



Underwater Lake Bed Survey

Broadwater Lake, Hillingdon

On behalf of Hillingdon Council

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Richard Weston, Hillingdon
Lewis Jenkins, Quod

Written by: Oliver Huxley BSc MSc and Stephanie Harper BSc PhD
Reviewed by: Stephanie Harper, Ruth Copeland Phillips, Matthew Johns and Julie Bywater
Harper Environmental Limited
www.harperenvironmental.co.uk

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1 Introduction

1.1 Background

Hillingdon Council (or “the client”) instructed Harper Environmental Ltd to carry out underwater lake bed surveys in support of the proposed development of a watersports facility and activity centre at Broadwater Lake, Harefield (hereafter called ‘the Site’). The central Ordnance grid reference for the Site is TQ 04371 89613.

1.2 The Site

The Site forms part of the Mid-Colne Valley SSSI and is designated for “*significant ornithological interest, particularly for the diversity of breeding woodland and wetland birds, and for the numbers of wintering wildfowl*”¹.

The whole Site covers an area of approximately 76 hectares (ha) and is approximately centred on National Grid Reference TQ 04396 89593. The Site comprises an access road from Moorhall Road, the lake itself with an associated lagoon (south-east corner of the lake), a peninsula at the south-east corner, an existing sailing club (Broadwater Sailing Club) at the north end of the lake, parts of the margins of the lake, and islands set within the lake. Part of the western and southern banks of the lake and adjacent open water lie just outside the red line boundary.

1.3 Evolution of development proposals

A planning submission was made in 2023 for the development of HWSFAC, with a large area of new land and beach to be created on the north-west shore of the peninsula, to house the new facility and provide boat parking and launch locations. The majority of the centre and north of the lake was proposed for water-based activities and sailing, and dredging proposed within the active area. To provide materials for the creation of the new land, two islands were proposed to be removed.

As a result of the planning application, objections from consultees were taken into consideration. The proposals have been revised to reduce the size of the development and move the location of the sailing beach to the north-east shore of the peninsula. Through consultation with a sailing expert and assessment of the numbers of children liable to use the new HWSFAC at any one time, it has been established that the area required for water-based activities (other than dinghy sailing) can be reduced to the area within the east channel only. The area of proposed dredging has also reduced to within the east channel only, out of view of the main lake.

The Site is shown in Figure 1.1 below – this shows indicative development proposals with location referencing (such as island numbers) to aid review of this report.

¹ Available: [1003469.pdf \(naturalengland.org.uk\)](https://naturalengland.org.uk/1003469.pdf)

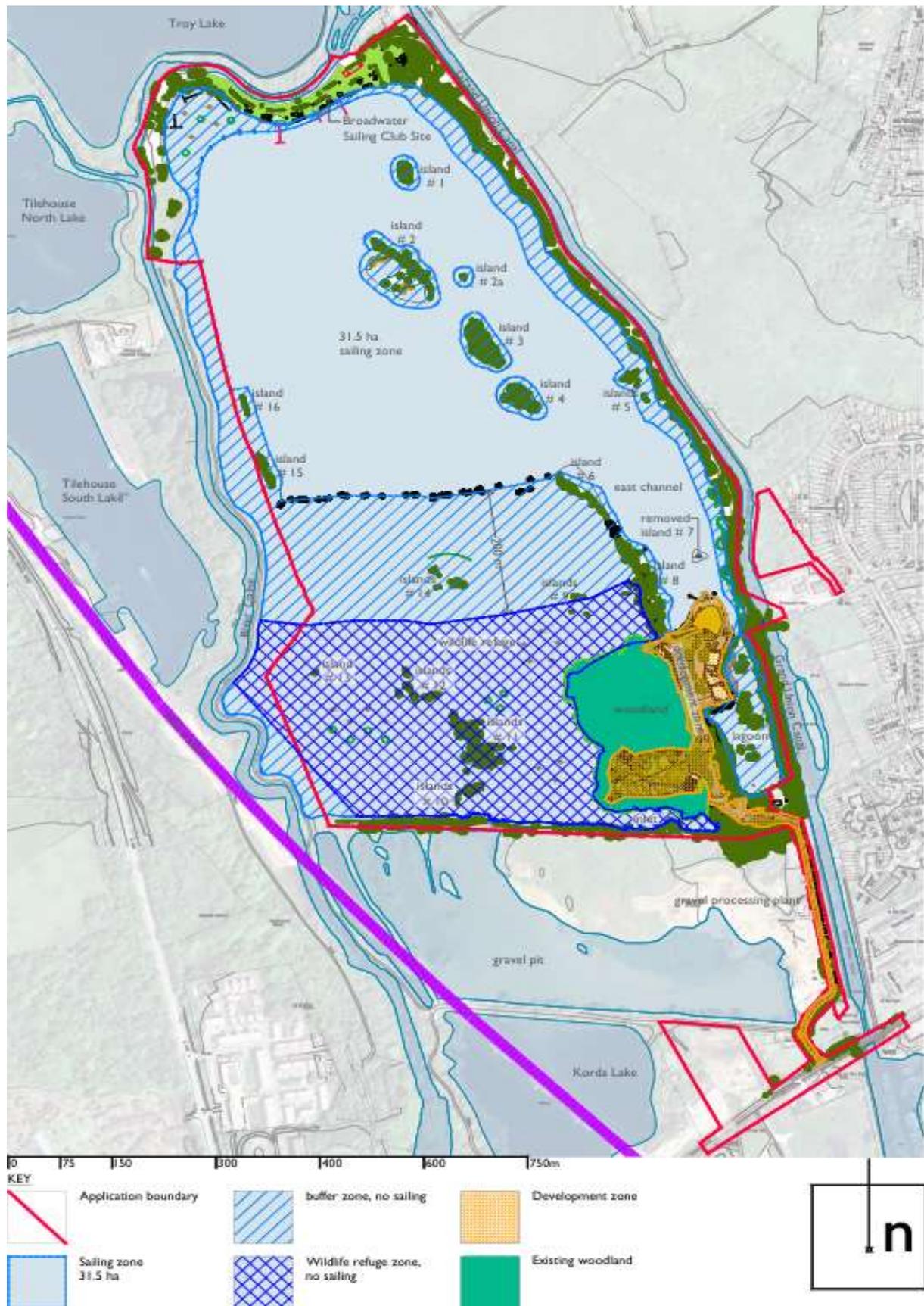


Figure 1.1 Site layout with indicative development proposals and location references

1.4 Previous surveys

A survey of the lake bed composition and vegetation cover was conducted in 2023 by Greengage using a boat, bathyscope and grapnel to view the bed and sample plants and bed materials. A map of sample locations is provided as Figure 1.2.

Sparse plants were found growing in most sampling locations. Species identified included lesser pondweed, hornwort, Canadian pondweed, algae. Seven quadrats only had lesser pondweed, which was the dominant species overall. One quadrat was bare gravel. A few locations were too deep for the survey methodology.

Although the Greengage (2023) survey was useful and confirmed the hard nature of the bed and relatively low plant cover, the method meant that deep locations (>4m) in the lake could not be surveyed. At depths greater than 2m, it was sometimes difficult to see the bed or to sample plants for identification purposes. The survey also did not provide visuals (photos, footage) to help people understand the underwater conditions.

The survey also did not include sampling points within the east channel.

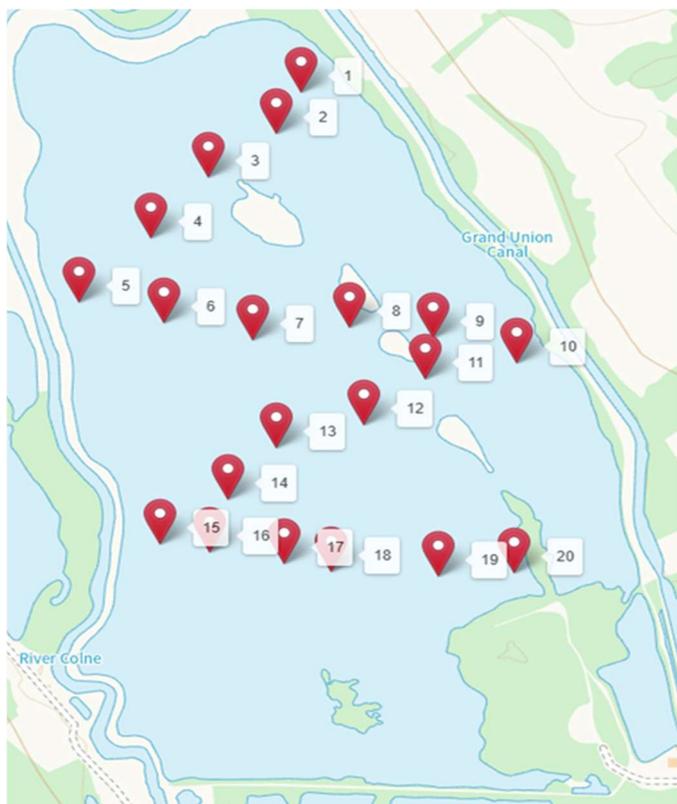


Figure 1.2 Map of 2023 survey locations

1.5 Requirement for further surveys

As noted above, the development proposals for Broadwater Lake were revised during 2024, with the east channel becoming the main focus for dredging and for water-based activities.

As a result of this revised location, further exploratory surveys of the lake bed were required:

- to provide information on the baseline conditions (to inform construction and dredging activities) and
- allow an assessment of potential impacts to fish, aquatic plants and macro-invertebrates, and water quality.

