PNW
Pacific Northwest Research Station

Science FINDINGS

INSIDE

issue fifty-four / july 2003

"Science affects the way we think together."
Lewis Thomas

THE TROUBLE WITH CONNECTEDNESS: DISTURBANCE AND ECOSYSTEM CRASHES


Credit: A.Bristol

Biocomplexity encompasses both the abundance and diversity of species and how communities are structured. It then considers how diversity factors structure the community both physically and compositionally.

IN SUMMARY

How do we promote resistance to disturbance, resilience when disturbance does occur, and forest health in general when forests and landscapes are actively managed for a variety of values? How do we manage for sustainability when humans and their consumption patterns are munching up the earth at alarming rates? How do we move beyond the now-controversial ideas of reserves and connecting corridors, the centerpiece of the Northwest Forest Plan?

New theories about how ecosystems renew themselves suggest some possible pathways from here to there. The development of panarchy theory, for example, and research into the ecological foundations of biodiversity are being synthesized into practical guidance for promoting forest health and sustainability. Old ideas about the importance of corridors are giving way to recognition of the importance of connectivity maintained by high permeability, varied dynamic landscapes, and ecologically high-quality patches; the patches are naturally and continually in states of rebirth, growth, and dissolution. Reduced connectedness and enhanced permeability, it seems, can increase resistance to agents of catastrophe and enhance resilience after catastrophes.

In order to preserve ecosystem health, therefore, we must consider the whole cycle of an ecosystem's development, including the value of both crash and recovery.

"You may drive out nature with a pitchfork, yet she'll be constantly running back."

Horace 65–8 B.C.

The patchwork quilt covering the forest lands of the Pacific Northwest has come to represent the logical outcome of heavy logging patterns and the particular policies of federal landowners during the latter part of the last century. On the one hand, the patches symbolize fragmentation and all its negative connotations: the break between wildlife and habitat, the loss of connectivity. On the other hand, numerous biodiversity studies are beginning to compile a case for the value of heterogeneity—or dissimilarity—at various levels of ecological organization from ecological communities within a forest to differences among communities within different forest types across a landscape.

Current federal land management in the Pacific Northwest, under the Northwest Forest Plan, is based on the idea of reserves to leave things be, corridors as connectors, and "matrix" lands to be managed for multiple values—the only place where timber can be harvested. But behind this kind of management, according to Andy Carey, research biologist with the Pacific Northwest Research Station, is a deeply held belief in the value of connectedness (everything is connected to everything else), equilibrium (static forest structures), and the "balance of nature." This belief does not allow us to design ecosystems that can adapt to long-term trends such as climate change.

What, then, are we to think of connectedness? Is it a good thing or a bad thing?

First, a definition. Despite all we learned about the values of sound connections between ecosystem components—a good thing—in the 1970s and 1980s, it is important now to recognize that too much connectedness between simplified ecosystems can render them highly vulnerable to catastrophic disturbance, Carey says. Not such a good thing.

In this sense, connectedness refers to tight coupling through homogeneity. Consider plantation monoculture an extreme case. Across a commercial private forest plantation, the likelihood of disease spreading, for example, is far higher than across a diverse, patchy landscape. A less extreme example is a nonplantation landscape where fire has been suppressed, where biodiversity is potentially undermined by the dominance of fewer species and the ecosystem is at high risk owing to large, connected fuel loads.

KEY FINDINGS

- The forest ecosystem study demonstrates that managing for ecologically appropriate spatial heterogeneity at a variety of scales promotes diversity in vascular plants, fungi, invertebrates, birds, small mammals, and carnivores.
- That study and others collectively demonstrate that spatial heterogeneity and compositional diversity reduce overall connectedness of ecosystems across a landscape. This increases both resistance to agents of catastrophe and ability to recover after disturbance.
- Reduced connectedness allows competing species to exist on a fine scale, prevents single predators from extirpating prey, inhibits the spread of diseases such as root rot and Swiss needle cast, reduces susceptibility to windthrow, inhibits the establishment and spread of invasive exotic plants and animals, and allows quick system recovery after ice and windstorms.

A certain degree of connectedness, Carey suggests, is healthy. As adaptation occurs, all the parts of a system can then bend and move as needed. But in an overly connected system, a kind of rigidity between the parts can occur, rendering the whole much more vulnerable to the dramatic shifts of catastrophic disturbance.

"You only have to look to epidemiology to see what happens if everything is too closely connected," says Carey. "The value of happy-and-peaceful-everything-is-connected-to-everything-else made a nice little story back in the sixties and seventies but in truth it's just a disaster waiting to happen."

The recent international spread of severe acute respiratory syndrome, exacerbated by the connection of continents by airplanes, is a chilling example.

What do we get when we turn the idea of connections on its head, throw in the complex roles of disturbance and effects of human activity, the truth of Nature's lack of a plan, and time? One possible scenario is described by panarchy theory.

