Ecological restoration and ecological engineering: Complementary or indivisible?

by James ARONSON, Andre CLEWELL & David MORENO-MATEOS

Highlights

– Ecology relies on engineering solutions to accelerate recovery, not control it.

– Engineers remove uncertainty; ecologists embrace uncertainty and pursue complexity.

– Ecological restoration reestablishes historic continuity, not prior states.

– Unlike engineering, restoration is more concerned with process than product.

In a recent editorial in *Ecological Engineering*, founder and editor, Bill Mitsch asked: “When will ecologists learn engineering and engineers learn ecology?” (MITSCH 2014). Fundamental to this question is our concept of nature. Ecologists study nature to determine what it is and how it functions. Ecologists are also conservative in the sense that they are protective of “nature” and urge prudent management and use of land, water, and ecosystems in order to satisfy those human values that are predicated on naturalness in the environment. Ecological engineers' work, in contrast, consists in part of transforming nature to provide benefits pertaining to the provision of natural goods and services, such as flood control and providing clean water, remediation of contaminants, and erosion control. This basic difference in orientation and terms of reference creates a gap to cross in the search for mutual understanding.

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Mitsch (2014:9) stated that ecological engineering has two goals, namely "the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance, and the development of new sustainable ecosystems that have both human and ecological value." This statement of goals closely follows the definition of ecological engineering given by Mitsch & Jørgensen (2004:23) as "the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both." These and similar statements by Mitsch over the years valiantly call for the restoration of disturbed ecosystems in a manner that unites ecologists and engineers in common cause. We applaud this effort; however, we advise that these definitions need revision to align with current concepts of ecological restoration if we seek mutual understanding. Terms like design and sustainable, for example, carry with them implications that impedes the dialog for which Mitsch has called. To understand why, requires a close look at ecological restoration.

What is ecological restoration?

"Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004). The tacit assumption in the early years of the development of modern ecological restoration was that assisted recovery would lead to reestablishing an ecosystem to the state of biodiversity and functioning that existed prior to its impairment. Sometimes this was possible, especially in stable, extra-tropical environments with relatively limited biodiversity, and particularly in ecosystems that could recover quickly to a pre-disturbance state, such as herbaceous marshes. This optimism was abetted by lingering allegiance to outdated concepts of climax communities and balance of nature. Ecologists have abandoned the ideal of truly recovering the past. They recognize that ecosystems are dynamic and life moves inexorably forward at a pace governed by flux, environmental instability, and the longevity of dominant organisms. This better-nuanced view of nature led ecologists to realize that an ecosystem was merely the temporal expression of biodiversity moving along an ecological trajectory over time. Ecological restoration may have seemed to be reconstructing ecosystems, but we now see that it is really about an interrupted ecological trajectory that we seek to reestablish. Historical continuity is what is being recovered (Clewell and Aronson 2013a, 2013b). The theoretical importance of recovering ecological trajectories is not a new concept in ecological restoration (Aronson *et al.* 1993); indeed it seems now to be on the way to becoming mainstream. International conventions (e.g., CBD 2012), intergovernmental platforms (e.g., IPBES 2013) and policy calls for massive action (e.g., IUCN 2014) show that ecological restoration is now recognized as a global priority for biodiversity conservation, combatting desertification and land degradation, and limiting the impacts of anthropogenic climate change (Aronson and Alexander 2013).

Interventions that are performed onsite to assist recovery are limited to those in only a few categories. Practitioners can ensure that:

– desirable species are present and undesirable species are absent,

– the physical environment supports the desirable species,

– the characteristic biotic community structure is developing,

– flows and exchanges of materials and organisms are occurring normally with the surrounding landscape,

– threats in the surrounding landscape that may cause a recurrence of impairment have been removed insofar as possible.

An ecological reference determines species composition and structure, not as a fixed model, but rather as a guide to allow planning, action, monitoring, and evaluation. Efforts are made to include as many as possible of the pre-impairment species in the restoration process, because these were presumably co-adapted species that previously assembled to form a sustainable ecosystem. A pre-project baseline inventory determines the needs for physical site repair at the project site and adjustments to normalize exchanges with the surrounding landscape. Both the ecological reference and baseline inventory are critically important for planning project implementation, because they determine initial biodiversity of the restored ecosystem and specific efforts needed to repair the physical environment.

