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Limnological Characteristics and Diatom Dominants in Lakes of Northeastern Poland

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Abstract: Determination of the relationships between environmental factors and diatom assemblages is usually made for several hundred lakes spread over a large area. However, the analysis of several lakes located near Lake Wigry also gives interesting results. Lakes in Wigry National Park (Poland)

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Introduction

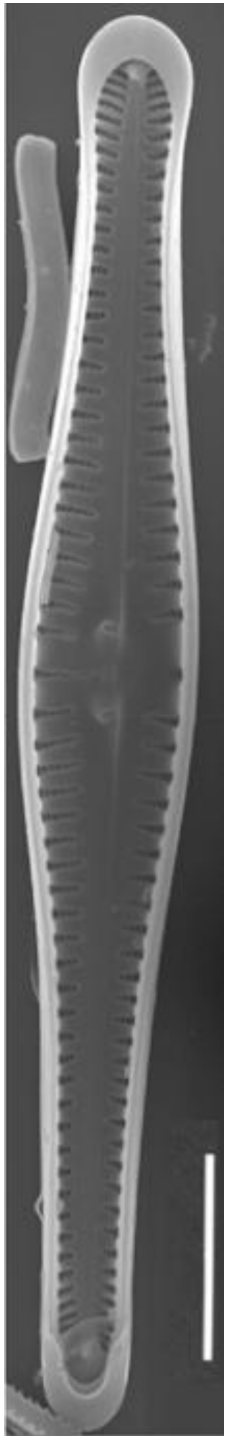
- Machine learning techniques are valuable tools for environmental studies. Unsupervised machine learning give us an opportunity to find exceptional perspective on problems in extensive monitoring.
- Lakes are hotspots of biodiversity as well as systems particularly sensitive to environmental change
- Shore-zone areas offer so many ecosystem services, lakes can be seen as among the world’s most threatened environments
- Lakes are threatened by direct (e.g., nutrient enrichment, forestry practices, and agriculture pressure) and indirect (e.g., climate change) effects
- Climate change on lakes’ water chemistry

Need of monitoring – diatoms as useful bioindicators

Muliczne

Białe Pierciańskie

Research objectives



- ➢Compare variables relating to physical and chemical characteristics of the different waters by usage of unsupervised machine learning. Setting the results against previous data for the same area
- ➢Examination of the lakes’ impacts on their diatom assemblages, set against previous findings for lakes within Wigry National Park

