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# Resurveying hedgerows in Northern Germany: Plant community shifts over the past 50 years

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ABSTRACT

Resurveying is a powerful approach to investigate responses of plant species communities to a changing environment. We present a resurvey of hedgerows from the "Knick" landscape of eastern Schleswig-Holstein, Germany. The original survey was done by H. E. Weber in 1967 and new data from totally 51 semi-permanent plots was sampled in 2015. Hedgerows are a key near-natural habitat that can harbour a great biodiversity in otherwise agriculturally intensified landscapes.

Our study reveals a distinct shift in the herbaceous species composition of the hedgerows over the past five decades. To understand the reasons for these changes, we compared the mean Ellenberg indicator values (EIVs) and measured pH values, as well as hedge shape parameters of the hedgerows between the recent and the original study. The main driver behind the change in species composition appeared to be the increase in nutrient supply. The hedge shape changed as well, indicating an altered hedgerow management. Interestingly, we found a contradictory relationship between measured pH values and mean EIVs for reaction: while the former showed a decrease over time, the latter suggested an increase.

Species richness decreased in some groups (shrubs and herbaceous forest species) but increased in others (grass species and arable weed species), with an overall decline in species richness. An analysis of the species' changes in frequency in relation to their EIVs showed that species with higher nitrogen and temperature scores were more likely to have increased.



## 1. Introduction

In an agriculturally intensified landscape, hedgerows often remain the last near-natural wooded habitat. Especially in sparsely wooded areas they perform an important function as possible refuge habitats for vascular plants that are otherwise restricted to forests (McCollin et al., 2000; Wehling and Diekmann, 2009a). Additionally, they can form linear corridors or even networks of woody habitat strips, and are thus able to connect fragmented forests (Roy and de Blois, 2008; Wehling and Diekmann, 2009b) and enable gene pool linkage of forest species (Van Rossum and Triest, 2012). In the context of habitat fragmentation and climate change this can be essential because species are expected to shift their distribution ranges polewards and need migration corridors. In recent time, hedgerows have received an increasing attention from conservation biologists because of their high biodiversity (Roy and de Blois, 2008).

In many European countries, hedgerows were laid out after the 17th century and maintained as living fences between fields and pastures, and to shelter agricultural land from erosion until today (Knauer, 1993; Weber, 2003). They typically consist of a bank on which shrubs were planted in one or two rows. Management such as coppicing is needed to keep the hedgerows thick and vital. Adjacent to the hedge banks, field margins are often established to protect the banks from accidental destruction by ploughing and herbicides or fertilisers. Those strips can be rich in endangered ruderal and arable weeds (Albrecht et al., 2009) as well as grassland species (Smart et al., 2002). Next to traditionally preserved hedgerows there are ditches on each side adjoining the banks. Hedgerows are thus structurally very heterogeneous, including shaded parts in the interior as well as forest edge conditions and open habitat in the adjacent field margins. There is also variation in exposure to solar radiation and wind. As a consequence, hedgerows offer a habitat to many different plant species (Critchley et al., 2013; French and Cummins, 2001), such as the functional groups of forest specialists and arable weeds, occurring closely together.

Over the past five decades, agricultural and hedgerow management practices have changed dramatically. Hedgerows are prone to an increasing load of agricultural fertilisers and other chemicals because they are adjacent to agricultural fields (Tsiouris and Marshall, 1998). The chemicals tend to accumulate in the hedgerow because they act as windbreaks and because crops grow less well in the shade in the direct proximity of the hedgerow and utilise less of the applied fertilisers

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(Mette, 1994). The deposition of atmospheric nitrogen is also amplified by the hedgerows' biofiltering function (Kovář et al., 1996). This all leads to eutrophication which herbaceous forest plants have been found to be susceptible to (Strengbom et al., 2003), especially species flowering in early spring (Diekmann and Falkengren-Grerup, 2002). Additionally, the hedgerow management practices have changed in a way that shrubs are coppiced less often compared to previous times (Carey et al., 2008) but with increasingly heavy machinery, and the banks are no longer maintained and degrade slowly (Höper et al., 1987; Schrautzer et al., 1996). Land-use changes and especially the increasing use of fertilisers and herbicides can cause a general loss of arable weed species but an increase in nitrophilous and herbicide-tolerant species (Baessler and Klotz, 2006; Hilbig and Bachthaler, 1992a, 1992b; Storkey et al., 2012).

To be able to detect changes in species richness and composition, historical vegetation plots need to be visited again and the collected vegetation data be compared. Such resurveys offer an opportunity to find out more about temporal shifts in species composition and to evaluate underlying causes (Kapfer et al., 2016). This in turn enables us to develop conservation practices to protect the remaining diversity in the agricultural landscape.

