Macrophyte Indicator based assessment of environmental change in Lake Durowskie.

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Content

Figure Contents

Table Contents

Introduction

Urban lakes are a valuable asset to towns – encouraging tourism and leisure activities whilst providing other functions. Indeed, lakes can be said to provide all of the main ecosystem service types defined by Muller (2000): provisioning (providing food in the form of fish and clean water), supporting and regulating services (by helping to regulate air and water quality) and cultural services (in the form of leisure activities and aesthetic beauty).

Macrophytes provide key ecosystem services in freshwater ecosystems, including preventing erosion and providing protection from toxic chemicals. Macrophyte species also provide refuge and food for a range of invertebrate species, including zooplankton which regulate the ecosystem (for example, zooplankton is known to reduce the occurrence of excessive cyanobacteria blooms. They also have substantial direct and indirect effects on the leisure activities of the lake – they make the lake more aesthetically pleasing and provide habitats for various vertebrate species (including fish utilised by anglers).

However, these economic activities may threaten macrophyte and ecosystem health. For example, it has been estimated (Goldyn 2018 pers. comm.) that anglers can introduce as much as 2kg of nutrient rich food matter per angler per day into the lake from fish bait. Motorboats used for leisure also generate strong waves which exert unnaturally strong erosion forces on the shoreline and littoral sediments.

Nutrient regulation arguably the greatest ecosystem service performed by macrophytes. Larger macrophytes, especially submergent species (those who do not rise above the water surface) can take up nutrients from the water and store them for years – by contrast, phytoplankton only stores nutrients for less than a single year (and sometimes only for days) (Lone et al. 2014). Preventing erosion along banks prevents sudden deposition of nutrient rich sediments (Horrpila et al. 2013). However in severely hypertrophic lakes, phytoplankton blooms can become extreme and can limit macrophyte growth and diversity. In effect, extreme hypertrophic conditions can stifle the very macrophytes that could remediate them. To solve this issue, more severe remediation can be used to allow macrophytes to re-establish and encourage the recovery of other taxonomic groups in short order.

Lake Durowskie is located at Wagroweic, Poland and covers an area of 143.7km^2. The lake was initially very hypertrophic when this study began in 2009, however a range of remedial measures (such as reducing nutrient inflow, immobilising phosphorus within sediments by iron treatment and eliminating local sources of pollution) have led to a marked improvement in the situation. Aerators were also used to improve the oxygen content of the lake after the marked decrease in oxygen caused by algae blooms. Bio-manipulation using pike was also performed to regulate the ecosystem in a top-down manner – the pike predated fish that were depressing zooplankton numbers and thus reducing the grazing pressure on phytoplankton and algae (the methodology used here was similar to Berg et al. 1997). A range of macrophyte based indicators have been utilised to monitor the progress of remedial efforts – including the ESMI and MIR indices, macrophyte coverage and macrophyte diversity. However, some problems in the area remain – in particular pollution from upstream.

The objectives of this study were to assess the ecosystem health at Lake Durowskie, using a range of macrophyte indicator species. In particular, the study sought to assess the effectiveness of restoration measures and to identify opportunities for improvement.

1. Materials and Methods

1.1. Study Area.

The Lake Durowskie, Wagrowiec, in the northwestern part of Poland. It's geographical location lies between N 52°49'6" and E 17°12'1". It is a postglacial lake with elongated shape. It has an area of 143.7 ha and a maximum depth of 14.6m. The lake is also connected with four other lakes; they are linked by the Struga Gołaniecka River. Therefore it is not just influenced by the city and human activities but also by the surrounding types of land uses as well as the comparatively natural vegetation of forests .

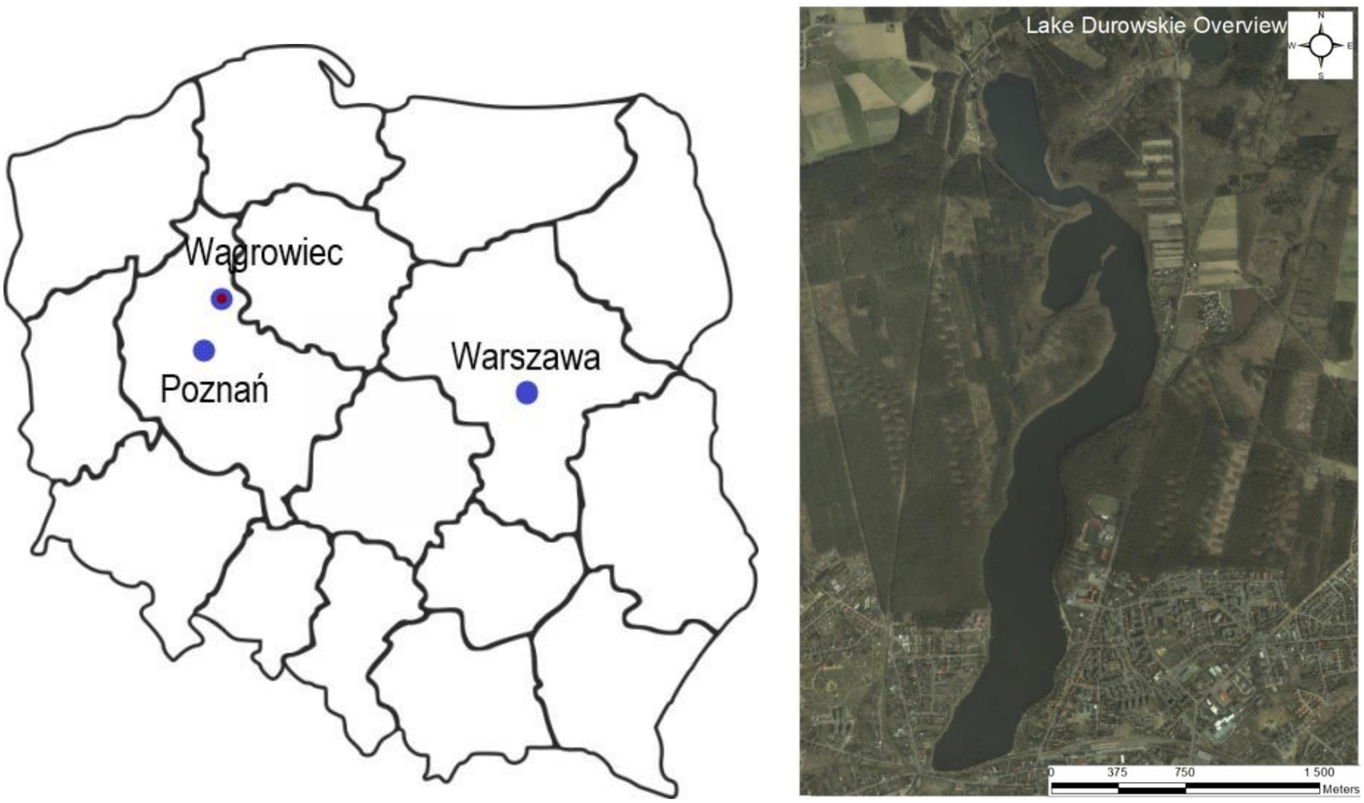

Figure 1. Map of Lake Durowskie

Table 1Typical characteristics of Lake Durowskie.