PANARCHY THEORY AND STABILITY

Simply put, panarchy theory, developed by Gunderson and Holling (2002), addresses ideas of stability. How do ecosystems absorb, buffer, or generate change?

The two widely accepted phases of ecosystem dynamics are exploitation, in which rapid colonization of recently disturbed areas occurs, and conservation, the slow accumulation and storage of energy and material. Panarchy theory adds two more stages. The first is release, or "creative destruction," in which accumulations of biomass and nutrients become increasingly susceptible to disturbance and are suddenly released by such agents as forest fire, insect pests, or intense grazing. The second is reorganization, which brings processes into play that work toward preparing the system for the next phase of exploitation in a potentially different setting of climate and disturbances.

Panarchy theory is constructive for considering some of our remaining land management options today and can help change them profoundly, Carey believes.

"Our traditional forest management approach has emphasized homogeneity and low diversity, engineering efficiencies with single species in which you predictably plant, fertilize, spray herbicides, harvest, and in effect, keep everything highly connected. Under such a system, any loss by disturbance becomes catastrophic, and the ability to recover less likely."

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Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
P.O. Box 3890
Portland, Oregon 97208
(503) 808-2137

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Forest Service

Several philosophies on forest management currently prevail. The more recent conservation biology approach looks to an elusive past for guidance about what we should be producing from any given ecosystem, he says, and bases its approach on protecting as many individual species as possible. By contrast, disturbance ecology sees each biotic site as resulting from whatever disturbance has hit that site plus a random drawing from the species pool for the exploitation and conservation phases. Historical range of variability offers sideboards between which we try to steer our forests.

"Whatever the guiding philosophy, what most of these approaches miss is the idea that ecosystem development is not entirely based on random chance, nor on a very specific set of circumstances that once existed in the past," Carey says. "The past may not be reproducible, and I believe we'd be better off looking to produce the phenomena we want at a time that's right for them. Self-organizing, or adaptive, systems offer us this opportunity, a chance to look to the future rather than trying to restore an elusive or ill-defined past."

LAND MANAGEMENT IMPLICATIONS

- Systems not managed with ecologically appropriate spatial heterogeneity and compositional diversity are at greater risk of catastrophic disturbance owing to low resistance and resilience. They would thus require more external inputs (site preparation, herbicides, pesticides, fertilizers, protective barriers) to ensure narrow goals are achieved.
- Variable-density thinnings to promote compositional diversity and heterogeneity across the landscape contribute to forest health, and are increasingly being used on the ground by federal, state, and private land managers.
- Wood production is compatible with conservation of biodiveristy and can be used to promote forest health. Conversely, narrow-focus silviculture can induce risk factors for various forest health issues.

BIOCOMPLEXITY AND RESTORING BIODIVERSITY

So how do the tenets of panarchy theory relate to biodiversity and sustainability?

To most scientists, single-species conservation and natural reserves seem insufficient for protecting biodiversity, and to much of the public, conventional forestry seems suspect in sustainability, according to Carey.

"In the Pacific Northwest, comparisons of natural and managed coniferous forests support the idea that both single-species conservation and conventional forestry are unlikely to be successful. The reason is that biocomplexity is more important than individual habitat elements in maintaining the diversity of forest ecosystems and their capacity to produce useful goods and services."

Biocomplexity?

Biocomplexity goes beyond the genes, species, and populations of biological diversity, beyond the communities, ecosystems, processes, and economic and ecological goods and services of biodiversity. Biocomplexity encompasses how communities are structured—their collection of species—and looks at diversity at certain levels of organization. It also takes into account how those diversity factors structure the community both physically and compositionally.

In natural forests, biocomplexity is a given: many ecosystem elements are patchily distributed, including live trees from the preceding stand, large fallen trees, trees with cavities used for denning and nesting, berry-bearing shrubs, shade-tolerant trees in the midstory, forbs, mosses, and fruiting bodies of fungi, among others. Groups of these elements can form distinct patches.

"Thus we have biotic legacies from preceding forests, propagules from adjacent stands, forest structuring processes, and development of heterogeneity across the forest ecosystem interacting to produce both overall compositional diversity and patch diversity, or what we call habitat breadth," Carey explains. At the landscape scale, a similar phenomenon can be brought about. We need, he says, to manage in ways that promote such biocomplexity.