Given the survey constraints noted during the 2023 surveys, the survey methodology was revised to utilise a remotely operated vehicle (ROV). This is an aquatic environment survey tool (submersible) with a camera and powerful LED lamps. The ROV is able to capture detailed video footage of the lake bed even at considerable depth where light levels are very low, or where suspended sediment clouds the water. By using an ROV to film the lake bed it is possible to make up-close visual observations of lake bed materials (rocks, sand, silt etc), plant species and coverage. The location and depth of the observations can also be easily recorded. Using an ROV removes the risk involved with undertaking a visual assessment of the lake bed in a more traditional way using a diver.

The survey included the main open water area of Broadwater Lake, to provide further context as to the habitat conditions within the lake and provide useful information for habitat mitigation, enhancement and management proposals.

The results may be used in a variety of ways:

- to inform development proposals and dredging;
- to locate and avoid or remove obstructions on the lake bed;
- to provide information on food sources in the lake for birds and fish;
- to look for habitat suitable for fish such as European eel *Anguilla Anguilla*;
- to look for invasive species; and
- to inform a Lake Naturalness Assessment (used to assess condition as part of a Biodiversity Net Gain Assessment).

2 Methodology

2.1 Site visits

In total, five surveys were undertaken between July and October 2024. During all visits, the site was fully accessible with suitable weather conditions for surveying the lake.

2.2 Equipment

All survey locations were accessed using a boat with outboard motor. Surveys were completed with the BlueROV2 by Blue Robotics, a remotely operated vehicle (ROV). This is a compact, highly manoeuvrable ROV which is well suited to lake surveys. The ROV records HD video, which is relayed live to a laptop above water. This allows the identification of areas of interest in real time, so these can be explored thoroughly.

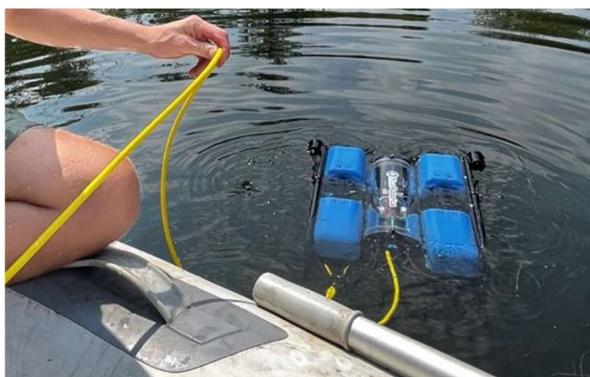


Figure 2.1 BlueROV2

Additionally, a Ping2 Sonar Altimeter and Echosounder was used during surveys. This device sends an ultrasonic pulse into the water via a piezoelectric transducer, which then listens for echoes. With this information, it can calculate the distance to the strongest echo, which is the lake floor or a large obstruction on it. This allowed the accurate recording of depth and identification of objects during surveys.

2.3 Survey method

At each survey point the boat was anchored and used as the location reference. The ROV was then launched and piloted to the lakebed. Once optimum depth has been achieved a 15m radius around the boat was explored. The ecologist used the ROV to scan the area, making notes on obstructions, plant species present and bed composition (gravel, sand, silt). An estimate of percentage coverage of vegetation was also made. The survey was continued until an accurate understanding of the habitat has been achieved. If a change in habitat or area of potential interest was discovered a more intensive search was conducted. The ROV was then brought to the surface and navigated around the same survey path on the lake surface, to allow the sonar to record the water depth at various locations. An average depth was then calculated from the data.

2.4 Data analysis

When back onshore, the footage was reviewed to ensure that nothing had been overlooked while on the water. Images and video clips were then produced to accurately represent the attributes of each specific location.

All data was then updated to Epicollect5, a platform that presents the data within an interactive map where location-specific data can be easily reviewed.

2.5 Constraints

There were no constraints that might affect the validity of the survey results.

2.6 Surveyors and competence

Oliver Huxley completed the lake surveys and wrote this report. He holds a Master's degree from the University of Leeds in Environment and Development. He has two seasons experience in ecological consultancy and has experience with robotics. Oliver also holds the RYA Powerboat Level 2 certificate.

Ben Osborne assisted Oliver with ROV surveying and boat handling. Ben has worked as a geophysical surveyor for two years after completing a BSc (Hons) from Plymouth University in Ocean Exploration and Surveying. Ben also holds the RYA Powerboat Level 2 certificate.

Stephanie Harper, who partly wrote and reviewed this report, has a BSc (Hons) and PhD in Environmental Sciences, with a year at Bordeaux University studying freshwater ecosystems and aquatic ecotoxicology at post-graduate level. She has 18 years of experience in ecological survey and consultancy.

Ruth Copeland-Phillips reviewed the report generally and assisted with some of the surveys. She has a PhD in Environmental Sciences and 10 years' experience working in lacustrine and freshwater rivers.

Julie Bywater reviewed the lake bed photos and assisted with aquatic plant identification; she has 25 years' experience as a freshwater aquatic ecologist.

Matt Johns reviewed the lake bed photos and information relating to European eel *Anguilla anguilla*. He is a freshwater scientist with 20 years' experience in fisheries.

3 Results

A total of 85 locations were surveyed during the 2024 site visits. The complete dataset uploaded to Epicollect5 can be accessed at: <https://five.epicollect.net/project/broadwater-lake-survey>.

Survey locations are presented in Figure 3.1 below.

3.1 Depth and bathymetry

The BlueROV2 survey confirmed the results of the bathymetric surveys undertaken at the lake previously (UoN 2024, FiveRivers, 2022).

Below the water, the banks of the lake and its islands dropped away abruptly. Shallow areas were very limited and only encountered very close to the lake edges and around islands. Shallow areas extended only 20-30cm into the lake before dropping steeply away to depths of 2m or more. No gently shelving areas were identified during the exploratory surveys.

Of the 85 sampling points, only 15 were less than 2m deep. Where deep water became suddenly shallow in discrete locations in open water areas, this was due to the presence of piles of boulders and gravel.

The lake bed surface was very uneven which showed its man-made origins, rather than having a smooth topography which a natural lake would have.

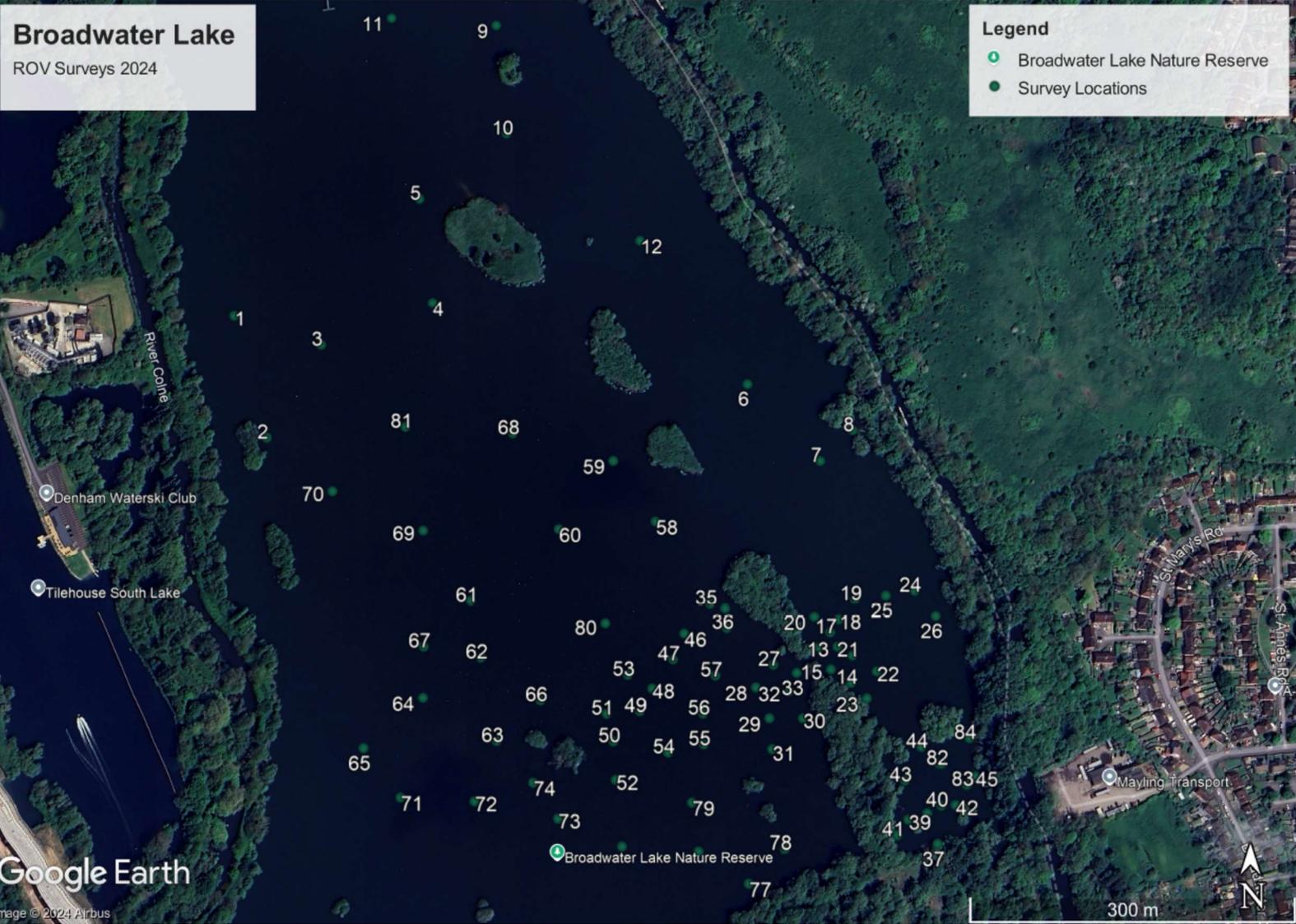


Figure 3.1 Map of 2024 survey locations

3.2 Bed composition

Approximately 55% of the lakebed surface consisted of soft, fine-grained silt that was easily disturbed by the movement of the ROV thrusters. Most of this area was bare, with scattered, isolated patches of Nuttall's waterweed *Elodea nuttallii*.

