A guide for integration of community ecology in landscape architecture:
The Ecological Filter Framework

Authors:

Breitschopf, Eva[1,2] (eva.breitschopf@uit.no); Clemmensen, Thomas Juel[2]; Bråthen, Kari Anne[1]

[1] UiT – The Arctic University of Norway, Department of Arctic and Marine Biology
[2] UiT – The Arctic University of Norway, Academy of Arts

Highlights:

1. We introduce a framework to support the integration of ecology in landscape architecture. This framework is based in and expanding from established community theory.

2. The framework structures ecological knowledge into five tangible and applicable categories: dispersal, abiotic, biotic factors, commonly integrated in community theory, adding feedback mechanisms and aesthetic factors as separate categories.

3. We illustrate each category with examples and outline the frameworks potential for application in landscape architecture practice, theory, and for fostering transdisciplinary collaboration with ecologists.

Abstract

The accelerating biodiversity crisis, driven by habitat change and urbanization, underscores the need to integrate ecological knowledge and landscape architecture. This paper introduces the Ecological Filter Framework (EFF), as a tool to foster this integration. By structuring complex ecological knowledge into tangible categories, the EFF is meant to empower practitioners to shape environments with solid foundation in the science of ecology.

Grounded in modern community ecology and inspired by the Integrated Community Theory, the EFF structures ecological knowledge into five interconnected filters: dispersal, abiotic, biotic, feedback, and aesthetic factors. These filters provide a systematic approach to understanding species assembly and community dynamics, enabling landscape architects to design biodiverse, resilient environments aligning ecological principles and project objectives.

The EFF could serve as both a "checklist" for site analysis and a communication tool to support collaboration between ecologists and landscape architects. This framework offers a pathway for deeper integration of ecology into landscape architecture, aimed at advancing both theory and practice in response to global environmental challenges.

Introduction:

Integrating ecology into landscape architecture: addressing the biodiversity crisis

Ongoing and accelerating environmental deterioration causes the loss of biodiversity, consequently hampering ecosystem functioning globally and therefore diminishing ecosystems' ability to support human well-being. Among the five major drivers of this crisis, habitat change plays a central role, largely driven by human spatial demands, with urbanization emerging as a key contributor (IPBES 2019). By 2050, an estimated 68% of the projected global population of 9.7 billion people will reside in urban areas (United Nations Department of Economic and Social Affairs 2018). This rapid urbanization underscores the urgent need to design landscapes for human use in concordance with biodiversity.

Landscape architecture plays a pivotal role in addressing this challenge and has strong ambitions to design environments for sustainability (IFLA World 2021) and to support biodiversity in practice (IFLA Europe 2023). This implicates a strong need to integrate ecological knowledge from planning and designing to realizing projects and their maintenance.

The importance of this integration has conceptionally been recognized early on, e.g. in the design of Central Park, New York (Olmsted and Vaux 1858)). With the notion of "design with nature" (McHarg 1969) reference to the concurrently developing science of ecology (Haeckel 1866; Odum 1953) became explicit. Conceptualizing the integration of ecology in landscape practices gained momentum in the end of the 20th century (Forman 1995; Dramstad 1996; Nassauer 1995) and continues to evolve (Ahern 2005; Beck 2013; Steiner et al. 2019; Tabassum et al. 2020).

With this development and the escalating biodiversity crisis an increasing number of landscape professionals are reporting ecologically focused practices. However the integration of ecology into landscape architecture remains challenging (Breitschopf, Berthelot, et al., in prep).

Challenges in applying ecological knowledge in landscape architecture

Both ecology and landscape architecture operate across multiple, interdependent levels of scale and are highly context dependent. While this shared complexity is a precondition that enables the disciplines' integration, it also renders the process inherently challenging.

