DIVERSITY OF SEDIMENT DIATOM ASSEMBLAGES IN STANDING WATERS (FLANDERS, BELGIUM): GEOGRAPHICAL PATTERNS AND RECENT CHANGES

Luc Denys
Institute of Nature Conservation, Kliniekstraat 25, B-1070 Brussel, Belgium
luc.denys@instnat.be

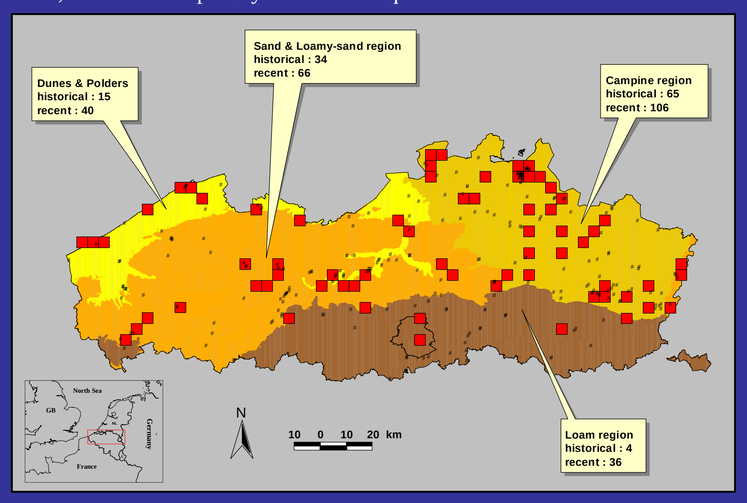
INTRODUCTION

The most recent intensification of land use and industrial development in Western Europe resulted in biodiversity loss for many groups of organisms. To examine whether this applies to limnic diatoms in the Flemish region, diversity characteristics of recent sediment assemblages from fresh standing waters and of similar assemblages dating from the period 1852-1943 are compared. Possible changes are explored at three levels: 1. sample (inventory) diversity, 2. habitat (differentiation) diversity, and 3. regional species richness. Finally (4), the differentiation of diatom assemblages in relation to the major ecological subdivisions of the region (Table 1) are examined with respect to species array, specificity and fidelity.

Table 1. General original character of standing waters in the four ecological subregions.

	conductivity	pH	nutrients
Campine region	**low** (medium)	**acid** (neutral)	**low** (medium)
sand & loamy-sand region	(low) **medium**	(acid) **neutral - alkaline**	(low) **medium**
loam region	**fairly high**	**alkaline**	(low) **medium - high**
dunes & polders	**high** (some salinity)	**alkaline**	(medium) **high**

Fig. 1. Map of Flanders with the four ecological subregions, number of samples and sampling locations. Recent samples represented by black dots, historical samples by red 4x4 km squares.

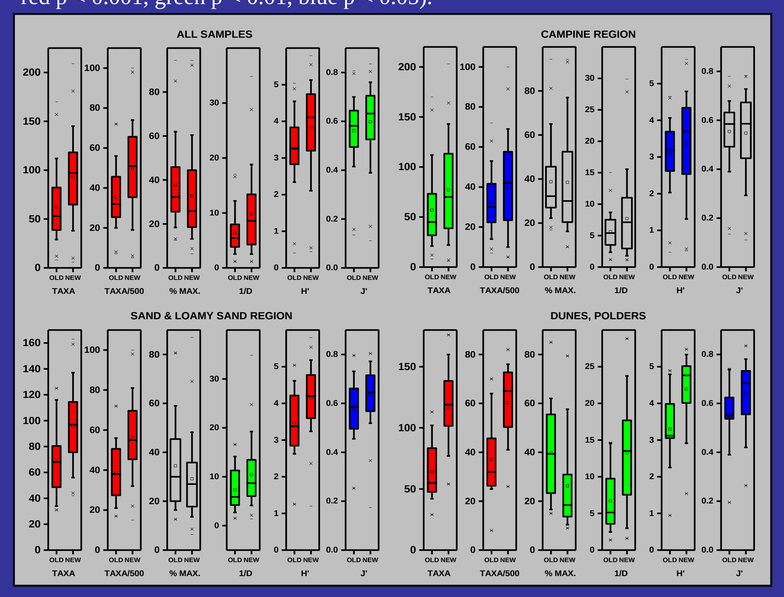


RESULTS

1. Sample diversity

Sample diversity tends to be slightly lower in the Campine than elsewhere (Fig. 2). In general, species diversity and evenness increased, but dominance-related measures remained unchanged in the Campine.

