From restoration to resilience ecology: Do we need a new paradigm*?

* And what can we do about it?

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We have relied on natural recovery or the practice of ecological restoration to heal damaged landscapes

- **Ecological restoration**: the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. – *SER International Primer on Ecological Restoration* (2004)

- **Restoration ecology**: the study of the relationships among organisms and their environment in a restoration context. – *Falk et al.* 2006

All species and ecosystems are adapted to high-frequency (interannual to decadal change)
Climate variation has always kept many species in climatic disequilibrium

Range shifts of chestnut (*Castanea dentata*), beech (*Fagus grandifolia*) and eastern hemlock (*Tsuga canadensis*) in eastern North America tracking changing temperatures following the Last Glacial Maximum. From Davis 1981.

Millar and Woolfenden (in press).
So what has changed? Why are we* so worried?

* 97% of scientists
Global Temperature (meteorological stations)

Predicted temperature increases under two scenarios
Rise in average surface temperature by 2081-2100*

Lowest scenario (RCP 2.6)  Highest scenario (RCP 8.5)

*Predicted change from period 1986-2005
Source: IPCC
Changes in the global climate system are driving direct ecosystem effects that are rapid, substantial, and out of phase with natural dynamics.

Drought stress appears to be heading for unremittingly severe levels

Dashed line: Most negative FDSI in last 1,000 yr

Williams et al. 2012, *PNAS*
Projected species range shifts in response to 21st century warming

- Poleward migration $\sim 10 - 80$ (160) km century$^{-1}$
- Upslope movement $\sim 60 - 100$ m century$^{-1}$
- Winners and losers at all scales

Parmesan and Yohe 2003; Colwell and Rangell 2009; Chen et al. 2011; Notaro et al. 2012
The central scientific and management challenge of our time:

How will organisms and ecosystems adapt to rapid reorganization of the Earth system?

Do we need to adopt more flexible paradigms of ecosystem conservation and management?
What is “ecological resilience”?  
Hobbs and Suding 2009

“The capacity of an ecosystem to recover to its pre-disturbance composition, structure, and/or function over time.”

- Departs from ecological restoration by relaxing the constraint to return to historical conditions
- Even these concepts may be inadequate to the challenge of adapting to a changing world.
Small scale disruption, rapid recovery, individuals survive (persistence dominates)

Case 1: Rapid, small scale disruption, rapid recovery, individuals survive ("resilient")

Spatial scale (ha)  Temporal scale (year)

1  1  10  100  1000  10  1

Ecosystem  Community  Species  Population  Individual
Landscape re-burns in the Chiricahua Mountains, a Madrean “Sky Island”

Nested sequences of fire severity (U,L,M,H) in 2 events

Chiricahua maps and images: Jesse Minor, U.Arizona
Post-fire succession in the Chiricahuas after two events
Photo points, J. Minor
Moderate-scale disruption, decadal recovery, some turnover in species (recovery processes)
Near-total overstory tree mortality in large ($10^4$ ac) high-severity patches, 2011 Las Conchas Fire, Jemez Mountains, NM

Fires can trigger abrupt, dramatic change
Large, high-severity disturbances can accelerate the pace of landscape transformation from decades/centuries to days/weeks
Following mortality events, species persistence is dependent on recruitment, but climate may preclude establishment.

Colwell and Rangel 2009; Jackson et al. 2009
Large scale disruption, multi-decadal response, change in community (type conversion, reorganization)
Restoration and management options must anticipate inevitable ecosystem change

Millar and Stephenson 2015, Science
Thus, in addition to its traditional roles, restoration can also enhance:

1. **Resistance**: Ability to endure external stressors without changing state.

2. **Resilience**: Return to the pre-disruption state after exposure to external stressors.

3. **Response (adaptation)**: Change some properties in response to external stressors while retaining essential characteristics.

Drever et al. 2005; Millar et al. 2007; Benson et al. 2011
Resilience means accepting change

1. Which kinds and degrees of change are adaptive, and which are destructive of biodiversity and ecosystems?
2. How does a resilience framework affect decisions and actions on the ground?
3. Are we prepared to let go of some current ecosystems, or would doing so violate our core principles?
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