The science of ecology seeks to explain the workings of the living world: how organisms interact with each other and their environments across space and time (Begon and Townsend 2020). In itself interdisciplinary, ecology encompasses a wide range of organization (individual organisms to ecosystems and biomes) spatial and temporal scales (millimetres to the global scale; seconds to millennia) and includes complex feedback mechanisms, processes, and nonlinear dynamics (Levin 1998; Holling 2001). This vast scope of ecology can offer essential insights into the structure and function of virtually all types of living systems that landscape architects may shape (including marine, freshwater and terrestrial systems).

However, to integrate this wide range of knowledge directly into the practice of landscape architecture can be difficult (Ahern 2013). It requires reconciling ecological insights with site-specific objectives (Steiner 2011), visual imperatives (Nassauer 1995; Steiner 2019), timelines, and practical constraints of design interventions (Nassauer and Opdam 2008; Steiner 2011). Additionally, divergence in methods and terminology between the disciplines further contributes to the persistent challenge of applying ecological science in landscape design (Makhzoumi 2000).

To bridge this gap, there is growing recognition of the need for frameworks that translate ecological knowledge into forms that are legible, actionable and scalable to designers—without diluting its scientific rigor (Musacchio 2009; Ahern 2013; Qiu et al. 2025).

Here we propose a framework that aims to structure ecological knowledge, outlining categories and logic, to make it tangible and applicable for landscape architects. The framework seeks to convey understanding of what ecological content matters, in which context it matters, and why it matters. It thereby aims to empower landscape architects to shape environments for people in concordance with

92 biodiversity, with a foundation in ecological science. Furthermore, we aim to address the terminology

93 gap to facilitate close collaboration between ecologists and landscape architects.

94 The Framework:

95 Ecological communities and ecological filters

96 *"In nature nothing exists alone."—Rachel Carson (1962), Silent Spring*

97 Ecological communities are groups of species that occur together at the same place and time,

98 interacting with one another the abiotic environment (Bowman and Hacker 2024). Species from all

99 kingdoms are part of ecological communities: Bacteria and cyanobacteria; protozoa, algae and slime

100 molds; fungi; plants; and animals.

101 Virtually every landscape architecture project engages with ecological communities, whether by

102 encountering thriving assemblages of species, their remnants or their absence. In each case, the act

103 of design inherently involves decisions that affect, introduce, remove or exclude organisms on-site.

104 This can modify community dynamics, making understanding the workings of ecological communities

105 essential for informed intervention.

106 To support this informed decision making we propose the Ecological Filters Framework, grounded in

107 modern community ecology. It is inspired by the Integrated Community Theory (ICT (Lortie et al. 2004))

108 and the concept of ecological filtering (also termed assembly and response rules (Keddy 1992; Weiher

109 and Keddy 1995; Götzenberger et al. 2012)) which conceptualizes how species assemble to ecological

110 communities in nature.

111 How species assemble to communities is an ongoing debate in community ecology that has evolved

112 to integrate two historical perspectives: community assembly is influenced by random stochastic

113 processes (Hubbell 2001) AND determined by abiotic and biotic factors at a given site (Lortie et al.

114 2004; Vellend 2010; Götzenberger et al. 2012).

115 We take departure in this perspective, formalized as the ICT by Lortie et al. (2004), due to its compelling

116 logical construction that encompasses the ideas of other community ecological theories. The ICT with

117   its concept of ecological filtering sets other ecological theories in a structured context more operable

118   for application in landscape architecture.

119   Like the ICT, classical community theories interconnect the effects of abiotic factors with the biotic

120   interaction of species, though they differ in focus. For instance, the *Theory of Limited Similarity*

121   (MacArthur and Levins 1967) emphasized species' abiotic niches, proposing that species can only

122   coexist when their resource demands are sufficiently different from each other to avoid competition.

123   This concept was adapted by Grime (1973) into the *Theory of Competitive Exclusion* which places

124   greater emphasis on interspecific interactions, particularly competition. The *Competition-Ruderal-*

125   *Stress Concept* (Grime 1974) explains community assembly by angling the integration of abiotic and

126   biotic factors to grouping species into types according to their habitat. In contrast, the *Intermediate*

127   *Disturbance Hypothesis* (Connell 1978) focuses on processes that shape species diversity in a

128   community by combining abiotic stress and biotic disturbance with competition and facilitation.

