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The Ecosystem Services and Biodiversity of Novel Ecosystems: A literature review

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Review Paper

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

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ABSTRACT

Scientists, policy makers, and managers use ecosystem services and biodiversity metrics to inform management goals of novel ecosystems. Fragmented knowledge of the ecosystem services provided by novel ecosystems contributes to disagreement over these systems and how they should be managed. To address this gap, we conducted a systematic review of refereed articles to understand how novel ecosystems have changed ecosystem services and biodiversity. Despite anthropogenic drivers of change, we found that the literature on novel ecosystems is focused on ecological rather than social aspects of novel systems. Our review highlights the frequency that novel ecosystems enhance both ecosystem services and biodiversity. More than two-thirds of studies reported biodiversity equal to or above the reference state, while the portion of studies reporting increased cultural, provisioning, and regulating services was even greater. Still, we urge caution in interpreting these trends, as they exist in part due to degraded ecosystem baselines and inconsistent framing. Finally, the wide range of management recommendations we reviewed reflects both the diversity of novel ecosystems and substantial disagreement among researchers and managers about what novel ecosystems actually mean for society.

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

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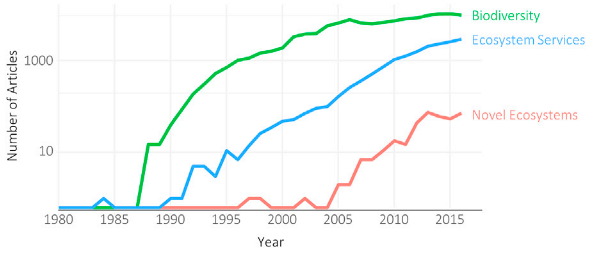

Fig. 1. Annual number of publications that referenced novel ecosystems (NE), biodiversity (B), or ecosystem services (ES) in their title or abstract, between 1980 and 2016. Values are log-scaled for comparison.

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 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

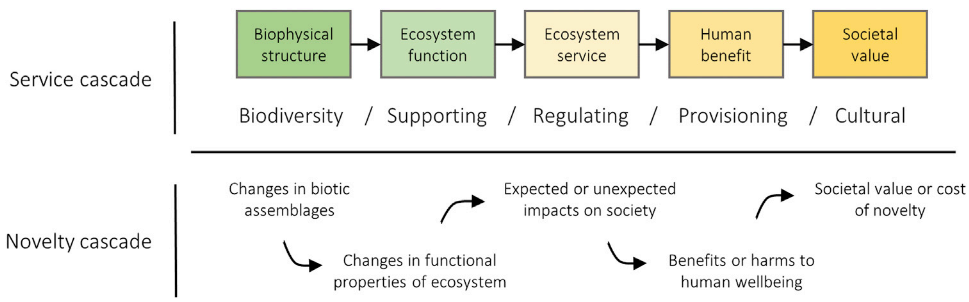

Fig. 2. The service cascade illustrates the benefits society derives (right) from the structure and function of ecosystems (left). Novel ecosystems (NE) contain species assemblages that historically did not exist within a given biome, and as a result, can alter both ecosystem function and resulting services.

Table 1
Studies on novel ecosystems and that measured changes in biodiversity or ecosystem services were coded by biome, reference condition, assembly, framing, and management implications.

Metric	Categories	Reference
Location	Latitude/longitude; Country	N/A
Biome (historical)	Aquatic; Desert; Forest; Grassland; Tundra; etc.	Campbell (1996)
Methodology	Quantitative; Qualitative; Mixed-methods, etc.	N/A
Baseline	Historical/natural; Abandoned/modified	Hobbs et al. (2014)
NE assembly	Self-assembled; Designed; Hybrid	Higgs (2017)
Service framing	Service; Disservice; Tradeoff; Neutral; Not applicable.	N/A
Management recommendation	Manage for novelty; Manage against novelty; Tolerate novelty; Not applicable	Truitt et al. (2015)
Ecosystem metric	Biodiversity; Supporting (nutrient cycling, photosynthesis, primary production, soil formation, water cycling, etc.); Regulating (climate regulation, disease regulation, erosion regulation, natural hazard regulation, pollination, water regulation, etc.); Provisioning (biochemical, genetic resources, fiber and fuel, food, etc.); Cultural (aesthetic value, recreational, sense of place, etc.)	Millennium Ecosystem Assessment (2005), The Economics of Ecosystems and Biodiversity (TEEB, 2010; De Groot et al., 2010)
Direction of change (relative to baseline)	Increase; Decrease; Both (increase & decrease); None	N/A

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 biodiversity do not necessarily correlate to areas that maximize ES (Naidoo et al., 2008). This has led others to argue that the focus of ecosystem management should be on ecosystem functions, which proponents say can be maintained despite changes in biodiversity (Cadotte et al., 2011). On the other hand, there may be unforeseen tradeoffs between biodiversity and ecosystem functions provided by introduced species (Maes et al., 2012). Further, the baseline from which change is measured makes a critical difference in determining the extent and direction of change in BES, although it is sometimes ill-defined in ecosystem studies (Gonzalez et al., 2016).