Location	Commune and district Wągrowiec
Surface	143.7 ha
Volume	11 322 900 m^3
Maximum depth	14.6 m
Average depth	7.9 m
Main tributary	Struga Golaniecka
Surface of the entire sampling area	236.1 km^2
Surface in the direct catchment area	1.581 ha
Share of agricultural area	58.26 %
Share of forests	33.52 %
Urban areas	8.25 %

Sourses:Macrophytes report 2017.

2.2. Data gathering

Data was taken along the entire shoreline of the lake by visual assessment (for emergent plants) and by anchor (submergent species), primarily from a small oar-propelled boat. Each association and feature was recorded and mapped using GPS. The borders of each association were found to determine patch area and patches were identified using the Braun-Blanquet method, due to its' high field-time efficiency (Wikum & Shanholtzer 1978). For patches of submerged species, maximum depth was found using a dropped anchor.

An additional assessment was performed at the outflow of the lake to determine dominant species. Here, dominant species were assessed for % of area and ranked for dominance. The outflow itself is well shaded by trees and receives treated rain water from Wagroweic. A noticeable amount of litter was present at the outflow which may increase nutrient and contaminant concentration.

All materials and methodologies used were consistent with the other studies on Lake Durowskie performed by the Adam Mickiewicz University since 2010 to ensure data reliability. Data was gathered between June 29th and June 30th 2018.

2.3. Data Analysis

All GPS coordinates were imported to QGIS For conversion to a shapefile and then moved to ARCGIS v 10.5. The points were then used to create additional shapefile layers for each species association. The geometry calculator tool was subsequently used to calculate spatial areas of extent; these were then imported into Microsoft Excel software for calculation of the ESMI index (see below) and for calculation of total areas per species and % of covered area.

2.4. Evaluation (ESMI and MIR)

According to the Water Framework Directive of the European Union there are two methods of calculation to find out the ecological state of the water quality: the ESMI (Ecological State Macrophyte Index) and the MIR (Macrophyte Index for Rivers) (Ciecerska, Kolada & Ruszczynska 2013), which were calculated using the field data.

The ESMI index was calculated following the methodology prescribed by the EU Water Framework Directive

$$ESMI = 1 - \exp\left[-\frac{H}{H_{max}} \cdot Z \cdot exp\left(\frac{N}{P}\right)\right]$$

$$H = -\sum \frac{n_i}{N} \cdot \ln \frac{n_i}{N}$$

$$H_{max} = \ln S$$

$$Z = \frac{N}{P_{isob2.5}}$$

where:

H – diversity index of phytocenosis

ni – area of polygons one of association in percent per cover

N – all cover of macrophytes

Hmax - coefficient of variation of the theoretical maximum

S – number of associations

Z – occupancy index

izob. 2.5m – area of littoral limited by isobath 2.5m

P – area of the lake

Table 2. below displays the classification of the ecological state of deep stratified lakes to the value of the ESMI index.

Table 2. Classification of the ecological state by ESMI.

Ecological status	**ESMI Index**
Very good	0.680-1.000
Good	0.410-0.679
Moderate	0.205-0.409
Poor	0.070-0.204
Bad	<0.070

Table 3. shows the values of the indicator value for each species, the coverage for each species, and the weight factor. The MIR index is used as a biological indicator value, which gives an indication of the water quality of running waters. The formulae is illustrated by Table 3 and formulae. Its' classification is shown in Table 4 after.

$$MIR = \frac{\sum L_{i*} W_{i*} P_i}{\sum W_{i*} P_i} * 10$$

L and W are indicator values for each species and P = percentage coverage (split into discrete categories) for that species.

Table 3. The MIR calculation.

Species name	**L**	**W**	**P**	**L*W*P**	**W*P**
Butomus umbellatus	5	2	6	60	12
Acorus calamus	2	3	2	12	6
Potamogeton pectinatus	1	1	6	6	6
Hildenbrandia rivularis	6	1	5	30	5

Phalaris arundinacea	2	1	1	2	1
Lysimachia thrysiflora	7	3	1	21	3
Cladophora sp.	6	2	4	48	8
Myriophyllum spicatum	3	1	1	3	1
Bidens frondosa	-	-	-	182	42
Calystegia sepium	-	-	-		
Lycopus europaeus	-	-	-		
SUM				364	84

Table 4. Classification of the ecological state by MIR.

Ecological status	**MIR Index**
Very good	≥44.5
Good	44.5-35.0>
Moderate	35.0-25.4>
Poor	25.4-15.8>
Bad	<15.8

2.5. Factor Correlations

The ESMI and Coverage Area of macrophytes results from this study (and the previous studies from when the studies began in 2009) were correlated using against data gathered by the partnering study teams. The factors correlated were total Phosphorus at the outflow, total phosphorus at the inflow to the lake, invertebrate biomass per meter and invertebrate biodiversity.

Confidence levels were set at 5%. Due to the limited number of data points, non-parametric Spearman rank correlations were used. All statistical analyses were performed in R v.3.4.4. (R Core Team 2018).

3. Results

3.1. Macrophyte Associations.

During the study, 23 different associations were observed. *Phragmitetum communis* was by far the most widespread species, occupying almost 58% of all macrophyte covered areas in the lake.

Table 5. Area of observed macrophyte associations.

Name of association	Sum of area	% Area
Phragmitetum communis	65243,095	57,99
Myriophylletum spicati	15238,476	13,55
Typhetum angustifoliae	13627,852	12,11
Fontinaletum antipyreticae	11929,701	10,60
Nupharo Nymphaetum	3430,566	3,05
Potametum perforiati	704,395	0,63
Caricetum ripariae	699,472	0,62
Acoretum calami	685,832	0,61
Nitellopsidetum obtusae	245,638	0,22
Najadetum marinae	186,929	0,17
Scirpetum lacustris	148,231	0,13
Sparganietum erecti	69,545	0,06
Charetum contrariae	69,366	0,06
Butametum umballati	65,868	0,06
Thelypteridi Phragmitetum	29,516	0,03
Potametum lucentis	29,229	0,03
Glycerietum maximae	21,957	0,02
Charetum tometosae	20,718	0,02
Eleocharitetum palustris	20,424	0,02
Caricetum acutiformis	13,219	0,01
Cicuto Caricetum pseudocyperi	11,465	0,01
Typhetum latifoliae	6,510	0,01
Iridetum pseudacori	1,378	0,001
Total	**112499.3832**	**100**

