be dependent on the life span of the organisms as well as the intervals at which humans perform their observations (Vale 1988; Bestelmeyer et al. 2011). Less resilient stability domains are indeed a cause for concern. But in the rush to find and designate their dynamics according to any single overarching model we should be wary about skipping over several degrees of freedom available to us for elucidating and working with the idiosyncrasies of human-impacted landscapes.

## Final Comparisons

Vale's *Plants and People* and Holling's resilience theory balanced out some of the radical indeterminism that often appeared to be the sole defining feature of nonequilibrium ecology. Their models allow for developmental and nondevelopmental perspectives on ecological organization to coexist. Yet as similar as they are, *Plants and People* shows the value of a geographical perspective (Table 1). Vale's more observer-cognizant model recognizes that what we will ultimately detect as a threshold, a stability domain, or a regime shift—no matter what you label it—will ineluctably reflect the impress of our tools and ideas about human purpose. Resilience theory, on the other hand, infers more ontological certitude about the entities and outcomes of ecological change. It provides a more empirical basis for the identification and categorization of ecological phenomena impacted by humans.

Resilience theory's explanatory power and correspondence to observed ecological changes continue to be recognized. In reaction, geographers could bemoan that once again they have become followers rather than trend setters. Such admonitions might be unnecessary. *Plants and People* is more pragmatic in a philosophical sense. It does not presuppose any one given human purpose or desired end point related to how social and ecological systems should interact. Nor does it assign judgments on the human utility residing in any particular state or stability domain. In this way, *Plants and People* incorporates nondevelopmental perspectives more strongly. It is this kind of contextual sensitivity that defines much of geography and sets it apart from ecology (Cote and Nightingale 2012).

There is another reason why Vale's work might have as much relevance for geographers as resilience theory: the commitment to the human–environment

***Table 1*** *Comparison of Thomas Vale's* Plants and People *and C.S. Holling's resilience theory*

| | ***Plants and People*** | **Resilience theory** |
|---|---|---|
| Similarities | Reconciliation of tight mechanisms of Clements with loose individualisms of Gleason | |
| | Compromise between reductionism and holism | |
| | Dual nature of stability | |
| | Cyclical feedbacks, threshold transitions, multiple states, and hysteresis | |
| Origins | Empirical ecology, plant successional theory | Theoretical and mathematical population ecology |
| Scale | Values of human observers shape the uses and purposes of the model | Values of human observers assumed universal and inherent to the model |
| Time | More historical and less firmly wedded to cyclical rhythms | Cyclical and more ahistorical |
| Basis for knowledge | Observer-specific epistemology | Ontological certitude |
| Causality | Contingencies of human values and ecological change | Mechanistic or structural necessity |



tradition. Vale's mentors included James Parsons and Daniel Luten, cultural–environmental geographers at the University of California, Berkeley. Another of Vale's books was *Progress Against Growth* (1986), a collection of Luten's writings. In them, one encounters many of the issues regarding sustainability that resilience theory addresses. Much of Vale's published legacy grapples with the question of how we can embed humans within ecological systems and attempt to understand the consequences for both (Vale 1987, 1998, 2001, 2003, 2005). Questions of human purpose lie at the heart of Vale's vegetation dynamics model in *Plants and People*. With its pragmatic outlook, a more open door has been left for the user to perceive the world, the human place in it, and our impress on it over time.

Some of this pragmatic open-endedness is evident in how Vale has a stronger emphasis on the noncyclical role of time. In resilience theory, nested adaptive cycles of growth, conservation, release, and reorganization animate ecosystems and social–ecological coevolution. In it one interprets a structural necessity as to how humans and ecosystems should or ought to share the planet. Vale's model is less oriented toward such cyclical, coevolutionary dynamics. Its tone speaks more to undefined human–environment futures. Compromises, strategies, and solutions will arise from more contingent intersections of human values and ecological change.

In closing, the intellectual context out of which resilience theory and Vale's model developed likely prompted some of their similarities. Such convergence of thought should not be altogether uncommon. Relatively independently both models derived analogous generalizations about the nature of ecological thresholds and multiple states. When taken together, they provide not only an ontological tool for documenting human impacts but also an epistemological awareness of how models, scale, and human values are relevant to comprehending ecological change. ■

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J. ANTHONY STALLINS is an Associate Professor in the Department of Geography at the University of Kentucky, Room 817, Patterson Office Tower, Lexington, KY 40506–0027. E-mail: ja.stallins@uky.edu. His research focuses on the organism–environment interaction and its representation in physical and human geography.

JOY NYSTROM MAST is a Professor in the Department of Geography and Earth Science at Carthage College, Kenosha, WI 53140–1929. E-mail: jmast@carthage.edu. Her research interests include biogeography, forest ecology, and mountain geography, with a focus on exploring ecological disturbances using spatial analyses and dendrochronological techniques.

ALBERT J. PARKER is Professor Emeritus in the Department of Geography at the University of Georgia, Athens, GA 30602–2502. E-mail: ajparker@uga.edu. His research interests include biogeography, forest ecology, vegetation dynamics, and environmental history.