These tensions compel a closer examination of the scientific literature on NE and how biodiversity and ES continue to inform the research and management of NE. Because NE are often found in anthropogenic landscapes where social values are embedded in land use decisions, it is important to assess the management and restoration goals of NE as a value-based activity rather than a value-neutral "scientific" process (Davis and Slobodkin, 2004). Thus, the objective of this review is to understand where and how the concepts of NE and the biodiversity and ecosystem services (BES) cascade intersect in the empirical research. We first ask, when, where, how, and what types of BES were studied? Second, what are the reference conditions and types of assembly in the novel systems, and how did BES provisioning change relative to the baseline? Third, how are BES framed by the authors and did this align with any proposed management recommendations? To do so, we apply the service cascade model (Fig. 2) to record how studies of NE have approached BES, from measuring change in ecosystem structure on one end of the cascade to measuring changes in social value on the other. The intent of this synthesis is to motivate and guide future research that will advance the conservation of increasingly human-dominated ecosystems.

2. Material and methods

We systematically reviewed the literature on NE up to October 2016. Using the search engine Scopus, we identified 355 articles that contained the term "novel ecosystem" in either the title, abstract, or keywords. Of those papers, 253 were removed because they (a) did not report changes in BES, or (b) were not empirically-based or modeled. Coding of articles was based explicitly on the data and interpretations presented by authors in order to avoid individual coder bias and to maintain the original spirit of the study. To ensure inter-reviewer reliability, each paper was reviewed independently by two reviewers, and a third reviewer was assigned to address any discrepancies.

We recorded measures of biodiversity alongside ES according to the service cascade model for each study, recognizing the important normative differences between these indices. The connection between NE and ES in the reviewed paper was determined to be either explicit (e.g., the term "ecosystem service" was used to describe the units of analysis) or implicit (e.g., ES was not used in the paper, but authors reported changes in biodiversity, ecosystem functions or ES that indirectly or directly contribute to human well-being, as described in TEEB, 2010). As illustrated in Fig. 2, we approach biodiversity, supporting, regulating, provisioning and cultural services as indices that occur along a spectrum relating to human benefits and values.

Table 1 summarizes the information we coded in each article. The geographic location and analog biome of the study NE were categorized using the typology in Campbell (1996), including aquatic, desert, forest, grassland, and tundra biomes. We identified the country in which the study occurred and noted the income ranking of that country as classified by the World Bank (Fantom and Serajuddin, 2016). The reference state of the NE was characterized as historical/natural or abandoned/modified based on definitions from Higgs et al. (2014) and Jackson and Hobbs (2009) on change within and outside a historical range of variation. For instance, the baseline was characterized as abandoned or modified if authors explicitly mentioned past human disturbance such as drained peatlands, secondary forest, or abandoned agricultural fields. Following Higgs (2017), the assembly of the system was described as self-assembled, designed, or a hybrid, including agricultural and urban ecosystems (Alison, 2012).

We recorded metrics used to measure each BES and coded whether authors reported an increase, decrease, or no relationship in the provision of BES in the novel state compared to provision in the reference state. In some cases, both an increase and decrease were observed (e.g., when multiple metrics were used to report changes in a BES). If the authors reported more than one measure within the same BES (e.g., richness and abundance), we described those measurements as a single observation to avoid pseudoreplication. We coded the overall normative framing of the study to understand how authors described the impact of the novel systems on BES, i.e., did the change to novelty provide a service for humans, a disservice, or tradeoffs among services? Finally, we coded the management recommendations made by the authors according to the typology proposed by Truitt et al. (2015): managing against novelty (e.g., active restoration), tolerating novelty (e.g., monitoring), or managing for novelty (e.g., assisted migration, remediation).

We report our observations as both the total and the relative proportion within the reviewed papers. Unless otherwise specified, these values represent either (a) the count/portion of articles that met our review criteria or (b) the count/portion of changes in a specific BES category. We use chi-squared tests to describe the association between coded variables. Tests were performed using the *chisq.test* function in R (R Development Core Team, 2016). Pairwise frequencies were tested using the *chisq.post.hoc* function from the *fifer* package (Fife, 2017). Since the aim of our review was primarily descriptive, and the majority of the studies we reviewed reported changes in only a single BES category, we did not explicitly control for pseudoreplication (e.g., via random-effects). Observations were aggregated and graphed using the *ggplot2* package in R (Wickham, 2009). We present stacked bar charts as both absolute counts and as proportions.

