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Review Paper

The ecosystem services and biodiversity of novel ecosystems: A literature review

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1. Introduction

Anthropogenic landscapes contain novel ecosystems (NE) that differ substantially in structure and/or function compared to their historical conditions (Ellis and Ramankutty, 2008; Lugo, 2009; Hobbs et al., 2009). Such novelty may impact the ecosystem services (ES) and biodiversity that directly or indirectly benefit society (Collier, 2014). Indeed, many NE are the result of actions intended to modify how certain services are provided. In a human-dominated world, there is a pressing need to integrate research on the patterns, processes, functions, and benefits or detriments of NE. Given the increasing influence of these concepts (NE, ES, and biodiversity) on contemporary conservation and management (e.g., Johnson, 2002; Graham et al., 2014; Muñoz-Erickson et al., 2014), the need for a synthesis of the research linkages between NE, ES and biodiversity is acute, particularly research addressing the services and disservices generated by NE.

The scientific literature on NE continues to grow (Fig. 1). Initially applied to ecosystems containing "species compositions and relative abundances that have not occurred previously within a given biome" (Hobbs et al., 2006), the exact meaning of novelty continues to be debated, including whether novelty is always the consequence of human actions (Hobbs et al., 2006, 2009; Lugo, 2009), or whether NE that are designed differ from those that self-assemble (Higgs, 2017). At another level, the discussion surrounding novelty also speaks to the persistent challenge that land managers, policy makers, and conservation scientists face when defining relevant and appropriate management goals in altered ecosystems (Zedler, 2007). As proposed in the literature on no-analog ecosystems (Williams and Jackson, 2007) and reconciliation ecology (e.g., Rosenzweig, 2003), management of NE may require novel approaches (e.g., Firn et al., 2010) including those that may move the system further

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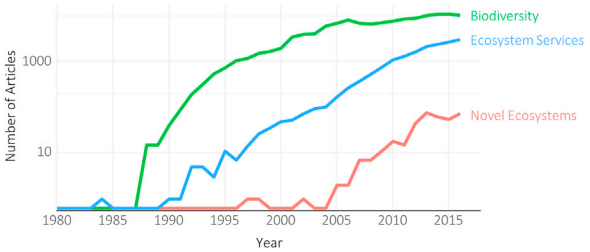

Fig. 1. Annual number of publications that referenced novel ecosystems (NE), biodiversity (B), or ecosystem services (ES) in their title or abstract, between 1980 and 2016. Values are log-scaled for comparison.

from historical conditions (Truitt et al., 2015). Some land managers have shifted away from restoring to a historical reference baseline and towards the management of natural capital, ecosystem functions, and ES (Jackson and Hobbs, 2009; Perring et al., 2013). Others have advocated for restoring ecological processes over structure and composition (Nilsson and Aradottir, 2013; Harris et al., 2006) or embracing "hybrid" ecosystems comprised of both historical and novel elements (Hobbs et al., 2009; Higgs, 2017). Those embracing NE have tried to look beyond historicity to identify specific values that result from NE (Light et al., 2013) including habitat that supports biodiversity or services such as carbon sequestration (Harris et al., 2006).

Ecosystem services has emerged as an integrated framework for managing ecosystems in an increasingly human-dominated world (Harris et al., 2006; Lele et al., 2013). Defined as the benefits natural systems provide to humans (Balmford et al., 2002), this "nature for people" paradigm (Mace et al., 2012) has been increasingly adopted by governments and nonprofit organizations to frame, plan, and allocate resources (Posner et al., 2016). It must be noted, however, that the issue of service valuation continues to be one of the most contested aspects of ecosystem services (Dempsey and Robertson, 2012). There is a notable divide between those that see ecosystem function as something that can be quantified in monetary terms (e.g., Polasky and Segerson, 2009) versus those that explicitly reject one-dimensional valuation schema as being both impossible and undesirable (Pascual et al., 2017).

The rapid adoption of ES has led to debate over how services should be grouped and whether categories of services should be considered equivalent or hierarchical (La Notte et al., 2017). The four categories presented in the Millennium Ecosystem Assessment (MEA, 2005) continue to be the most widely used, though numerous variations have since been proposed. Notably, the Economics of Ecosystems and Biodiversity report (TEEB, 2010) expanded on the MEA to address the link between biodiversity and ES (De Groot et al., 2010). Haines-Young and Potschin (2010) illustrated this connection using a "service cascade" model (also see Boerema et al., 2017). As shown in Fig. 2, biophysical structures and processes (e.g., biodiversity) underlie ecosystem functions (e.g., the MEA's supporting services) that create services or disservices (e.g., the MEA's provisioning, regulating, and cultural services) that directly or indirectly benefit or harm society. Institutions, social values, and individual preferences shape the polices, decisions, and behaviors that can intentionally or unintentionally lead to novel ecosystems.

The ES literature seeks to catalog the benefits ecosystems provide to humans for the sake of their conservation and sustainable use (Costanza et al., 1997; Daily, 1997a; MEA, 2005) yet the link between biodiversity and ES is complex and in some cases tenuous (Ricketts et al., 2016). Management that emphasizes ES may conflict with the aim of conserving biodiversity (Bullock et al., 2011; Mace et al., 2012; Zedler et al., 2012), not least because of the distinctly instrumental lens favored in the ES literature. Maximizing individual services can negatively impact other services or underlying biological diversity, although synergies between ES and biodiversity are possible given the right ecological and social conditions (Adams, 2014; Smith et al., 2017). Some ecologists contend that abandoning traditional restoration in favor of ES is dangerous as areas of high

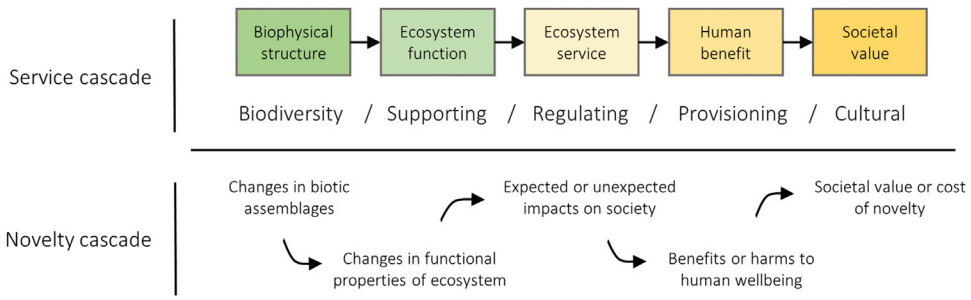

Fig. 2. The service cascade illustrates the benefits society derives (right) from the structure and function of ecosystems (left). Novel ecosystems (NE) contain species assemblages that historically did not exist within a given biome, and as a result, can alter both ecosystem function and resulting services.