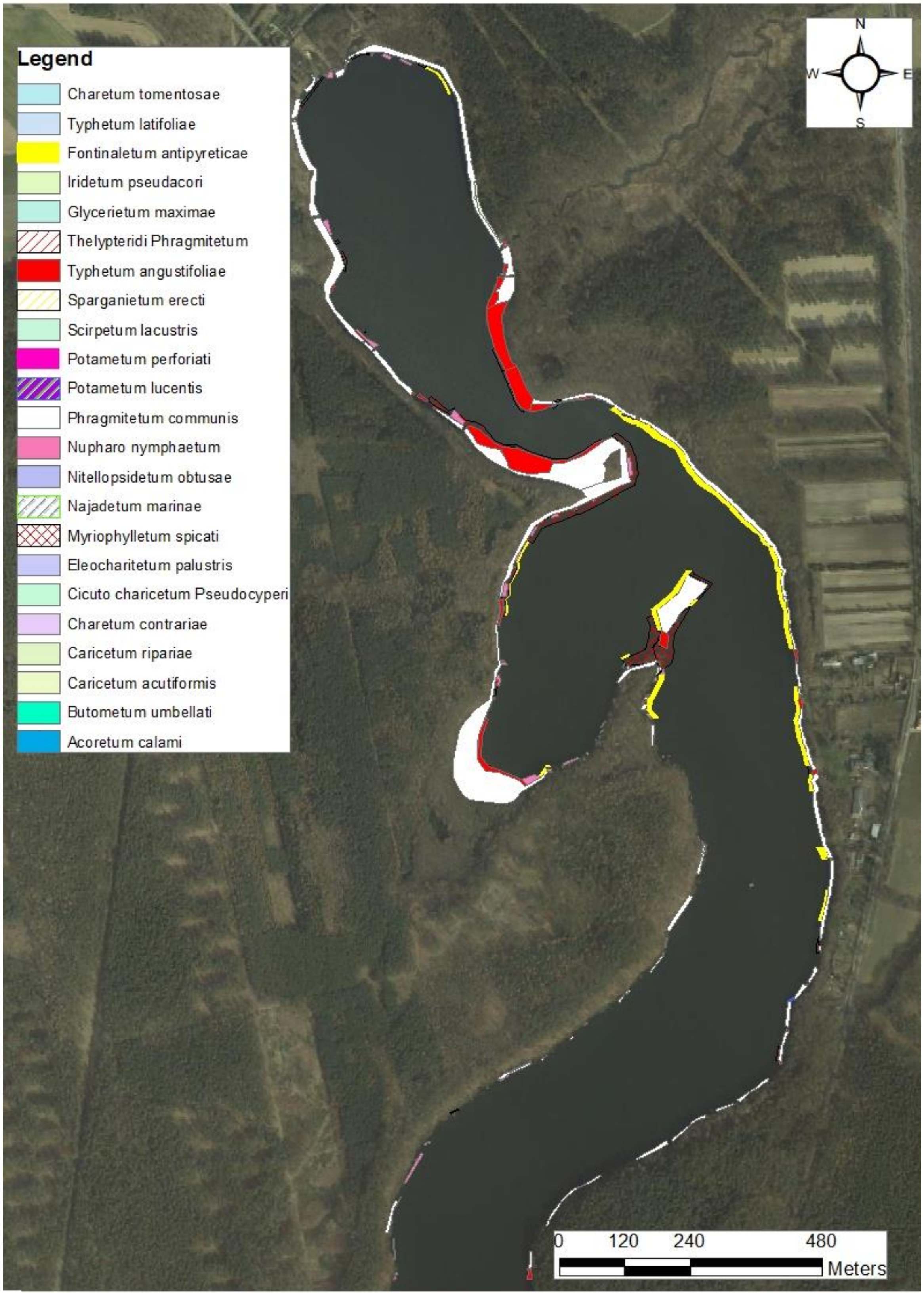

Figure 2.North section of the lake.

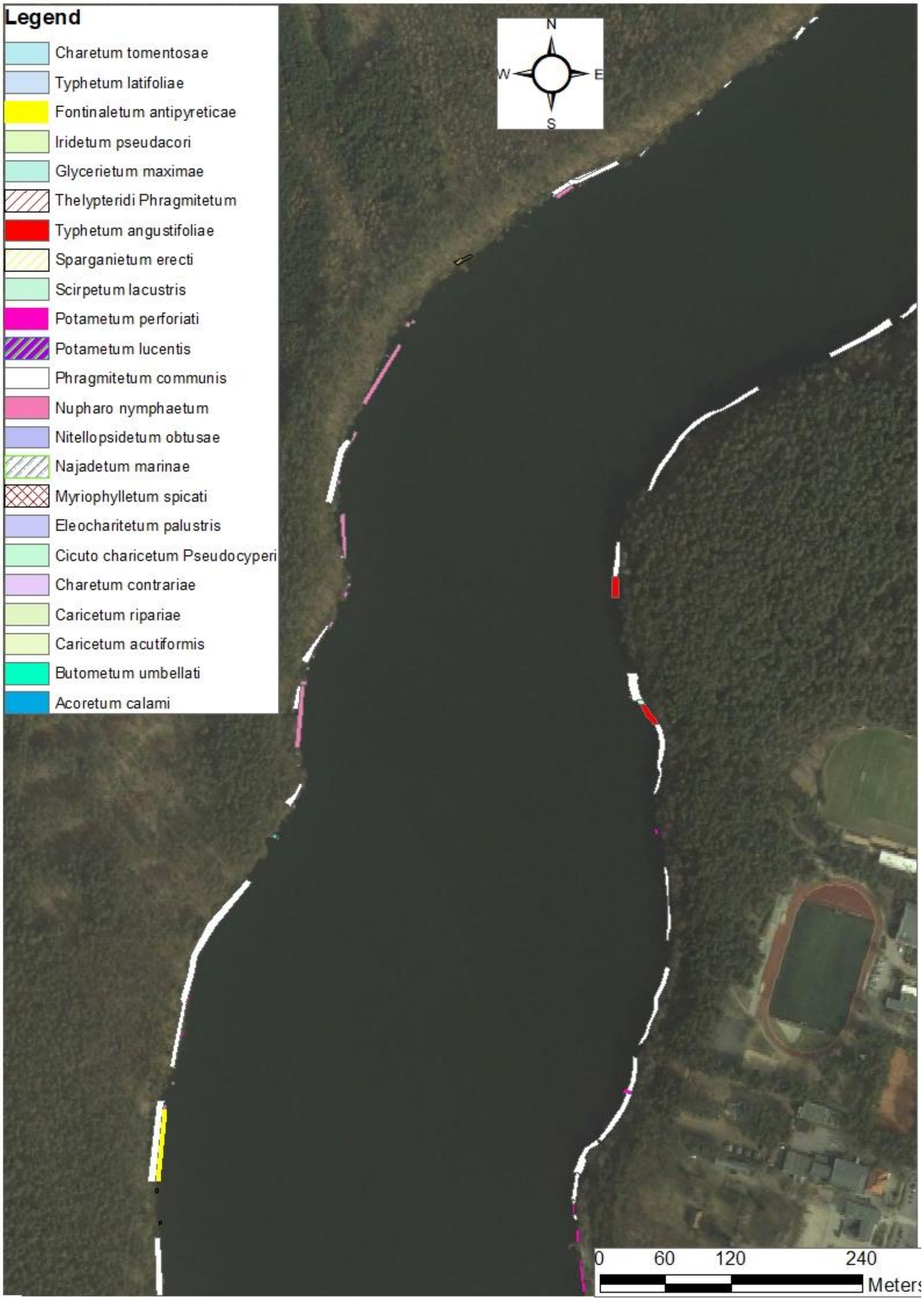

Figure 3. Central section of the lake.