Once ecological processes have returned to normal levels of function, evidence of self-organization (or self-design to use Mitsch's term) will become evident, mainly in terms of plant growth and reproduction, and spontaneous recolonization by native biota. Ecological complexity will gradually manifest in terms of habitat diversity and niche diversification. The capacity for resilience to disturbance will increase, and the capacity for self-sustainability will develop commensurately with that of ecological reference ecosystems. These attributes emerge as manifestations of normal ecological processes and not directly from practitioner intervention.

An ecosystem is considered restored as soon as self-organization becomes evident and onsite project work by practitioners is no longer needed. Completion of a restoration project is similar to healing in the medical profession. A medic can set the bone in a leg so that it heals in the pre-break position. Upon becoming ambulatory the patient is considered healed. The initiation of self-organization in an ecosystem undergoing restoration would be equivalent to the time that the patient became healed.

MITSCH (2014:13) wrote, "…engineering is a field devoted to removing uncertainty and controlling natural processes." Predictability of the outcome, control of ecosystem processes, and removal of doubt are not germane considerations to ecological restoration projects (Table 1). The intent of ecological restoration is to embrace uncertainty as one of greatest defining qualities of this enterprise. Future states of biodiversity and ecosystem dynamics will reflect the constraints and fluctuations of contemporary environmental and societal conditions to which the ecosystem in question must continually adjust (SER 2004:1).

Design, Sustainability and Ecological Engineering

The fundamental concept to engineering of design is problematic in respect to ecological restoration. Design implies a product. You design a building or bridge always with a final product in mind. You plant a garden or a tree farm with a crop as the intended product. A natural or semi-cultural ecosystem is not a product. Rather, it is the temporal expression of ceaseless ecological development. What is sustained is not a static

Attribute	Ecological restoration	Ecological engineering
Predictability	Restored ecosystems are dynamic and their biodiversity is not entirely predictable across time.	Ecologically engineered ecosystems are designed or managed in a predictable manner to provide desired services.
Complexity	Complexity builds over time as a consequence of constant species turnover.	Given the low number of species required for most intended services, the amount of interactions generated, and thus complexity, is low.
Long-term cost	Although an impaired ecosystem will likely need a series of interventions to recover its historic trajectory, it should require no maintenance other than normal land management costs.	To keep a high delivery of services, engineered ecosystems require regular maintenance costs. These costs may be orders of magnitude larger than standard land management costs.
Natural capital value	By hosting large numbers of species, the potential goods and services are large and not always recognized until after project completion.	By focusing on single or a few services, the lower number of species provides less natural capital than in restored ecosystems.

Table 1.
Major attributes found, or aspired to, in projects driven by the paradigms of ecological restoration and ecological engineering. Columns refer to the extremes between ecological restoration and engineering, but a gradient exists between both extremes.

ecosystem but instead a dynamic process. What we call an ecosystem is only a temporal manifestation of biodiversity generated by that process. When sustainability is understood from that perspective, only then can we expect to see ecologists and engineers fully appreciate each other and working together in synergy.

MITSCH revealed his understanding of this issue when he wrote about self-design: “Ecosystem restoration, as currently practiced throughout the world, is done by practitioners who have little experience in design…and by engineers who do not appreciate the capabilities of ecosystems to self-design….” Self-design is the antithesis of design that is intended to produce an outcome by removing uncertainty and asserting control of natural processes.

Design in ecological restoration refers not to a product or outcome but instead to strategies and tactics for conduct of a restoration project. Will the restoration be performed with minimal assistance to foster natural regeneration? Or will it draw upon technological solutions with extensive site preparation, soil amendments, and dense plantings of nursery stock? Will restoration be conducted all at one time or will it be prolonged in phases to allow adaptive management? These are the sorts of questions that restoration ecologists consider with regard to design. To eliminate confusion, we strongly advise that design in the traditional engineering sense be deleted from definitions and discussion pertaining to ecological restoration.