3. Results

One hundred and five articles met the review criteria stated above. The studies reviewed were authored between 2007 and 2016. Approximately three-fourths of the articles measured changes in biodiversity (76%), primarily measured as changes in species abundance or richness; half of studies measured changes in ES alone (45%); and one-fifth measured both biodiversity

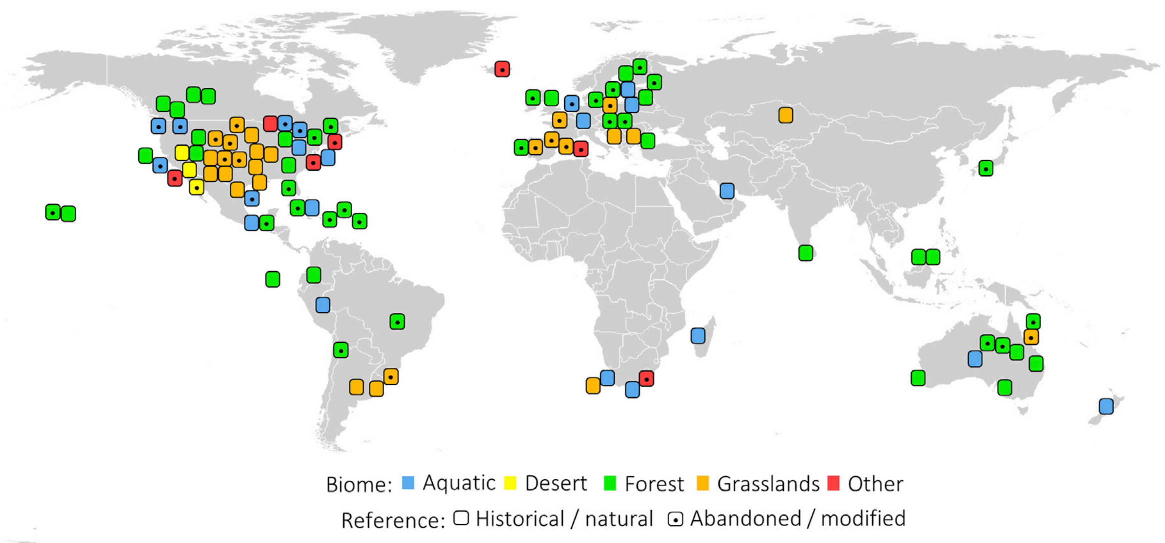

Fig. 3. Novel ecosystems where biodiversity and ecosystem services (BES) have been studied. Studies were most common in Europe and North America. Changes in BES were frequently reported in reference to abandoned/modified ecosystems, particularly in Europe and in some places in the North America.