129   Ecological filtering, however, does not stress one of these foci as more important than the other,

130   making it a good candidate for the basis of a versatile and applicable framework for addressing multiple

131   scales and objectives in landscape architecture. Moreover, it unites stochastic, abiotic and biotic

132   factors as influential in separable yet interconnected and meaningful units, offering a structured approach

133   applicable for landscape architecture.

134   The Ecological Filters Framework (EFF):

135   We adapt the concept of ecological filtering and the ITC with its metaphor of three filters – (1)

136   stochastic/dispersal factors, (2) abiotic factors, and (3) biotic factors) – that exclude organisms from the

137   global species pool (i.e. all species that exist) to form the local species pool (i.e. those species that

138   coexist in a functional community at a specific location and time) (Lortie et al. 2004). The filters are

139   hierarchical in nature and conceptualized as categories that together explain community assembly. To

140   tailor the framework to the needs of landscape architecture we expand it to include five filters (Figure

141   1.)

142 We introduce feedback mechanisms (4), commonly understood as indirect interactions between

143 abiotic and biotic factors, as a separate filter to allow for an explicit integration of time and process in

144 landscape architecture. Furthermore, we add aesthetic factors (5) as a filter to allow for the integration

145 of people's preferences tightly linking the framework to the practice of landscape architecture with

146 imperatives for public acceptance.

147 In the following sections, we present the proposed framework both in text and diagram (Figure 1.)

148 illustrating its potential application with examples for each filter.

149
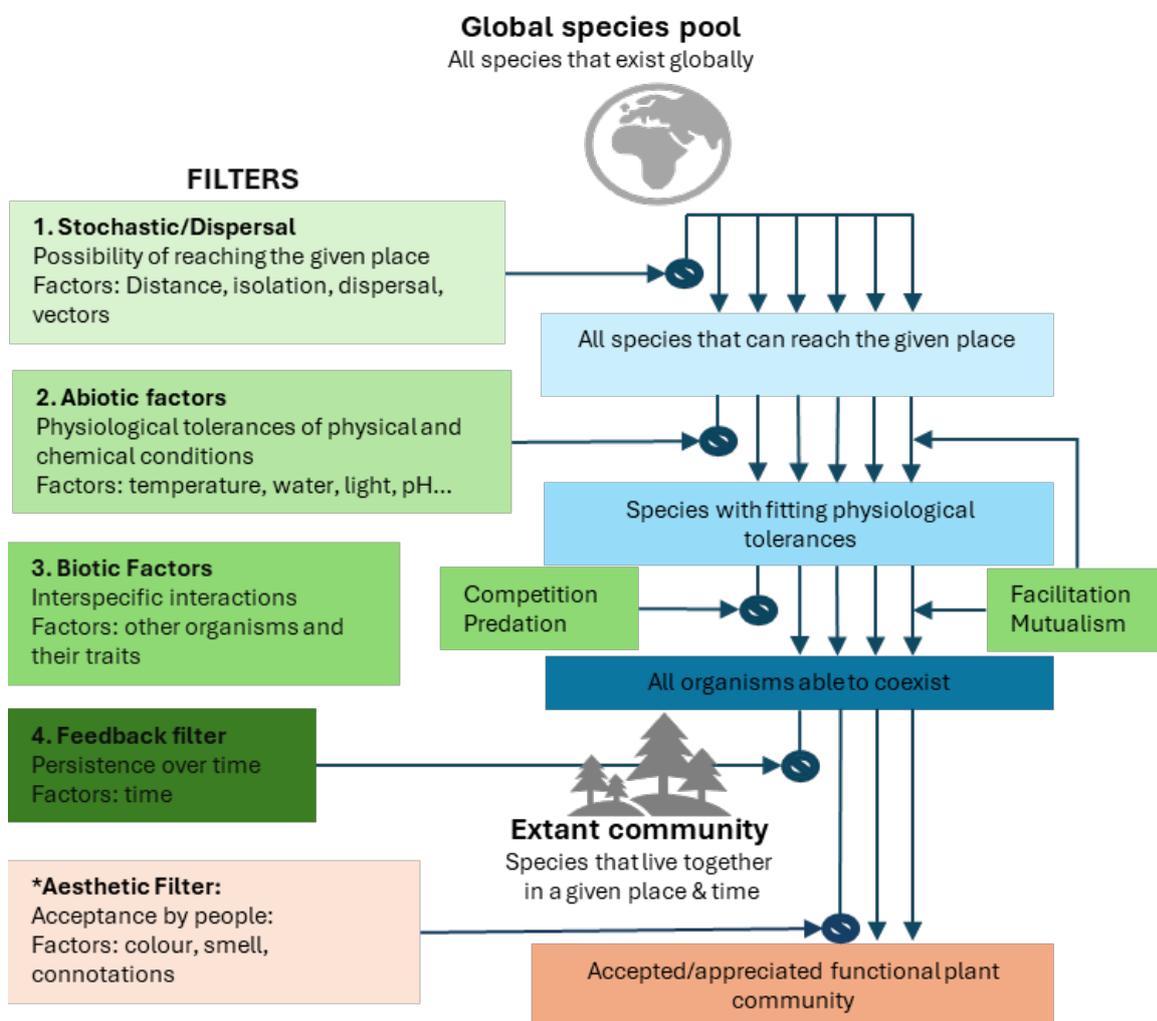
150 **Figure 1***:* The Ecological Filters Framework