Białe Pierciańskie

Białe Wigierskie

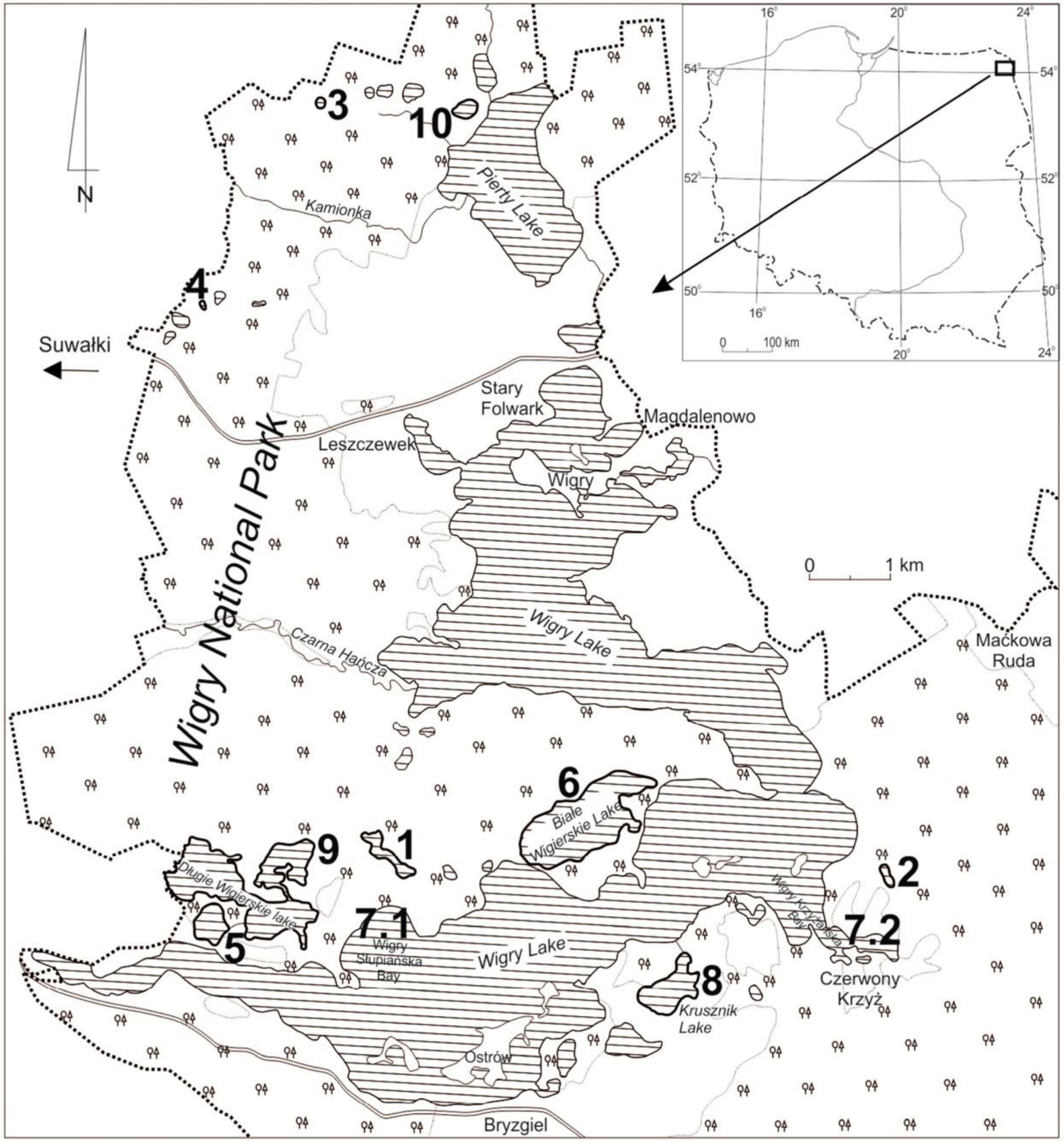
Wigry

Gomphonema vibrio var. *subcapitatum* (A. Mayer) J. H. Lee

Study Area

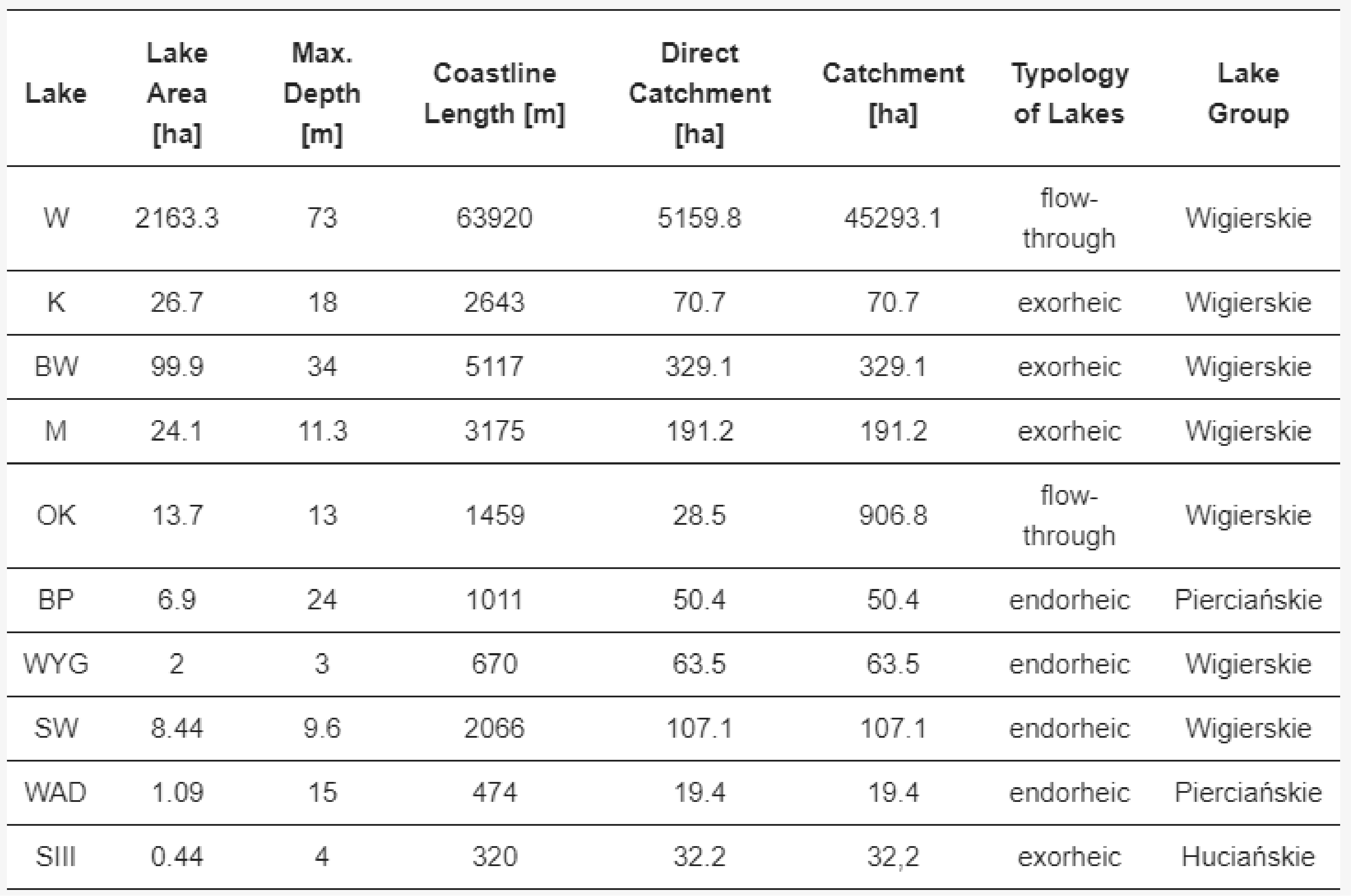
- Poland - Wigierski Park Narodowy
- Located in NE Poland
- Temperate climate transitional between the maritime and the continental
- Lakes - glacial and postglacial origin
- shore-zone vegetation – helophytes: common reed (*Phragmites australis* (Cav.) Trin. ex Steud), common club-rush (*Schoenoplectus lacustris* L.),

