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Biodiversity of hedgerows surrounding a point source of nitrogen pollution (Wensleydale, Northern England)

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ABSTRACT: Hedgerows studied in Wensleydale (Northern England) play an important role in the landscape in filtering acid pollutants including N compounds. Simultaneously, they serve as a captivity storage for N in this type of (agricultural) landscape. The biodiversity of the hedge herb layer shows a clear dependence on the distance from the N source. Hedge orientation and the nature of the adjacent patches (field or a pasture - etc.) had a much lesser effect. Three types of herb stands were distinguished - the first without any distinct dominant (with the highest index of diversity), the second with a „shade-tolerant" dominant and the third with a „light-tolerant" dominant (with the lowest index of diversity).

KEYWORDS: nitrogen pollution; hedgerows; plant species diversity; herb dominance.

Introduction

Biodiversity is a fundamental feature of any biological system and is manifested hierarchically at every level of the natural world from the organismal genes to the ecosystems of the globe. It may be defined as the variation in the property of classes of living entities (SOLBRIG 1991). According to DIAMOND (1988), four sets of factors determine the diversity of niches in a community: (1) quantity of resources, (2) quality of resources, (3) species interactions, and (4) community dynamics. Another contributor to community diversity is trophic diversity (COHEN 1978). The experience of many authors working on pollution problems, demonstrates that biological diversity often depends on environmental stress and disturbance events (KOVÁŘ 1990).

In intensively managed agricultural landscapes, the maintenance of relatively high species diversity is usually associated with a suitable proportion of linear features (e.g.

BUNCE & al. 1992, KOVÁŘ 1992). Hedgerows especially, belong to a specific group of elements and are given much attention because they are in decline in traditional British landscapes (BARR et al. 1991). These linear features are important both for fauna and flora (BUNCE & HOWARD 1990). In regions abundant in arable land and also in atmospheric pollution, hedges acquire other functions, e.g. of acting as sinks and filters (KOVÁŘ & al. 1996).

What is the relationship between biodiversity of the herb layer accompanying hedgerows and their position/distance from the source of N pollution? Is biodiversity of these stands comparably influenced by other parameters?

Methods

Study area

The establishment of the study area took into consideration previous investigations of air chemistry and throughfall enrichment (INESON 1991, KOVÁŘ & al. 1996) around the agricultural point source of ammonia pollution in a valley in North Yorkshire (Wensleydale, Fleets Farm near East Witton). Air chemistry in the area is dominated by ammonia, and the forests down-wind from the point source (a pig farm) show a marked enrichment in throughfall concentrations and fluxes of ammonium. The synergetic co-deposition of sulphate onto forest canopies in the locality has been confirmed (KENNEDY-SKIPTON 1992). The pig farm is located in the river Ure niveau, 100 m above the sea level. The sides of the valley rise up to 180 m a.s.l. (over 200 m a.s.l. on the south). The orientation of the valley is approximately west to east, and the prevailing winds also come from this direction. The landscape is used mainly for mixed agriculture; the bottom of the valley and the lower levels being used as sheep and cattle pastures together with woods mainly consisting of *Picea abies* and *Pinus sylvestris*. The soils are greatly influenced by glacial drift and are mainly brown. The geology of the bedrock changes within the cross-section of the valley: with upper carboniferous sandstones below and conglomerates above (THOMSON 1992).

Sampling and data analysis

The study area was covered by a net of monitoring points where concentrations of ammonia/nitrate nitrogen in rain water were regularly measured (for details see KOVÁŘ & al. 1996). Four gauges (6 cm in diameter and 8 cm height) were set up at each site at the hedge bottom, under the hedge canopy on the soil surface, in the first half of June. In each of the four quadrants, a set of the same gauges was fixed at the hedge top level, under the open sky. The retained water samples of rainfall and throughfall were collected weekly (where precipitation was present). Out of the total 7 measuring intervals, 4 yielded water samples during the time of monitoring from June 12 to August 8). The water samples were analyzed for pH and the two forms of nitrogen, NH_4-N and NO_3-N, using automated simultaneous colorimetry (auto analyzer). Nitrate (plus nitrite) was reduced to nitrite by an alkaline solution of hydrazine sulphate with copper as catalyst. With sulphanilamide and naphthyl-ethylendiamine dihydrochloride, it produced a dye measured colorimetrically. Ammonium was analyzed using the sensitive sodium salicylate - hypochlorite method with nitroprusside as catalyst (GENTRY & WILLIS 1988).