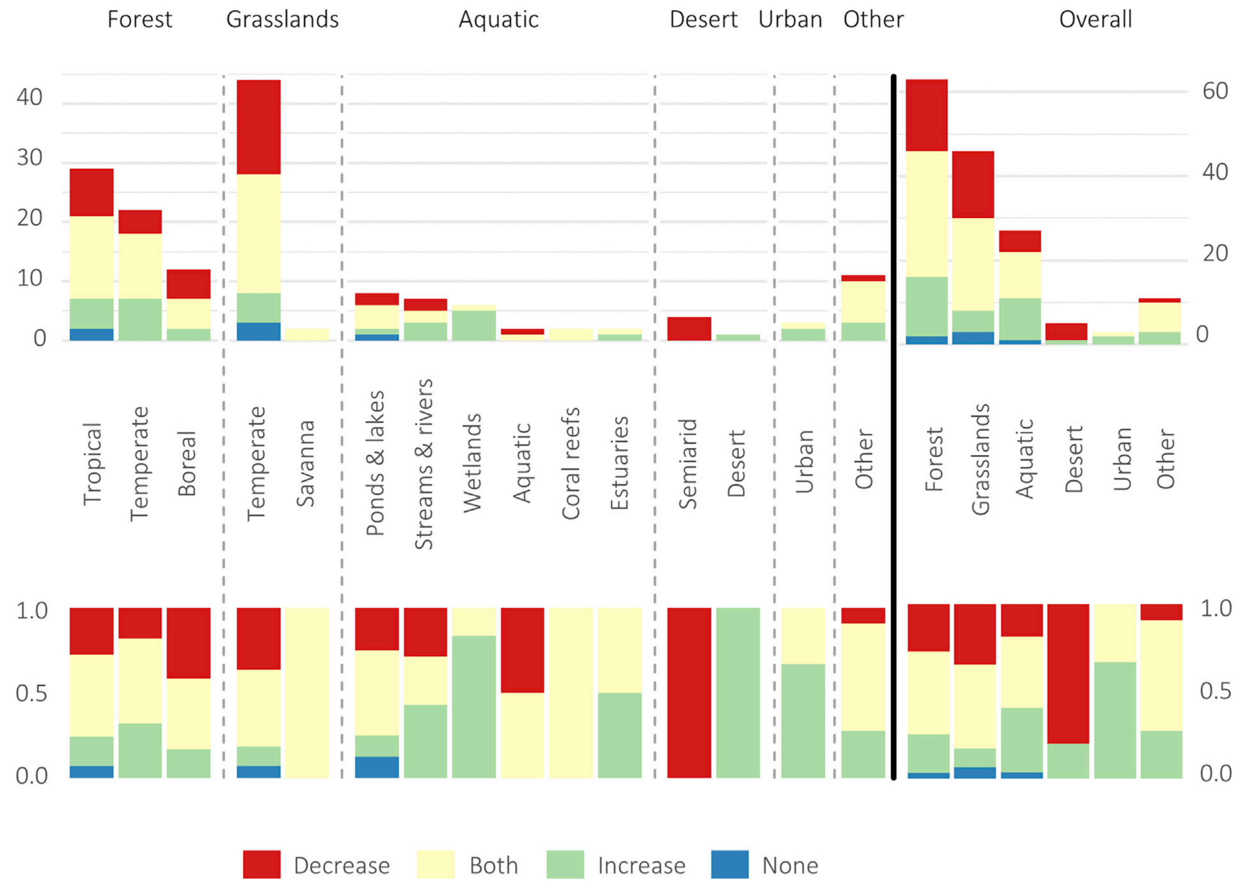

Fig. 4. Changes in biodiversity and ecosystem services by biome and sub-biome. Count (top) and proportion by category (bottom) of ecosystem services and biodiversity by relative change from the reference system. "Increase" and "decrease" represent clear directional changes in the BES metric; "Both" denotes cases in which both increases and decreases were reported; "None" denotes no reported or identified change. The majority of studies on novel ecosystems occurred in forests, grasslands, and aquatic biomes.

and ES (21%). Half of the 105 articles reviewed (45%) addressed ES explicitly while the remainder made the connection to ES implicitly. In total, these studies reported 157 discrete measures of BES.

3.1. What novelty?

The NE described in these studies ranged from human-designed (e.g., artificial ponds used for irrigation), to post-anthropogenic disturbance succession (e.g., old fields with successional forest), to currently disturbed ecosystems (e.g., an oil palm plantation). The novel systems were located on 6 continents, from tropical Borneo to Manhattan, New York (Fig. 3). The NE most commonly studied occurred within forest (45%), grassland (26%), and aquatic (20%) biomes (Fig. 4). A small number of studies focused on desert biomes (3%). Some systems (7%) did not fit into these common categories (e.g., fynbos, deciduous shrubland, urban). Despite the wide geographic range of the studies, most (77%) were conducted in developed countries in the northern hemisphere.

Of the 157 individual BES measures recorded, biodiversity was the most common (52%), followed by primary production (12%), nutrient cycling (8%), and soil formation (7%) (Fig. 5). All other ES measures were found in fewer than 2% of the studies. The majority of studies were observational (91%), while 7% were model-based, and the remainder (2%) used mixed-methods.

3.2. Novelty compared to what?

Fifty-three percent of papers compared the novel system to a historical reference while the remainder compared novelty to an abandoned, modified, or other anthropogenically-influenced state. Studies that compared novelty to an abandoned or modified baseline were proportionally greater in Europe compared to North America (Fig. 3). One-third (34%) of studies described self-assembled novel systems, while the others were the result of human design or active management (21%), a hybrid of both (40%), or it was unclear from the authors' description (5%).