The terms sustainable and sustainability also cause confusion in the way they are used in ecological engineering. Sustainability is an intangible ideal that defies verification. It can be assessed indirectly by comparing trends in recovery to local, intact reference ecosystems. Its assessment is further complicated in restored ecosystems that are located in fragmented natural areas where external management is needed to substitute for missing natural drivers on which sustainability depends. Pyrogenic ecosystems, particularly, require prescribed fires as surrogates for the much larger-scale fires that naturally ignited in unaltered landscapes. Constructed waterways may be needed as substitutes to maintain wetland hydrology. Such external management has become the norm, and the ideal of ever reaching natural sustainability fades accordingly.

Is Ecological Restoration a Subset of Ecological Engineering?

MITSCH & JØRGENSEN (2004:24) viewed ecological engineering as an amalgam encompassing a large number of modalities that are applied to stimulate environmental recovery and improvement, including ecological restoration. In this regard, they considered ecological restoration as a subset of ecological engineering. We disagree: ecological restoration is a not a subset of anything else. Ecological engineering was introduced as an approach that substituted living organisms and products of biological origin for inert materials such as concrete and steel. This new approach proved effective for solving problems within the purview of traditional civil engineering. These services commonly cost less to install, operate and maintain than traditional civil engineering solutions. They were more energy efficient and were less interruptive and intrusive on landscapes. Ecological engineering did not introduce ecological restoration and “…the restoration of ecosystems that have been substantially disturbed by human activities…” (MITSCH 2014:9). Ecological restoration has a long history (JORDAN & LUBICK 2011) that goes back as far if not further than that of ecological engineering.

Ecological engineering is essentially problem-solving; its approach is technical and proactive rather than nurturing. The nurturing approach, which is used extensively in ecological restoration, relies insofar as possible on spontaneous recovery and on minimal interventions known as ‘assisted natural regeneration.’ The latter relies on spot-treatments to initiate larger-scale spontaneous recovery and on low-tech manipulations. The intent is to facilitate recovery of a natural system rather than to domesticate nature. Ecological engineering designs ecosystems as products for their capacity to provide socioeconomic value in terms of regulating and provisioning services (MILLENNIUM ECOSYSTEM ASSESSMENT 2005). Ecological restoration assists the recovery of ecological processes in order to recover impaired natural and semi-cultural ecosystems that satisfy not only socioeconomic values, but also cultural, personal, and ecological ones (CLEWELL & ARONSON 2013:15-31). Ecological restoration is by no means limited to the nurturing approach. Most ecological restoration projects rely at least in part on technical solutions from ecological engineering. Sometimes these solutions are the only available options for facilitating recovery. They are commonly elected in ecological restoration projects for accelerating time to project completion, and they are frequently required in permit and contract stipulations.

Traditional engineering approaches are applied to architecture, road-building, agronomy, and other disciplines, but traditional engineers do not consider these other disciplines as subsets of engineering. Ecological restoration relies at least as much on horticultural approaches as engineering approaches, but horticulturalists don't claim ecological restoration as subsets of horticulture. Ecological restoration is a broadly interdisciplinary modality that draws from the approaches and technologies of many fields, including engineering. For all of these reasons, we cannot accept the idea that ecological restoration is a subset of ecological engineering.

An alternative definition of ecological engineering was offered by Clewell and Aronson (2013:258 and 209-212): Ecological engineering is "the manipulation and use of living organisms or other materials of biological origin to solve problems that affect people." This definition avoids terms like 'design,' 'sustainability,' 'nature,' and 'creation.' It neatly distinguishes ecological engineering from civil engineering. Above all, it allows for ecological engineering and ecological restoration to rely on each other without compartmentalizing and calling one a subset of the other. The SER Primer (SER 2004) gives a similar definition of ecological engineering.

