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The quality of flower-based ecosystem services in field margins and road verges from human and insect pollinator perspectives

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ABSTRACT

We contrasted traditionally used indicators of service provision quality, such as overall species richness and growth form composition, to three more specific functional properties: functional diversity, functional intensity, and functional stability. We defined flower colour as a functional trait perceived differently by humans and insect pollinators, and used user specific colour richness, flower size, and species richness within colour group as indicators of these three properties. We asked (1) do field margins and road verges provide flower-based ecosystem services with the quality of permanent grasslands; and (2) do traditional and detailed functional indicators of service provision quality agree on the service quality ranking of habitats?

In an agricultural landscape of central and south-eastern Estonia (115 × 95 km area, centroid 26°49′43″ and 58°54′49″) we sampled 87 field margins and 111 road verges as linear grassland-substitution habitats, and 84 permanent grasslands to scale their service quality.

Linear habitats generally provided service of lower quality than permanent grasslands, but detailed indicators showed less evident contrast among habitat types than the overall species richness and stronger contrast than the proportion of forbs. Detailed indices, however, had strong seasonal dynamics to take into account. Vegetation in the first year field margins had greater colour richness (functional diversity) and species richness within colour groups (functional stability), but the smallest flower size (functional intensity), in contrast to road verges. By the third year of succession, field margins had become more similar to road verges. Indication of service provision quality differed between humans and pollinators, but their estimates were correlated across habitats.

We showed that (1) combinations of specific service quality indicators provide more adequate information than generalized richness or growth form system, and (2) single grassland surrogate habitat type is an insufficient service providing substitute for permanent grasslands, although a mosaic of these habitats might be more efficient. Therefore, remnant fragments of semi-natural grasslands should receive top priority attention for conservation and restoration, particularly in agriculture dominated landscapes.

1. Introduction

The quality of ecosystem service provision of rural landscapes has become a prevailing concern in land use planning and agricultural policies (Garratt et al., 2014; Isaacs et al., 2008). In rural landscapes, permanent semi-natural grasslands have been one of the main service providing natural habitats for millennia, but agricultural intensification has reduced their area and species diversity (Cousins and Eriksson, 2001; Luoto et al., 2003; Poschlod et al., 2005), as well as service provision (Klein et al., 2007; Kremen et al., 2002; Potts et al., 2010). The concept of linear grassland-resembling habitats, such as road verges, grassy field margins, and ditch verges, has been promoted as grassland substitutes to compensate the loss of services (Olson and Wäckers, 2007). These linear substitute habitats are also the last areas of refuge for many grassland plant species (Aavik and Liira, 2009; Bokenstrand et al., 2004; Tikka et al., 2001) and arthropods (Batáry et al., 2012; Haaland et al., 2011; Thomas and Marshall, 1999). Linear grassland substitutes are

Abbreviation: CV, coefficient of variation.

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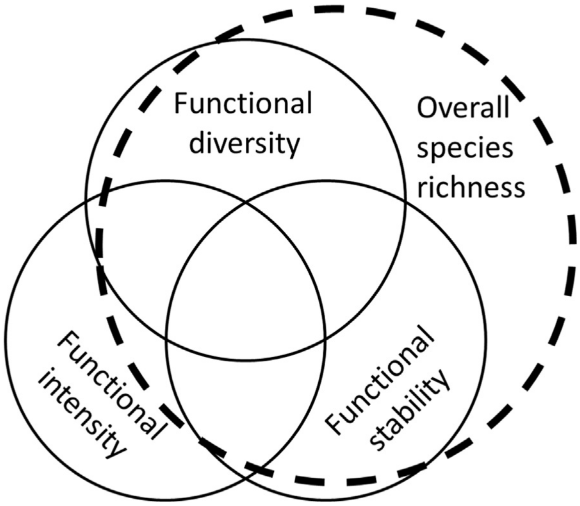

Fig. 1. Theoretical scheme of overlapping information among overall species richness and three functional properties of the ecosystem service provision quality: functional diversity, functional intensity and functional stability.

expected to mitigate the negative effect of habitat loss on specialist pollinators (Blaauw and Isaacs, 2014), who are more sensitive to habitat fragmentation and patch size than generalist pollinators (Jauker et al., 2009; Waser and Ollerton, 2006). The service provision quality of these substitute habitats, however, remains in question, because their habitat quality is affected by disturbances and pollution originating from neighbouring areas (Blaauw and Isaacs, 2014; Jantunen et al., 2006; Koyanagi et al., 2012), and by isolation from species source habitats (Jauker et al., 2009; Steffan-Dewenter and Tscharntke, 1999).