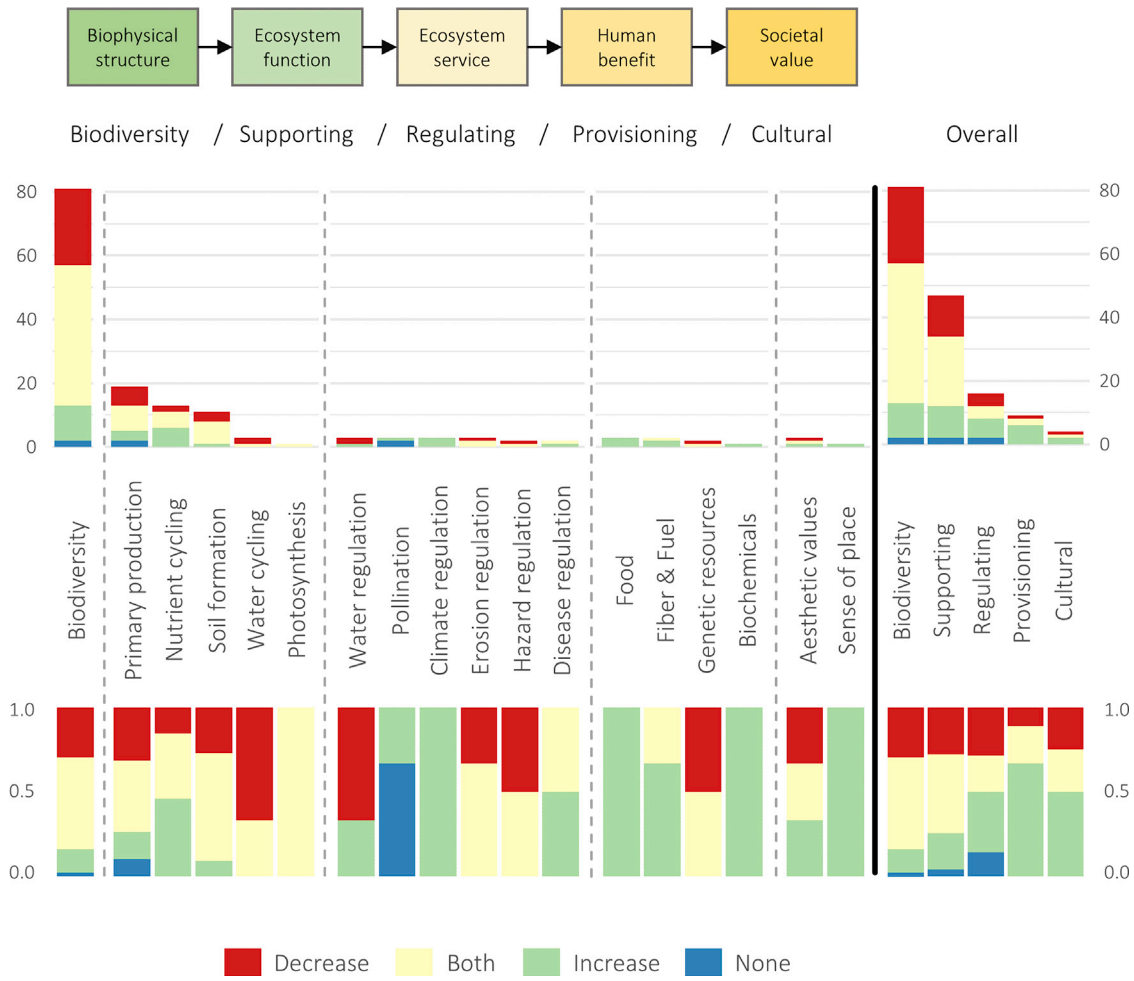

Fig. 5. Changes in BES by biodiversity or service category, arranged according to the service cascade model (top). NE studies focused on changes in BES located higher on the service cascade (biodiversity, supporting services). Increases in BES were proportionally higher at the lower end of the service cascade (regulation, provisioning, and cultural services).

Relative to reference conditions, 27% of studies reported a decrease in BES, 22% an increase, 47% changes in both directions, while 4% of studies of NE found no net change (Fig. 5). Aquatic studies reported twice as many BES increases compared to decreases (chi-squared = 9.59; df = 3; p = .02). By contrast, grassland and desert studies respectively reported 3 (chi-squared = 14.6; df = 3; p = .002) and 4 (chi-squared = 1.8; df = 1; p = .18) times more decreases. Forest studies reported roughly equal increases and decreases in BES, but more changes in both directions relative to other categories (chi-squared = 28.11; df = 3; p < .001). Directional changes in BES did not differ significantly between biomes (chi-squared = 47.3; df = 39; p = .17). There were significant differences between changes observed in BES stemming from historical versus modified and/or hybrid reference conditions (chi-squared = 17.5; df = 3; p < .001) (Fig. 6). Studies using a historical baseline reported nearly four times more negative changes in BES compared to studies using an abandoned or modified baseline. Likewise, studies using an abandoned or modified baseline reported nearly two times more increases in BES compared to studies using a historical baseline. BES changes did not differ among designed, hybrid, and self-assembled systems (chi-squared = 11.03; df = 6; p = .08).

3.3. Novelty: now what?

Changes in service provisioning by novel systems were most commonly characterized as tradeoffs (32%) or disservices (30%). Service (e.g., Quinn et al., 2014; Simaika et al., 2016) and neutral categorizations respectively represented 17% and 13% of the studies. Eight percent of the studies could not be categorized under this metric. Many authors expressed concern about the diminished capacity of a novel system to maintain native biodiversity or key ecosystem functions (e.g., Stromberg et al., 2007; Isbell and Wilsey, 2011), while others acknowledged that the current novel state actually protected the system from further degradation (e.g., Kueffer et al., 2010; Wolfe and Van Bloem, 2012).

