NOVEL ECOSYSTEMS

THE NEW NORMAL?

As humans continue to radically alter the environment, new species assemblages are emerging – combinations of organisms that have never been observed before. What does this changing world mean for ecology?

Delta of Mississippi River in Louisiana seen from space – contains modified Copernicus Sentinel data from ESA

In this article we look at the evolution of the novel ecosystem concept, tracing its history, its definition, and exploring the ongoing debates it has sparked. We'll also address the key questions that continue to challenge scientists and policymakers as they grapple with its implications.

WHAT IS A NOVEL ECOSYSTEM?

The definition of novel, sometimes also called "emerging," ecosystems has evolved over the last two decades, but there are a number of characteristics that are helpful in identifying them. Novel ecosystems:

- Comprise new species assemblages
- Have a suite of interactions and processes consistent with a self-organised, functioning ecosystem
- Are difficult to "restore" to a previous condition due to considerable/significant biotic and/or abiotic alterations

A useful definition emerged from a workshop on Pender Island, Canada, in 2013:

> **A novel ecosystem is a system of abiotic, biotic and social components (and their interactions) that, by virtue of human influence, differ from those that prevailed historically, having a tendency to self-organise, and manifest novel qualities without intensive human management.**
> (Hobbs, Higgs and Hall, 2013)

A key aspect of novel ecosystems is that they can include species living outside of their "historical" native ranges; either by anthropogenic introduction, whether intended or not, or through 'natural' range expansion, driven by e.g. climate change. Examples of terrestrial and marine novel ecosystems have only been increasing, whether they are formerly cultivated land seemingly 'stuck' in a state dominated by non-natives and an altered fire regime, algal-dominated coral reefs in polluted, warming seas, or woodlands with changed sub-canopy communities, with concomitant changes in interactions (Kuijper *et al.* 2024). Such examples would often be considered 'bad' from a restoration or conservation viewpoint. However, in some instances, novel ecosystems may provide benefits such as habitat for endangered plants and animals that are threatened by habitat loss elsewhere, or a valuable connection to nature for humans in peri-urban environments. If novel ecosystems can play that role, it will need to be reconciled with traditional conceptions of restoration and conservation (Clement *et al.* 2023), and relatively rigid strictures of conservation regulations: for instance, in a UK context, what constitutes Favourable Conservation Status if based on assemblage classifications from the 1970s to 1990s?


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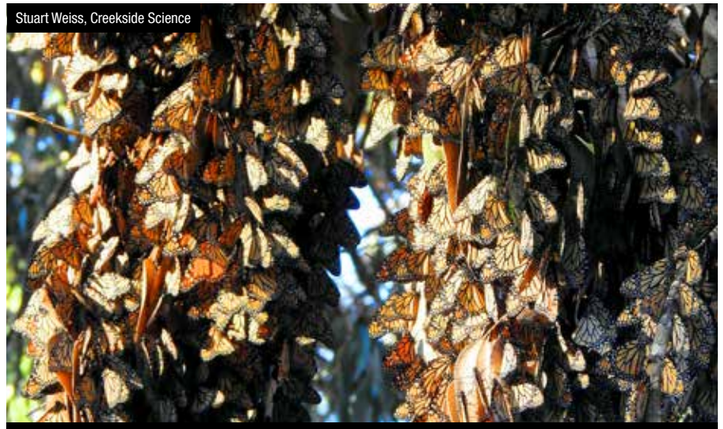
CASE STUDY

A 5-hectare forest monitoring plot in the Jean Lafitte National Historic Park & Preserve

LOUISIANA'S MISSISSIPPI RIVER DELTA REGION, USA

This ecosystem is a semi-permanent/permanent floodplain forest in the backswamp of Bayou des Familles. It is experiencing rapid subsidence and so, rapid relative sea level rise, leading to increasing hydroperiod. The forest canopy is dominated by *Taxodium distichum* and *Fraxinus profunda*. The understory is dominated by *Eichhornia crassipes* and *Salvinia minima*, two floating invasive aquatic species that are native to South America.


