Ecological restoration principes relative to *Nothofagus pumilio* (Poepp. & Endl.) Krasser (Nothofagaceae) forest restoration

Andre F. Clewell[1]
President Emeritus, Society for Ecological Restoration
Quincy, Florida, U.S.A.
clewellaf@gmail.com

Leaf surfaces are arranged in forested ecosystems so that solar radiation is effectively captured. In other words, the potential for photosynthesis is maximized as a function of plant community structure. In *Nothofagus pumilio* forest, tree crowns are densely branched and contain abundant, closely placed, small leaves that flutter on stout, subsessile petioles (Marticorena & Rodríguez, 2003) in windy realms of Tierra del Fuego, Chile. If sunlight escapes a leaf that was momentarily twisted on edge by the wind, that radiation is likely to be absorbed by another leaf that lies immediately below it. Light that escapes the tree canopy altogether may be captured by undergrowth plants, ephiphytes, or even corticolous bryophytes.

Other ecological aspects of forests are comparably efficient, such as mineral recycling and moisture retention, both of which are favored by copious organic matter in the soil (Armesto *et al*. 1992); by an abundance of burrowing soil organisms; and by a favorable microclimate (Promis *et al*. 2010). Like the effective arrangement of leaf surfaces, these ecological features are functions of community structure. This structure, in turn, is the product of ecological processes that collectively represent self-organization in a dynamic ecosystem.

Nothofagus pumilio forests resist wind and display resilience to ice storms. Trees have strong trunks that bear only a few, erect, stout principal branches. Being upright, these large branches escape breakage from ice accumulations. Numerous slender leaf-bearing branches arise from them (Fig. 1). These smaller caliper branches resist breakage by wind owing to their flexibility. The density of small, coriaceous leaves in the forest canopy tends to redirect much of the wind as flow above the canopy rather than through it, further protecting the trees. Even if these slender branches were damaged, they would regrow without need to produce much woody tissue. Resistance and resilience are the consequences of complex structural features that were derived from self-organizational processes in ecosystems. Resilience, in turn, ensures that *Nothofagus* forests are sustainable and will persist indefinitely into the future.

Recent fires, though, reflect climatic warming and drying which could trigger major adjustments in biodiversity. Perhaps *N. pumilio* will eventually be replaced by other species of *Nothofagus* (e.g., *N. antarctica*) or even by trees of other genera.

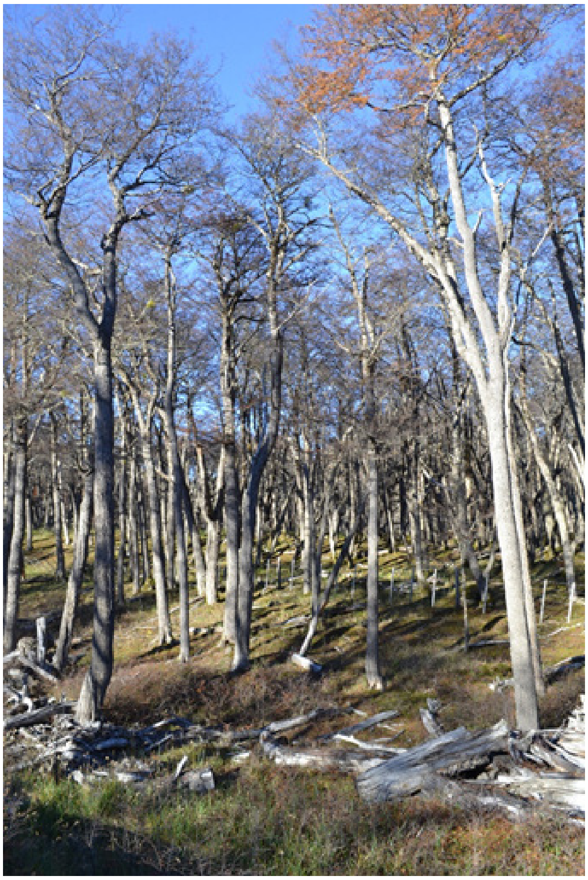

Fig.1. *Nothofagus pumilio* forest structure in Tierra del Fuego.