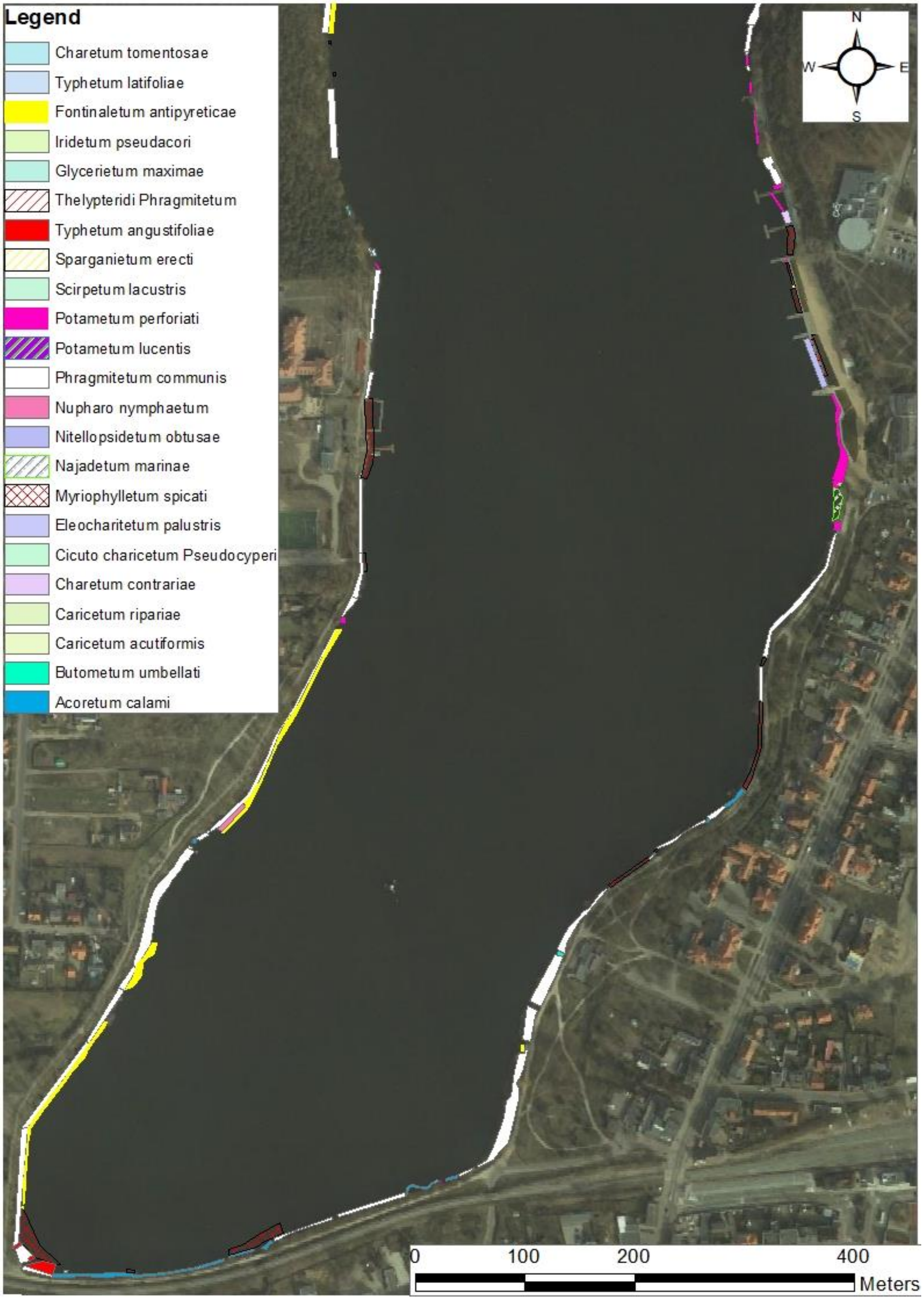

Figure 4. South section of the lake

Figures 2, 3and 4 illustrate the distribution of various macrophyte associations at different parts of the lake (map divided so that the communities are more visible). As in previous years, the northern part of the lake has a clear increase in macrophyte area and association diversity. The central area had lower macrophyte density, possibly being influenced by tree shade and intense waves. The southern part of the lake was more variable – some parts had thick macrophyte communities, whilst others were bare; perhaps because of much higher anthropogenic activity and smaller littoral zones.

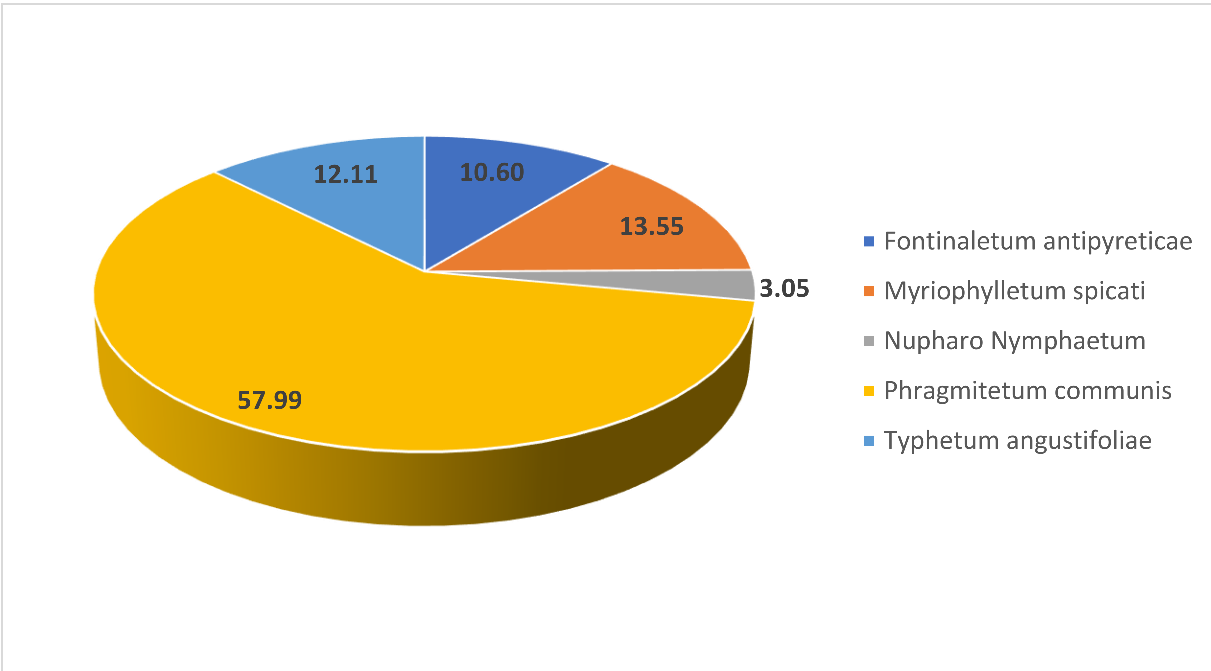

Figure 5. Dominant macrophyte associations 2018.

Phragmetetum communis was the dominant community, especially along the banks. All other associations (those not depicted here) occupied less than 1% of the lake area.