It was not possible to characterise the bed composition for approximately 30% of the lake bed, due to vegetation coverage, leaving small and occasional patches of bare ground. Areas dense in vegetation cover were more frequent closer to the land, while large, bare areas were more prevalent in open water and deeper areas.

Other areas of the lakebed were dominated by small rocks/pebbles, accounting for 10% of the lakebed. In general, these areas were found closer to land areas, especially in shallow areas of the east channel. Vegetation cover was low where small rocks were found.

Approximately 5% of the total area was characterised by boulders of varying sizes, averaging 0.4m in diameter. Elodea and algae were present in between the boulders. There was also generally a covering of algae on the boulders.



Photo evidencing the soft, bare sediment with scattered vegetation that covers 55% of the lakebed.



*Areas covered in *Elodea nuttallii*, which is thick and tightly knitted in areas.*



Areas where small rocks/pebbles dominate the lakebed.



Areas covered in green algae, often scattered among larger rocks.

3.3 Aquatic macrophytes

Nuttall's waterweed *Elodea nuttallii* was the dominant species observed during surveys; it was found in varying amounts at every survey point. Nuttall's waterweed is a non-native, invasive species which is known for its rapid growth rate. In some areas, plants were small and isolated, however others were densely knitted.

Later in the season, in some locations dense vegetation covered the lakebed and floated in rafts the water in one location.

Other species found in smaller amounts include lesser pondweed *Potamogeton pusillus*, hornwort *Ceratophyllum demersum*, and ivy-leaved Duckweed *Lemna trisulca*.



Close up image of the Nuttall's waterweed *Elodea nuttallii* found at all locations surveyed.



Raft formed by Nuttall's waterweed, evidencing the extent of its growth.



Hornwort *Ceratophyllum demersum* found at a few locations, primarily along the east shore of the east channel.



Myriophyllum alternifolium found at the south of the east channel.



Ivy-leaved Duckweed Lemna trisulca found growing around near islands in the central channel.



Lesser pondweed Potamogeton pusillus found in small amounts across the lake area.

During the final survey in October, it was observed that the entire lake had algae suspended within the water. Algae was also pooled around on the lake surface, especially near land areas.



Photo evidencing algae bloom from ROV camera.



Algal growth showing on lake surface.



Water clarity during surveys in August.



Water clarity decrease at same location in October, vegetation around rocks has also increased.

Appendix A provides the identification of all algal species by sampling location.

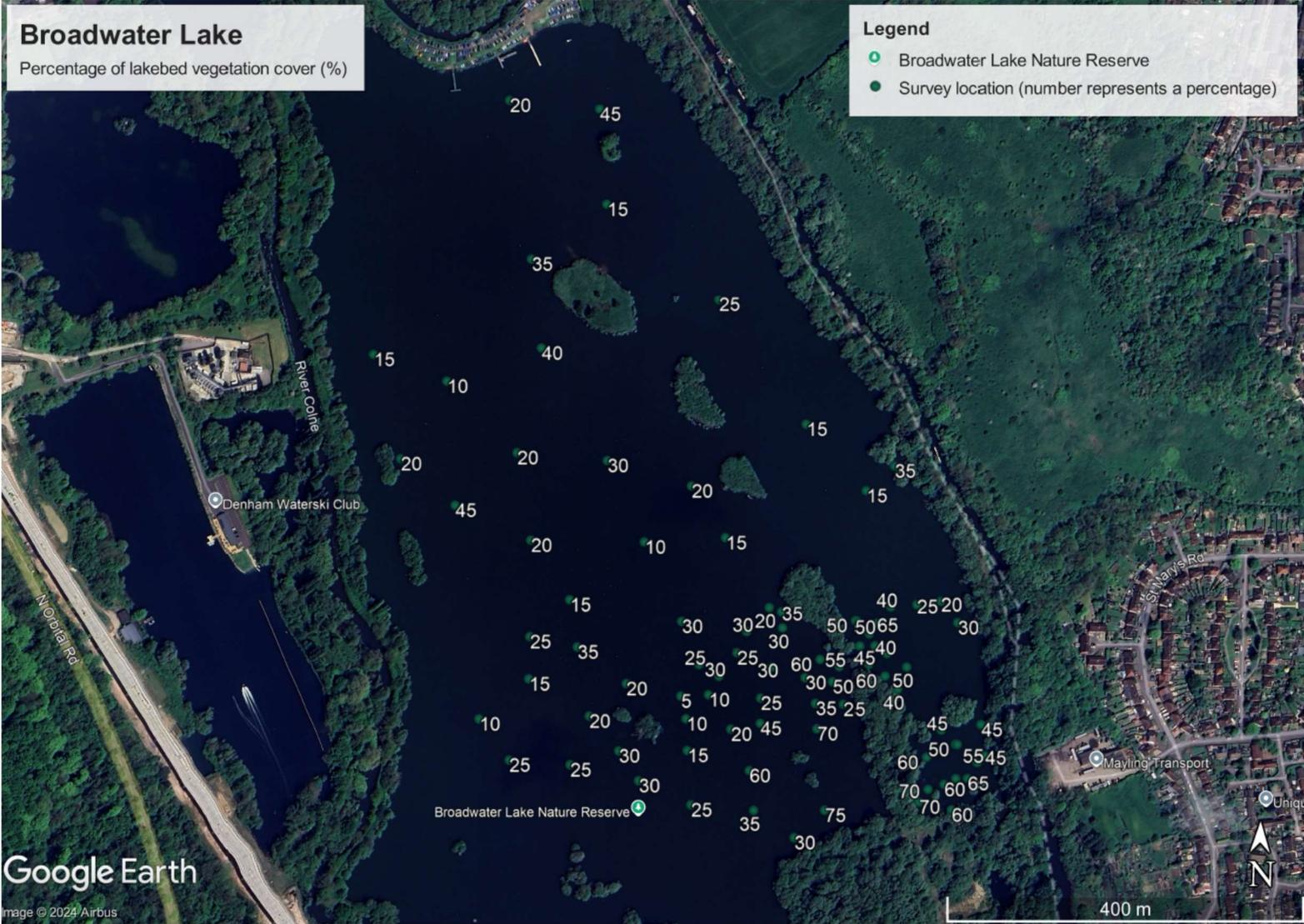
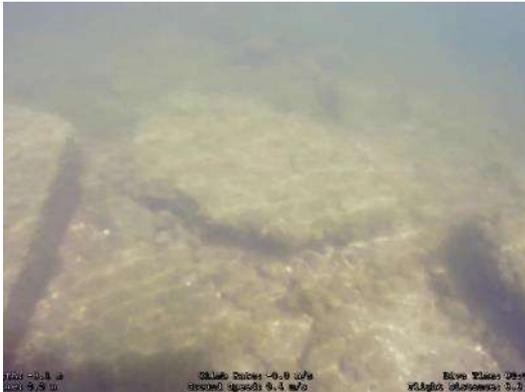


Figure 3.3 Map displaying the percentage of lakebed vegetation cover at each survey location.

3.5 Main obstructions

While surveying the lake, obstructions were located on the lakebed and along the banks of the lake. These obstructions appeared to be of human origin and were randomly encountered at certain locations of the lake, showing no pattern. Images, locations, and descriptions of the obstructions are provided below.



51.593847, -0.489289 – Area with large rocks and concrete blocks.



51.593847, -0.489289 - Area with rocks and concrete blocks.



51.59473, -0.490445 – Possible metal structure in water, difficult to confirm material due to algae.



51.593259, -0.48911758 – Corrugated metal structure held with posts and concrete blocks. Built on water close to bank.



51.593534, -0.48935160 – Orange grate, possibly metal.



51.594379, -0.490261 - Fallen trees in water, found often near banks around islands.



51.6002, -0.496802 - Unknown structure on lakebed, possibly used by sailing club.



51.599185, -0.495181 - Appears to be large round concrete structure, over 1m in diameter.



51.593509, -0.489089 - Concrete blocks, some nearly 1m in diameter.



51.593984, -0.489534 - Large rocks in shallow area. Boat had issues passing over freely.



51.593786, -0.49071461 – Sunken pontoon.



51.593878, -0.49079508 – Sunken pontoon

The locations of obstructions within the east channel are displayed in Figure 3.2 below.