Received: Mar. 2, 2015 Accepted: Mar. 9, 2015

If that happens, the ecosystem will persist and continue to function, although with a substantially altered species composition. As conservationists, we lament the prospect of losing the forest state with which we are intimately familiar. As ecologists, we embrace change as normal, thereby allowing ecosystems to respond to altered environmental conditions in order to remain adaptive. On account of a paucity of tree species in Patagonia and the propensity of *N. pumilio* forests to transform to a persistent shrubby lifeform following fires, it is more likely that a significant shift in species composition will not begin for decades or longer (Paritsis *et al*. 2015). In addition, warmer temperatures actually favor seedling establishment (Piper *et al*. 2013), as long as competitive herbaceous vegetation does not interfere (Vidal & Reif, 2011; Henn *et al*. 2014).

As restoration practitioners, we assist the recovery of impaired ecosystems, so that arrested ecological processes return to normal levels of function. Practitioners don't actually restore ecosystems; they only facilitate plant and animal interactions that are necessary for ecosystem recovery. A practitioner ensures that the appropriate species are present and that the physical environment supports them. Plants and animals—not practitioners—conduct self-organizational processes which stimulate the development of complex community structures and facilitate efficient ecological functioning, resilience, and sustainability. If practitioners exert additional influence than this on the recovery process, we would be creating nature according to our own conception, and the restored ecosystem would no longer be entirely "natural". Instead, it would be a form of landscaping or gardening. If we are to recover nature when we restore, we must take care to minimize our influence over natural processes.

When we restore an ecosystem, we want to know as much as possible about what that ecosystem was like prior to impairment and how it functioned ecologically. Reference sites and other reference information are sources of such knowledge. Our restoration efforts are much more likely to be successful and satisfying if we have made a serious effort to assemble a thorough ecological reference as a baseline for project planning (SER, 2004; Clewell & Aronson, 2013). For terrestrial ecosystems, usually the most important reference information pertains to vascular plants and their requirements for establishment and growth. These plants will comprise the community structure and will form the basis for food chains involved in ecological functioning. Ecosystems are complex systems, and we can only assume that all species contribute to normal ecosystem functioning. If a species is missing, it could impede normal functioning. For this reason, restoration practitioners should ensure that all vascular plant species known from reference sites occur on project sites, at least as a few individuals that can spread if conditions are favorable for them.

In this way, we are recovering the ecosystem to its former state prior to impairment. However, we realize that ecosystems are dynamic and prone to change, particularly in response to altered climatic regimes. Therefore, we should not be surprised or concerned if long-term states of biodiversity that are engendered by ecological restoration differ from the pre-impairment ecosystem or the reference state. We recover nature—or more precisely, natural processes—and not a particular prior state of an ecosystem. To reiterate, we don't restore ecosystems. We facilitate the resumption of natural processes, so that ecosystems can adapt to contemporary environmental conditions.

When we have assisted the recovery of an ecosystem to the point that it has regained the capacity to self-organize, anything else that we do to that ecosystem is management, not restoration. We can, if we wish, manage the restored ecosystem so that it continually resembles its pre-impairment state, as if it were an outdoor museum display. That would not be nature in a pure sense as much as it would be our portrayal or interpretation of nature in the past. There is nothing wrong with managing a restored ecosystem to remain in a pre-impairment state, if that is what satisfies our values. In public parks, such management is commonly desirable. However, it should be recognized as an expression of artifice and not as entirely natural phenomenon.

Ideally, ecological restoration relies insofar as possible on natural dispersal and regeneration, and we only "assist" as needed. Sometimes this ideal is superseded by pragmatic considerations, such as the need to plant nursery-grown stock densely in order to reduce the potential magnitude of colonization by invasive species. Seeds of *Nothofagus* spp. disperse poorly in nature, and planting nursery-grown stock may be the only option. Planting densities of *N. pumilio* may have to be greater than usual for forest restoration in order to initiate wind-resistant forest structure, although this assumption begs verification. This is the kind of question that restoration practitioners should frequently ask, because the development of restoration strategies and technology has only recently begun for Chilean forests (Zamorano *et al*. 2008).