151

Dispersal filter and stochastic factors (1)

The first category of factors influencing the assembly of an ecological community involves species' dispersal in relation to site location. Species of the global species pool with their distribution too far away, hindered by barriers or lack of dispersal vectors (largely determined by chance, i.e. stochasticity), cannot reach the site and thereby cannot be part of the local species pool (Hubbell 2001; Lortie et al. 2004)

Considerations for landscape architecture projects that could be inspired by the dispersal filter relate to managing dispersal barriers; whether and how it could be sensible to implement or overcome them. Both dispersal to and from site can be relevant. For example, projects that artificially overcome the dispersal filter by importing species may create an invasion risk to adjacent ecosystems. The import of ornamental plants, globally the dominant driver of plant species invasions (van Kleunen et al. 2018), falls under considerations categorized by the dispersal filter, warranting probing alternative options such as e.g. relying on local native species. Implementing barriers for dispersal of potentially invasive species from site could become relevant to reduce invasion risks if their usage or presence is given. As just one of many examples we illustrate this with the case of the many-leaved or garden lupine (*Lupinus polyphyllus*). Originally introduced as an ornamental plant to Fennoscandia from North America, it was later used in railway construction for erosion control (Fremstad and Elven 2004). Human interference, first as a vector to overcome the dispersal barrier of long distance from one continent to another, now further allows *Lupinus polyphyllus* to disperse along railways as dispersal corridors (Fremstad and Elven 2004). As a result, it is now member of local plant communities as a highly competitive species altering community structures and dynamics.

Conversely, projects that rely on the local species pool could be informed by the dispersal filter to reduce local dispersal barriers allowing for expansion of nearby populations. For example ensuring corridors for wind dispersed plants (Damschen et al. 2014) and removing barriers such as highly trafficked roads can encourage dispersal of the local flora and fauna to the site. In this case we draw on an example from the animal kingdom. To increase habitat connectivity disrupted by road systems a

178 mitigation project in northern England installed multiple tunnels to allow the dispersal of the great

179 crested newt (*Triturus cristatus*) between breeding and non-breeding ponds. This allowed the great

180 crested newt and other amphibians to expand their range and become part of local communities,

181 thereby supporting an intact food web in the ponds (Jarvis et al. 2019).

182 Dispersal patterns are determined by species' behaviour and habitat configuration (Rayfield et al.

183 2023). The dispersal filter, therefore, motivates to include analyses about the local species pool (native

184 and invasive animal, plant and microbial species) present or planned to be on site and surroundings.

