Meetings

Nutrient responses to ecosystem disturbances from annual to multi-millennial timescales

Novus Research Coordination Network annual meeting report, May 2013

The Novus Network annual meeting was held at H. J. Andrews Experimental Forest in Oregon, USA, from 22 May to 24 May 2013. The topic was: 'Nutrient responses to ecosystem disturbances from annual to multi-millennial timescales'. The 2013 workshop brought together 28 researchers from 21 institutions spread across three continents. The participants – 17 faculty members, five postdoctoral researchers and four graduate students – were chosen for variety in background, methods and research programs. All those involved focus on the questions of plant and ecosystem response to disturbance, but at a variety of temporal scales – ranging from one to million year spans. The network is open to any individual with an interest in ecosystem response to disturbance.

The goals of the network are: (1) to unify research and records of ecosystem disturbance and response across multiple timescales, from initial seasonal responses to long-term, millennial dynamics and longer; (2) to synthesize current conceptual research in the area of ecosystem disturbance and biogeochemical response; (3) to propose new methodologies; and (4) to guide young scientists.

Unifying ecosystem disturbance research across a variety of temporal scales

Many studies of ecosystem disturbance focus on short temporal scales: the years to decades following a given event. These studies have provided detailed insights into how plant species, landscapes and communities respond mechanistically to disturbance – how plant nitrogen (N) isotopic ratios change through succession, or how ash fall can increase soil phosphorus. For example, the 1988 Yellowstone fires have provided immense direct knowledge on post-fire ecosystem response (Turner *et al.*, 2003) for a variety of plant species, ecosystem processes, successional trajectories and developmental pathways. Yet, it is only a *c.* 25-yr record in a system that operates on multi-century timescales.

Biological processes which happen on short timescales may leave a long temporal legacy. For example, N fixation in certain early post-disturbance plant species (e.g. many *Lupinus* spp.) may have important, long-lasting effects on community organization and subsequent functioning. Given the long time-span required for many ecosystems to return to their previous state, and our limited observational record, there are two options if we want to gain an understanding of longer term ecosystem and biogeochemical dynamics post-disturbance: (1) space-for-time studies, which have many inherent limitations associated with comparison between separate locations; and (2) 'paleo' methods: sediment records, pollen records, ice cores, tree rings and other long-term records, which record the ecosystem biogeochemistry in a repeated fashion.

> *'A true understanding of long-term post-disturbance ecosystem dynamics will require using our knowledge of short-term, mechanistic processes to interpret long-term records of ecosystem disturbance and recovery.'*

Long-term paleo records are extraordinarily powerful for examining the relationship between ecosystems, disturbances and climate, but they lack a fine temporal resolution and have difficulty addressing questions related to single disturbance events and the associated ecosystem response for a variety of reasons. For example, mixing in lake sediments can limit the temporal resolution of cores and, although isolation of a single event is possible, it is difficult to estimate salient ecosystem-level variables, such as mortality, regeneration, net primary production (NPP) and others. As a result, paleo methods are often correlative, rather than mechanistic. Thus, it is difficult to reconstruct the short-term, mechanistic pathways which lead to the long-term ecosystem dynamics observed in paleo records, and equally difficult to extrapolate our short-term observations into long-term predictions of ecosystem development. Given the scale of global changes expected over the next century, we need both the climate/ecosystem relationship from paleo records and the mechanistic understanding from disturbance ecology, and, indeed, the strengths of one perspective can be used to address the weaknesses of the other (Fig. 1). New methods and conceptual models are required to link these two powerful perspectives. The purpose of this meeting, and the network, is to create these methods and linkages.

Several areas which would benefit from better conceptual models and new methods were identified at the meeting. First, better methods for the identification of disturbances in the biogeochemical record are needed. A major theme identified here was the 'complacency' of many ecosystems to disturbance. Many seemingly major disturbances have either a surprisingly low and/or transient effect on much of the biogeochemistry. This could either be because