The complete set of data was evaluated using regression analysis (Fig. 2) and the notched box-and-whisker plot expression (Fig. 3) was used in comparison of biodiversity among different stands. To asses the relation between biodiversity of the hedge herb layer and its distance from the source of pollution, 50 phytocenological relevés (Fig. 1) were collected (using the 7-grade Braun-

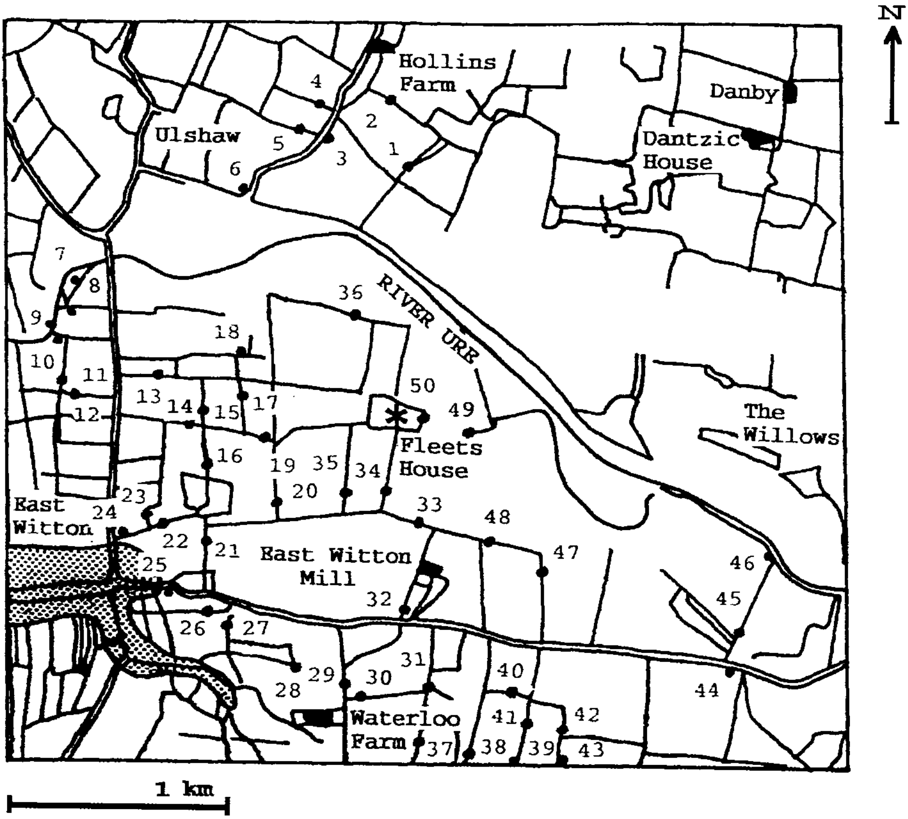

Fig. 1: Hedge sites where 50 phytocenological relevés were recorded within the studied area of Wensleydale.

Blanquet scale of abundance). The other parameters for each relevé were taken into account: orientation of hedges to the pollution source (transversely, lengthwise), trimmed hedge/non-trimmed hedge, continuous hedge/edge with breaks, hedge width, hedge height, leaf layer thickness, number of species, proximity of a pasture/field, ratio of light tolerant/shade tolerant species. The percentages of the particular species cover were also recorded for the calculation of the Shannon-Wiener index of diversity: $H' = \sum_{i=1}^{s} p_i \ln p_i$

(s - number of species, p_i - proportion of abundance of the i-species).

Within the relevé set, three types of stands were distinguished: those without a dominant, those with a light-tolerant dominant, and those with a shade-tolerant dominant because of the shelter effect of the hedgerow structure (as a dominant was considered any species with abundance greater than the grade 3 in the Braun-Blanquet scale, i.e. with more than 50 % abundance). Nomenclature of plant is used according to STACE (1992).

Table 1: Data on factors belonging to the stands where relevés of the herb layer of hedgerows were recorded [1.-50.: site; A: quadrant; B: distance (m); C: orientation to the source (transversely +; lengthwise -); D: trimmed hedge (+), non-trimmed hedge (-); E: continuous hedge (+); hedge with holes (-); F: hedge width (cm); G: hedge height (cm); H: leaf layer thickness (cm); I: number of species; J: Shannon-Wiener index of diversity (H'); K: proximity of a pasture (+) / field (-); L: ratio of light tolerant / shade tolerant species; M: a dominant present: (-) shade-tolerant, (+) light-tolerant.]