Fig. 2. Box plots of diversity measures for historical and recent samples (not shown for the loam region; box color indicates differences between periods: red $p < 0.001$, green $p < 0.01$, blue $p < 0.05$).



2. Habitat diversity

Overall, compositional turnover decreased slightly (Table 2). Except with abundance-based Sørensen distance, the average distance between recent assemblages tends to be lower as well (Table 2). At the level of subregions, the Campine differs from the other regions: here assemblages are now more varied than in the past, whereas elsewhere they became more similar.

Table 2. Compositional turnover and average distances.

	Historical samples	Recent samples	Δ (%)
	Compositional turnover (standard deviation units)		
all samples	**8.67**	7.65	-11.5
Campine region	5.67	**8.00**	41.1
sand & loamy sand region	**8.03**	7.46	-7.1
loam region	**7.07**	5.00	-29.3
dunes & polders	**4.56**	4.22	-7.5
	Average within-group Euclidean distance (x10^2)		
all samples	**29.2**	26.7	-8.6
Campine region	30.2	**30.5**	1.0
sand & loamy sand region	**27.5**	24.0	-12.7
loam region	**31.1**	24.7	-20.6
dunes & polders	**28.2**	22.6	-19.9
	Average within-group Sørensen distance (abundance based)		
all samples	0.85	0.85	0
Campine region	0.85	**0.87**	2.4
sand & loamy sand region	**0.85**	0.84	-1.2
loam region	**0.93**	0.84	-9.7
dunes & polders	0.80	**0.81**	1.3
	Average within-group Sørensen distance (presence based)		
all samples	**0.72**	0.66	-8.3
Campine region	0.72	**0.74**	2.8
sand & loamy sand region	**0.74**	0.64	-13.5
loam region	**0.72**	0.57	-20.8
dunes & polders	**0.65**	0.55	-15.4

Table 3. Estimates of taxonomic richness.

	Historical samples	Recent samples	
	Observed taxonomic richness		**ΔS (%)**
all samples	762	**1015**	33.2
Campine region	513	**762**	48.5
sand & loamy-sand region	522	**644**	23.4
loam region	264	**528**	100.0
dunes & polders	328	**574**	75.0
	Estimated taxonomic richness first-order jackknife		**ΔS (%)**
all samples	960 ± 25	**1239** ± 21	29.1
Campine region	655 ± 28	**945** ± 24	44.3
sand & loamy-sand region	699 ± 36	**809** ± 20	15.7
loam region	472 ± 37	**735** ± 17	55.7
dunes & polders	398 ± 26	**672** ± 24	68.8
	Estimated taxonomic richness second-order jackknife		**ΔS (%)**
all samples	1066	**1368**	28.3
Campine region	713	**1056**	48.1
sand & loamy-sand region	801	**912**	13.9
loam region	560	**824**	47.1
dunes & polders	469	**764**	62.9
	Estimated taxonomic richness Chao 2		**ΔS (%)**
all samples	976 ± 40	**1280** ± 48	31.1
Campine region	634 ± 27	**995** ± 47	56.9
sand & loamy-sand region	741 ± 44	**866** ± 47	16.9
loam region	549 ± 61	**737** ± 48	34.2
dunes & polders	538 ± 47	**759** ± 39	41.1
	Estimated taxonomic richness Michaelis Menten Means		**ΔS (%)**
all samples	804	**984**	22.4
Campine region	565	**794**	40.5
sand & loamy-sand region	634	**665**	4.9
loam region	**663**	565	-14.8
dunes & polders	441	**599**	35.8
	Incidence-based coverage estimator (ICE)		**ΔS (%)**
all samples	943	**1241**	31.6
Campine region	649	**923**	42.2
sand & loamy-sand region	703	**792**	12.7
loam region	647	**665**	2.8
dunes & polders	564	**748**	32.6

Acknowledgements

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3. Regional species richness

The gap between observed and estimated taxonomic richness generally amounts to 20-40 % (Table 3); insufficient sampling is even more conspicuous for the loam region. Nowadays, the Campine has the most taxa, but formerly the sand & sandy-loam region may have been the most speciose. Taxonomic richness increased, particularly in the Campine. The estimators suggest that taxonomic richness increased with c. 20-30 % between both periods. The largest increase probably occurred in the Campine and dunes/polders regions (Fig. 3). Many taxa are found at few sites only; these in particular account for the observed rise in species richness (Fig. 4).