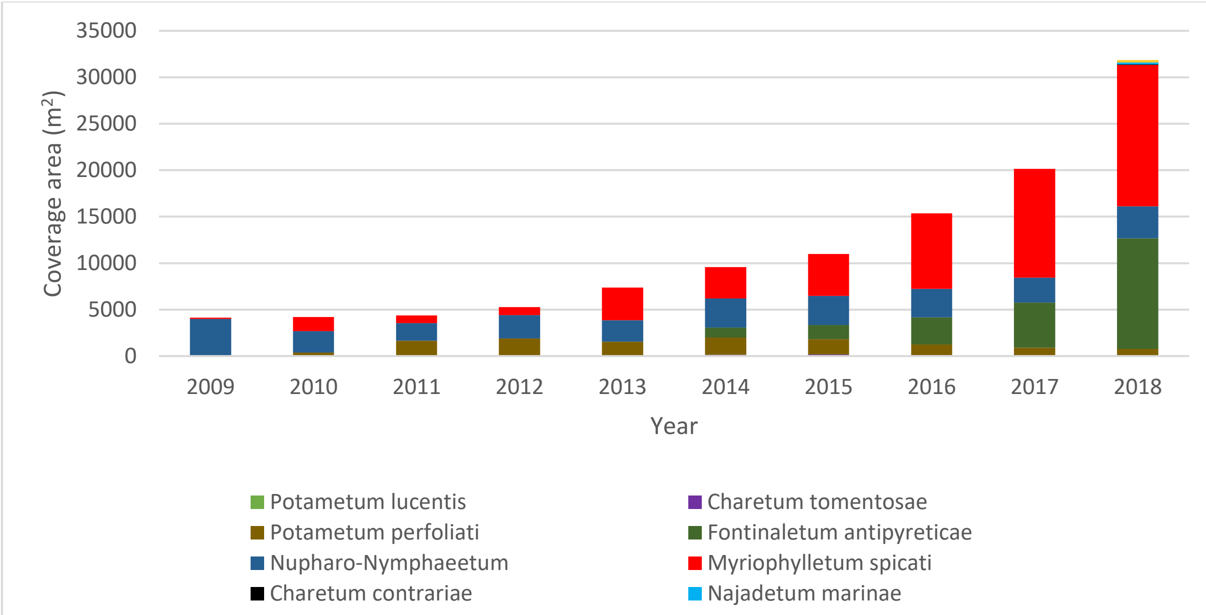

Figure 6. Submerged macrophyte area comparison.

Charetum contrariae, *Nitellopsidetum obtusae* and *Najadetum marinae* were observed for the first time this year, bringing the number of submerged macrophyte associations to 8. Total area of submerged macrophyte coverage rose to 31400m2 - an increase of over 50% from 2017. The submergent macrophytes were nonetheless restricted primarily to areas outside of the littoral zone. *Myriophiletum spicatti* remains the most abundant association, although *Fontinaletum antipyreticae* also increased substantially (it increased its' area by 145.7%).

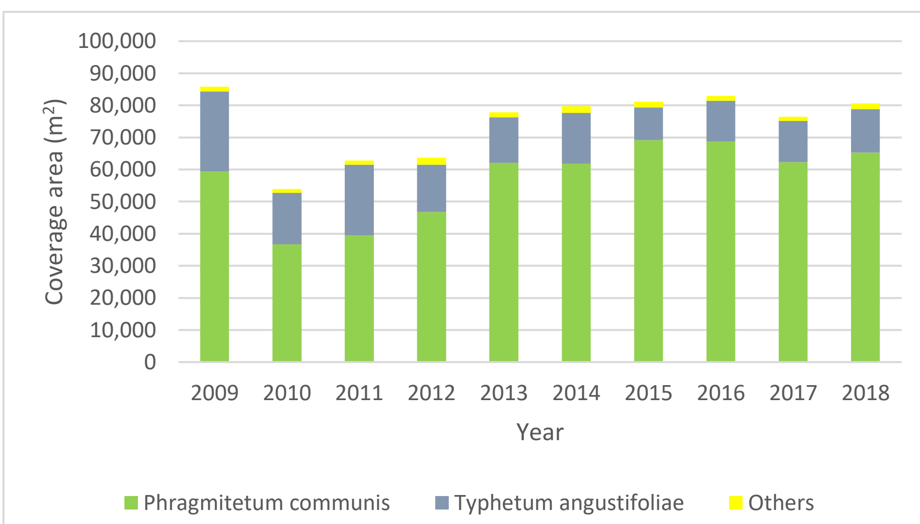

Figure 7. Emergent macrophyte area comparison.

The total area covered by emergent macrophytes increased from 2017 – although it has still not recovered to 2016 levels. The share of *Phragmetetum communis* increased slightly, though not at the expense of *Typhetum angustifolia* (both increased in area, though *P. communis* increased more). *Iridetum pseudacori* and *Cicuto Caricetum pseudocyperi* were observed for the first time in numbers.

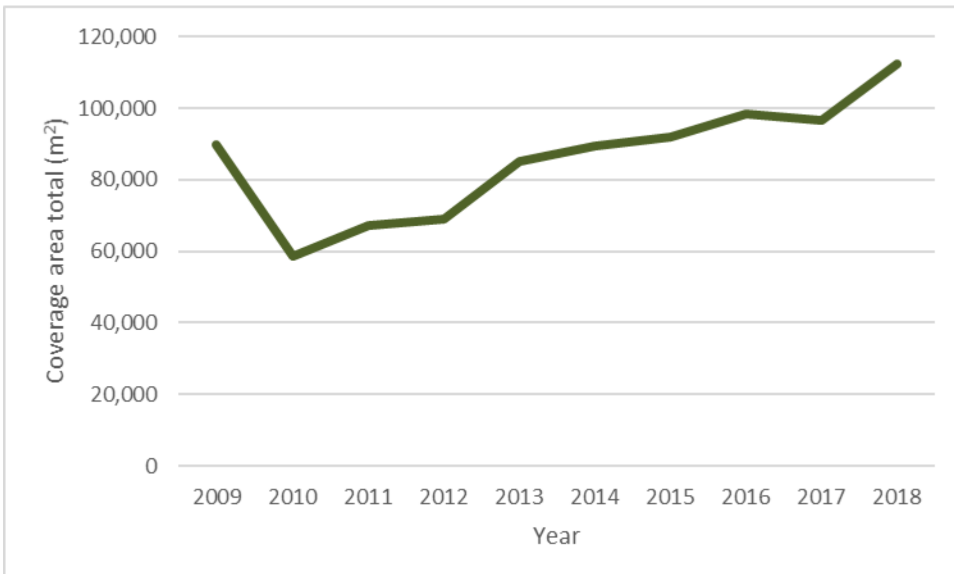

Figure 8. Total area covered by macrophytes at Lake Durowskie (2009-2018).

Since 2010 there has been an overall significant trend for increasing coverage of macrophytes. The total area of the lake covered by macrophytes increased substantially from 2017 – in 2017, the total area covered was 96611.8m^2 compared to 112507.8km2 this year (a 16.45% increase).

Table 6. Analyses the 2017-2018 result in more detail, showing that the main drivers of coverage increase were *Pragmetetum communis*, *Myriophylletum spicati*, *Fontinaletum antipyreticae* and *Typhetum angustifolia*. Most of the other species increased overall or stayed approximately the same – the exceptions being *Potametum perforiati*, *Charetum tomatosae* and *Eleocharitetum palustris* which all experienced major decreases in area.