Large-scale Ecological Restoration

Recently, additional confusion between ecological engineering and ecological restoration has arisen in relation to the terminology used in describing what are called large-scale ecological restoration projects, such as those in the Florida Everglades, Chesapeake Bay, and the Upper Mississippi River basin. These are neither ecological restoration projects nor are they 'projects.' Instead, they are vast programs of activities consisting of numerous, administratively coordinated but separate projects, very few of which qualify as ecological restoration in the way we define that discipline; however nearly all of them have an ecological engineering approach. Doyle and Drew (2008) and Mitsch (2014) described several such programs and there are dozen more worldwide. To continue calling them "restoration" only perpetuates this confusion and relegates the meaning of the term ecological restoration to that of a buzz word. For programs undertaken at large spatial scales, and especially those where a mosaic of natural, semi-cultural and human-dominated ecosystems interweave and interact ecologically and socioeconomically, and where a broad medley of personal, social, economic, cultural and ecological motivations come into play, another, larger concept is needed. At these scales, both disciplines – ecological restoration and ecological engineering – are required, along with natural resource conservation, regional planning, environmental education, and the hard work of consensus-building and public engagement. We propose that natural capital restoration (Aronson e*t al.* 2007; Blignaut *et al.* 2012; de Groot *et al.* 2013; Blignaut *et al.* 2014) is a more appropriate term to cover the broad array of activities required and to provide a vision on which all stakeholders can agree. To take one example, the Global Partnership for Forest Landscape Restoration [1] might consider this suggestion.

Ecological restoration may not provide as much of one particular ecosystem service for which a comparable design and engineered ecosystem was implemented, but it will likely provide a broader array of services with less need for long-term ecosystem management (Table 1). It also provides more capability for an ecosystem to respond and adapt to climate change and other external anomalies (Clewell & Aronson 2013a). As such, it offers greater hope of lasting benefits for the generations to come than any other approach we are aware of.

Who needs to learn what?

Let's return to Mitsch's quandary and try to answer it: "When will ecologists learn engineering and engineers learn ecology?"

1 - http://www.forest-landscaperestoration.org/

James ARONSON
Centre d'écologie fonctionnelle et évolutive (UMR 5175, CEFE - campus CNRS) 1919, Route de Mende 34293 Montpellier FRANCE
and
Missouri Botanical Garden P.O. Box 299 St. Louis, Missouri 63166-0299 USA

Andre CLEWELL
5812 Old Federal Road, Quincy Florida 32351 USA

David MORENO-MATEOS
Basque Centre for Climate Change, Alameda Urquijo 4, 48008 Bilbao, Spain. and IKERBASQUE, Basque Foundation for Science, Diaz de Haro 5, 48008, Bilbao SPAIN

Corresponding author
Email: james.aronson@cefe.cnrs.fr

We begin by eliminating from discussion those practitioners who perform interventions at ecological engineering and ecological restoration project sites. Those who are experienced are usually well versed in both the ecology and engineering relevant to their projects (Rieger *et al.,* 2014). For terrestrial and aquatic ecosystem restoration, much of the project work of an engineering nature pertains to repairs to the physical environment. Practitioners in the field are at least partially knowledgeable in these disciplines, and many are adept at conducting field tests, operating specialized equipment, preparing project plans and drawings, and performing other tasks generally associated with technology and engineering.

It is no secret that ecological engineers are quite vulnerable for their identification with failed wetland mitigation projects, many of which are touted as ecological restoration. Meta-analyses of wetland restoration projects consistently reveal marked underperformance relative to baseline reference states to recover their biological structure and biogeochemical functionality (Moreno-Mateos *et al.* 2012) and unclear roles of major restoration actions, like revegetation, to foster recovery of the plant assemblage (Moreno-Mateos *et al.* 2015). This revelation acutely demonstrates the need for engineers to learn ecology. These are the engineers who sign ecological restoration plans and draft ecological restoration projects for large engineering firms that receive contracts from government agencies to perform wetland mitigation. Other engineers are highly placed in those same government agencies that specify permit conditions for wetland mitigation projects, issue permits, and release contractors from permit liability upon project completion. One reason why so many wetland mitigation projects fail is that they lack sufficient biodiversity which, in turn, reflects inadequate attention to ecological references and the importance of insisting on the recovery of their species composition in ecological restoration projects. Explicit directions for performing much higher quality work have long been available (Kusler and Kentula 1990) and updated (Galatowitsch 2012) and have obviously been ignored.