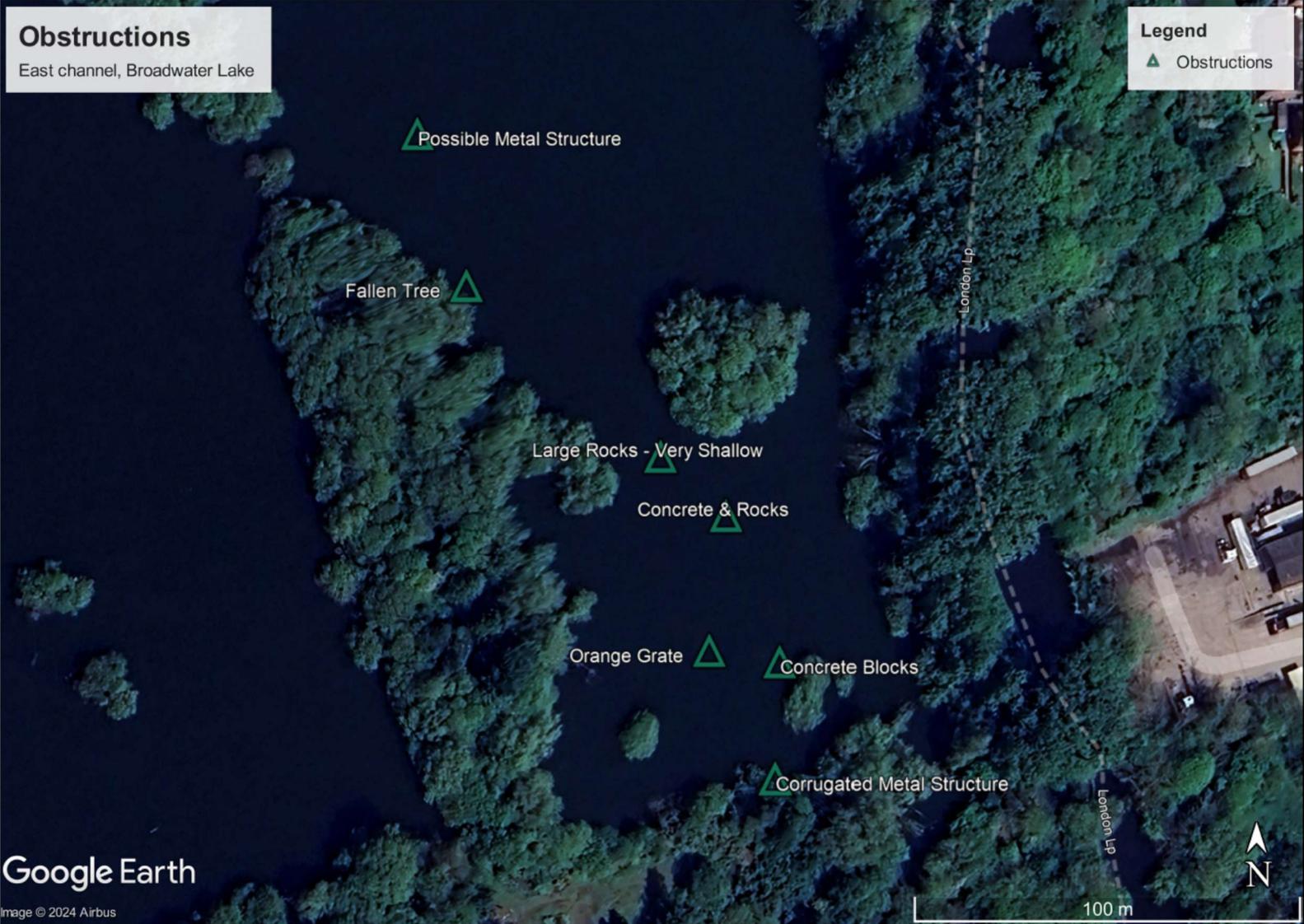


Figure 3.4 Obstructions found in east channel

3.6 Suitability for fish / eels

Surveys at Broadwater Lake have found that fish are present in low numbers. Eels *Anguilla anguilla* are confirmed to be present by the National Anguilla Club; specimens over 5lbs have been caught.

Although the ecology of eels is poorly understood, eels have been found to be very adaptable and will utilise most habitats. For hibernation they are known to burrow into soft mud deposits.

The lake bed habitat was assessed for its potential to support eels. 40% coverage of the lake bed on average in each location meant the weed was typically sparse. Dense patches developed in September; these were localised / limited in extent.

Crevices between large obstructions had accumulated thin deposits of soft sediments. These locations may present opportunities for eels to hibernate.

In terms of supporting fish and eels generally, the supply of weed (algae and benthic plants) present appeared to be sufficient food for the low populations of herbivorous fish the lake supports.

In terms of insect foods, with reference to the University of Northampton report and Bywater ecology report, macroinvertebrates were not abundant and populations lacked diversity. Signal crayfish offer a good food resource for eels.

Patches of sand are present which may be suitable spawning ground for fish. However emergent vegetation was only present in very small shallow locations, offering almost no habitat at all for small fish / fry to hide while they are growing into adults. The only significant refuge was offered by willow branches and roots within the water, these create overshadowed habitat that lacks suitable food.

4 Discussion

4.1 Recommendations

For the proposed development of HWSFAC, dredging activities are proposed for the east channel within areas less than 2m deep, to provide a clear area with uniform depth for water-based activities without grounding issues for boats, rafts etc. Water levels can vary by one metre or more in the lake, so this should provide a minimum water depth of 1m even during a drought year. The dredged materials will be used to create a beach from which boats may be launched.

It is recommended that dredging is kept at least 2m from the edges of the lake and retained islands (i.e. outside the defined water activities zone). Furthermore, any spare dredged materials should be placed within the shallowest zones of these undredged areas, to reduce the depth at the sides of the channel and to try to create areas of shallow sediment that plants and macroinvertebrates may colonise. The space between islands 6 and 8, and tip of island 6 seems to be a good area to create a larger area of shallows. Deposition areas should be planned in advance and informed by an update bathymetric survey of the specific locations. If required, revetements may be used to retain the deposited materials. Although relatively shallow, the east channel is still too deep for any significant areas of emergent vegetation to grow, or for the sediments to be of use for macroinvertebrates. Plants growing at these depths are less accessible to plant feeders such as swans and geese. By creating shallower areas (<1m deep and ideally <0.5m deep) the habitat in the channel will be enhanced.

Significant weed growth was observed in September 2024 in the east channel. Dredging is planned for September 2025 at the peak of vegetation growth. It is worth planning for initial removal of dense vegetation prior to dredging, to ensure works are not delayed by propellers being caught in weed.

Obstructions such as concrete and large boulders have been located in the east channel. These are testament to the artificial origins of the lake and are likely remnants of past quarrying and industrial activities. The location of these obstructions should be taken into consideration as they will may require special consideration, possibly removal before the main dredge.

Crevices between rubble piles / obstructions that are filled with sediment may provide refugia for eels. These piles should be carefully deconstructed by lifting off the top materials carefully and moving this away, without disturbing the underlying materials. This will allow eels to swiftly move away from any crevices without any harm. Works should be undertaken when water temperatures are above 10C so fish and eels will be very active and able to swim away quickly from any disturbance. To replace lost refugia, at least four artificial reefs and cave features for eels should be provided within the east channel.

4.2 Summary

- Keep dredging activities at least 2m from the lake and island edges;
- Use spare dredged materials to create shallows (<0.5m deep) between island 6 and 8 and in other carefully planned discrete locations; retaining structures (e.g. sand bags) may be required to hold the deposited sediment in place;
- Plan deposition areas in advance and ensure bathymetric survey is accurate (update survey may be needed for specific locations);

- Be aware of plant growth in September that may clog propellers;
- Be aware of large obstructions that may need removal to facilitate the main dredge;
- Careful deconstruction of rubble piles or obstructions is needed to avoid harm to eels; works should be done when water temperatures are above 10C; and
- Provision of artificial reefs and caves for eels should be provided to replace any lost refugia.

Appendix A Identification of algal species by location

Survey point		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Algae	Chara sp																										
	Filamentous algae		P			P			P						P	P			P	E		E	E	P			
	Nitellopsis sp																										
	Ulva sp																										
Bryophytes	Fontinalis antipyretica																										
Higher Plants	Ceratophyllum demersum						P	P		P	P			P			P	P	P								
	Elodea sp				E	E	P	P	P	P	P	P		E	E	E	P	<small>Flowering stems</small>	E		E	P	E		P	P	
	Lemna trisulca					P																					
	Potamogeton sp.					P					P					P											
	Unidentified		P																								
Other	Fine tree roots															P											

Survey point		26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
Algae	Chara sp						?		P											P							
	Filamentous algae			E			P		E	P				E				P		P	E					P	
	Nitellopsis sp																										?
	Ulva sp																										
Bryophytes	Fontinalis antipyretica					P?																					
Higher Plants	Ceratophyllum demersum												P		E	P	E		E		P	P		P		P	
	Elodea sp	?	E	E	E?		P	P		P	E	P	P		P	P	P	E	P		E	P	P		P	P	
	Lemna trisulca		E				P	P																		P	
	Potamogeton sp.							P					P			P				E							
	Unidentified																										
Other	Fine tree roots												P														

Survey point		51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	
Algae	Chara sp									E	P	P	E		P				E		E						
	Filamentous algae			E	P																			P	P		
	Nitellopsis sp																										
	Ulva sp																									P	
Bryophytes	Fontinalis antipyretica																										
Higher Plants	Ceratophyllum demersum		P			P						E										P				E	
	Elodea sp	P	E	P	P		P	P	P		P	E	E	P	P	P	P		P	P				E	P	P	
	Lemna trisulca					P													?								P
	Potamogeton sp.					P													P								
	Unidentified																										
Other	Fine tree roots																										

Survey point		76	77	78	79	80	81	82	83	84	85
Algae	Chara sp					P					
	Filamentous algae	P	P	P				E	P		
	Nitellopsis sp										
	Ulva sp										
Bryophytes	Fontinalis antipyretica										
Higher Plants	Ceratophyllum demersum	P	P			P			P		P
	Elodea sp	E	P	E	P	P	?			P	P
	Lemna trisulca					P					
	Potamogeton sp.										E
	Unidentified										
Other	Fine tree roots										

Notes: Most likely Elodea nutallii
 Fine leaved pondweed, probably Potamogeton berchtoldii or P. pusillus, both found in the macrophyte survey
 No plants in survey points 1 or 3 but Epiphytic algae at 3

Key: P = Present
 E = Extensive

Report

Preliminary investigations of the ecological status of Broadwater SSSI

Presented by:

**ENVGEO Research Team
University of Northampton
Development Hub
Cliftonville Road
Northampton,
NN1 5FS**

Presented to:

Harper Environmental Ltd

On Behalf of:

Hillingdon Council

Presented in November 2024

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1 Introduction

On behalf of Hillingdon Council (“the client”) Harper Environmental Ltd. instructed University of Northampton (UON) to carry out aquatic surveys at Broadwater Lake (the Site) to help clarify the ecological status of Broadwater Lake. The surveys are required to support a planning application to develop a new outdoor, water-based activities centre (Hillingdon Water Sports Facility and Activities Centre – HWSFAC) at Broadwater Lake.