and lesser bulrush (*Typha angustifolia* L), for Humic lakes floating mats -(*Scheuchzeria palustris* L., Cyperaceae, Ericaceae) peat mosses and brown mosses



1—Suchar Wielki (SW), 2—Wygorzele (WYG), 3—Wądołek (WAD), 4—Suchar III (SIII), 5—Okrągłe (OK), 6—Białe Wigierskie (BW), Wigry 7.1—Słupiańska Bay (WS), 7.2—Wigry (WK) Krzyżańska Bay, 8—Krusznik (K), 9—Muliczne (M), 10—Białe Pierciańskie (BP).

Limnological characteristics of lakes

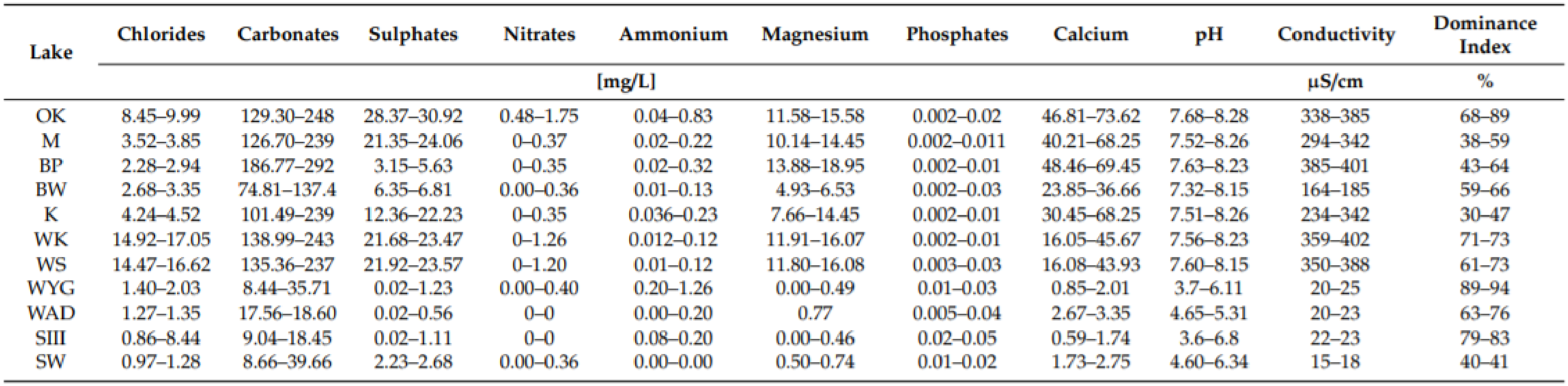


Lake	Lake Area [ha]	Max. Depth [m]	Coastline Length [m]	Direct Catchment [ha]	Catchment [ha]	Typology of Lakes	Lake Group
W	2163.3	73	63920	5159.8	45293.1	flow-through	Wigierskie
K	26.7	18	2643	70.7	70.7	exorheic	Wigierskie
BW	99.9	34	5117	329.1	329.1	exorheic	Wigierskie
M	24.1	11.3	3175	191.2	191.2	exorheic	Wigierskie
OK	13.7	13	1459	28.5	906.8	flow-through	Wigierskie
BP	6.9	24	1011	50.4	50.4	endorheic	Pierciańskie
WYG	2	3	670	63.5	63.5	endorheic	Wigierskie
SW	8.44	9.6	2066	107.1	107.1	endorheic	Wigierskie
WAD	1.09	15	474	19.4	19.4	endorheic	Pierciańskie
SIII	0.44	4	320	32.2	32,2	exorheic	Huciańskie