We see a great need for engineers at middle and higher levels who develop and execute policy, and those who sponsor, administer, plan, and direct projects to receive training in ecological principles and their application in ecological restoration projects. Workshops for that purpose can provide this training. However, it is our experience that ecological knowledge gained will not find its way readily into project plans unless policy makers and administrators, particularly those in public agencies (also those in transnational organizations and large non-governmental organizations), authorize its adoption. The lag time could be generational until a new wave of ecologically savvy engineers, natural resource professionals, and policy makers assume top-level administrative positions and the legal and political climates become more favorable.

Ecologists may only know a little engineering, but unless they are licensed to sign plans and permits, their engineering input is advisory. Therefore, it may not be important for an ecologist to learn engineering above a modest level. On the contrary, if engineers are to prepare ecologically viable and relevant plans, they need to be well versed in ecological principles, applied ecology, and at least comfortable with the kinds of questions ecologists are asking about ecosystems and biological communities at a restoration site.

J.A., A.C. & D.M.M.

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References

Aronson, J. 2011. Sustainability science demands that we define our terms across diverse disciplines. Landscape Ecol. 26, 457-460.Aronson, J., and S. Alexander. 2013. Ecosystem restoration is now a global priority: time to roll up our sleeves. *Restor. Ecol.* 21, 293–296.

Aronson, J., Milton, S.J., Blignaut, J.N. Editors. 2007. *Restoring natural capital: Science, business and practice.* Island Press, Washington, DC. pp. 3-8.

Aronson, J., Blignaut, J.N., Milton, S.J., le Maitre, D., Esler, K., Limouzin, A., Fontaine, C., de Wit, M., Mugido, W., Prinsloo, P., van der Elst, L., Lederer, N. 2010. Are socio-economic benefits of restoration adequately quantified? A meta-analysis of recent papers (2000-2008) in *Restoration Ecology* and 12 other scientific journals. *Restor. Ecol.* 18, 143-154.

Blignaut, J.N., Aronson, J. de Groot, R.S. 2014. Restoration of natural capital: A key strategy on the path to sustainability. *Ecol. Eng.* 65, 54-61.

Clewell, A.F., Aronson, J. 2006. Motivations for the Restoration of Ecosystems. *Conser. Biol.* 20, 420-428.

Clewell, A.F., Aronson, J. 2013a. *Ecological Restoration: Principles, Values, and Structure of an Emerging Profession*, 2nd Ed. Island Press, Washington, D.C

Clewell A., Aronson, J. 2013b. The SER Primer and Climate Change. *Ecol. Manage. & Rest.* 14,182-186.

Convention on Biological Diversity. 2012. UNEP/CBD/COP Decision XI/16. Ecosystem Restoration.

http://www.cbd.int/doc/decisions/cop-11/cop-11-dec-16-en.pdf. (Accessed 26 January, 2016).

Doyle, M., Drew, C.A. (Eds.) 2008. *Large-scale ecosystem restoration: five case histories from the United States.* Island Press, Washington, D.C.

Galatowitsch, S. 2012. *Ecological restoration.* Sinauer Associates, Sunderland, Massachusetts.

Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). 2013. Deliverable 3(b)(i): Thematic assessment on land degradation and restoration.

http://ipbes.net/work-programme/objective-3/45-work-programme/459-deliverable-3bi.html. (Accessed 26 January, 2016).

International Union for Conservation of Nature (IUCN). 2014. Forest and Landscape Restoration.

https://www.iucn.org/about/work/programmes/forest/?22347/forest-landscape-restoration-partnership-shares-group-knowledge-four-different-countries-one-common-goal (Accessed 26 January, 2016).

Jordan, W.R. III, Lubick, G. 2011. *Making nature whole.* Island Press, Washington, D.C.

Kangas, P. C. 2004. *Ecological Engineering Principles and Practice.* Boca Raton: Lewis Publishers, CRC Press.

Kusler, J.A., Kentula, M.E. 1990. Executive summary. Pages xvii-xxv in: Kusler, J.A., Kentula, M.E., *Wetland creation and restoration the status of the science.* Island Press, Washington, D.C.

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being synthesis.* Island Press, Washington, D.C.

Mitsch, W.J. 1993. Ecological engineering – a cooperative role with the planetary life-support systems. *Environ. Sci. & Technology* 27, 438-445.

Mitsch, W.J. 2012. What is ecological engineering? *Ecol. Eng.* 45, 5-12.