185 Additionally, it highlights the importance of examining the configuration and fragmentation of habitats

186 both on and adjacent to the site. This includes considerations of connectivity beyond and within the

187 site, as well as the functions of the landscape mosaic. The dispersal filter invites to strongly draw on

188 principles and insights from landscape ecology.

189 ## *Abiotic filter (2)*

190 The second category of factors relevant to community assembly concerns local abiotic conditions and

191 is also referred to as environmental filter (Kraft et al. 2015). Organisms that reach a site (i.e. pass filter

192 1) can only be part of the local community when the physicochemical conditions, that is abiotic factors

193 such as e.g. water availability and temperature regimes, on site fall within their tolerances (Keddy

194 1992; Lortie et al. 2004; Fraaije et al. 2015).

195 The abiotic filter motivates to analyse the abiotic conditions on site enabling landscape architecture

196 projects to identify and adjust for potential mismatches between species selection and abiotic

197 conditions, either with site manipulation or adapting the species selection. For example, landscape

198 contouring to influence water drainage (e.g. accumulation of water in dips for higher moisture in the

199 soil) or selecting plants of the local species pool that are adapted to the water availability on site

200 (e.g. drought resistant species from the local species pool) could facilitate building thriving

201 communities with high productivity and resilience.

202 Here we illustrate with examples from two angles: adjusting species collection and/or water availability

203 by creating microclimates. An Australian study (Wynn 2009) highlights the importance of appropriate

204   species collection. The study found that drought resistant species from the local species pool,

205   consistently outperformed exotic ornamental species under different drought-stress and irrigation

206   regimes, making them water-efficient and resilient**,** requiring significantly less irrigation to thrive.

207   The traditional rainwater-harvesting technique of semi-circular bunds exemplifies how shaping the

208   landscape can adjust limiting abiotic factors. An Iranian study (Mousavi et al. 2019) found that these

209   half-moon shaped soil-depressions effectively increase soil moisture which raised the number of plant

210   species and their abundance within them.

211   Information on factors such as water availability, abiotic soil conditions (pH, nutrient availability,

212   texture, porosity…), temperature ranges, light and photoperiod, wind and pollution could support

213   decision making in the design process and are found within the abiotic filter.

Biotic filter (3)

214

215   Thirdly, community assembly is influenced by biotic factors. Species that reach a location and tolerate

216   the abiotic conditions on-site (i.e. pass filter 1 and 2) can only be part of the local species pool when

217   they are able to coexist (Grime 1973; Bruno, Stachowicz, and Bertness 2003; Lortie et al. 2004; Kraft

218   et al. 2015). Interactions between organisms steer their coexistence. Negative interactions, such as

219   competition for limiting resources, can result in competitive exclusion (Grime 1973). Positive

220   interactions such as facilitation can be necessary for species to persist in the community (Brooker et

221   al. 2008).

222   The biotic filter could support landscape architecture projects in leveraging biotic interactions on-site.

223   Supporting positive interactions (facilitation and mutualism) (Brooker et al. 2008), managing negative

224   interactions (competition and antagonism) and designing for niche complementarity can increase the

225   number of species able to coexist (Godoy et al. 2020). This, in turn, can enhance ecosystem functions

226   and thereby be instrumental for highly productive, resilient and resistant communities (Reich et al.

227   2012; Weisser et al. 2017; Godoy et al. 2020)

228   Here we provide several examples from the plant world to illustrate both positive and negative biotic

229   interactions:

230   Studies from alpine environments (Molenda et al. 2012; Bonanomi et al. 2016) highlight the potential

231   of including nurse plants in harsh environments (e.g. arid conditions, critical temperatures or little soil).