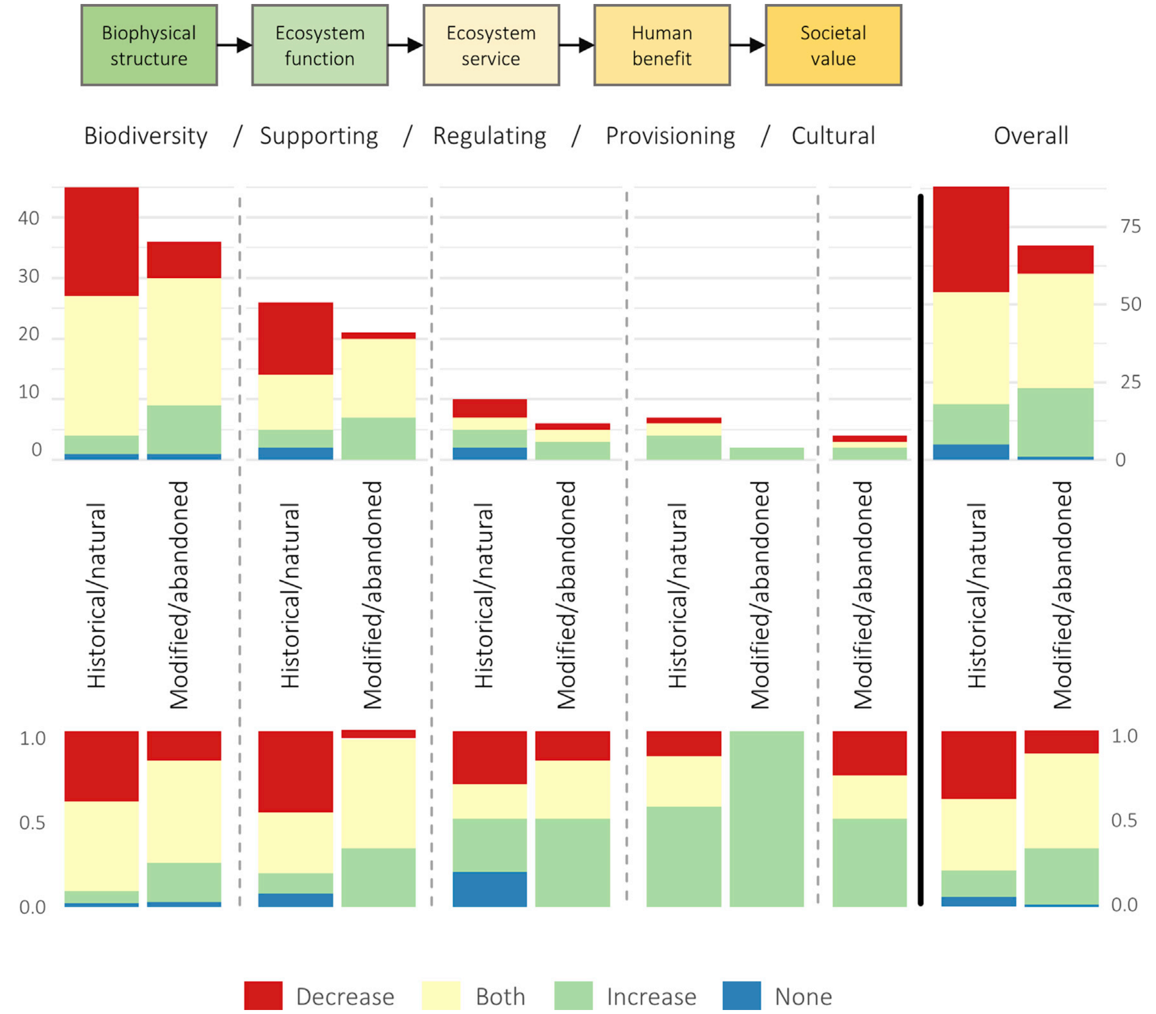

Fig. 6. Changes in BES for studies that used a historical/natural baseline to report changes versus studies that referenced a modified/abandoned baseline. Historical/natural reference conditions fall within the historical range of variation, while modified/abandoned reference conditions were altered due to past human disturbance.

Most (70%) of the studies reviewed described management implications (Fig. 7). Of these papers, slightly more recommended management for novelty (39%) compared to management against novelty (34%) while a quarter (27%) recommended tolerating novelty. Studies that recommended management for novelty were more likely to frame changes in ES as positive compared to those that recommended management against novelty (chi-squared = 119.51, df = 12, $p < .001$). For example, Simaika et al. (2016) found that artificial ponds in the Cape Floristic Region, South Africa, enhance dragonfly populations. Similarly, Fortier et al. (2016) recommend managing for hybrid poplar plantations in riparian buffers in Quebec, Canada to support forest conservation in other parts of the watershed.

4. Discussion

This review explored the state of the literature on NE and synthesized documented impacts of novelty on biodiversity and ecosystem services (BES). Despite an increased interest in these frameworks, especially in the conceptual literature, the number of empirical studies on NE that directly measure biodiversity and/or ES remains limited. Of the literature that does exist, our review highlighted both benefits and costs of NE on BES. Management recommendations were as varied as the novel systems assessed, and there remains substantial disagreement among researchers about what novel ecosystems mean for society. We highlight several key findings and implications for research below. Research recommendations are highlighted in Table 2.