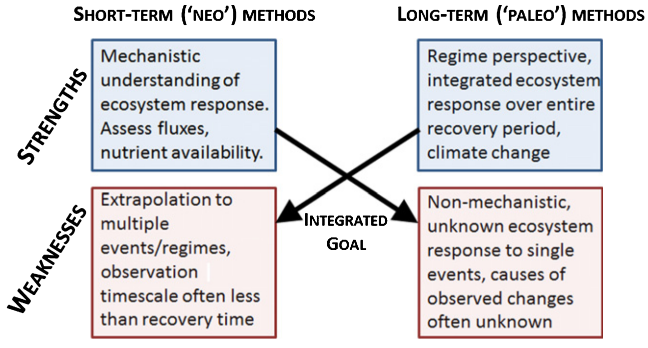

Fig. 1 The strengths and weaknesses of each perspective on ecosystem biogeochemical response to disturbances are complementary.

the ecosystem response to disturbance is in fact small or that it is not recorded in the paleo data. For example, the severe mountain pine beetle epidemic in North America has had surprisingly little impact on aquatic N fluxes (Rhoades *et al.*, 2013) and carbon emissions (Brown *et al.*, 2010). Some insect outbreaks can be identified via tree rings, but these methods are species and site specific and limited in their ability to detect spatially limited events. Jesse Morris (University of Idaho, Moscow, ID, USA), a Novus-sponsored post-doctoral researcher, presented interesting work from the southern Rocky Mountains, USA, detailing the sensitivity of lake sediment records to disturbances (Morris *et al.*, 2013). As the biogeochemical record preserved in paleo data sources presents the integration of all disturbance processes on ecosystem development, we need to have these important processes represented in our disturbance history reconstructions.

Moving to a mechanistic understanding of the observed dynamics in paleo records will require not only the identification of individual events, but also an understanding of the characteristics of these disturbances. Without a knowledge of disturbance characteristics (such as biomass consumption during a fire, percentage mortality or intensity) or the immediate post-disturbance environment (e.g. erosion, soil characteristics), it is difficult to ascribe a mechanistic basis to the observed dynamics in the paleo record. Bridging this gap by the creation of better proxies for spatial extent, vegetation mortality, severity (e.g. NPP reduction) or other salient variables would greatly aid in linking our knowledge of ecosystem response to individual events with longer term paleo records already in existence. For example, the morphology, amount and variability in lake sediment charcoal may be useful in determining historical fire characteristics, but is still subject to difficulties in determining catchment size, questions regarding post-fire erosion, post-disturbance vegetation establishment and other unknowns.

Moving from disturbance characteristics to post-disturbance recovery in plant communities is also difficult. The key issue here is tracing biogeochemical fluxes and processes in the environment, as opposed to simply stocks. Laci Gerhart-Barley (Kansas State University, Manhattan, KS, USA), another Novus post-doctoral researcher, reported on the new methods, known limitations and potential for the use of isotope measurements from tree rings as a means to estimate nutrient dynamics in plant communities (e.g. Hart & Classen, 2003; Bukata & Kyser, 2007). Recent human disruptions to the global N cycle have been immense, and the consequences of this unprecedented biogeochemical alteration have been difficult to quantify. Strong theoretical predictions of N saturation have been challenging to confirm, and the assessment of the severity of changes has been limited by the lack of long-term 'baseline' biogeochemical data. Wood $\delta^{15}N$ analysis is particularly valuable in this regard, as tree ring chronologies can stretch back thousands of years, providing baseline data before large-scale impacts, such as the Industrial Revolution, and smaller scale changes in local land-use patterns. In addition, studies of wood $\delta^{15}N$ can be compared with syntheses of modern foliar and soil N cycling, scaling plant physiological responses from individual organism responses to stand-level patterns of ecosystem N cycling. For example, wood $\delta^{15}N$ data can be used to assess nutrient translocation within an individual tree (e.g. Elhani *et al.*, 2003), coupled to $\delta^{15}N$ of other ecosystem pools to define stand-level nutrient dynamics (Choi *et al.*, 2007) or coupled with lake sediment data to characterize ecosystem N cycling in response to changing disturbance regimes over the course of 150 yr (McLauchlan *et al.*, 2007). Wood $\delta^{15}N$ has been used to document the establishment of avian nesting colonies in coastal forests (Lopez *et al.*, 2010) and combined with other wood chemical analyses to model the historical prevalence of acid rain (Kwak *et al.*, 2011). These examples document the myriad uses across multiple scales for which wood $\delta^{15}N$ data can provide critical insight, both for current analyses and for modeling historical conditions. At this point, published wood $\delta^{15}N$ studies are scattered geographically around the globe and intellectually across disciplines. Consequently, wood N techniques are still relatively underdeveloped, but have the potential to provide important information on plant physiological responses under natural conditions, and in response to increased N deposition as a result of anthropogenic activity and following disturbance events. The analysis of $\delta^{15}N$ trends in long-term wood chronologies and chronosequences will extend our knowledge of N dynamics, tree physiology and ecosystem response under current and historical climate conditions and disturbance regimes.