Stuart Weiss, Creekside Science

CASE STUDY

Eucalyptus and monarch butterfly roost sites

BIG SUR AND THE CALIFORNIA COAST, USA

More than a hundred groves of non-native eucalyptus, primarily *Eucalyptus globulus*, growing in the mild climate of the immediate California coast, have been adopted by monarch butterflies as overwintering roost sites, thereby greatly expanding the monarchs' range beyond the few ancestral overwintering sites in groves of native Monterey pines. These eucalyptus groves now require careful forest management to maintain the sunny, wind-sheltered microclimate nooks that the monarchs seek. The understories are often dominated by poison oak (*Toxicodendron diversiloba*) but are capable of supporting many native shrubs if tended appropriately.

WHEN DID THE CONCEPT OF A NOVEL ECOSYSTEM EMERGE?

Evidence that ecosystems had been changing permanently as a result of human activity, through drivers including land transformation and climate change, began to emerge in the latter part of the 20th century. The first mention of "novel ecosystems" in peer-reviewed literature came from Chapin and Starfield's 1997 modelling work on Arctic Alaska, and this term started to be used widely, alongside "emerging ecosystems," in the early 2000s.

In 2006 Richard Hobbs and colleagues explored the accumulating evidence for novel ecosystems as a system response to anthropogenic environmental change, and the implications of this for how ecosystems might be managed and for contemporary approaches to conservation. At the same time, people working in restoration ecology began to consider the implications of climate change for their activities. In an area traditionally wedded to either reproducing "historical" systems, or aiming for targets of "native ecosystems," issues are readily apparent. A rapidly changing environment may mean historical precedents are unhelpful. Indeed, attempts to "force" stable novel systems "back" to a historical state by traditional restoration and conservation approaches might result in systems collapse. In 2009 Hobbs *et al.* published an opinion piece in TREE which suggested that, provided novel ecosystems had the characteristics listed above, they could be considered legitimate targets for management, as they are likely to be persistent and resilient under changing conditions which brought them about.

Since then, the concept has attracted a lot of scientific interest: a recent Web of Science search indicates over 600 publications to date with novel ecosystem in the title, abstract or text, with numbers increasing by about 60 papers per year; covering subjects as wide as the impact of wolves recolonising novel ecosystems to attitudes of experts accepting novel ecosystems as a valid approach with the caveat of close monitoring and evidence gathering. Indeed, the importance of ecological novelty was emphasised as one of five priority themes for ecological research in a recent British Ecological Society strategy document (Malhi *et al.* 2023).

CONTROVERSIES

The scientific debate around the novel ecosystem concept includes a range of criticisms, from there being insufficient evidence to support the argument through to it could give industry and government an excuse to "trash" nature – this latter argument also being deployed two decades earlier when ecological restoration was gaining traction. However, despite these criticisms, the evidence for novel ecosystems appearing continues to mount, and it doesn't appear that novel ecosystems are being used to excuse degradation. Another issue was whether managers would be able to identify when and where novel ecosystems have arisen. Recently, the use of the term has highlighted the widespread likelihood of novel ecosystems (by one estimate, 50% and 80% of the terrestrial surface by 2100 and 2300 respectively (Ordonez *et al.* 2024)) due to new climatic conditions outpacing migration capacities and/or existing climate relationships becoming disaggregated. This emphasises the urgent need to understand novel ecosystem emergence and functioning and the implications for conservation and restoration.

Two issues remain around the novel ecosystem concept that have pertinence for conservation and restoration policy and practice:

1 RESTORATION TARGETS

Restoration and conservation generally focus on habitats or ecosystems as seen in the guidelines that have proliferated during the UN Decade on Ecosystem Restoration. For example, the Society of Ecological Restoration has "Standards and Guidelines" for ecological restoration based on "native Indigenous ecosystems". Although widely adopted, this remains a contentious approach, considering the difficulties associated with adopting rigid standards, which do not recognise the dynamic nature of ecosystems under normal conditions. Not taking account of environmental change could lock sites into being conserved or restored around a set of species that could lead to system collapse.