Fig. 3. Historical and recent species accumulation curves (± SD, 50 random draws without replacement).

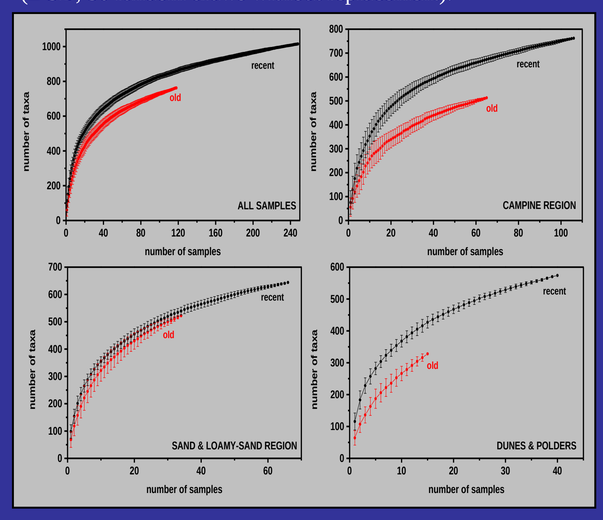
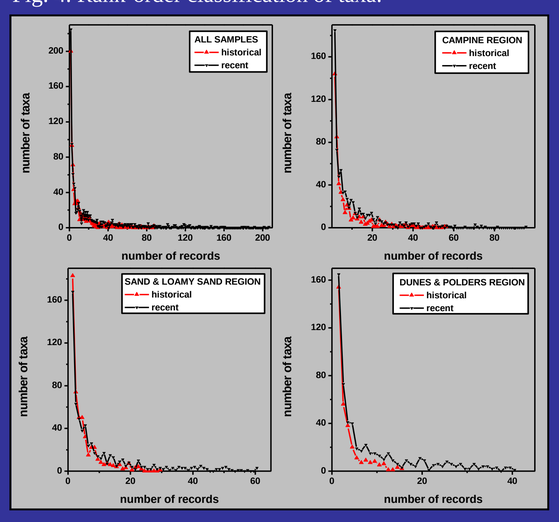


Fig. 4. Rank-order classification of taxa.



4. Biogeographic differences

MRPP analyses (Table 4) indicate that, given adequate sample size, each subregion presents a particular species pool and range in assemblage composition. The loam region is less well differentiated, however. DCA ordinations show that a larger proportion of Campine samples now differs markedly from all others than in the past (Fig. 5). The proportion of very specific taxa appears to have decreased, while that of ubiquists may have risen slightly in all subregions other than the Campine (Fig. 6). On average IndVal scores also tend to be somewhat lower nowadays (Table 5).

Table 5. Comparison of average specificity, fidelity and IndVal per taxon.

** $p < 0.01$, *** $p < 0.001$		Campine region	sand & loamy-sand region	loam region	dunes & polders
average specificity score	historical	31.9 ± 39.1	29.9 ± 36.4	16.3 ± 30.4	22.0 ± 36.2
	recent	34.3 ± 37.5	22.4 ± 29.1	19.7 ± 27.9	23.7 ± 33.1
	p, trend	** ↑	** ↓	*** ↑	*** ↑
average fidelity score	historical	7.6 ± 12.8	9.1 ± 13.2	12.7 ± 20.7	8.5 ± 16.2
	recent	7.7 ± 12.3	9.6 ± 16.7	10.7 ± 19.4	11.6 ± 20.5
	p, trend	n.s.	*** ↑	** ↓	*** ↑
average IndVal score	historical	3.6 ± 8.0	3.3 ± 5.6	5.6 ± 11.1	4.3 ± 10.6
	recent	3.3 ± 7.7	2.7 ± 5.2	3.8 ± 7.8	4.1 ± 8.4
	p, trend	n.s.	** ↓	n.s.	** ↓