1.1 The Site

Broadwater Lake forms part of the Mid-Colne Valley SSSI and is designated for “significant ornithological interest, particularly for the diversity of breeding woodland and wetland birds, and for the numbers of wintering wildfowl” (Natural England,1986).

The whole Site covers an area of approximately 76 hectares (ha) and is approximately centred on National Grid Reference TQ 04396 89593. The Site comprises an access road from Moorhall Road, the lake itself with an associated lagoon (south-east corner of the lake), a peninsula at the south-east corner, an existing sailing club (Broadwater Sailing Club) at the north end of the lake, parts of the margins of the lake, and islands set within the lake. Part of the western and southern banks of the lake and adjacent open water lie just outside the red line boundary.

1.2 Requirement for the surveys

The lake-based surveys reported here have been requested in order to provide information towards a lake condition / naturalness assessment, and to help establish the ecological status of the lake.

1.3 Scope

This report presents the results of surveys undertaken to allow the assessment of a range of physical, chemical and biological parameters. Surveys were undertaken by boat to collect water and sediment samples. The depth of the lake bed was measured (bathymetric survey) at a number of points as part of the surveys. Surveys were targeted to the north shore of the peninsula and around the east channel – these are the

areas most liable to be impacted by development proposals for HWSFAC (as at the time of writing).

Section 2 presents the methodologies for the fieldwork, laboratory analysis and map production undertaken. Section 3 presents the sampling strategy. Section 4 presents the results. Section 5 reports the conclusions while Section 6 makes recommendations for further monitoring and management.

The appendices provide further detailed information not included within the main body of the text. Appendix 1 sets out the macroinvertebrate taxa recorded. Appendix 2 provides useful notes on three non-native invasive species identified to be present or potentially present at the lake (demon shrimp, red signal crayfish, zebra mussel).

2 Methods

2.1 Field work

Fieldwork took place in the week commencing 17th June 2024. The following activities were undertaken:

- Bathymetric survey;
- Identification of the extent and nature of benthic sediments using an Ekman grab;
- Undertake sampling of benthic sediments to determine, organic matter content (%), particle size;
- Pelagic macroinvertebrate sweep;
- Littoral zone macroinvertebrate sampling;
- Water sampling to determine suspended solids and preliminary nitrate and soluble reactive phosphate levels (orthophosphate); and
- On-site measurements using a Aquameter (AM200) and Aquaprobe (AP800); temperature, dissolved oxygen (%), electrical conductivity, pH.

2.2 Laboratory Analysis

Following collection of the samples, laboratory analysis was then undertaken at the University of Northampton, Environmental laboratories in June and July 2024. The following techniques and procedure were carried out:

2.2.1 Sediment

- Organic Matter (loss on ignition)
- Particle size distribution (by laser granulometry following organic matter pre-treatment and sieving to remove > 2 mm fraction)

N.B Magnetic susceptibility was not investigated in this initial study as source apportionment of benthic sediments has not been considered at this stage.

2.2.2 Water testing

- Suspended sediment concentration
- Nitrate and phosphate

2.2.3 Macro invertebrates

Identification of macroinvertebrates to family level was undertaken in the laboratory and Biological Monitoring Working Party (BMWP) and Average Score per Taxa (ASPT) scores provided along with summaries of INNS and potential impacts (please see appendix 2).

2.3 Bathymetric Map Production

Data obtained from the bathymetric survey was used to create a bathymetric map of the lake using GIS. Bathymetric survey records were merged and entries with missing depth or location data were removed, resulting in a dataset of 10,764 points. The location data (decimal degrees) were projected on to the British National Grid (EPSG 27700) in QGIS (ver. 3.34). No additional post-processing was applied to the GNSS (GPS) positions. The provided instrument readings for depth were rasterized (cell size = 5 m) in CloudCompare (ver. 2.13) using the average depth recorded in each cell. Cells with no data were filled using kriging interpolation¹ (KNN = 8). The datasets are also available in a common geospatial format, if required.

3. Sampling Strategy

Surveys were undertaken on the 17th and 20th June 2024 using a boat with electric motor (for minimal disturbance to wildlife). Equipment used included a Sonarmite V5 Echo Sounder (water hydrographic surveying equipment) which allowed the identification of appropriate sampling sites, based on depths, which allowed the collection of representative samples.

Surveys were targeted to areas of the lake proposed for use by HWSFAC, mainly around the northern shore of the peninsula and within the east channel.

The bathymetric survey was completed using a Trimble Geo7X and Sonarmite V5 Hydrographic Echo Sounder.

On both dates there were constraints to the sampling regime due to the presence of fishermen at sites near points 12 and 13, as shown on Figure 1. A summary of sampling techniques and analysis is shown in Table 1.

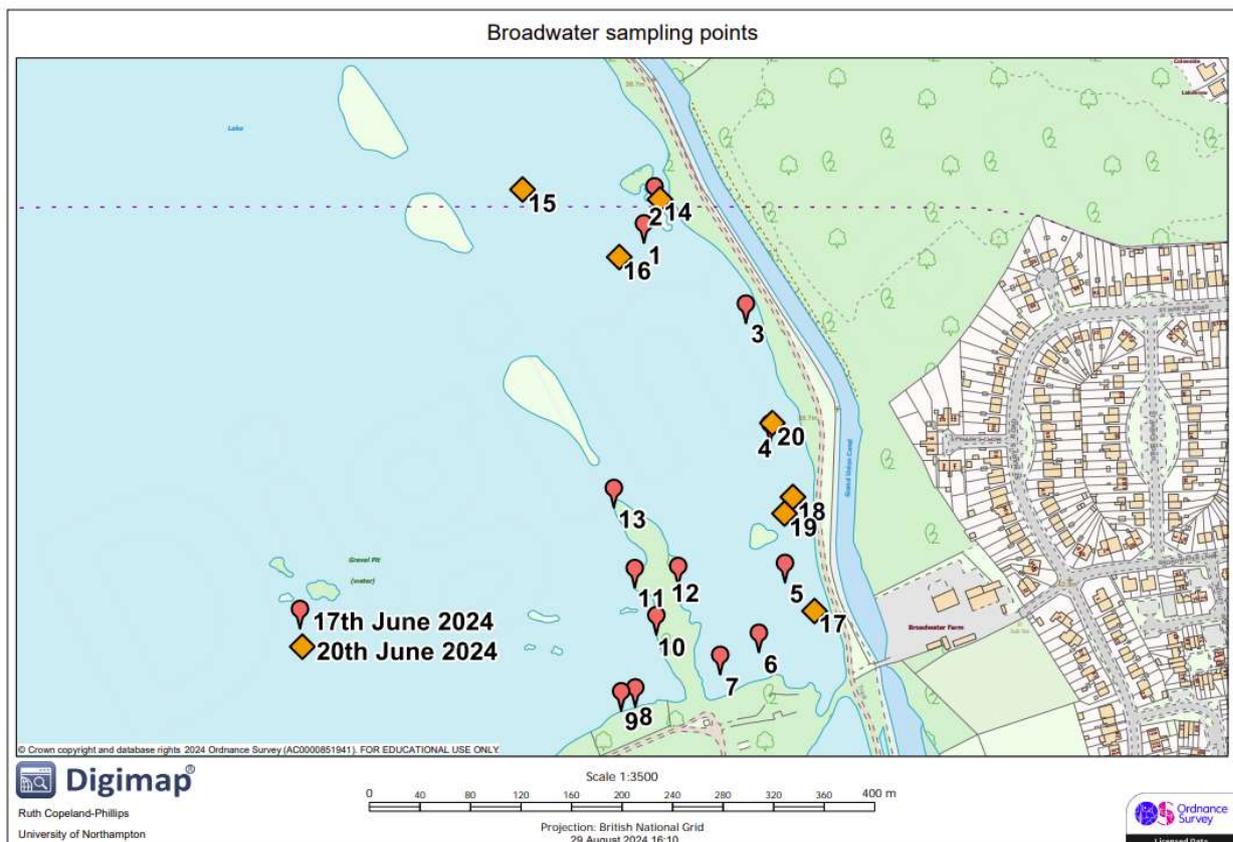


Figure 1: Sampling points within Broadwater Lake 17th and 20th June 2024. (Copeland-Phillips, 2024)

Table 1: Description of sample points and samples taken within Broadwater Lake 17th and 20th June 2024.