2 NON-NATIVE SPECIES

It has long been recognised that a large majority of non-native species cause no observable harm. However, some cause massive problems, as highlighted by the recent IPBES Invasive Alien Species Assessment. We are still poor at predicting which non-natives will become invasive, and this uncertainty will increase in a changing climate. This raises issues concerning the extent to which novel ecosystems could become strongholds for future invasive non-native species as well as how ecosystem functioning will be affected where non-natives have few predators, pathogens and/or herbivores.

▼ Welsh mudwort *(Limosella australis)*

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CASE STUDY

A Welsh harbour

PORTHMADOG HARBOUR, CARDIGAN BAY, NORTH WEST WALES

Porthmadog became one of the main ports for the Welsh slate trade in the 19th century. When returning from overseas, ships needed to unload their ballast; initially, these mixed rocks (e.g. Scandinavian granites, sandstones, limestones) formed quaysides around the harbour. Once complete, an alternative unloading point was required. A sandbank to one side of the main channel was deemed suitable, and from these sandy origins and timber foundations, Cei Balast (Ballast Island) came into being.

Perhaps Cei Balast is the archetypal novel ecosystem: over the years it has become a self-sustaining, functional "Dense continuous scrub" ecosystem of UK native plants (e.g. *Prunus spinosa*, *Crataegus monogyna*) and species from around the world (e.g. *Matricaria disciodea*, *Oenothera agg.*) on an abiotic stage that is entirely changed from the historical system.

Cei Balast may not raise conservation conundrums, but the wider Porthmadog environment does. In adjacent saltmarsh, a diminutive plant has taken up residence with only a few isolated Welsh populations – Welsh mudwort. Yet its common name and listing on Schedule 8 of the Wildlife and Countryside Act (1981) belies its non-native origins and likely introduction through ballast. Scientifically, mudwort is *Limosella australis*. What should become of this nationally scarce and rare plant that most likely arrived from eastern North America?

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CASE STUDY

A decommissioned quarry

PUSLINCH, ONTARIO, CANADA

This is a novel ecosystem from a local decommissioned quarry that was left to undergo succession before there were regulations about quarry closures. It is a mixture of species that are forming a mosaic of dry and wet alvars – which do not exist as a natural system in the species mixture seen here, and should not be in the area because there aren't many alvars locally (most of the quarried rock is well below soil surfaces). A red flower *Aquilegia canadensis* does colonise exposed rock but is not common in the area and is not considered as a local species. This was not a cultivar, so it is not a garden escape (it can disperse on wind or far ranging animals).

WHAT'S NEXT IN STUDYING NOVEL ECOSYSTEMS?

As the evidence for functioning, and self-sustaining novel ecosystems continues to accumulate there is a hard question to be answered – if we can't compare a novel ecosystem's ecological, conservation and/or restoration value by similarities to existing or historical examples, what can we measure? Increasingly work is looking at the scale of the whole system rather than focusing on species identity – are systems properties being exhibited, such as resilience to perturbation. Indeed, is the resilience in the system unhelpful or helpful for conservation and restoration goals? The following questions are a priority amongst those which need to be asked:

- How do we identify novel ecosystems – and does it even matter if novelty is going to be the new normal?
- How and when does something become a novel ecosystem?
- Should we deliberately produce novel ecosystems as part of conservation and restoration programmes, or must they exclusively be accidental consequences of anthropogenic drivers?
- How does conservation/restoration guidance need to evolve to take account of the reality of novelty?

This is an exciting area for research, and its philosophical roots can be equally applied to any system which needs to be managed. Importantly, understanding these systems and acting on the evidence gained is pressing in our rapidly changing environment. ✺

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