Table 6. Comparison association coverage 2017-2018.

	2017		**2018**		**Difference**	
Species name:	**Total area(m^2)**	**%macrophyte coverage**	**Total area(m^2)**	**%macrophyte coverage**	**Total area %**	**% Change.**
Phragmitetum communis (Garms 1927 , Schmale 1931)	62346.3	64.533	65243.1	57.99418	2896.8	4.646
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	12804.6	13.254	13627.85	12.11371	823.3	6.429
Myriophylletum spicati (Soo 1927)	11713.3	12.124	15238.48	13.54539	3525.2	30.096
Nupharo-Nymphaeetum (Tomaszewicz 1977)	2685.9	2.780	3430.567	3.049409	744.7	27.727
Fontinaletum antipyreticae (Kaiser 1936)	4855.0	5.025	11929.7	10.60424	7074.7	145.720
Potametum perfoliati (W, Koch 1926)	817.0	0.846	704.3952	0.626133	-112.6	-13.787
Acoretum calami (Kobendzz 1948)	368.5	0.381	685.8321	0.609632	317.4	86.125
Caricetum ripariae (Soo 1928)	337.9	0.350	699.4723	0.621757	361.6	107.015
Charetum tomentosae (Corillion 1957)	31.7	0.033	20.7178	0.018416	-11.0	-34.580
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	136.7	0.141	148.2312	0.131762	11.5	8.437
Typhetum latifoliae (Soo 1927)	115.1	0.119	6.51043	0.005787	-108.6	-94.344
Butometum umbelati (Konczak 1968)	64.7	0.067	65.86803	0.05855	1.1	1.776
Sparganietum erecti (Roll 1938)	82.2	0.085	69.54541	0.061818	-12.6	-15.353
Eleocharitetum palustris (Schennikov 1919)	154.5	0.160	20.42395	0.018155	-134.1	-86.784
Glycerietum maximae (Hueck 1931)	21.4	0.022	21.95682	0.019517	0.5	2.426
Thelypteridi-Phragmitetum (Kuiper 1958)	37.9	0.039	37.9	0.026236	0.0	0.000
Caricetum acutiformis (Eggler 1933)	1.1	0.001	13.21905	0.01175	12.1	1125.450
Potametum lucentis (Hueck 1931)	36.0	0.037	29.2286	0.025981	-6.8	-18.817
Nitellopsidetum obtusae	0.0	0.000	245.638	0.218346	245.6	New
Phalaridetum arundinaceae	2.1	0.002	0.0	0.000	-2.1	Absent 2018

Cicuto-Caricetum pseudocyperi (Boer 1942)	0.0	0.000	11.46529	0.010191	11.5	New
Charetum contrariae	0	0	69.3662	0.061659	69.4	New
Najadetum marinae	0	0	186.9287	0.16616	186.9	New
Iridetum pseudacori (Eggler 1933)	0	0	1.37774	0.001225	1.4	New
Total	**96611.8**	**100.0**	**112507.8**	**100.0**	**16.45%**	

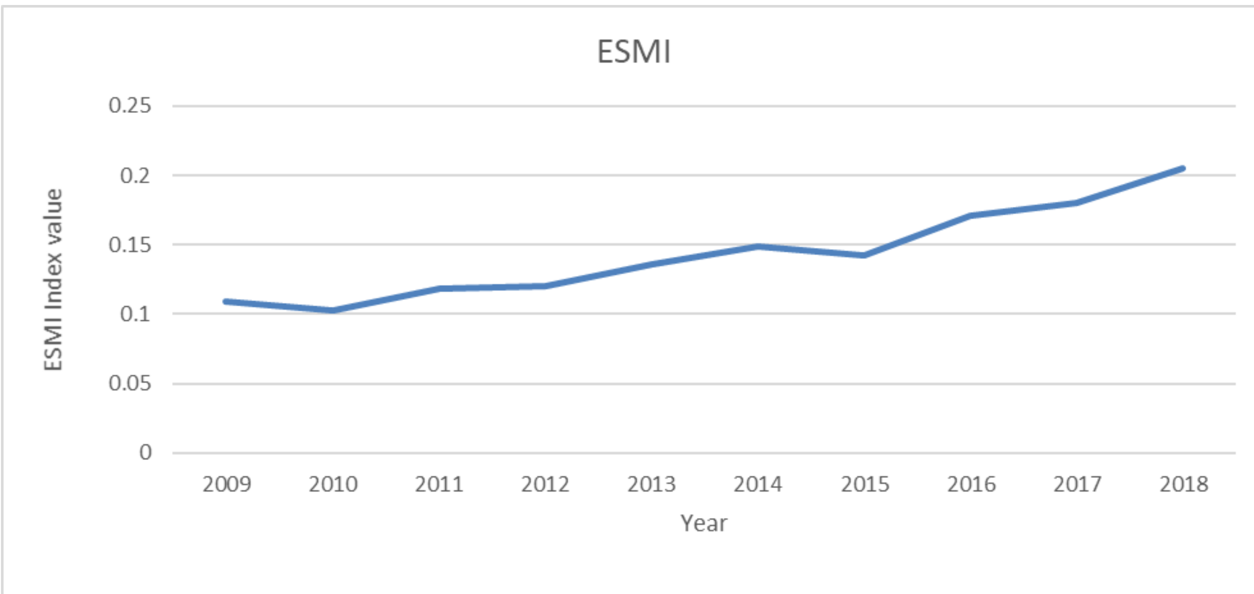

Figure 9. Graph of ESMI results by year (2009-2018).

Each year the ESMI result has improved, however as Figure X. shows the overall rating can still only be considered Moderate.

Ecological status	ESMI Index	MIR Index
Very good	≥ 0,680	≥44.5
Good	≥ 0,410	44.5-35.0>
Moderate	≥ 0,205	35.0-25.4>
Poor	≥ 0,070	25.4-15.8>
Bad	< 0,070	<15.8

Figure 10. ESMI thresholds with 2018 result highlighted.

The result can be considered "Moderate".

3.2. Species associations at the outflow and MIR index.

11 species were observed at the outflow, an increase from 8 in 2017. *Lysimachia thrysiflora*, *Lycopus europaeus*, *Calystegia sepium* and *Bidens frondosa* were new records – although *Mentha aquatica* was not observed this year. *Butamus umbellatus* and *Potamogetum pectinatus* were the dominant plant species, whilst *Hildenbrandia rivularis* was the dominant algae species.

Table 7. Species coverage at outflow (%).

Species Name	Percentage coverage (%)	Cover coefficient
Plant species	-	-
Butomus umbellati	24	6
Acorus calamus	1	2
Potamogeton pectinatus	25	6
Lycopus europaeus	<1	-
Phalaris arundinacea	<1	1
Lysimachia thrysiflora	<1	1
Calystegia sepium	<1	-
Myriophyllum spicatum	<1	1
Bidens frondosa	<1	-
Algae species	-	-
Hildenbrandia rivularis	6	5
Cladophora glomerata	4	4

Of the observed species, *Calystegia sepium*, *Bidens frondosa* and *Lycopus europaeus* are not considered useful indicators for calculating the MIR index (Ciecierska & Dynowska 2013). Using the relevant species, the MIR index for this outflow was calculated – returning a result of 43.33 (or "good", as illustrated below in Figure X.)