Generic model	Timber-wildlife	(duration, years)	Natural development	Active management:	simple	complex
Stand initiation	Grass-forb	(2–5)	Disturbance and legacy	Ecosystem reinitiation creation	x	x
	Shrub	(3–10)				
	Open sapling pole	(8–20)	Cohort establishment			
Stem exclusion	Closed sapling-pole-sawtimber	(40–100)	Canopy closure	Canopy closure	x	x
			Biomass accumulation/ competitive exclusion	Competitive exclusion	x	
				Biomass accumulation	x	
Understory reinitiation	Large sawtimber	(10–100)	Maturation	Understory reinitiation	x	x
			Vertical diversification	Canopy stratification	x	x
				Niche diversification		x
Old growth	Old growth	(700)	Horizontal diversification	Natural old growth		x
	Climax		Pioneer cohort loss	Natural climax		x

Stages of forest development based on ecological processes. Stages used in a generic model of forest development contrasted with structure-based timber classes used in a wildlife habitat relationship model, a model of Douglas-fir forest development under natural conditions, and a model for active ecosystem management.

FOREST MANAGEMENT AS JUGGLING ACT

Northwest forests are asked to provide a potentially impossible array of values: commodities; revenues for landowners, schools, and roads; economic support to local communities; habitat for forest wildlife and plants; recreational and spiritual experiences; and clean air and water. A single-focus history of timber management, however, has simplified forest ecosystems, enabled invasion by exotic species, unbalanced biotic communities, reduced prey biomass for predators, and hindered functioning of food webs.

Controversy over the utility of the Northwest Forest Plan and its reserve/corridor/single-species and matrix "sacrifice zone" approach has raised questions for Carey about better ways of managing landscapes in the Pacific Northwest and elsewhere around the world.

To address these questions, he took on a broad-scale investigation called the forest ecosystem study. Several decades of quantitative studies by Forest Service researchers around the Northwest uncovered geographically stratified data on plant, reptile, amphibian, bird, and mammal communities in old-growth, mature, and young forests. Similar studies on the spotted owl, including its prey base, habitat use, and demography, followed. Finally, comparative studies of natural and managed forests in the Northwest region helped researchers design treatments to restore lost biodiversity to managed stands. The treatments were then tested experimentally and by simulation modeling.

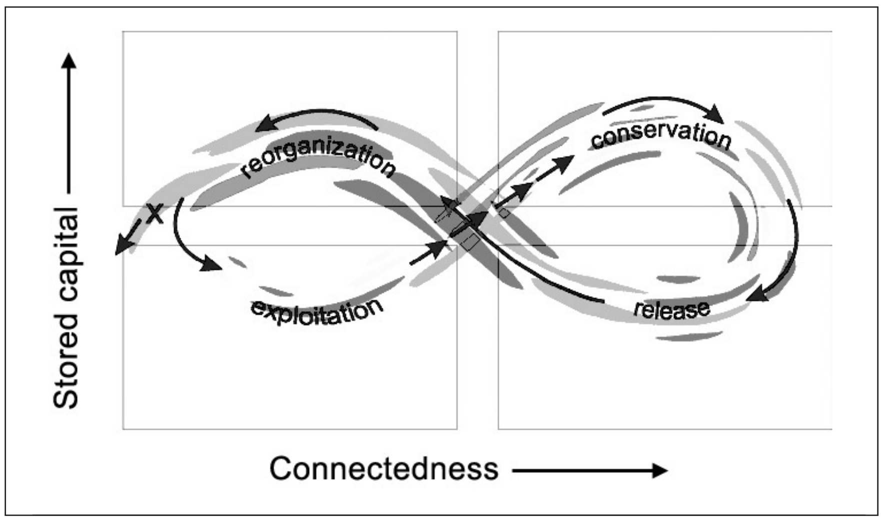
By using published and established models, Carey formulated five ecological indices to track landscape function and evaluate the ecological tradeoffs of alternative silvicultural systems and landscape management scenarios. They included the ability to support wide-ranging threatened species, capacity for vertebrate diversity, forest-floor function, ecological productivity, and production of deer and elk populations.

All management constraints selected included a relatively even flow of outputs on a decadal basis, Carey explains. Under the Northwest Forest Plan, 40 percent of the land base was withdrawn from management because of riparian constraints alone, and significant parts of the remaining landscape were so fragmented and overdispersed as to become economically infeasible to manage. Other alternatives took a more flexible approach to types of harvest and regeneration, rotation ages, riparian management, and tree species diversity, and came up with only 18 percent of the land base removed from management.

MANAGING FOR MULTIPLE VALUES

Based on results from 20 years of research, Carey believes it is absolutely possible to manage for multiple values.

The research findings show strong support for the idea that connectedness can actually counteract forest resilience, and suggest that panarchy theory has value in explaining the dynamic phases of ecosystem development. Maintaining heterogeneity across ecological scales can bolster a variety of elements central to forest health, Carey explains. These include the diversity and structure (biotic integrity) of various ecological communities; the integrity of such keystone complexes as the Douglas-fir/truffle/flying squirrel/spotted owl complex; resistance to wind and ice storms and invasion by exotics; and resilience after disturbance from wind and ice storms, wildfire, root disease, or mechanical disruption during harvest.