	A	B	C	D	E	F	G	H	I	J	K	L	M
1.	S	760	-	-	+	200	400	350	10	0.98	-/-	2.33	-
2.	S	920	+	+	+	150	200	130	11	1.62	+/-	1.75	.
3.	S	860	-	+	-	120	180	60	9	1.59	+/-	0.80	.
4.	S	960	+	+	-	120	200	150	11	1.72	+/+	2.66	.
5.	S	960	+	+	-	100	130	100	12	1.87	+/+	1.40	.
6.	S	800	-	+	+	100	130	60	14	1.78	+/-	0.75	.
7.	Z	1080	-	+	+	120	150	80	12	1.78	+/+	1.20	.
8.	Z	1000	+	+	-	100	150	80	8	1.44	+/+	1.66	.
9.	Z	1040	-	-	+	200	300	170	13	1.78	+/+	0.60	.
10.	Z	1000	+	+	+	120	130	40	7	0.80	+/+	1.33	.
11.	Z	1000	-	+	+	100	130	70	11	1.53	+/+	0.66	.
12.	Z	940	+	+	+	100	150	40	6	1.38	+/+	0.50	.
13.	Z	700	+	+	+	100	150	50	4	0.77	+/+	1.00	+
14.	Z	600	+	+	+	100	150	50	5	0.94	+/+	1.50	.
15.	Z	560	-	+	-	100	130	50	3	0.64	+/+	2.00	-
16.	Z	560	-	+	+	80	150	80	6	1.13	+/+	2.00	.
17.	Z	480	-	+	-	80	150	80	4	0.91	+/+	1.00	.
18.	Z	500	+	+	-	80	150	80	5	1.47	+/-	4.00	.
19.	Z	380	+	+	-	80	150	50	7	1.44	+/+	2.50	.
20.	Z	440	-	+	-	100	150	40	6	1.02	+/-	6.00	.
21.	Z	700	-	+	-	100	170	50	8	1.63	+/-	7.00	.
22.	Z	800	+	+	+	100	170	80	5	1.15	+/+	1.50	-
23.	Z	800	-	+	+	100	150	80	8	1.01	+/+	5.00	.
24.	Z	940	-	+	+	120	180	100	14	1.99	+/-	7.00	.
25.	J	840	+	+	+	100	150	100	15	1.66	+/-	0.87	.
26.	J	820	+	+	+	120	200	100	11	1.64	+/+	0.57	.
27.	J	800	-	+	+	100	150	100	12	2.08	+/-	1.00	.
28.	J	1000	+	+	+	100	180	130	11	1.93	+/-	0.57	.
29.	J	800	-	+	+	100	150	100	4	0.93	+/+	3.00	.
30.	J	800	+	+	-	80	150	60	7	0.86	+/+	1.33	-
31.	J	800	-	+	-	80	170	60	6	0.87	+/+	5.00	.
32.	J	600	-	+	+	120	200	100	12	2.05	+/-	2.00	.
33.	J	300	+	+	+	100	200	100	3	0.15	+/-	3.00	+
34.	J	300	-	+	-	100	180	100	3	0.33	+/-	3.00	+
35.	J	300	-	+	-	70	160	100	3	0.33	+/-	3.00	+

Table 1 - continued

	A	B	C	D	E	F	G	H	I	J	K	L	M
36.	S	320	+	+	+	70	150	100	4	0.97	+/-	3.00	.
37.	J	1000	-	+	+	100	180	100	7	0.88	+/+	3.00	.
38.	J	1000	-	+	-	100	170	100	10	1.66	+/+	1.66	.
39.	J	1160	+	+	-	80	160	60	6	0.97	+/+	5.00	.
40.	J	900	+	+	-	80	150	60	10	1.09	+/+	2.33	.
41.	J	1000	-	+	-	70	170	80	8	0.70	+/+	7.00	+
42.	V	1100	-	+	-	80	150	60	6	1.05	+/+	6.00	.
43.	V	1200	+	+	+	80	170	60	7	0.74	+/+	1.33	+
44.	V	1200	+	+	+	100	170	80	14	1.90	+/-	0.55	.
45.	V	1100	+	-	+	300	300	170	5	0.98	+/+	1.50	-
46.	V	1100	+	+	+	80	170	60	4	0.97	+/-	3.00	.
47.	V	600	-	+	-	60	150	80	4	0.97	+/-	3.00	.
48.	V	480	+	+	+	70	150	80	11	1.40	+/-	2.66	.
49.	V	200	+	+	+	100	150	40	5	0.98	+/-	4.00	-
50.	V	100	-	+	-	100	170	130	4	0.69	+/-	3.00	.