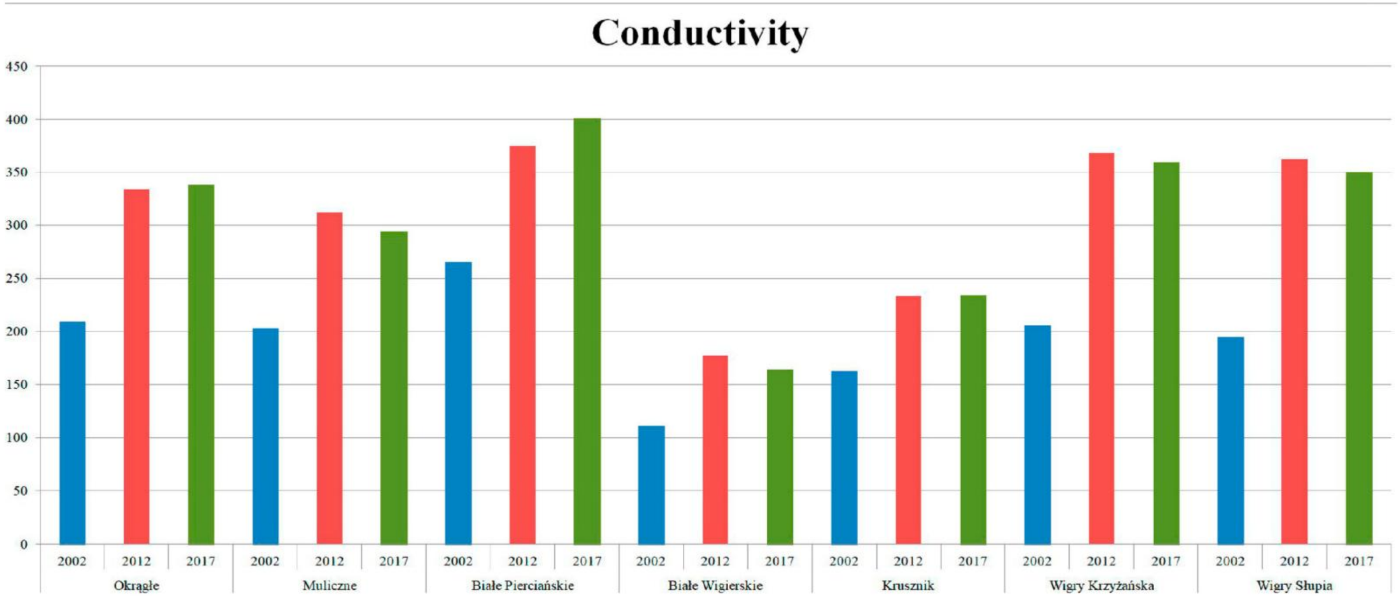
Methods

- 44 water samples - physical and chemical properties - spring (May 2015, May 2017), summer (September 2017), and autumn (November 2016) from 11 sampling points
- Unsupervised Machine Learning were used to analyze variables:
  - Hierarchical Cluster Analysis (HCA) was applied to the chemical data to identify the main sources of variation within given lakes and to produce a classification of the bodies of water analyzed (Ward's minimum, Euclidean distance)
  - Principal Component Analysis was used to visualize a sample grouping in line with physical and chemical variables
- Generalized Linear Models (lm function) with the categorical independent variable (group) to investigate differences between HCA groups, The dominance index was calculated as DI = p1 + p2, i.e., the sum of the two highest abundance values (%) in a sample.

Results - Physical, chemical and biological characteristic of the studied lakes.



Lake	Chlorides	Carbonates	Sulphates	Nitrates	Ammonium	Magnesium	Phosphates	Calcium	pH	Conductivity	Dominance Index
	[mg/L]									µS/cm	%
OK	8.45–9.99	129.30–248	28.37–30.92	0.48–1.75	0.04–0.83	11.58–15.58	0.002–0.02	46.81–73.62	7.68–8.28	338–385	68–89
M	3.52–3.85	126.70–239	21.35–24.06	0–0.37	0.02–0.22	10.14–14.45	0.002–0.011	40.21–68.25	7.52–8.26	294–342	38–59
BP	2.28–2.94	186.77–292	3.15–5.63	0–0.35	0.02–0.32	13.88–18.95	0.002–0.01	48.46–69.45	7.63–8.23	385–401	43–64
BW	2.68–3.35	74.81–137.4	6.35–6.81	0.00–0.36	0.01–0.13	4.93–6.53	0.002–0.03	23.85–36.66	7.32–8.15	164–185	59–66
K	4.24–4.52	101.49–239	12.36–22.23	0–0.35	0.036–0.23	7.66–14.45	0.002–0.01	30.45–68.25	7.51–8.26	234–342	30–47
WK	14.92–17.05	138.99–243	21.68–23.47	0–1.26	0.012–0.12	11.91–16.07	0.002–0.01	16.05–45.67	7.56–8.23	359–402	71–73
WS	14.47–16.62	135.36–237	21.92–23.57	0–1.20	0.01–0.12	11.80–16.08	0.003–0.03	16.08–43.93	7.60–8.15	350–388	61–73
WYG	1.40–2.03	8.44–35.71	0.02–1.23	0.00–0.40	0.20–1.26	0.00–0.49	0.01–0.03	0.85–2.01	3.7–6.11	20–25	89–94
WAD	1.27–1.35	17.56–18.60	0.02–0.56	0–0	0.00–0.20	0.77	0.005–0.04	2.67–3.35	4.65–5.31	20–23	63–76
SIII	0.86–8.44	9.04–18.45	0.02–1.11	0–0	0.08–0.20	0.00–0.46	0.02–0.05	0.59–1.74	3.6–6.8	22–23	79–83
SW	0.97–1.28	8.66–39.66	2.23–2.68	0.00–0.36	0.00–0.00	0.50–0.74	0.01–0.02	1.73–2.75	4.60–6.34	15–18	40–41