MATERIAL AND METHODS

Recent data: 248 littoral sediment samples from selected permanent and fresh standing waters, collected from 1998 to 2001 (Fig. 1). **Historical data:** 118 sediment samples collected from this habitat between 1852 and 1943, mostly taken from herbarium specimens of macrophytes (Fig. 1). **Preparation:** treatment with concentrated hydrogen peroxyde; slides prepared using Naphrax®. **Counts:** 500 valves along random transects; detailed inventory of remaining taxa. **Abundance:** percentages with 0.02 % extra for each taxon oustside count; uniform taxonomy (some lumping); marine-littoral taxa excluded.
Taxonomic richness: observed number of taxa and incidence-based estimators (first and second-order jackknife, Chao 2, Michaelis Menten Means, Incidence-based Coverage - ICE). Calculated with EstimateS 6.0b1. **Diversity indices:** number of taxa in sample (TAXA), number of taxa in the count (TAXA/500), percentage of most abundant taxon (% MAX.), 1/D (reciprocal of Simpson's dominance), H' (Shannon, log 2 base) and J' (evenness); calculated with Biodiversity Professional Beta 1997. **Compositional turnover:** gradient length of the first axis in Detrended Correspondence Analysis (DCA; CANOCO 4.0). **Average within-group distances:** using Euclidean (on abundance basis) and Sørensen distance (for abundance and incidence data); from Multiple Response Permutation Procedure (MRPP) analyses (PC-Ord 3.2). **Differences in assemblage composition between regions**: MRPP. **Specificity, fidelity, combined Indicator Value (IndVal):** Indicator Species Analysis (PC-Ord 3.2). **Statistical tests:** Mann-Whitney *U* (Statistica 5.1).

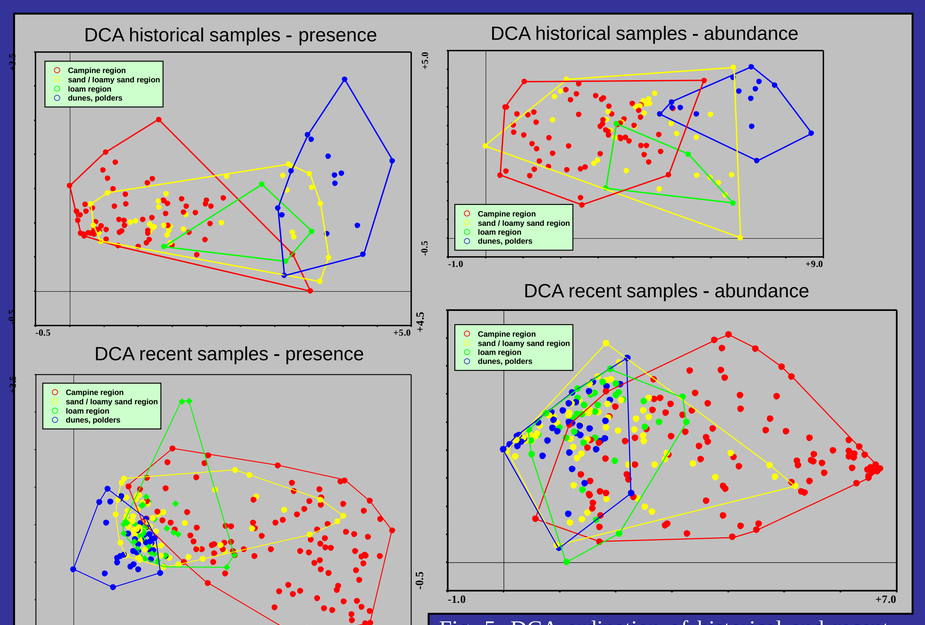


Fig. 5. DCA ordination of historical and recent samples with incidence or abundance data (axes 1 and 2) and indication of subregions.