232   These facilitating plant species enable other species to be part of the local community in areas with

233   abiotic conditions otherwise intolerable to them, consequently increasing species richness (O'Brien et

234   al. 2019). For example, moss campion (*Silene acaulis*), a cushion plant, has been found to lower abiotic

235   stress (i.e. strong fluctuations in air temperature and soil moisture) within its canopy. This facilitation

236   allows a higher number of other plant and arthropod species to become part of local communities

237   (Molenda et al. 2012; Bonanomi et al. 2016). Other facilitation-based strategies could include

238   supporting plant-microbe-symbioses (Moreau et al. 2019). Mycorrhiza, the mutualistic symbiosis

239   between plants and fungal partners, is essential for plant fitness (Delavaux et al. 2017)). Similarly, the

240   symbiosis between legume plants (e.g. clovers (*Trifolium sp.*) and nitrogen fixing bacteria *(*e.g.

241   *Rhizobia)*, supports plant growth. Including legumes therefore can enhance productivity of the whole

242   community by increased soil-nitrogen content (Qiao et al. 2024).

243   Additionally, designing for high niche complementarity with high species richness of primary producers

244   can increase the likelihood for facilitation to occur and resources of a given site to be used more

245   completely which can result in higher productivity (Godoy et al. 2020) and contributing to the

246   appearance of lushness and greenness (Breitschopf, Feicht, et al., in prep).

247   Conversely, the significance of avoiding competition and antagonism can be illustrated with studies on

248   crowberry (*Empetrum nigrum*). The dwarf shrub has been found to chemically inhibit germination and

249   growth of other plants species, i.e. antagonistic allelopathy (González et al. 2015), thereby gaining a

250   competitive advantage and causing the loss of other species from the community (Bråthen et al. 2024).

251   The biotic filter motivates analysis of biotic interactions and biodiversity on-site: The identity of rare

252   and common species, functional groups and nature types on-site could provide valuable insights on

253   which biotic interactions steer the present community or that might be lacking. Furthermore, the

254   number, relative abundances and genetic diversity of individuals, species and populations are essential

255　factors for optimizing ecosystem functions and therefore ecosystem services as potential benefits for

256　landscape architecture projects.

Feedback filter (4)

258　Community composition changes over time. We add feedback mechanisms, in the ITC commonly

259　integrated with the abiotic and biotic filter (Lortie et al. 2004), as a separate category to stress the

260　impact of temporal development and make it more operable for landscape architecture. Species

261　initially unable to cope with abiotic factors on site might be able to survive due to changing abiotic

262　factors (filter 2) caused by the effects of prolonged presence of other species (filter 3). Or species that

263　have been part of the community can be excluded over time, due to increasing negative ecological

264　interactions (filter 2), (Connell and Slatyer 1977; Lortie et al. 2004; Kraft et al. 2015) e.g. intra- and

265　interspecific competition can increase over time (Herben et al. 2003), soil pathogens can accumulate

266　(Kulmatiski et al. 2008; Bezemer et al. 2018).

267　The feedback filter motivates to analyse processes that influence community composition over time.

268　This could support landscape architecture projects in maintaining intended qualities over time or

269　anticipating and designing their change.

270　For example considering succession, the gradual and predictable change of community composition

271　over time (Meiners et al. 2015), could help to pin-point the desired ecosystem state and to implement

272　measures for steering its development. We draw on a Norwegian study to illustrate. To halt the

273　development from earlier successional stages, e.g. meadow vegetation to an increasing dominance of

274　woody species such as shrubs and trees, people have used prescribed burning and shifting grazing

275　regimes as intermediate disturbance to improve fodder quality since prewritten history (Vandvik et al.

276　2005). On the island of Karmøy, land managers have revived this neglected traditional practice,

277　successfully reducing woody biomass, reducing fire risk, improving fodder quality and controlling the

278　spread of invasive Sitka spruce in endangered heather (*Calluna vulgaris*) heathlands.

279 The feedback filter captures processes that stabilize the community such as decomposition, nutrient-,

280 water-, and carbon- cycling and the processes that can change them such as succession and plant soil-

281 feedbacks (van der Putten et al. 2013) are captured by the feedback filter.