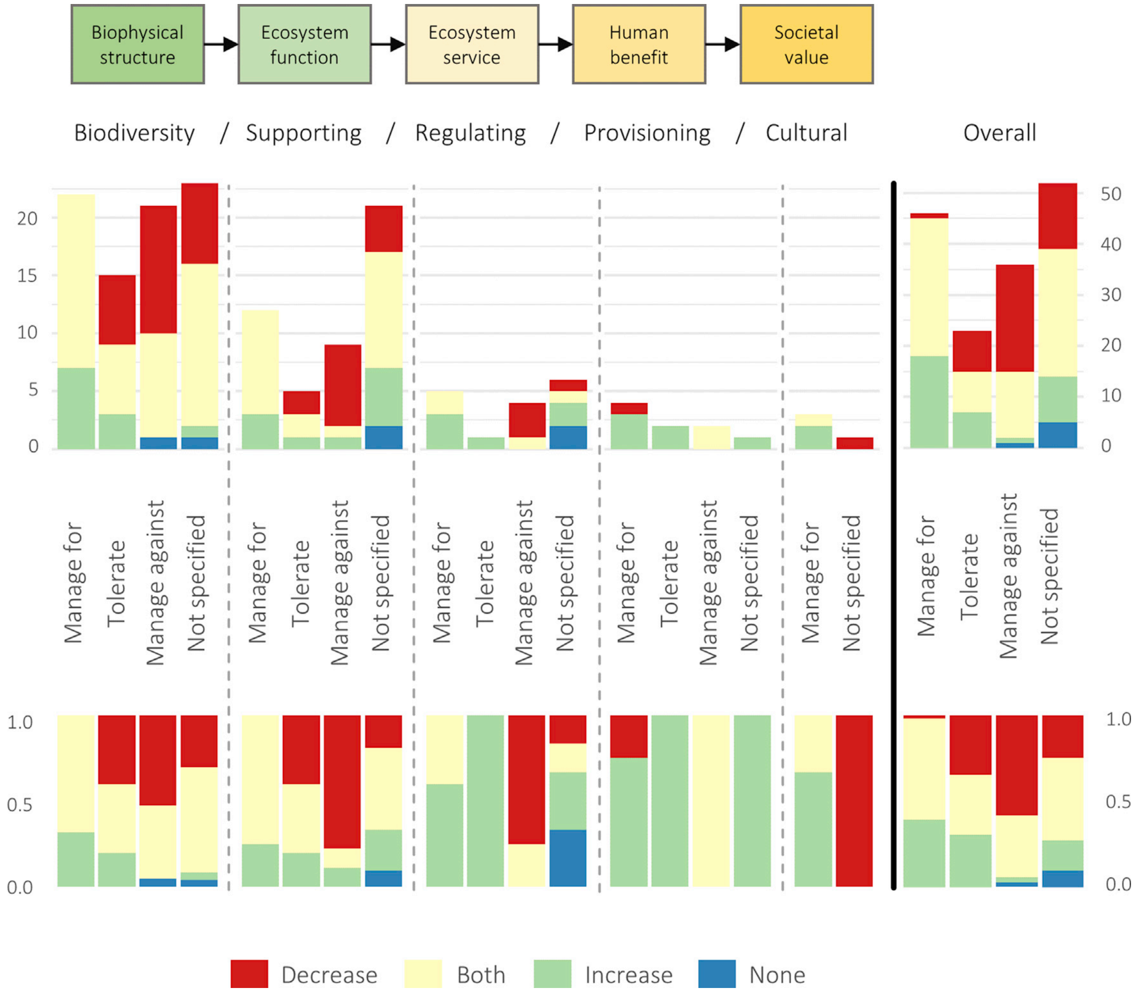

Fig. 7. Changes in BES grouped by authors' management recommendation for the NE. Studies that recommended management for novelty promoted active maintenance or enhancement of novel conditions, while studies that recommended management against novelty encouraged active restoration of conditions and functions similar to historical states. Some studies recommended tolerance, such as continued monitoring or directing resources to other critical needs.

4.1. Biophysical focus

Studies on NE were more likely to report characteristics or functions of the system not directly connected to human consumption and well-being (e.g., biodiversity, supporting, and regulating services, as opposed to provisioning or cultural services). Most studies on NE focused on changes in biodiversity compared to other ecosystem functions or services. Only 32% of the papers that measured biodiversity explicitly mentioned ES (and most of those only examined supporting services), which suggests that many authors approach NE from an exclusively biophysical frame. Of those studies that did measure ES, fewer considered impacts on ES further down the service cascade (Figs. 2 and 4), nearer the formation of social and economic values that underlie management decisions and institutional priorities. The preference for quantifying biodiversity and supporting services could be explained by several factors: (1) the concept of biodiversity is more established than ES, (2) biodiversity can be quantified through widely accepted methodologies and metrics, and/or (3) many ecologists may consider their work to reside within ecological, rather than socio-ecological systems, making the benefits provided to humans a secondary concern. Given that most NE are shaped by anthropogenic drivers, the lack of attention paid to social processes represents a clear gap that future cross-disciplinary research should address.

4.2. Novelty brings tradeoffs

The relationship between novelty and elements of the ecosystem services cascade was more neutral than expected. Our review suggests that novelty led to far more tradeoffs than outright positive or negative changes in BES. This finding runs counter to the frequently expressed concern that the term "novel" is just a stand-in for "severely degraded" (Murcia et al.,

Table 2
Research recommendations for measuring change in novel ecosystems.

1. More attention is needed on the effects of novel ecosystems on provisioning or cultural services, i.e. the impacts of novelty on social and economic values that underlie management decisions and institutional priorities.
2. Researchers should clearly identify the baseline from which ecosystem changes are measured, specifically identifying the extent of human influence on the system at the time measurements were begun.
3. Novel ecosystem research should be expanded to encompass multiple trophic levels and taxonomic groups to determine the extent to which homogenization versus substitution drive trends in novel ecosystems.
4. More research is needed in the Global South in order to better understand the impact of shifts to novelty globally, and particularly in places with vulnerable human populations.