Results and discussion

Retention of nitrogen in hedges

Fig. 1 presents a map showing the location of the source of pollution (a pig farm) in the centre, and the pattern of phytocenological relevés in its surroundings. The hedges are mostly trimmed, and are dominated by *Crataegus monogyna* in their woody stratum locally mixed species such as *Sambucus nigra*, *Prunus spinosa*, *Coryllus avellana*, *Fraxinus excelsior*, *Ulmus glabra*, and *Acer pseudoplatanus*. It is not only the rate of concentrations of NH_4-N and NO_3-N in the rainwater and throughfall water within time, but also their ratios, both for rainfall and throughfall, which provides information on the changes of water quality as affected by hedges (KOVÁŘ & al. 1996). The pH ratio is lowered both in the rainfall and throughfall. Acidification through the action of H and Al ions displaces base cations, especially Ca, from the root plasmalemma which leads to membrane disintegration and plant damage (e.g. BRUNET & NEYMARK 1992).

The results described in other presentation (KOVÁŘ & al. 1996) may be summarized as follows: (1) the hedges with the dominant hawthorn (*Crataegus monogyna*) buffer significantly acid precipitation which was influenced by N emitted by the pig farm (approx. by 2 units of pH), (2) hedges change the ammonia/nitrate ratio of throughfall with respect to rainwater, according to their location within the area (most efficient are those to the east of the source of pollution) and to the thickness of canopy leaf layer (more efficient are non-trimmed hedges), and, specifically, (3) *Sambucus nigra*, being an allochtonous component of the hedgerows, largely influence the throughfall water chemistry (pH, ammonium and nitrate-N rise, presumably from nutrients leached out of

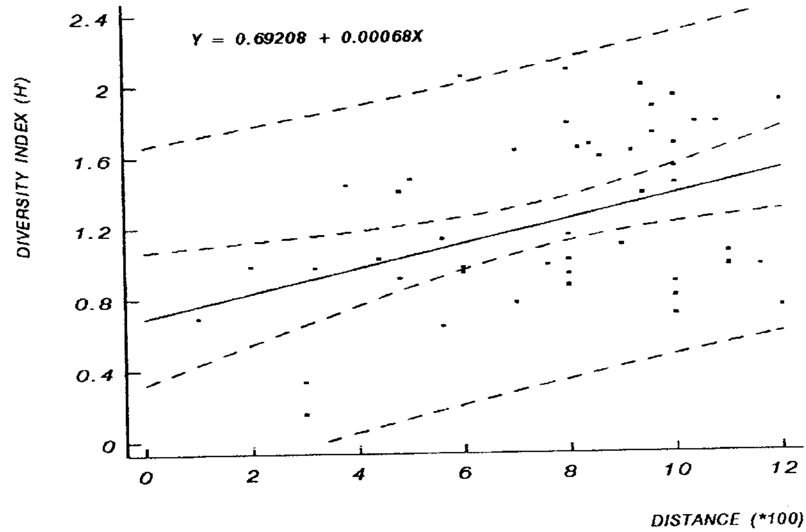

Fig. 2: Regression of index of diversity (H') on distance [m] from the pollution source (pig farm) in Wensleydale.