Sample Number	Location	Samples taken	Depth observations*	Laboratory analysis
1	51.596341, - 0.49055	Benthic sediments Water sample	>4m	Particle Size analysis Suspended Sediment N and P
2	51.59662, - 0.490421	Benthic sediments Water sample Macroinvertebrate sweep	~1m	Particle Size analysis Suspended Sediment N and P Identification
3	51.595761, - 0.489406	Water sample Macroinvertebrate sweep	~0.5m	Suspended Sediment N and P Identification
4	51.594899, - 0.489159	Benthic sediments Water sample	>4m	Particle Size analysis Suspended Sediment N and P
5	51.593900, - 0.489019	Water sample Macroinvertebrate sweep	<0.5m	Suspended Sediment N and P Identification
6	51.59339, - 0.489332	Benthic sediments Water sample	~3m	Particle Size analysis Suspended Sediment N and P

7	51.59325, - 0.48978	Benthic sediments** Water sample	~2m	Particle Size analysis Suspended Sediment N and P
8	51.593004, - 0.490755	Littoral zone macroinvertebrate sweep	N/A	Identification
9	51.592964, - 0.49092	Littoral zone macroinvertebrate sweep	N/A	Identification
10	51.593557, - 0.490449	Littoral zone macroinvertebrate sweep	N/A	Identification
11	51.593895, - 0.490709	Littoral zone macroinvertebrate sweep	N/A	Identification
12	51.593878, - 0.490193	Littoral zone macroinvertebrate sweep	N/A	Identification
13	51.594484, - 0.490964	Littoral zone macroinvertebrate sweep	N/A	Identification
14	51.59667, - 0.49036	Aqua probe	~1m	Readings reported
15	51.59676, - 0.49193	Aqua probe Benthic sediment sample***	~2m	Readings reported Particle Size analysis Loss of Ignition
16	51.59626, - 0.49083	Aqua probe Benthic sediment sample***	>4m	Readings reported Particle Size analysis Loss of Ignition

17	51.5937, - 0.48869	Aqua probe Benthic sediment sample***	~2m	Readings reported Particle Size analysis Loss of Ignition
18	51.59452, - 0.48891	Aqua probe Benthic sediment sample***	>5m	Readings reported Particle Size analysis Loss of Ignition
19	51.59440, - 0.48901	Benthic sediment sample****	~3.5m	Particle Size analysis Loss of Ignition
20	51.59505, - 0.48913	Benthic sediment sample***	>4m	Particle Size analysis Loss of Ignition

**Depth observations should be taken in conjunction with bathymetric survey.*

***macroinvertebrates were observed within the benthic sediment sample. The specimens were preserved and identified and are reported.*

****samples sent to Dr Jason Jordan @ Coventry University for diatom analysis*

*****sample retrieved from benthic sediments was predominantly gravel and stone, this is reported in particle size section.*

4. Results

3.1 Bathymetric Survey

The lake surface can be seen in Figure 2 alongside the survey track. Smoothed contours obtained from this surface are presented in Figure 3.

Important: The uneven distribution of survey data and the use of interpolation contribute to uncertainty (error) in the resulting interpolated depths. Discrepancies are likely to exist between the readings obtained from the SonarMite Hydrographic Echo Sounder and from other instruments or surveys. Please interpret the results with care. Should additional survey data become available, please get back in contact to have the two appended figures replotted.

- Figure 2. Interpolated raster surface for the areas surveyed on 17 & 20 June 2024; and
- Figure 3. Interpolated contours for the areas surveyed on 17 & 20 June 2024.

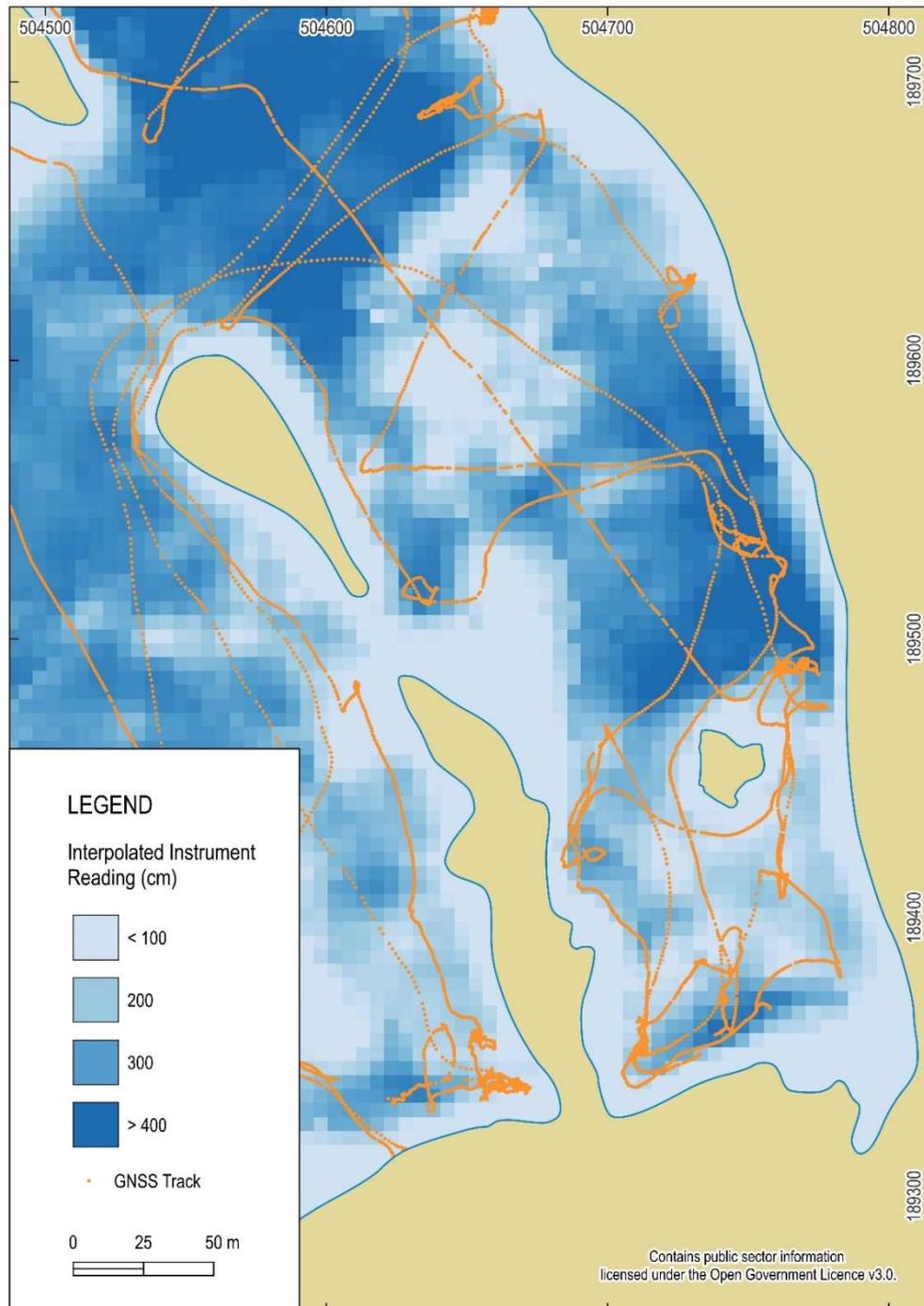


Figure 2. Interpolated raster surface for the areas surveyed on 17 & 20 June 2024.

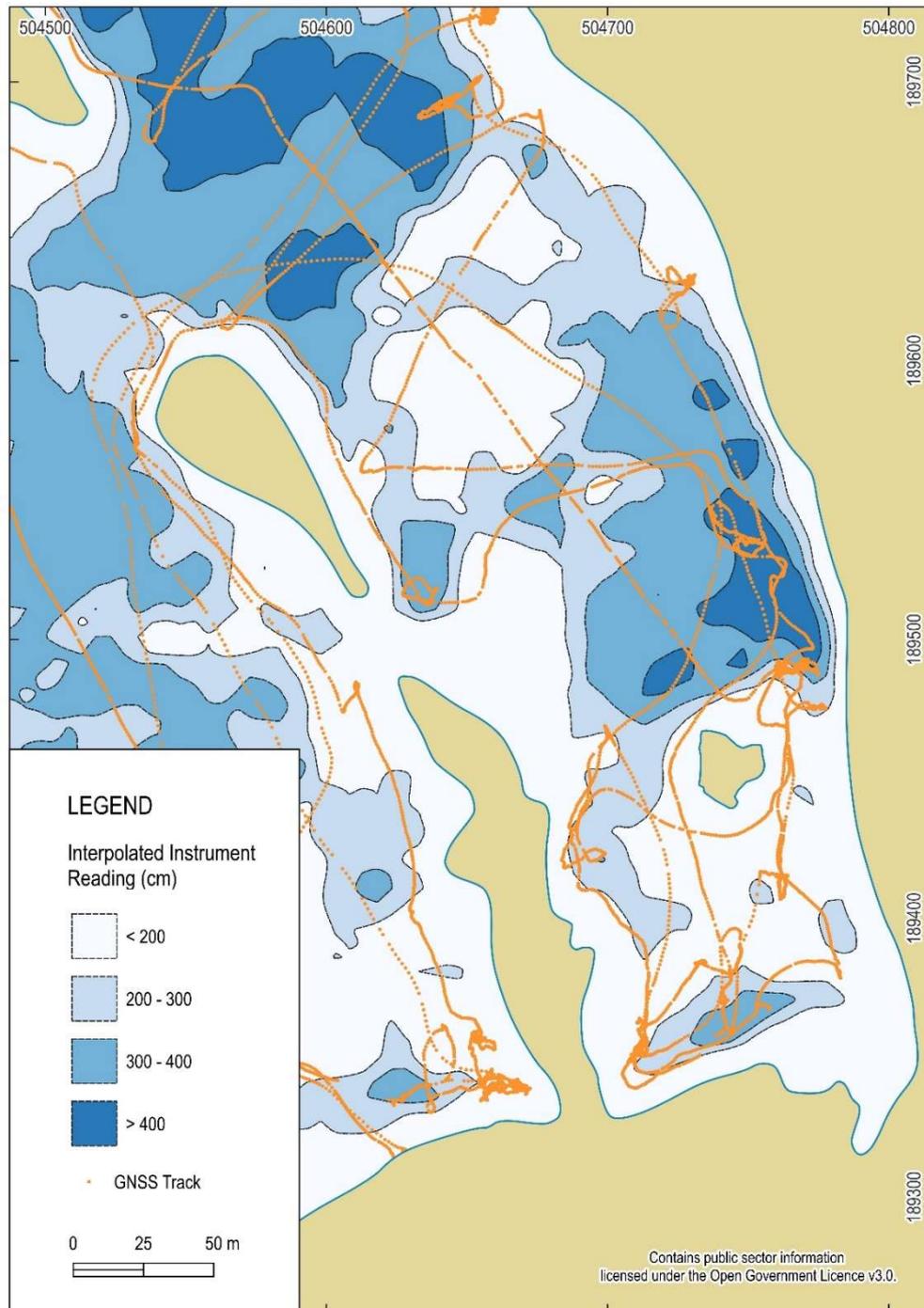


Figure 3. Interpolated contours for the areas surveyed on 17 & 20 June 2024.