2014). Studies were more likely to report benefits of novelty when from an abandoned or modified baseline versus historical or natural baselines. Whether BES increased or decreased from the baseline varied along the service cascade gradient. Researchers were more likely to report decreases of biodiversity and supporting services in NE and increases of cultural, provisioning, and regulating services (although there were notably few studies in our review that assessed these latter services).

The studies we reviewed frequently reported biodiversity in NE as similar or higher than reference conditions. Vellend et al. (2013) noted similar patterns, finding no trend of plant community richness declines over time, at least at the local scale. Yet these findings may not provide a complete picture. First, loss of biodiversity at higher trophic levels can have a profound effect on ecosystem function. For example, loss of wolves from Yellowstone National Park, USA, had a profound effect on species diversity and ecosystem function (Ripple and Beschta, 2012); similarly, loss of sea otters has had a significant effect on kelp forest abundance and diversity (Estes et al., 1998). Second, species richness can remain high in novel systems while also becoming more homogenous at larger spatial scales (McKinney and Lockwood, 1999; Olden et al., 2004). For example, Vellend et al. (2013) and Olden et al. (2004) identify homogenization for certain taxa in novel ecosystems; yet other researchers highlight species substitutions following ecosystem changes, as seen with the replacement of a native with a non-native pollinator for the Hawaiian ieie (Cox, 1983) and replacement of native with non-native plant species use by monarch butterflies (Lane, 1993). This tension highlights the need for further research across trophic levels and taxonomic groups to determine the extent to which homogenization versus substitution drive trends in novel ecosystems.

4.3. *Novel compared to what*

Most ecological studies focus on the estimated 25–40% of the terrestrial biosphere that remains as wildlands (Ellis, 2011), while much less attention has been placed on field sites that are actively used by humans (Martin et al., 2012). This bias omits a significant portion of the globe that has been more profoundly and directly altered by human activities. It may also lead to a conflation of modified or novel ecosystems with degraded systems. However, a striking number of studies on NE (~70%) reported biological richness and diversity equivalent to or exceeding reference baselines (Fig. 5). Increases in species richness may have resulted from species invasions that exceeded loss of natives for some taxa (e.g., Ellis et al., 2012) or species ranges that have shifted with changing climate (Dornelas et al., 2014).

A surprising number of studies (~55%) used an already-modified baseline system as the reference condition, a choice that may reflect the fact that many novel landscapes lack a relevant historical analog. This issue has been noted by others (e.g., Gonzalez et al., 2016), who show that syntheses of biodiversity change are often biased, including how species losses are counted during an ecosystem disturbance. For example, many European studies compared novel systems against a legacy of past land uses (e.g., Csecserits et al., 2011) or provided analogous functions of native systems that were already diminished (e.g., Quine and Humphrey, 2010; Calviño-Cancela and Neumann, 2015), which may bias research towards finding increases in BES provision in novel systems (e.g., Plieninger and Schaich, 2014; Komonen et al., 2016). By contrast, studies from North America tended to reference a historical baseline and were more likely to report diminished BES in the NE (e.g., Martin et al., 2014; Twidwell et al., 2016).

4.4. *Novelty through a narrow lens*

Our review brought to light certain biases in the NE literature that must be addressed to serve pressing needs for knowledge to inform management of novel ecosystems; we highlight two here. First, the literature reviewed rarely measured socio-cultural services. A deeper assessment of how and whether NE provide critical BES requires an integrated empirical approach, potentially involving interdisciplinary teams of scientists to effectively integrate biological, physical, and social science disciplines. Second, there are few studies in the Global South. The majority of the papers we reviewed (81%) were from “high income” countries (as defined by the World Bank), 16% from “upper middle income,” and 3% from “lower middle” or “low” income countries. As Martin et al. (2012) point out, the geographic bias of ecologists toward study sites in wealthy countries can be understood in the context of scientific and disciplinary precedent and funding biases. Yet with increasing population, urbanization, ecological vulnerability, and dependence on local ES in less-developed countries (United Nations Environment ProgramU, 2006; McGranahan et al., 2007; Baird, 2009), the emphasis on certain geographic areas could hamper conservation efforts in areas that maximize benefit to both people and ecosystems.

5. Conclusion

A growing body of literature emphasizes the importance of NE as a conservation framework (e.g., Hagerman and Satterfield, 2014) and the need to develop novel management that supports the biodiversity and ecosystem service provision of these systems (e.g., Seastedt et al., 2008; Simberloff and Vitule, 2013). Our review of NE revealed a number of important patterns in the literature. First, while many degraded systems are novel, not all novel systems are degraded. In the majority of studies reviewed, novel ecosystems supported biodiversity and ecosystem services, although this relationship requires further scrutiny. Second, the benefits and impacts of novelty were closely linked to how novelty was framed by authors. The consequences of novel ecosystems clearly depend on novelty "from what" and "because of what," issues that were often under-described. Third, while novelty is typically defined by changes in biotic assemblages, this definition may fall short of producing actionable and relevant research for an increasingly anthropogenic world. Ecosystem management is not conducted in a social vacuum and understanding the social drivers and implications of novelty is an important frontier that research on novel ecosystems must address.

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