There are many ways to improve degraded natural areas other than full-fledged ecological restoration, including rehabilitation, re-vegetation, remediation, reclamation, ecosystem management, and habitat management for single species re-introductions. All of these activities are welcome for the recovery of impaired ecosystems. In contrast to ecological restoration, none of them necessarily reconnects an ecosystem's past to its future by assisting the resumption of failed ecological processes and reestablishing processes of self-organization, structural complexity, resilience, and sustainability as it existed prior to impairment. For ecosystem recovery on protected lands, ecological restoration is usually the only acceptable form of assisted recovery in order to regain lost natural values.

The steps comprising an ecological restoration project are described conveniently online (SER, 2005) and further elaborated by Rieger *et al*. (2014). Anyone who is engaged in conceiving, planning, implementing, administering, or regulating ecological restoration projects will find these references quite useful.

ACKNOWLEDGEMENTS

I thank Tein McDonald for reviewing an earlier draft of this paper.

REFERENCES CITED

Armesto, J. J., Cassasa, I. & Dollenz, O. (1992) Age structure and dynamics of Patagonian Beech forests in Torres del Paine National Park, Chile. *Vegetatio*, 98, 13-22.

Clewell, A. F., & Aronson, J. (2013). *Ecological restoration: principles, values, and structure of an emerging profession* (2nd ed.). Washington, D.C.: Island Press.

Clewell, A. F., Rieger, J. & Munro, J. (2005). *Guidelines for developing and managing ecological restoration projects* (2nd Ed.). http://www.ser.org/ and Tucson: Society for Ecological Restoration. Accessed 25 February 2015.

Henn, J. J., Anderson, C. B., Kreps, G., Lencinas, M. V., Soler, R., & Pastur, G. M. (2014). Determining abiotic and biotic factors that limit transplanted *Nothofagus pumilio* seedling success in abandoned beaver meadows in Tierra del Fuego. *Ecological Restoration,* 32, 369-378.

Marticorena, C. & Rodríguez, R. (2003). Fagaceae. In C. Marticorena, & R. Rodríguez (Eds.) *Flora de Chile* (pp. 64-76). Universidad de Concepción, Concepción.

Paritsis, J., Veblen, T. T., & Holz, A. (2015). Positive fire feedback contributes to shifts from *Nothofagus pumilio* forests to fire-prone shrublands in Patagonia. *Journal of Vegetation Science,* 26, 89-101.

Piper, F. I., Fajardo, A., & Cavieres, L. A. (2013). Simulated warming does not impair survival and growth of *Nothofagus pumilio* in the southern Andes. *Perspectives in Plant Ecology, Evolution and Systematics*, 15, 97-105.

Promis, A., Caldentey, J., & Ibarra, M. (2010). Microclima en el interior de un bosque de *Nothofagus pumilio* y el efecto de una corta de regeneración. *Bosque*, 31, 129-139.

Rieger, J., Stanley, J., & Traynor, R. (2014). Project planning and management for ecological restoration. Washington, D.C.: Island Press.

SER (Society for Ecological Restoration, Science and Policy Working Group) (2004). The SER primer on ecological restoration. http//www.ser.org/.

Vidal, O. J. & Reif, A. (2011). Effect of a tourist-ignited wildfire on *Nothofagus pumilio* forests at Torres del Paine Biosphere Reserve, Chile (Southern Patagonia). *Bosque*, 32, 64-76.

Zamorano, C., Cortés, M., Echeverría, C., Hechenleitner, P., & Lara, A. (2008). Experiencias de restauración con especies forestales amenzadas en Chile. In M. González-Espinoza, J. M. Rey-Benayas & N. Ramírez-Marcial (Eds.) *Restauración de bosques in América Latina* (pp. 17-37). Mexico, D.F.: Mundi-Prensa Mexico, S.A. de C.V.