Ecological status	ESMI Index	MIR Index
Very good	≥ 0,680	≥44.5
Good	≥ 0,410	44.5-35.0>
Moderate	≥ 0,205	35.0-25.4>
Poor	≥ 0,070	25.4-15.8>
Bad	< 0,070	<15.8

Figure 11. MIR and ESMI index thresholds (Ciecierska & Dynowska 2013).

with highlighted MIR result for 2018.

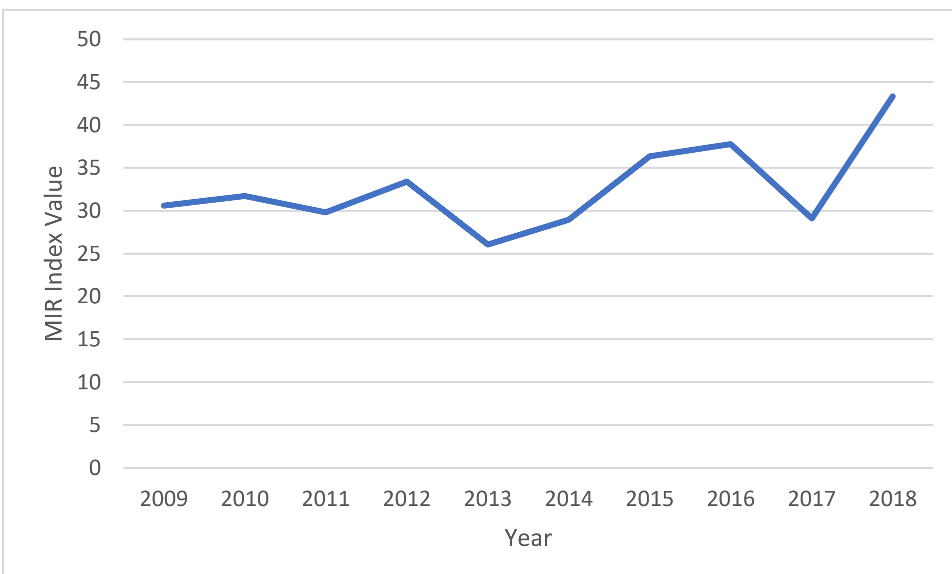

Figure 12. Graph of MIR index results per year (2009-2018).

The MIR index this year has improved significantly since 2017 and is the best result since the study began in 2009. The 2018 result restores the overall positive trend.

3.3. Invertebrate and phosphorus correlations.

The results for ESMI index and macrophyte coverage area (P <0.05 for both tests) against invertebrate biomass per meter were both significant. The results are illustrated by Figure X below. However, neither ESMI or macrophyte coverage were significantly correlated with invertebrate biodiversity (P > 0.05)

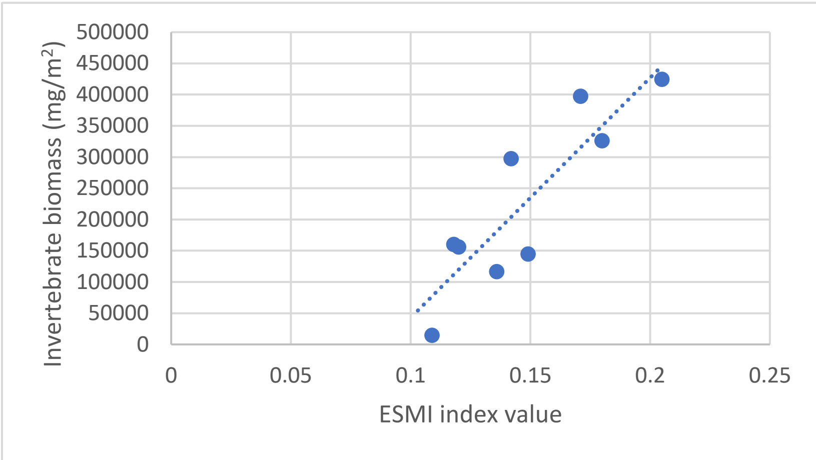

Figure 13. ESMI index value

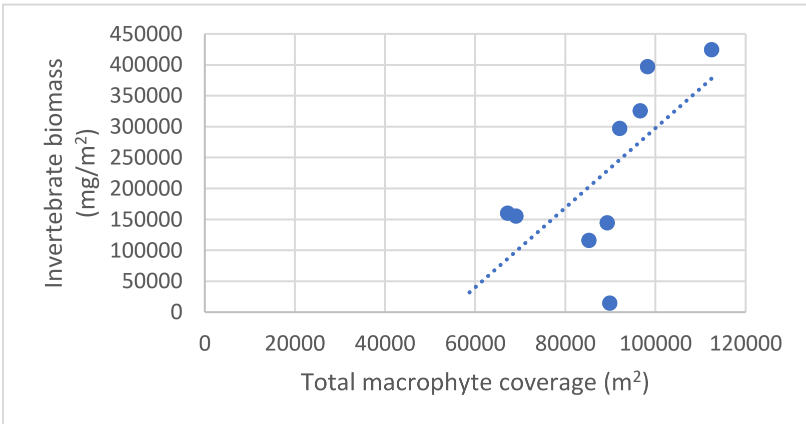

Figure 14. Tatal macrophytes coverage.

The result for phosphorus inflow against total macrophyte coverage area was also significant (P 0.03413). The result for total macrophyte coverage area against outflow phosphorus load was not significant (P > 0.3536). By contrast, ESMI was not significantly correlated with either inflow phosphorus load or outflow phosphorus load (P > 0.05 for both tests).

4. Discussion:

One new species was *Ceratophyllum demersum* – an indicator of hypertrophic conditions. It was abundant in the lake in the first few years of the study, but as restoration progressed and conditions in the lake improved it disappeared. This year however, a few specimens were found in the north part of the lake, near the new housing development. This could indicate that the houses and associated infrastructure may be leaching nutrients into the lake. It was not abundant enough to have formed an association yet (even a small one) – but it should be a subject of checks next year.

Phragmetum communis was, as in previous years, the most common emergent species (and by far the most widespread of all macrophytes on the lake). *Typhetum angustifolium* was once again the second most common emergent species. Both species thrive under eutrophic conditions (although can tolerate lower nutrient conditions) so their abundance is not necessarily a good indicator for improving lake health. However, their biomass will still absorb and store nutrients from the lake (Xu et al. 2014) and it should be noted that other emergent species are also starting to increase at the site, such as *Iridetum pseudacori* and *Charetum contrariae*.

The reduction in *Phalaris arundinacea* (no associations were observed in the lake, unlike last year) was positive overall – it is an invasive alien species (Morrisey & Molofsky 1998) which competes with native plants. However, it was still present in the lake outflow and it seems probable that some individuals remain in the lake itself; it could therefore increase in coverage and impact native species if conditions return to their prior eutrophic state.