3.2 Water Quality

Readings of water quality (pH, DO, EC, Temp and Salinity) were taken at Broadwater Lake at 4 different sample sites (14, 16, 17 and 18, see figure 1) on 20th June 2024 using an Aquameter. The average readings are displayed in Table 2.

Table 2: Summary of the average reading taken 20th June 2024 using Aquaprobe (AP800).

Parameter	Value and units
pH	6.85
Temperature	20.5°C
Electrical Conductivity	884 $\mu\text{S cm}^{-3}$
Dissolved Oxygen	75%

The pH of lake water can be expected to range between 6-9, depending on a number of factors including depth, productivity and underlying geology. The pH at Broadwater is neutral at around 6.85.

The average temperature of the Lake was $>20^{\circ}\text{C}$ which would be expected in a shallow temperate lake in summer.

Electrical Conductivity (EC) of water is a measure of the water's ability to conduct an electric current, normally reported as here in $\mu\text{S cm}^{-3}$. The purer the water the lower the conductivity; freshwater can have values of between 0-1500 $\mu\text{S cm}^{-3}$

Broadwater Lake has a relatively high EC but it should be noted that this is reflective of the total dissolved solids in the water (e.g. sodium, potassium, chloride, carbonate etc), as well as the underlying and catchment geology, run off, atmospheric inputs and bacterial metabolism. EC is a function of temperature, increasing with temperature.

The observed dissolved oxygen was 75% and again will be representative of temperature, in cooler months values of $>80\%$ would be expected. For fish the normal range is 80-100% and below 40% would be cause for concern (Angling Trust, 2022).

3.3 Organic Matter

% organic matter from benthic sediments was found to be between 3-19%. It must be considered that the lake is not of natural origin, and it would be expected to find lower organic matter than in other natural lentic systems as sediment deposition has only occurred during the life of the lake.

Table 3: Site number and % organic matter as determined using LOI.

Site Number	%Organic Matter
1	14%
2	9%
4	20%
6	13%
7	8%
15	13%
16	13%
17	14%
18	18%
19	3.5%
20	8%

Sediments with more than 20% organic matter are generally considered as “organic” (peat like). The sediments found within Broadwater are considered within a normal range. There is a variation in the level of organic matter, but this is due to a number of factors:

- Changes in benthic substrate (site 19 for example was stony)
- Proximity to shore and overhanging vegetation
- Internal primary production from presence of vegetation (submergent macrophytes)

Organic matter within lakes comes from internal production and in this case most likely from submerged macrophytes which dominate areas of the surveyed lake (autochthonous source). External sources (allochthonous) will most likely include the overhanging vegetation surrounding the lake. Lake sediments are important to monitor

as these sediments can contain legacy nutrients which can be recycled to and from the water column. However, Broadwater is a relatively young lake (<50 years old) therefore, sediment nutrient composition could be critical to eutrophication and lake water quality. The amount of observed submergent macrophytes could enhance sediment organic and nutrient values over the years and should be monitored to ensure that future issues of eutrophication are avoided. Sediment nutrient concentrations are often critical to lake eutrophication and potentially reflect lake water quality and health (Carey and Rydin, 2011; Klamt et al., 2019; Waters et al., 2020)

3.4 Particle Size analysis

Particle Size analysis is used to determine the range of particles within a sediment and can help to classify the sediment type. Generally, it is considered that particles <2 μm = clay, 2-63 μm = silt and 63- 2000 μm = sand. The percentage of each fraction from the samples taken from the lake is shown in Figure 4.

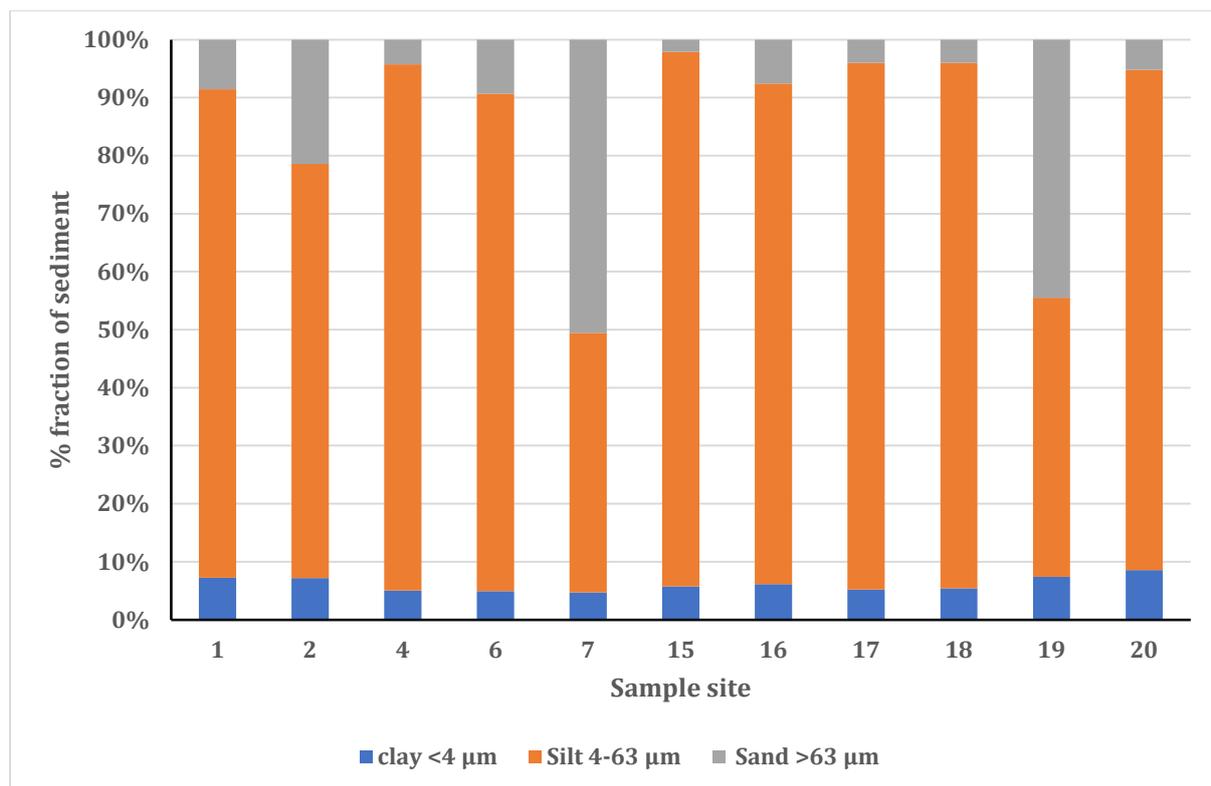


Figure 4: % fraction of sediment as related to particle size at each of the sampling points.

As Broadwater Lake was originally a mineral quarry the range of sediments would be expected to vary. Referring to the bathymetric survey there is a range of depths in this area of the lake. The nature of the benthic sediments are a reflection of a number of

factors including both allochthonous and autochthonous sources. It is interesting, however that some areas lack “sediment” such as site 19 and site 7 which have remained predominately sand with some gravel observed within the initial sample. Site 19 was ~3.5m in depth and yet no/little sediment had accumulated. The sediment taken from site 7 (~2m depth) had some macroinvertebrates within the sample. These were extracted for identification (see section 3.2.5 and appendix 1). The nature of the sediment at this site which was >50% sand, would have been conducive to benthic fauna. Sediment which is predominately silt sized reduces the penetration of light through increased turbidity, inhibits primary production (Yamada and Nakamura, 2002), causes damage to soft tissues and clogging of gills (Kemp et al., 2002). The increase in sedimentation in a freshwater environment causes physiological and behavioural responses as well as changes at the community level (Noe et al., 2020).

3.5 Suspended Sediment

Water samples taken on 17th June 2024 from sites 1-7 were filtered to establish the concentration of suspended sediment and the results are shown in Table 4.

Table 4: Suspended sediment mg l⁻¹ from each of the sampling sites

Sample Site	Suspended sediment mg l ⁻¹
1	24.14
2	23.13
3	6.67
4	6.76
5	3.34
6	3.42
7	6.69

Suspended sediment concentration (SSC) is an important parameter for describing lake water quality. Such sediments serve as a transport medium for nutrients, pollutants and bacteria (Loperfido, 2014). Increased SSC can decrease light penetration and clarity and therefore limit the growth of plants and algae at a primary trophic level (Henley et al., 2000). SSC was calculated for samples taken from sites 1-6. The highest SSC was observed at sample sites 1 and 2 (Table 4). Taken in conjunction with the initial nutrient observations (reported in section 3.6 below), the potential reason for high SSC at this

point could be an input to the lake from the adjacent canal. Suspended sediment levels in lakes can have negative effects but all samples taken were under 25mg l⁻¹ were “good” in terms of water quality (relating to fish).

3.6 Nitrate and Phosphate

Water samples taken from Sites 1-7 were analysed for nitrate and phosphate levels post- removal of suspended sediment and are shown in Table 5.

Table 5 Nitrate and Orthophosphate (both in mg l⁻¹) at each of the sampling sites

	Sample Site						
	1	2	3	4	5	6	7
Nitrate (NO₃) mg l⁻¹	15.84	3.96	4.4	3.96	6.60	5.28	2.64
Orthophosphate (PO₄³⁻) mg l⁻¹	0.68	1.01	0.45	0.32	0.36	0.42	0.33

Sample site 1 was observed to have higher levels of nitrates than the rest of the sites which again indicates (in conjunction with the SSC results) that there could be an inflow point to the lake in proximity to the sample location. The other values reported for nitrate are acceptable levels and do not exceed 50 mg L⁻¹. The 1991 Nitrates Directive (91/676/EEC) means that all water bodies are subject to a maximum nitrate (NO₃) concentration of 50 mg l⁻¹. The remaining samples (2-7) are in line with typical groundwater levels across the UK of <10 mg l⁻¹.