Mitsch, W.J. 2014. When will ecologists learn engineering and engineers learn ecology? *Ecol. Eng.* 65, 9-14.

Mitsch, W. J., Jørgensen, S.E. 2004. *Ecological engineering and ecosystem restoration.* John Wiley and Sons, New Jersey.

Moreno-Mateos, D., Meli, P., Vara-Rodríguez, M. & Aronson, J. 2015. Ecosystem response to interventions: Lessons from restored and created wetland ecosystems. *J. Appl. Ecol.* 52, 1528–1537.

Moreno-Mateos, D., Power, M.E., Comín, F.A., and Yockteng, R. 2012. Structural and functional loss in restored wetland ecosystems. PLoS Biology 10, e1001247.

Rieger, J., Stanley, J., Traynor, R. 2014. Project *Planning and Management for Ecological Restoration.* Island Press, Washington, D.C.

SER 2004. SER International Primer on Ecological Restoration. Society for Ecological Restoration. Tucson, www.ser.org (Accessed 26 January, 2016).

Summary

Ecological restoration and ecological engineering: Complementary or indivisible?

Ecological engineering and ecological restoration are distinct disciplines, both of which are urgently needed to reverse global environmental damage. Relative to ecological restoration, ecological engineering provides outcomes that are more predictable but with lower diversity. It also aims to provide higher functionality with respect to one or a few ecosystem services, relative to ecological restoration which aims at full, long-term recovery of lost ecosystem services. Ecological engineering generally incurs higher maintenance costs and provides lower values of natural capital than ecological restoration. In particular, we contend that "large scale restoration projects" include little restoration and should be recognized as "large scale rehabilitation programs" more aligned with ecological engineering principles and the overriding aim of restoring natural capital. Engineers and ecologists must work together and learn from each other if our work is to generate significant societal benefits.

Résumé

Restauration écologique et ingénierie écologique : complémentaires ou consubstancielles ?

L'ingénierie écologique et la restauration écologique sont deux disciplines distinctes, toutes deux nécessaires pour contrer la détérioration environnementale mondiale. Par rapport à la restauration écologique, l'ingénierie écologique fournit des résultats plus prévisibles mais moins diversifiés. L'ingénierie écologique vise également à fournir une fonctionnalité supérieure à l'égard d'un ou de quelques services écosystémiques par rapport à la restauration écologique qui vise la récupération complète et à long terme des services écosystémiques perdus. L'ingénierie écologique induit généralement des coûts de maintenance supérieurs et fournit des valeurs de capital naturel plus faibles que la restauration écologique. Plus particulièrement, nous soutenons que les "projets de restauration à grande échelle" incluent peu de restauration et devraient être reconnus comme des "programmes de réhabilitation à grande échelle" plus alignés sur les principes de l'ingénierie écologique et l'objectif primordial de restauration du capital naturel. Les ingénieurs et les écologistes devraient travailler ensemble et apprendre les uns des autres si l'objectif consiste à générer des bénéfices sociétaux significatifs.

Resumen

Restauración ecológica e ingeniería ecológica: ¿complementarias o indivisibles?

La ingeniería ecológica y la restauración ecológica son disciplinas distintas, necesitándose ambas para revertir el deterioro ambiental mundial. En relación a la restauración ecológica, la ingeniería ecológica proporciona resultados que son más predecibles pero de baja diversidad. La ingeniería ecológica también tiene como objetivo el proporcionar una mayor funcionalidad con respecto a uno o varios servicios ecosistémicos, a diferencia de la restauración ecológica que tiene como objetivo pleno es la recuperación a largo plazo de los servicios ecosistémicos perdidos. La ingeniería ecológica normalmente entraña mayores costes de mantenimiento y proporciona valores de capital natural más bajos que la restauración ecológica. En particular, sostenemos que "los proyectos de restauración a gran escala" incluyen poca restauración y deberían ser reconocidos como "programas de rehabilitación a gran escala" más en línea con los principios de ingeniería ecológica y el objetivo primordial de restaurar el capital natural. Ingenieros y ecologistas deben trabajar juntos y aprender unos de otros si nuestro trabajo es generar beneficios sociales significantes.