Conclusions

A true understanding of long-term post-disturbance ecosystem dynamics will require the use of our knowledge of short-term, mechanistic processes to interpret long-term records of ecosystem disturbance and recovery. This will require new methodologies, new proxies for disturbance and ecosystem characteristics, and new conceptual frameworks. This meeting discussed several promising methodologies, developed testable conceptual models to link short- and long-term disturbance theory, and fostered collaboration and constructive networking between researchers at a variety of organizations and career stages.

A formal manuscript detailing the conceptual development of the conference is forthcoming. Any interested parties are encouraged to become involved in the network; for more information, visit the Novus website at http://novusrcn.wordpress.com.

Brian Buma

University of Alaska Southeast, 11120 Glacier Hwy, Juneau, AK 99801, USA
(tel +1 907 796 6200;
email brian.buma@uas.alaska.edu)

References

Brown M, Black TA, Nesic Z, Foord VN, Spittlehouse DL, Fredeen AL, Grant NJ, Burton PJ, Trofymow JA. 2010. Impact of mountain pine beetle on the net ecosystem production of lodgepole pine stands in British Columbia. *Agricultural and Forest Meteorology* **150**: 254–264.

Bukata AR, Kyser TK. 2007. Carbon and nitrogen isotope variations in tree-rings as records of perturbations in regional carbon and nitrogen cycles. *Environmental Science and Technology* **41**: 1331–1338.

Choi W, Chang SX, Bhatti JS. 2007. Drainage affects tree growth and C and N dynamics in a minerotrophic peatland. *Ecology* **88**: 443–453.

Elhani S, Fernandex Lema B, Zeller B, Brechet C, Guehl JM, Dupouey JL. 2003. Interannual mobility of nitrogen between beech rings: a labeling experiment. *Annals for Forestry Science* **60**: 503–508.

Hart SC, Classen AT. 2003. Potential for assessing long-term dynamics in soil nitrogen availability from variations in delta 15N of tree rings. *Isotopes in Environmental and Health Studies* **39**: 15–28.

Kwak JH, Lim SS, Chang SX, Lee KH, Choi WJ. 2011. Potential use of $\delta^{13}C$, $\delta^{15}N$, N concentration, and Ca/Al of *Pinus densiflora* tree rings in estimating historical precipitation pH. *Journal of Soils and Sediments* **11**: 709–721.

Lopez C, Mizota C, Yamanaka T, Nobori Y. 2010. Temporal changes in tree-ring nitrogen of *Pinus thunbergii* trees exposed to Black-tailed Gull (*Larus crassirostris*) breeding colonies. *Applied Geochemistry* **25**: 1699–1702.

McLauchlan KK, Craine JM, Oswald WW, Leavitt PR, Likens GE. 2007. Change in nitrogen cycling during the past century in a northern hardwood forest. *Proceedings of the National Academy of Sciences, USA* **104**: 7466–7470.

Morris JL, Roux PCL, Macharia AN, Brunelle A, Hebertson EG, Lundeen ZJ. 2013. Organic, elemental, and geochemical contributions to lake sediment deposits during severe spruce beetle (*Dendroctonus rufipennis*) disturbances. *Forest Ecology and Management* **289**: 78–89.

Rhoades CC, McCutchan JH Jr, Cooper LA, Clow D, Detmer TM, Briggs JS, Stednick JD, Veblen TT, Ertz RM, Likens GE *et al.* 2013. Biogeochemistry of beetle-killed forests: explaining a weak nitrate response. *Proceedings of the National Academy of Sciences, USA* **110**: 1756–1760.

Turner MG, Romme WH, Tinker DB. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and Environment* **1**: 351–358.

Key words: biogeochemistry, disturbance, ecosystem dynamics, fire, pollen, resilience, sediment.