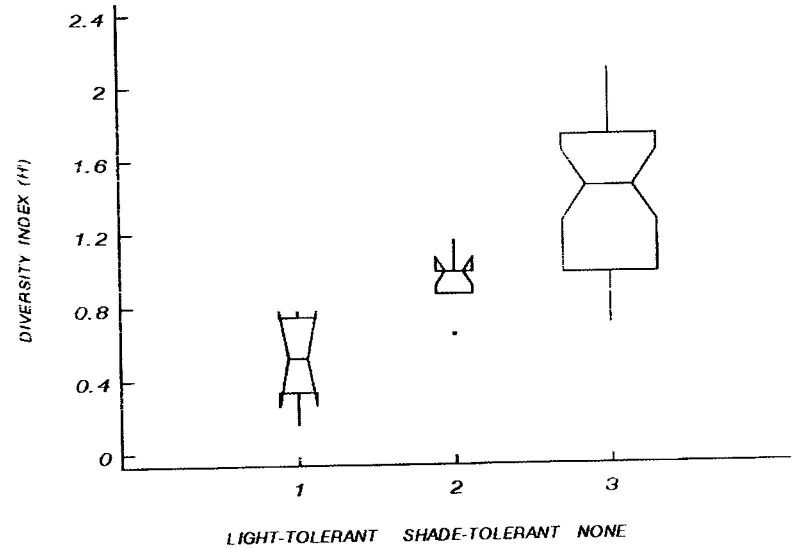

Fig. 3: Notched box and whisker plot for diversity index (H') in different stands of hedgerow herbs: (1) with a light-tolerant dominant, (2) with a shade-tolerant dominant, and (3) without a dominant. The box encloses the middle 50 % of data (i.e. between the upper and the lower quartile), with the median in the middle. The length of the notch represents an approximate 95 % confidence interval for the median. Whiskers extend to the extreme points within 1.5 interquartile ranges from the quartile. Data points beyond this range are plotted individually.

leaves). There is a hypothesis that the deposition of nitrogen-containing materials, such as ammonium or nitrate, could produce nutrient imbalances in the foliage and alter growth and stress tolerance (MCCUNE & BOYCE 1992). On the other hand, plant species reinforce patterns of nutrient availability in ecosystems through their uptake and use of nutrients (HOBBIE 1992). This could influence the overall distribution of herb dominants within the local network of hedgerows. All the sites from the southern and eastern quadrants show more or less higher values of N retained, and also higher fluctuations of values which could coincide with greater exposure to the meteorological characteristics (precipitation, wind, location of the source of pollution - the configuration of the river valley supports such an exposure).

Species diversity of the hedge herb layer and its relationship to other parameters

In addition to the evaluation of the number of species and their abundance expressed in percentages, it was useful to distinguish stands with a distinct dominant (i.e. such with abundance greater than the grade 3 in the Braun-Blanquet scale; i.e. with more than 50 % abundance). Moreover, among such dominants, there are those that are distinguishable as „light-tolerant" (e.g., *Bromus sterilis, Agropyron repens, Holcus mollis*), as opposed to „shade-tolerant" (e.g., *Urtica dioica, Alliaria petiolata, Mercurialis perennis*).

Among the parameters recorded for 50 phytocenological relevés (Fig. 1), there is a significant regression relationship between the Shannon-Wiener index (H') of diversity and the distance from the source of pollution (not taking into consideration the orientation or location at the quadrants; one problem is necessary to mention - an absence of functional hedgerows in the northeast of study area). The number of species increases, as well as the H' index, with the distance from the farm (Fig. 2).

None of the factors recorded in Table 1 affected the species diversity as much as the distance from the farm (Fig. 2). There is a strong relationship between this distance and the load (i.e. critical load) of nitrogen in the environment (LILJELUND & TORSTENSSON 1988). In general, the composition of the species present and their spatial distribution around the farm, could provide a method for the establishment of the gradient of nitrogen indicator values (ELLENBERG 1988).

The N load influences not only the herb botanical composition of hedgerows, but also shade provided by woody species (given by the size and structure of hedges). All the three types of sites (without a superdominant, with „light-tolerant" and „shade-tolerant" dominants) differ significantly in the indeces of species diversity H' (Fig. 3). The highest index of diversity at the median (H'= 1.4) applies to stands without dominants, whereas the lowest (H'= 0.5) concerns stands with light-tolerant dominants, i.e. those where the hedges were mechanically disturbed and more light could thus pass through.

Regional extrapolation represents a problem - every landscape type probably has its own structures of N accretion (i.e. storages) derived from nitrogen accumulation (KESNER & MEENTEMEYER 1989). The hedgerows in fragmented landscapes such as Wensleydale could provide a specific barrier mechanism, that is important in the accumulation of N.

Interspecific interactions complicate the task of generalization of the results, for example the interaction between plants and N accumulation is frequently mentioned in heather stands, e.g. FOWLER & al. 1992. The presence of tolerant and sensitive populations of individual species (ABRAHAMSEN & TVEITE 1983) may indicate a level below that the species may occur, especially in agricultural landscapes. Such variation could be associated with crop weeds present as „light-tolerant" dominants, or as components of the herb layer of hedgerows (e.g., *Bromus sterilis*).

Conclusions

Species diversity, incorporating the number of species and their abundance (H'), reveals significant differences within the study area and is dependent upon the distance from the N source (i.e. increases with distance from the source). This is also essential to consider the parameters of the hedge which influence the presence of „light-tolerant" or „shade-tolerant" dominant of the herb layer, or where no species is dominant, because these stands have the greatest diversity.

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