Aesthetic filter (5)

283 Additional to the filters 1 to 4, ecological communities in landscapes for human use are influenced by

284 factors tied to people's aesthetic preferences. Whether intended as ornamentation, wind or view-

285 blockage, erosion prevention or for other ecosystem services, the creation and maintenance of

286 ecological communities in the vicinity of people is dependent on public acceptance (Anderson and

287 Renaud 2021). This adds on to the filters that shape ecological communities without direct human

288 context. To address this we expand the ICT with the aesthetic filter as a separate category, linking

289 ecological characteristics to how they are perceived and appreciated by people.

290 The aesthetic filter could inspire the selection of species, community characteristics and design

291 principles that cater to people's preferences. Here we exemplify with both abstract and applied

292 studies.

293 Hůla and Flegr (2016) showed that in the Czech Republic, people have distinct preferences concerning

294 flower traits e.g. shape and colour. People preferred radial symmetry over complex bilateral

295 symmetry and appreciated blue flowers most, favouring yellow flowers least.

296 Studying plant diversity in artificial plant communities revealed that both biologists and lay-people

297 appreciated communities with 16 species more than communities with lower species richness

298 (Breitschopf and Bråthen 2023).

299 And designing flowerbeds with exclusively native species in Northern Norway showed that while

300 species-rich communities were generally appreciated, a fully ordered design decreased their appeal

301 (Breitschopf, Feicht, et al., in prep)

302 The aesthetic filter motivates to analyse local cultural preferences for species selection and community

303 characteristics. This could enable the use of design techniques such as e.g. cues to care and other

304 orderly frames to shape ecologically sustainable, biodiverse environments that also perform regarding

305 sense of place, feeling of safety, intentionality and control, enhancing public acceptance (Nassauer

306 1995; Meyer 2008).

Application

308 As this framework is intended as a tool tailored to needs of landscape architects, we want to outline

309 how it may be applied.

310 First and foremost its structuring character is intended to make the vast scope of ecological knowledge

311 relevant for landscape architecture graspable. This would make it applicable in practice and theory.

312 The framework's filters structure ecological knowledge into tangible entities logically interconnected.

313 In practice this could serve as a "checklist" in site analysis to gain insights on the ecological condition

314 and functioning on-site. Consecutively investigating the filters could distil main themes of importance

315 to shaping thriving ecological communities in a given project. Some filters might be more relevant in a

316 given context than others. In combination the filters could guide and inform decision making to

317 approach project objectives, e.g. site manipulation (filter 1+2), species or community type selection

318 (filter 2+3+4), implementing processes for maintenance or development over time (filter 3+4) and

319 design interventions to align ecosystem integrity and people's preferences s (filter 3+4+5) (Breitschopf,

320 Feicht, et al., in prep). Even though consecutive in logic the filters may need to be applied in differing

321 order on site.

322 We acknowledge that each filter might remain somewhat opaque, hopefully made more transparent

323 with the examples throughout this text. Since the filters hold knowledge that can fall in the expertise

324 of differing sub-disciplines the framework could guide the search for an expert ecologist to support

325 further analysis and drafting possible interventions. The framework may also serve as a

326 communication tool between landscape architects and ecologists, fostering mutual understanding by

327 bridging their ways of thinking and clarifying terminology.

328 This bridging can be taken further to theoretical approaches at the interface of ecology and landscape

329 architecture (e.g. Breitschopf, Berthelot, et al. (in prep)).

330 The framework was shaped by and proofed instrumental in our teaching in courses of ecology for

331 landscape architecture. We hope that the EFF, that emerged from our own inter- and transdisciplinary

332 practices in research, education and on-site, can foster further and closer integration of ecology in

333 landscape architecture.

Author contributions

335 EB and KAB conceived the idea for the Ecological Filters Framework. EB developed the final form of

336 the framework supported by KAB and TJC. EB led the manuscript writing. All authors contributed

337 critically to the drafts and approved its publication.

Conflict of interest

339 We have no conflict of interest to declare

Acknowledgements

Data availability statement

345 There was no data involved in the preparation of this manuscript.

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