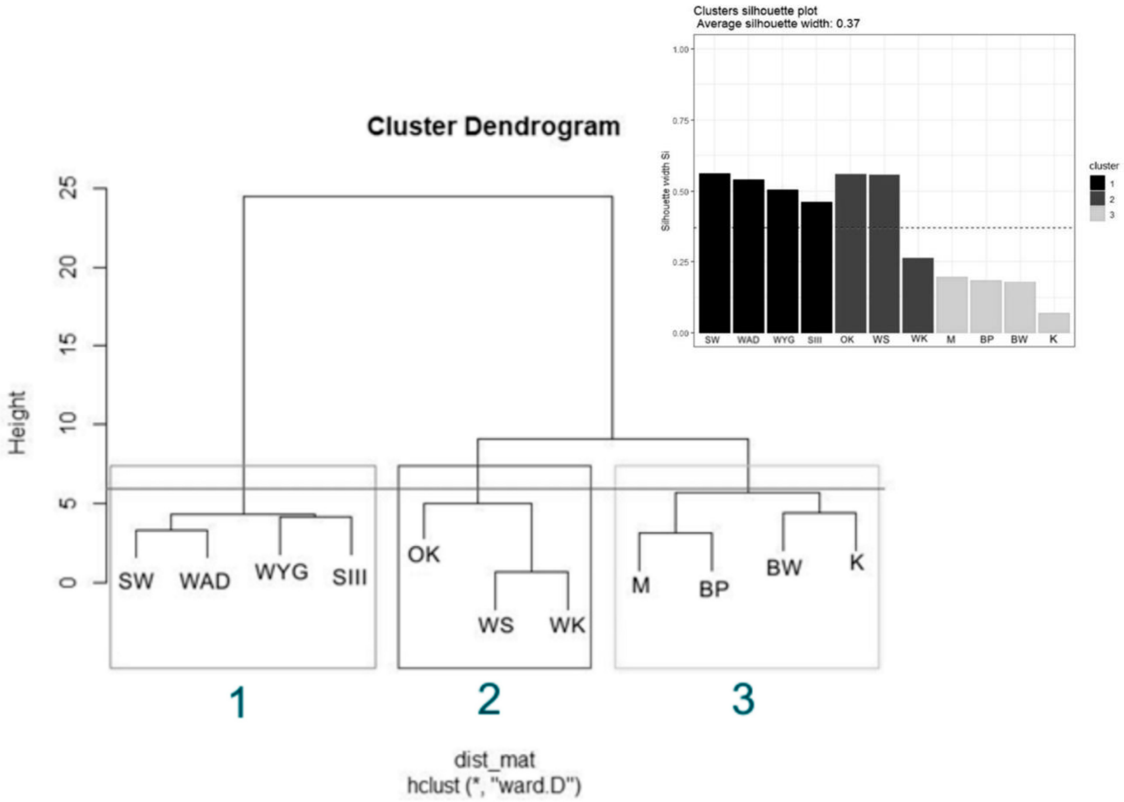


Changes in conductivity: our results from summer in comparison with data from 2011/2012 and 2002 (modified after Górniak (Ed.), 2014 and Górniak, 2006).

Results HCA

Hierarchical Cluster Analysis (HCA) for physical and chemical variables - Lakes in the first group disharmonic—box (1): SW, WYG, WAD, and SIII. Lakes in the second group harmonious with greater human impact on the environment—box (2): OK, WS, and WK. Lakes in the last group harmonious with low human impact on the environment—box (3) were BW, K, M, and BP.