According to panarchy theory (Hollings 1992), adaptive systems go through four phases: exploitation, conservation, release, and reorganization. The stages of the cycle represent changes in connectivity and stored capital in the system.

"Our research demonstrates the potential for reconciliation of interest in wood production, sustainable human communities, recovery of threatened species, maintaining forest health, and promotion of general sustainability when compared to narrow-focus approaches," he says. "Narrow-focus approaches maximize the net present value of wood, set aside reserves for threatened species and maintaining biodiversity, and magnify concerns over ecosystem health due to past management and prior disturbance events that have led to simplified and over-connected ecosystems."

Management methods to alleviate narrow-focus outcomes are all based in part on inducing spatial heterogeneity through variable-retention harvest systems and also on variable-density thinning. They include retaining legacies of individual live trees, dead trees, coarse woody debris, or even patches of uneven-aged forest, and actively restoring missing key elements of biocomplexity. Observing that natural young forests

WRITER'S PROFILE

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can exhibit many of the attributes of old-growth forests, Carey believes the emphasis on conserving legacies within managed forests is central, a lesson he learned from guru Jerry Franklin (professor, ecosystem sciences, University of Washington, College of Forest Resources).

"Thinning influences all structuring processes, including decadence and development of heterogeneity across the landscape. Thinning with underplanting restores tree species diversity and accelerates canopy stratification and understory development. Retaining decadent trees, wounding trees, and inoculating trees with top-rot fungi, all promote decadence essential to ecosystem development," says Carey.

Carey notes that conservation biologists once argued the relative merits of single, large reserves versus multiple, small reserves; the need for conserving genetic diversity, and the need to restrict active management. At the same time, forest managers focused on plantation management, transportation networks, and watershed restoration.

"Now it is becoming recognized by both groups that extensive active management for biodiversity is needed to restore degraded ecosystems and to produce fully functional forests outside of reserves," he says. "Research has shown that reserve systems could become self-fulfilling prophecies of highly isolated diverse forests separated by impoverished second-growth forests and developed areas."

Carey's research suggests that the dynamic mosaics produced by intentional management have high biocomplexity at multiple scales and high biodiversity. Thus, he supposes that these landscapes should be resistant to disturbance and resilient when disturbance does occur.

PANARCHY THEORY AND MANAGEMENT

Panarchy theory's foundations of adaptive cycles, both social and ecological, have profound implications for management, according to Carey.

Take, for example, the immeasurable ecological and social values of old-growth forests. "Once lost, it is unlikely that any particular old growth could be reproduced either through natural succession or through intentional management simply because the biophysical conditions of its development are not subject to unvaried natural repetition, or to human control," he says. "Furthermore, the complete species composition of old growth has not been determined, so it is impossible to demonstrate its successful re-creation."

Attempts to harvest old growth will be contentious and lead to litigation. "The awe-inspiring size of old-growth structures induces values associated with its existence that can never be addressed by the scientific method alone," Carey explains. "It would also be useful for us to remember that, try as we might to mimic nature, nature has no plan." Thus, he notes, our improved knowledge of old growth and its importance to people for its ecological, scientific, and spiritual values, suggests that it might best be reserved rather than harvested.

Patches symbolize fragmentation and all its negative connotations, but numerous biodiversity studies are beginning to compile a case for the value of heterogeneity within certain complex forest types.

Taking the remaining small percentage of old growth out of management would contribute to rather than detract from the adaptive cycle of death and renewal. Its legacies to the landscape around it and to society far outweigh its removal from timber production, Carey says.

Just as old-growth forest will pass in its own, albeit long, timeframe, so ecosystems have a natural rhythm of change, through disturbances that can produce "crashes" for differing periods. Recovery follows, in a huge variety of forms. Restricting this rhythm will produce surprises, few of them pleasant. "Reduced variability means reduced resiliency. When you add in homogenization of forests to produce increased connectedness, the result is increased numbers of surprises," he explains.

The recurrence of surprises leads Carey to suggest another alteration to management approaches: "In an age of computer modeling, developing predictive tools should have a lower priority than designing systems that are flexible enough to undergo renewal after unexpected events." Translation: reduce unnatural levels of connectedness within the ecosystems we manage. The future of biological diversity, biodiversity, and biocomplexity may just depend on it.

"Life, like a dome of many-coloured glass, stains the white radiance of Eternity, until Death tramples it to fragments."

Percy Bysshe Shelley, 1792–1822

FOR FURTHER READING

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Andrew B. Carey is a research biologist and leader of the Ecological Foundations of Biodiversity Research Team in Olympia, Washington. He has spent his career comparing old-growth forests to managed forests in an effort to devise management systems appropriate to diverse land ownerships (large federal to small and private) and to providing people with the diverse products and values they want and need from forests.

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