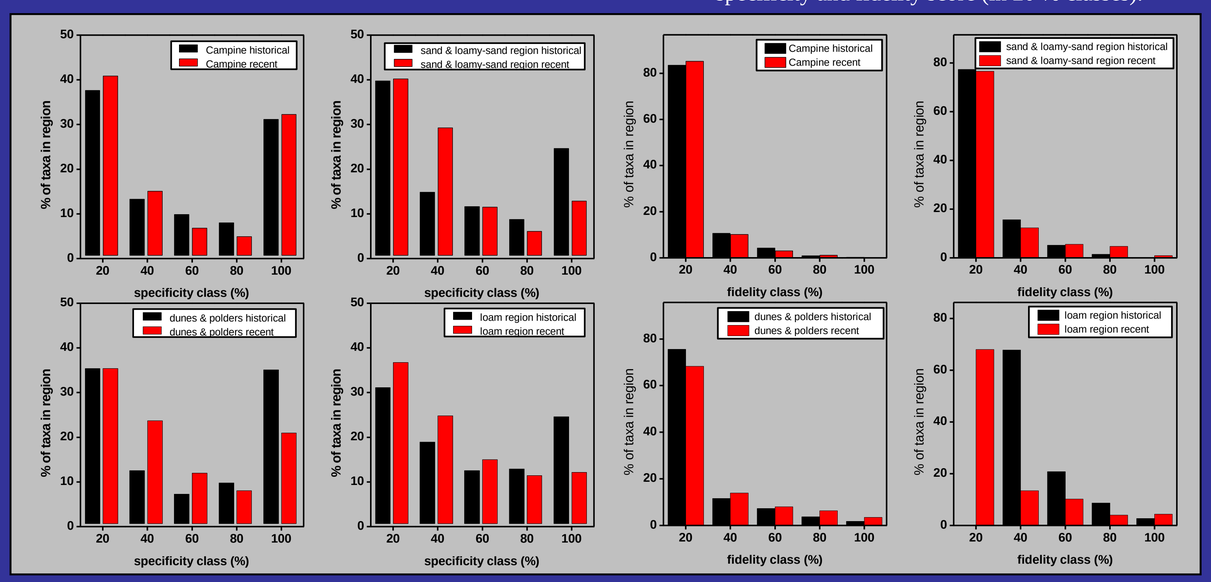
Table 4. Results of pairwise MRPP. Historical data in upper part of matrix, recent data in lower part.

ABUNDANCE-BASED; EUCLIDEAN DISTANCE					
* $p < 0.05$, ** $p < 0.01$; *** $p<0.001$	**Campine region**	**sand & loamy-sand region**	**loam region**	**dunes & polders**	
Campine region	–	**	n.s.	***	**OLD**
sand & loamy -sand region	***	–	n.s.	**	
loam region	***	n.s.	–	n.s.	
dunes & polders	***	***	**		
	RECENT				

ABUNDANCE-BASED; SØRENSEN DISTANCE					
* $p < 0.05$, ** $p < 0.01$; *** $p<0.001$	**Campine region**	**sand & loamy-sand region**	**loam region**	**dunes & polders**	
Campine region	–	***	n.s.	***	**OLD**
sand & loamy -sand region	***	–	n.s.	***	
loam region	***	*	–	n.s.	
dunes & polders	***	***	***		
	RECENT				

INCIDENCE-BASED; SØRENSEN DISTANCE					
* $p < 0.05$, ** $p < 0.01$; *** $p<0.001$	**Campine region**	**sand & loamy-sand region**	**loam region**	**dunes & polders**	
Campine region	–	***	**	***	**OLD**
sand & loamy -sand region	***	–	n.s.	***	
loam region	***	**	–	*	
dunes & polders	***	***	***		
	RECENT				

Fig 6. Percentage distribution of taxa according to specificity and fidelity score (in 20 % classes).



CONCLUSIONS

• Species diversity of individual samples increased. • Habitat heterogeneity decreased, except in the Campine region. • More samples must be analysed for reliable estimation of regional taxonomic richness. • The present diatom inventory probably accounts for only c. 2/3 of the actual number of taxa. • Regional taxonomic richness increased, especially in the Campine region; some likely causes are eutrophication and creation of deep waters. • Biogeograpically, the Campine now stands out more than before (persistence of less nutrient-rich habitats, ascent of mineral-acid waters ...), while other subregions may have become slightly more similar in this respect.