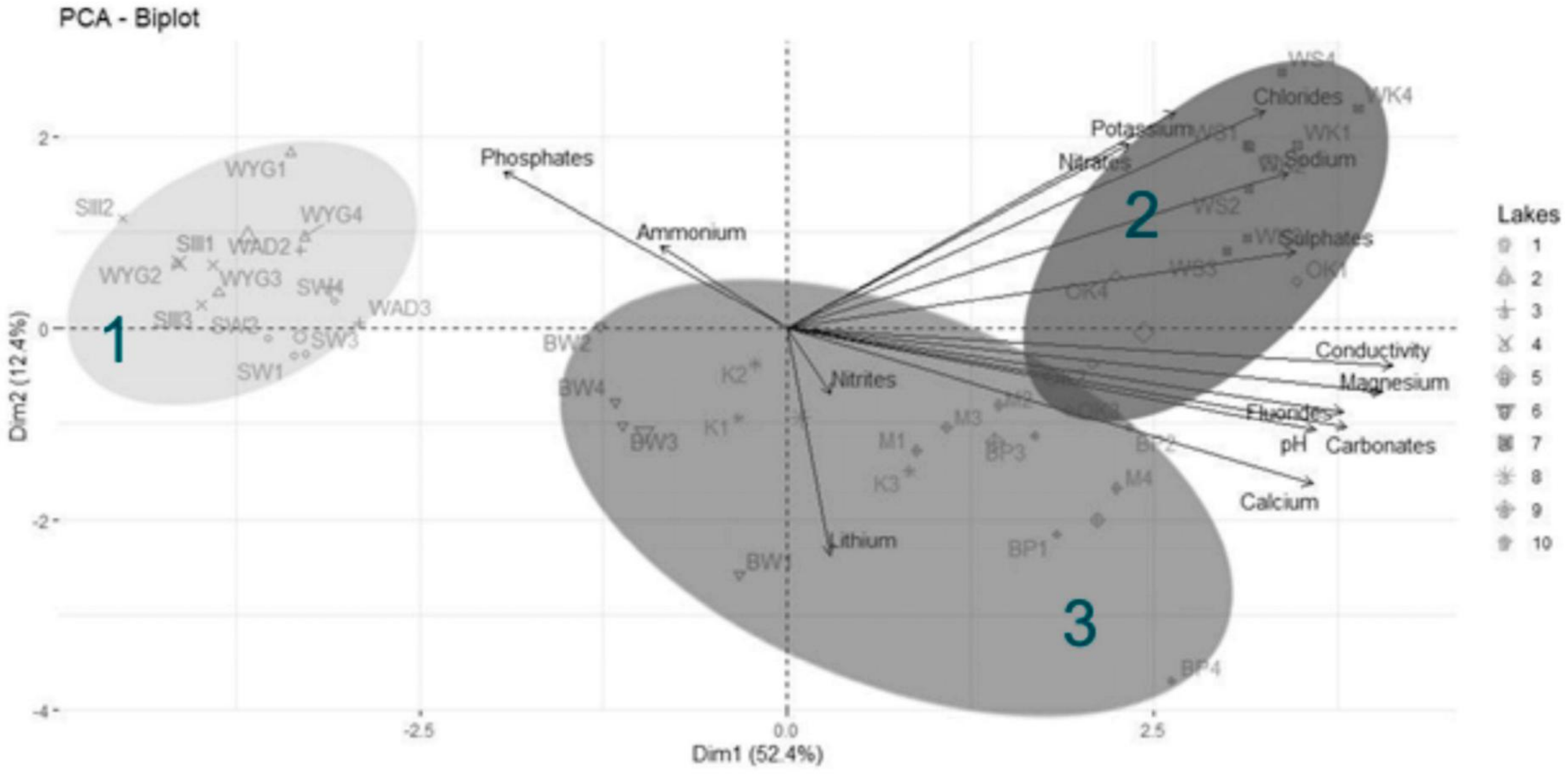
The mean Silhouette width (used to analyze the effectiveness of grouping) was 0.37. The prediction strength of these three clusters were estimated as 0.86 (PS > 0.8, strong support).