The substantial increase in submergent macrophyte coverage and association diversity was arguably the most positive finding of this year's study. Submergent macrophytes are even more effective at removing excess nutrients from the water body and preventing extreme. Though *Myriophiletum spicatti* was the most common submergent macrophyte, submergent diversity improved significantly from previous years.

One weakness of this year's study was the insufficient number of depth measurements taken for submergent macrophytes. However, the area and diversity findings (coupled with the physio-chemical, micro-invertebrate and algae-based studies) mean that a comprehensive assessment was still possible.

The increase in macrophyte coverage could help to explain the sharp reduction in macro-invertebrate numbers seen in the lake this year. Because macrophytes compete with phytoplankton and reducing algae blooms, some macro-invertebrates see a reduction food availability. However, in the long term macro-invertebrates will benefit from increased macrophyte coverage and, especially, macrophyte diversity.

The number of associations observed increased significantly from last year – in 2017 18 different associations were observed, compared to 23 this year. This is a promising observation – more diverse associations could mean a more resilient ecosystem and more effective ecosystem services. The new associations will provide habitats for a broader range of fish, invertebrate and microplankton species, filter out different toxins and be more resistant to a broader range of problems (for example, reducing the likelihood that a disease could decimate the macrophyte communities – a serious danger if only a few species were present).

The improvement of the MIR index to 42.33 was encouraging, and could indicate that the restoration measures have improved the condition of the lake. However, it should be noted that whilst the ESMI index also witnessed a noticeable improvement, the overall ESMI status is still Moderate. It is possible that the lake itself continues has absorbed unwanted nutrients and contaminants, thus keeping the outflow relatively healthy. It should also be noted that precipitation between the previous study and this one was unusually low – meaning reduced relative run off of nutrients. One way of assessing the root cause of ongoing limitations could be to perform MIR assessments at the inflows to the lake as well. The low position of the ESMI score within the Moderate category, despite improvements from previous years, can be explained by changes in the ESMI threshold this year.

The significant positive correlations for macrophyte coverage and the ESMI index when tested against invertebrate biomass could indicate that the macrophyte restoration measures are having an effect on other aspects of ecosystem health at the lake. However, the absence of a significant correlation between either ESMI or macrophyte coverage and the other target variables (phosphorus outflow and invertebrate biodiversity) could indicate that further measure need to be taken. The small number of data points may also mask significant correlations, so analysis in subsequent years may reveal other trends. Despite the small sample size, the result for phosphorus inflow affecting macrophyte coverage could imply that measures taken to reduce P inflow could positively impact macrophyte spread. It is also possible that variables were responding to an unconsidered factor.

Overall, the lake appears to be in moderate to good condition. However, some weaknesses and threats remain – in particular, continuing inflow of nutrients and contaminants from the lakes and rivers upstream outside of Wagroweic’s jurisdiction.

5. Recommendations:

Strengthening and continuing relationships with different partner organisations, such as Nanchang Institute of Technology, is advisable. New perspectives and new knowledge bases could help to improve the situation at Lake Durowskie at a faster rate. Continuing the summer school will help to ensure that reliable and complete data is gathered into the future, and the existing substantial improvements to the lake are not lost.

Fostering cooperation with the other towns at lakes upstream of Lake Durowskie could help to eliminate pollution which is being produced and transported throughout the system. Until the sources of pollution at the other lakes are eliminated, Lake Durowskie will be unable to reach it's full ecological potential. Reducing nutrient leaching into the river in particular could lead to profound improvements.

Continuing the restoration and anti-pollution measures that have led to the vast current improvement are essential, so that the lake does not return to it's previous condition. Artificially reintroducing strong native submerged macrophyte species, such as charophytes, could accelerate restoration within the lake (Hilt et al. 2006) and help to reduce the establishment of invasive species such as *P. arundinacea* (Morrisey & Molofsky 1998). Though reducing the inflow of nutrients and contaminants is essential to long term lake health, other restoration measures will still be needed (Katsev 2017).

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Annex 1: ESMI Calculations

Name of association	Sum of area	n/N	ln	ln x h	% Area	H max	Z	exp(N/P)	Bracket	ESMI
Phragmitetum communis	65243.09508	0.579941819	-0.54483	-0.31597	57.99418025	3.135494	0.536734	1.00049	- 0.22938	0.205
Myriophylletum spicati	15238.47601	0.135453867	-1.99912	-0.27079	13.54538627					
Typhetum angustifoliae	13627.85164	0.121137127	-2.11083	-0.2557	12.11371232					
Fontinaletum antipyreticae	11929.70114	0.106042372	-2.24392	-0.23795	10.60423693					
Nupharo Nymphaetum	3430.566852	0.030494096	-3.49022	-0.10643	3.049409477					
Potametum perforiati	704.3952369	0.006261326	-5.07336	-0.03177	0.626132532					
Caricetum ripariae	699.4722555	0.006217565	-5.08038	-0.03159	0.621756525					
Acoretum calami	685.8321217	0.006096319	-5.10007	-0.03109	0.609631895					
Nitellopsidetum obtusae	245.6380005	0.002183461	-6.12684	-0.01338	0.218346086					
Najadetum marinae	186.9287072	0.001661598	-6.39998	-0.01063	0.166159762					
Scirpetum lacustris	148.2311767	0.001317618	-6.63193	-0.00874	0.131761768					
Sparganietum erecti	69.5454128	0.000618185	-7.38872	-0.00457	0.061818484					
Charetum contrariae	69.3662033	0.000616592	-7.3913	-0.00456	0.061659185					
Butametum umballatis	65.8680311	0.000585497	-7.44305	-0.00436	0.058549682					
Thelypteridi phragmitetum	29.5156994	0.000262363	-8.24578	-0.00216	0.026236321					
Potametum lucentis	29.2285995	0.000259811	-8.25556	-0.00214	0.02598112					
Glycerietum maximae	21.95682	0.000195173	-8.54163	-0.00167	0.01951728					
Charetum tometosae	20.7178001	0.000184159	-8.59971	-0.00158	0.018415923					
Eleocharitetum palustris	20.4239504	0.000181547	-8.61399	-0.00156	0.018154722					
Caricetum acutiformis	13.2190504	0.000117503	-9.04904	-0.00106	0.011750331					
Cicuto Charicetumpseudocyperi	11.4652901	0.000101914	-9.19138	-0.00094	0.010191425					
Tyfetum latifolia	6.5104299	5.78708E-05	-9.7573	-0.00056	0.005787081					
Iridetum pseudacori	1.37774	1.22466E-05	-11.3103	-0.00014	0.001224664					
Total	112499.3832			-1.33934						
				1.339343						

Annex 2: MIR Calculations

Species name	L	W	P	l x w x p	w x p	MIR Result
Butomus umbellatus	5	2	6	60	12	
Acorus calamus	2	3	2	12	6	
Potamogeton pectinatus	1	1	6	6	6	
Hildenbrandia rivularis	6	1	5	30	5	
Phalaris arundinacea	2	1	1	2	1	
Lysimachia thrysiflora	7	3	1	21	3	
Cladophora sp.	6	2	4	48	8	
Myriophyllum spicatum	3	1	1	3	1	
Bidens frondosa	-	-	-	182	42	
Calystegia sepium	-	-	-			
Lycopus europaeus	-	-	-			**43.33333**