The evaluation methodology of ecosystem services is still evolving, and usually only a single aspect is emphasised – either the quantity or quality of a service – as no single indicator can characterise both (Groot et al., 2002; Hooper et al., 2005; Lawler et al., 2002). For instance, many generalised flagship indicators quantify service as biomass production or carbon storage in a community (Costanza et al., 2007; Montagnini and Nair, 2004), whereas quality is represented by the richness of species or functional groups (Garibaldi et al., 2011; Peterson et al., 1998). The latter diversity-based estimation of service quality is based on the assumption that the functional redundancy in multi-species communities (Cadotte et al., 2011; Díaz and Cabido, 2001) will assure stability of a service or resilience of a system (Holling, 1973; Tilman and Downing, 1994). Therefore, functional groups should be defined as service providing units or functional units instead of defining individual species as service providers (Kremen, 2005; Luck et al., 2003).

We suggest that service provision quality should be evaluated with a set of trait-based service provision properties that include three equally important components (Fig. 1): (1) functional diversity, as the diversity of trait levels (within trait variability or variability range can also be used) (Campbell et al., 2012; Fontaine et al., 2005); (2) functional intensity (including abundance), as the intensity of each functional trait level, estimated as average per service providing unit; and (3) functional stability, as the stability of service provision through time, e.g. indicated by species richness within a trait level (Laliberté et al., 2010; Yachi and Loreau, 1999). Functional stability can be evaluated in two time scales – seasonal variability (Wray and Elle, 2014) or fluctuation over years, including resilience to disturbances (Pillar et al., 2013; Tilman and Downing, 1994; Wardle et al., 2000).

Although humans are considered to be the main user group of ecosystem services (Daily, 1997), many services are mediated to humans by other organism (taxonomic or functional) groups (Lavorel et al., 2013) and the same functional trait can provide different services (de Bello et al., 2010; Lavorel and Grigulis, 2012). In such hierarchically complex and/or multi-functional systems (e.g. food webs or plant-pollinator interactions), service provision quality indicators remain poorly developed (Biesmeijer et al., 2006; Haddad et al., 2011; Leigh, 1965), because the estimation of service provision quality does not consider the direct user group and its perception of the service providing functional trait.

A plant's flower is one such multi-user service providing unit, and flower colour is a functional trait related to the perception of a flower to its users. The primary ecological function of flower colour is to attract pollinators (Altshuler, 2003; Ghazoul, 2006; Giurfa and Lehrer, 2004), but flower colour and its diversity are also appreciated as a source of direct aesthetical service to humans (Clay and Daniel, 2000). Therefore, the diversity of colours, the visibility, and flowering duration can readily be associated with environmental ethics or promote nature conservation (Akbar et al., 2003; Junge et al., 2009; Lindemann-Matthies et al., 2010), particularly as the presence of flowers with various colours and with continuous flowering throughout the growing season maintains the stability of service supply (Balzan et al., 2014; Kearns and Inouye, 1997; Rathcke, 1983). The correlation between the suitability of habitat for pollinators and aesthetic service for humans seems evident (Hopwood, 2008; Kells et al., 2001), but because colour scheme perception differs between humans and pollinators (Arnold et al., 2009), this correlation could be misjudged. Correlations of more detailed properties of service provision, such as functional diversity, intensity, and stability among user groups is quite unexplored, and is further complicated by the seasonal and yearly variability of flowering.

We challenged the widely accepted opinion that overall richness is a sufficient proxy for service provision quality (Balvanera et al., 2006; Isbell et al., 2011; Maestre et al., 2012), because it might not describe the asynchrony in species' growth rates and flowering times throughout the season (Stevens and Carson, 2001). We hypothesise that three specific service quality metrics would reveal more detailed and more adequate indication of potential service provision quality of a habitat than overall richness or a simple growth form composition. To assess this hypothesis, we used flower-based service as an example, and examined flower colour as a service-regulating functional trait in grassland-like linear habitats (road verges and field margins). Service provision of road verges and field margins was evaluated from the perspective of two trait (flower) user groups – humans and pollinators *sensu lato*. Applied questions to be answered for landscape planners are (1) can widely used species richness describe the ecosystem service quality for direct flower trait user groups, and (2) how much do trait-based service properties in road verges and field margins differ from grasslands from the perspective of humans and pollinators?

2. Materials and methods

2.1. Data collection

The 115 × 95 km study area is located in central and south-eastern Estonia with the centroid coordinates 58.4289 N and 26.2626 E (Fig. 2). The region features lightly undulating terrain (elevation of 40–100 m a.s.l.), and is dominated by historically used agricultural land. The climate in the study area is temperate; the mean annual temperature is 5.6 °C and the mean annual precipitation is 600–700 mm. Characteristic changes of agricultural landscapes in Estonia have been the restructuring and enlargement of crop fields during the 20th century. Prescribed by the EU common agricultural policy (CAP), the creation of grassy field margins was initiated in 2011 in Estonia.