Wigry

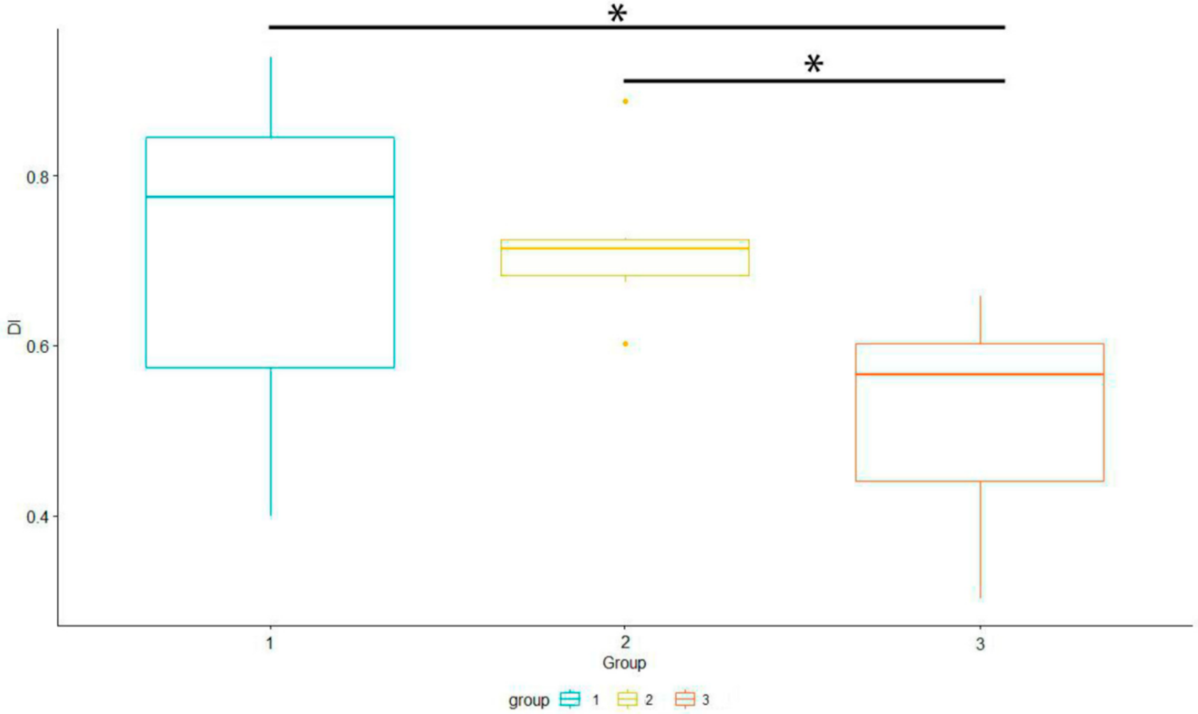
Results PCA

Principal Component Analysis (PCA) for physical and chemical variables in the studied reservoirs. Ellipses on the biplot represent cluster groups (from HCA). The cumulative explained variation (for axis 1 and 2) is 64.8%. Lakes in group 1 (disharmonic): 1—SW, 2—WYG, 3—WAD, and 4—SIII. Lakes in group 2 (harmonious with a greater human impact on the environment): 5—OK, 7—WS and WK. Lakes in group 3 (harmonious with a more limited human impact on the environment): 6—BW, 8—K, 9—M, and 10—BP. Ellipses on the biplot represent cluster groups (HCA).



Results GLM

Differences in Dominance Index between groups. * showed significant differences ($p < 0.05$) between groups 1–3 and 2–3. Group 1 – disharmonic, Group 2 - harmonious with a greater human impact on the environment, Group 3 - harmonious with a more limited human impact on the environment.