Up to now, there have been only few resurvey studies of hedgerow habitats. Huwer and Wittig (2012) presented a study from the Westphalian Basin, Western Germany, which focused on changes in the frequencies of plant species of different phytosociological groups, and Staley et al. (2013) in a study from England emphasised the influence of management practices on woody species and typical herbs of the hedgerow interior. So far no resurvey has been conducted in the very hedgerow-rich area of Schleswig-Holstein, Northern Germany, for which a large historical data set is available. The original study was done by H. E. Weber (1967a, 1967b) about 50 years ago in the summers of 1962 and 1963, including an extensive vegetation sampling of hedgerows distributed all over Schleswig-Holstein. The resurvey provides a unique insight to the floristic changes of hedgerows in Northern Germany. Whereas hedgerow research most often has focused exclusively on forest specialists (McCollin et al., 2000; Staley et al., 2013; Wehling and Diekmann, 2009a), we also include the functional group of arable weed species being a natural part of the hedgerows (MLUR, 2013). Additionally, unlike other resurvey studies of hedgerows, there were old pH measurements available that offer a rare opportunity to directly assess the influence of a changing soil environment.

Our main research questions were:

(1) Was there a shift in the herbaceous plant species richness and composition of hedgerows over the past five decades?
(2) Can this shift be linked to a change in environmental factors or in the hedge shape and if so, which are the most influential variables?
(3) Does the direction of change differ between functional plant groups such as herbaceous and woody species or forest and arable weed species and what does this mean for hedgerow management and conservation?

## 2. Methods

### 2.1. Study area

The study was conducted in the hedgerow-rich east of Schleswig-Holstein, the northern-most federal state of Germany (Fig. 1). This area is characterised by a young morainic, hilly landscape formed during the last glaciation. The soils are predominantly calcareous and relatively nutrient-rich. The climate in the study area is suboceanic and characterised by moderately warm summers and mild winters. The mean annual temperature is 8.9 °C, the yearly precipitation amounts to about 770 mm (DWD, 2012).

In the federal state of Schleswig-Holstein, only 166,800 ha (10.6%) are covered by forests, while 1,102,400 ha (69.8%) are used for agriculture (DESTATIS, 2014a). This enhances the importance of hedgerows for the area because they offer additional wooded habitat within the agricultural land. In the study area, the construction and management of hedgerows, which are locally called “Knicks”, has a long tradition. They originally served as living fences but they soon also proved to be a highly valued source for timber and firewood and protected the fields as well as the cattle from wind and rain.

In Schleswig-Holstein and many other regions in North-western Europe, hedgerows were usually planted on a raised bank, the material for which was gained by digging ditches on each side. While these ditches have mostly been filled up by now, the hedge banks are still an important part of the hedgerows. Traditional management includes coppicing of the shrub layer every 9 to 11 years as well as frequent mending of the banks and planting of saplings in gaps of the shrub layer (Jessen, 1937). Even though the land consolidation processes taking place during the second half of the last century reduced the hedgerow network in Schleswig-Holstein from roughly 75,000 (Marquardt, 1950) to 46,000 km (Eigner, 1982), it is still very dense compared to other parts of the country.

### 2.2. Vegetation sampling & environmental variables

A list of locations of the original plots from Weber (1967a, 1967b) was obtained from the Institute for Ecosystem Research at the University of Kiel. The information provided was used to transfer the position data into the geographic coordinate system. Hedgerows were included in the resurvey if they could be identified on a recent map according to their geographic location and their direction. In consequence of the imprecise position data ($\pm$25 m), a plot was accepted for a resurvey if the possible deviation between the original plot location and the next appropriate hedgerow was smaller than 30 m. The plot centre of the resurvey was placed as close to the original plot position as possible. However, vegetation resurveys are robust to plot location uncertainties (Kopecký and Macek, 2015). Due to the land consolidation processes many hedgerows included in the original study no longer exist. Newly coppiced hedgerows were included, while partly degraded hedgerows were only considered if a bank was still visible and if at least 50% of the bank was covered with shrubs. Of 286 hedgerows that were reported from the area in the original study, 220 could not be recovered on a recent map, 15 had to be excluded due to strong degradation and finally, 51 could be resurveyed.

Because the original study was carried out in summer, the sampling was done in June and July 2015 even though this might miss spring flowering plants. The plot length in the original study was given as usually varying between 60 and 80 m of a hedgerow. For the resurvey, we applied a fixed length of 70 m. The plot width was defined by the borders of the adjacent fields in accordance with the original study, meaning that the field margins were also included in the sampling. The vegetation survey included all vascular plants and was based on percentage cover estimation of each species. Brambles, although distinguished on a lower taxonomic level in the original survey by Weber (1967a, 1967b), were recorded as *Rubus fruticosus* agg. and *Rubus corylifolius* agg.

We determined the width of the bank foundation, the height of the hedge bank relative to the field (excluding ditches) and the height of the shrub layer (Fig. 2). In accordance with the original study, soil samples from the upper 30 cm were taken in the middle of the plot and the hedge bank in April 2016 at all plots for which the old pH values were available (27 of 51 plots). Because Weber (1967a) reported a sample depth variability of 30–40 cm, 15 samples were additionally taken from down to a depth of 40 cm to test if this influences the results. The soil samples were analysed with the same methods as used in the original study. In the laboratory, 10 g of air-dried and sieved soil were mixed with 25 ml of 0.1 M KCl and shaken for 1.5 h. The pH value was