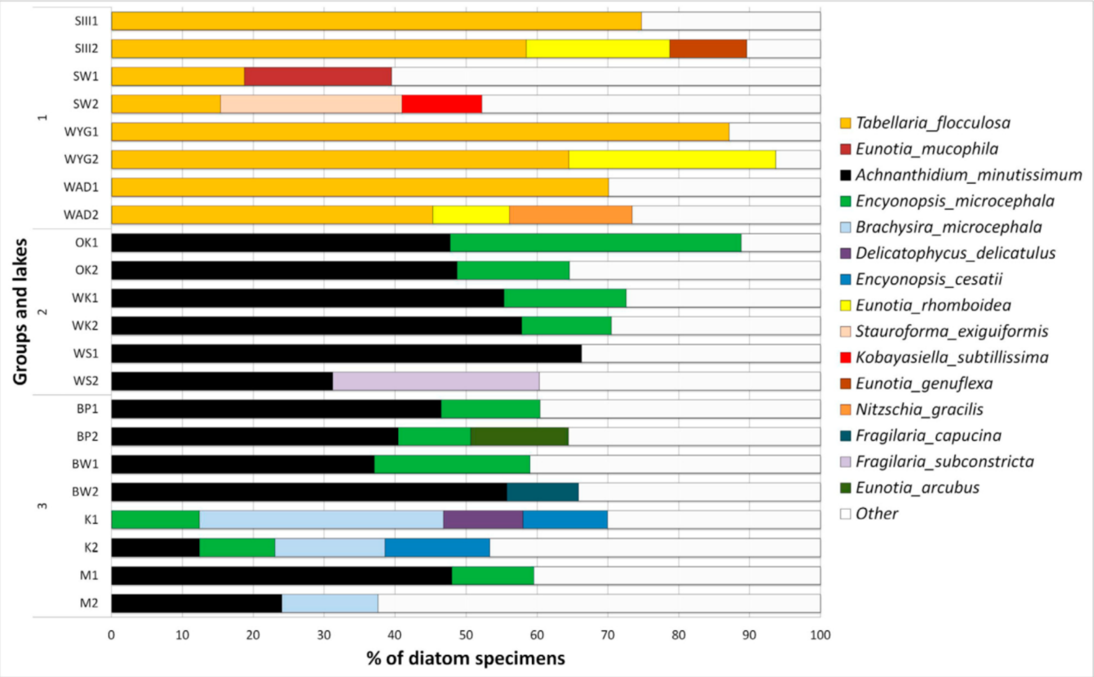

Wygorzele

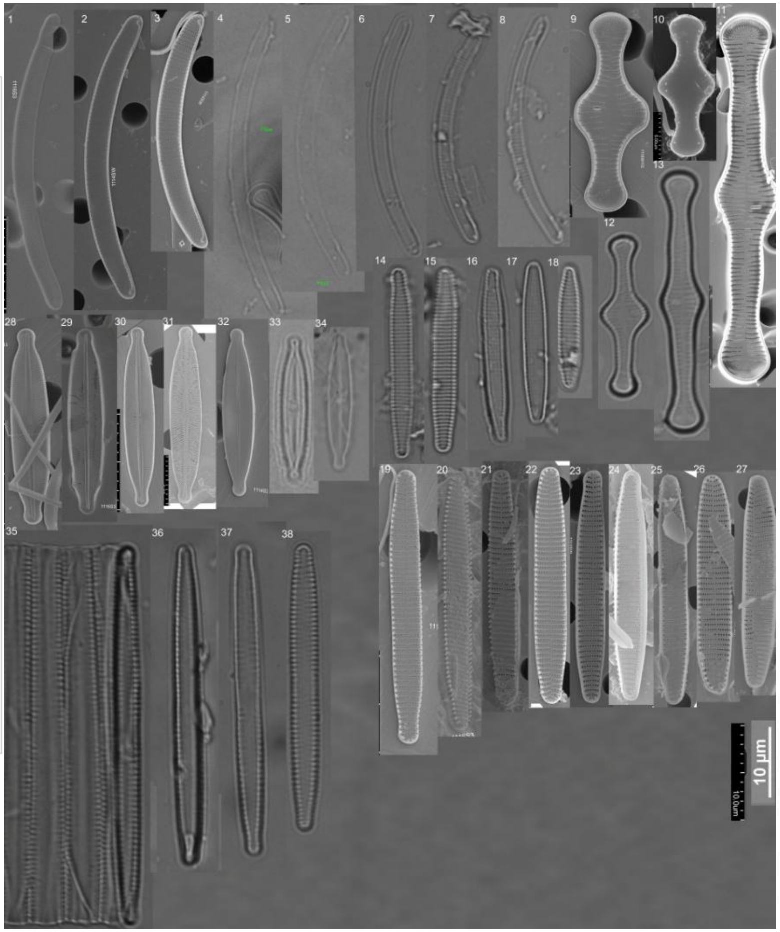

Suchar Wielki


Suchar – one of disharmonic lakes

Results – relative abundance

Relative abundance of the most numerous diatom taxa found in examined lakes group (1)—SW, WYG –, WAD, SIII, group (2)—OK, WSand WK, group (3)—BW, M and BP. Notation 1 (as e.g., in BW1) spring samples, notation 2 (as e.g., in BW2) autumn samples.

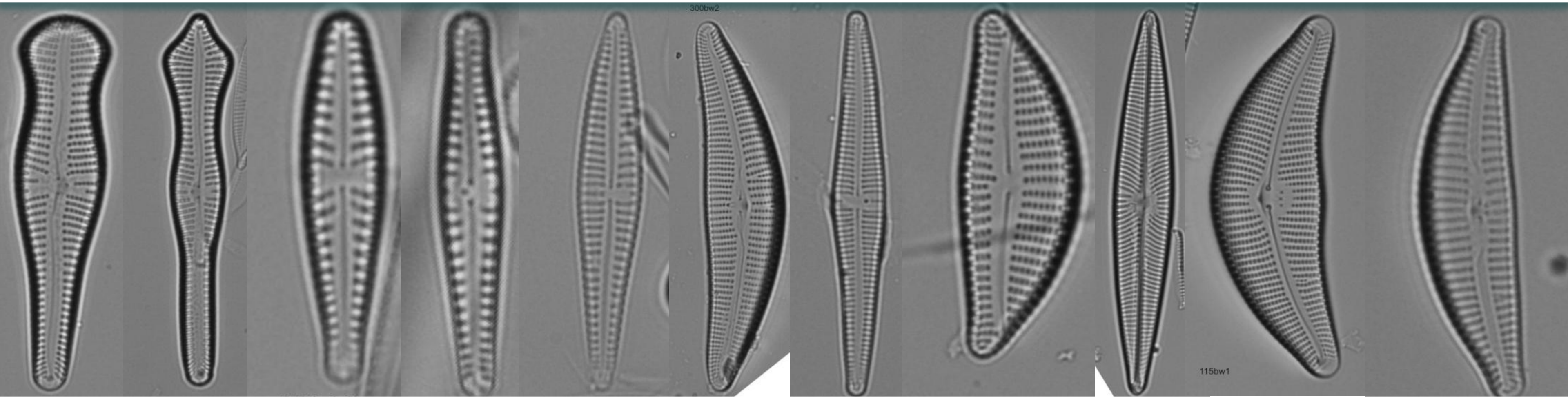




Dominant species: *Achnanthidium minutissimum* 1–10, *Brachysira microcephala* 11–17, *Delicatophycus delicatulus* 18–23, *Encyonopsis microcephala* (24–26 and 37–39), *E. cesatii* (27–30), *Eunotia rhomboidea* (31–36), *E. arcubus* (40–43), *E. genuflexa* (44–47).

Conclusions

- Unsupervised machine learning techniques - Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA) clearly separated off disharmonic lakes (of low pH and rich in allochthonous matter), as opposed to harmonious ones. The latter were divided into groups indicating human impact on the environment as either high or low, with this assessment depending mainly on content of chloride and sulfate ions.
- Lakes impacted by anthropopression and disharmonic had the strongest dominance structure.
- The three groups had different dominance structures, given the abundance of dominants as well as the Dominant Index (mean values being: (1)—70.54%, (2)—72%, and (3)—54.58%, Generalized Linear Models with the categorical independent variable (for 1–3, 2–3) p value < 0.05).
- The high figure in the first case can be considered due to the more severe environmental conditions experienced (low pH and the presence of humic acids); on the other hand, the high DI in group 2 can be associated with anthropopression indicators.



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