Orthophosphate is often referred to as phosphate and it can be used by plants (including algae) immediately. Monitoring phosphate in water is useful because it provides a good indication of ecological risk such as eutrophication. Phosphate is routinely monitored by the EA for the Water Framework Directive and as part of the assessment of Special Areas of Conservation.

The recommended annual average for orthophosphate in rivers is 0.1 mg⁻¹ and orthophosphate levels below 0.15 mg l⁻¹ are considered ideal to prevent eutrophication. As shown in Table 5 the values for Broadwater suggest that the lake is now Eutrophic with values on this initial survey suggesting a range of 0.33-1.01 mg⁻¹.

A recent review has demonstrated that trophic status and lake depth are important in determining chlorophyll a, and the role of N is secondary, but important in eutrophic

lakes, especially shallow ones (Zhao et al., 2023). While these findings could not be applied to every lake it does suggest that P reduction can be effective in the mitigation of eutrophication in deep lakes but in lakes such as Broadwater both reductions in N and P could be a more effective strategy (Zhao et al., 2023). In shallow lakes, further enrichment of N could reduce the resilience of lake ecosystems, in terms of a reduction of submerged macrophytes (Gonzalez Sagrario, et al., 2005; Olsen et al., 2015; Phillips et al., 2016).

3.7 Macroinvertebrates

Table 6 below shows the overall BMWP/ ASPT scores at each of the sample sites (please refer to Table 1 for details of sampling locations and the nature of the sampling). While INNS were found at some sites, they have not been counted in the BMWP/ASPT calculations.

Table 6: BMWP and ASPT scores for each of the sites with overall quality ratings

Sample site	BMWP	Number of scoring Taxa	ASPT	Overall quality
2	38	9	4.2	Poor
3	16	5	3.2	Poor
5	17	6	2.8	Poor
7*	11	4	2.75	Poor
8	29	7	4.1	Poor
9	27	7	3.8	Poor
10	36	9	4.0	Poor
11	34	8	4.25	Poor
12	35	7	7	Moderate
13	39	10	3.9	Poor

*sample taken from the pelagic zone and indicative of benthic macroinvertebrates

Further details of taxa can be found in Appendix 1. The assemblages of macroinvertebrates found at all the sites was repetitive and there is an inherent lack of diversity. It is important to note that in samples 3, 5, 9, 11 and 13, *Dikerogammarus haemobaphes* “Demon shrimp” was observed in the samples although these are not scored within the BMWP or ASPT scoring. Evidence of crayfish (*Pacifastacus leniusculus*) was also observed around sites 11 and 13. A half shell of a Zebra Mussel (*Dreissena polymorpha*) was found within a kick sample from site 8 (littoral zone). It is

suspected that it has been deposited there and not necessarily indicative of its presence within the lake as no other individuals or remains were found.

5. Conclusions

- Broadwater Lake is potentially in a eutrophic state although results of diatom assemblage information is outstanding.
- The nitrate and phosphate concentrations are considered high and further monitoring is recommended.
- The nature of the sediment is heterogeneous and is dependent on location and depth. While there does not appear to be external sources of sediment it is suggested that the origin of the sediment is from internal production and also from overhanging vegetation (autochthonous and allochthonous).
- The macroinvertebrate communities indicate poor water quality although this is potentially due to the lack of littoral zones currently around the lake.
- The bathymetric survey highlights the ranges of depths of the lake which are a legacy of its previous use and typical of a non-natural water body.
- Evidence has been found of three INNS which need further monitoring. *Dikerogammarus* have been shown to reduced biodiversity within aquatic macroinvertebrates assemblages and crayfish overpopulation can also enhance sedimentation rates within lakes due to burrowing within banks as well as leading to further decline in biodiversity within the lake. Please see notes on INNS (Appendix 2) for further information.

6. Recommendations

- Further investigation of diatom assemblages over a long term (annual) monitoring to ensure establish trophic levels of the lake.
- Potential sources of both point and diffuse pollution should be investigated with reference to the adjacent canal and river systems.
- Further development of shore zones and reduction in depth changes around the lake would enhance biodiversity for macroinvertebrates.
- The bathymetric survey should be used to target further monitoring in shallow areas which are potentially leading to further internal production of sediment through excessive submerged macrophyte growth. Monitoring may include visual surveys as well as sampling.
- Management of INNS needs to be considered in future planning to maintain and enhance lake biodiversity.

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Appendix 1: Macroinvertebrate families and sites.

Sample site	Family and BMWP	Number of scoring Taxa	ASPT	Overall quality
2	<p>Gastropoda Physidae-3 Viviparidae-6</p> <p>Bivalvia Sphaeriidae-3</p> <p>Crustacea Gammaridae-6 Asellidae-3</p> <p>Hemiptera (Bugs) Corixidae-5</p> <p>Trichoptera (Caddisflies) Limnephilidae-7</p> <p>Hirudinea (Leeches) Glossiphoniidae-3</p> <p>Diptera (Fly Larvae) Chironomidae- 2</p> <p style="text-align: center;">Total 38</p> <p>Non recorded species (INNS) Bivalvia Dreisseniidae</p>	9	4.2	Poor
3	<p>Gastropoda Physidae-3</p> <p>Bivalvia Sphaeriidae-3</p> <p>Crustacea Asellidae-3</p> <p>Hemiptera (Bugs) Corixidae-5</p> <p>Diptera (Fly Larvae) Chironomidae- 2</p> <p style="text-align: center;">Total 16</p> <p>Non recorded species (INNS) <i>Dikerogammarus haemobaphes</i> (demon shrimp)</p>	6	3.2	Poor

5	<p>Gastropoda Planorbidae-3</p> <p>Crustacea Asellidae-3</p> <p>Hemiptera (Bugs) Corixidae-5</p> <p>Hirudinea (Leeches) Glossiphoniidae-3</p> <p>Diptera (Fly Larvae) Chironomidae- 2</p> <p>Oligocheata (true worm) Oligochaeta- 1</p> <p style="text-align: center;">Total 17</p> <p>Non recorded species (INNS) <i>Dikerogammarus haemobaphes</i> (demon shrimp)</p>	6	2.8	Poor
7*	<p>Gastropoda Physidae-3 Planorbidae- 3</p> <p>Crustacea Asellidae-3</p> <p>Diptera (Fly Larvae) Chironomidae- 2</p> <p style="text-align: center;">Total 11</p>	4	2.75	Poor
8	<p>Gastropoda Physidae-3 Planorbidae-3</p> <p>Crustacea Asellidae-3</p> <p>Hemiptera (Bugs) Corixidae-5 Notonectidae-5</p> <p>Zygoptera (damselflies) Lestidae-8</p> <p>Diptera (Fly Larvae) Chironomidae- 2</p> <p style="text-align: center;">Total 29</p>	7	4.1	Poor
9	<p>Gastropoda Lymnaeidae-3</p>	7	3.8	Poor

	Planorbidae-3 Crustacea Gammaridae-6 Asellidae-3 Hemiptera (Bugs) Corixidae-5 Notonectidae-5 Diptera (Fly Larvae) Chironomidae- 2 <p style="text-align: center;">Total 27</p> Non recorded species (INNS) <i>Dikerogammarus haemobaphes</i> (demon shrimp)			
10	Gastropoda Lymnaeidae-3 Planorbidae-3 Crustacea Gammaridae-6 Asellidae-3 Hemiptera (Bugs) Corixidae-5 Notonectidae-5 Zygoptera (damselflies) Coenagrionidae- 6 Hirudinea (Leeches) Glossiphoniidae-3 Diptera (Fly Larvae) Chironomidae- 2 <p style="text-align: center;">Total 36</p> Non recorded species (INNS) <i>Dikerogammarus haemobaphes</i> (demon shrimp)	9	4.0	Poor
11	Gastropoda Planorbidae-3 Crustacea Gammaridae-6 Asellidae-3 Hemiptera (Bugs) Corixidae-5	8	4.25	Poor

	Notonectidae-5 Trichoptera (Caddisflies) Limnephilidae-7 Hirudinea (Leeches) Glossiphoniidae-3 Diptera (Fly Larvae) Chironomidae- 2 <p style="text-align: center;">Total 34</p> Non recorded species (INNS) <i>Dikerogammarus haemobaphes</i> (demon shrimp)			
12	Crustacea Gammaridae-6 Asellidae-3 Hemiptera (Bugs) Corixidae-5 Notonectidae-5 Zygoptera (damselflies) Coenagrionidae- 6 Anisoptera (dragon flies) Aeshnidae- 8 Diptera (Fly Larvae) Chironomidae- 2 <p style="text-align: center;">Total 35</p>	7	7	Moderate
13	Gastropoda Physidae-3 Lymnaeidae-3 Planorbidae-3 Bivalvia Sphaeriidae-3 Crustacea Gammaridae-6 Asellidae-3 Hemiptera (Bugs) Corixidae-5 Notonectidae-5 Trichoptera (Caddisflies) Limnephilidae-7 Diptera (Fly Larvae)	10	3.9	Poor

	Chironomidae- 2 Total 39 Non recorded species (INNS) <i>Dikerogammarus haemobaphes</i> (demon shrimp)			
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*sample taken from the pelagic zone and indicative of benthic macroinvertebrates

Appendix 2: Notes on Invasive Non Native Species

Nonnative species are plants or animals which have been introduced to the UK from all over the world. While most are harmless there are around 10-15% which harm the environmental and wildlife and can impact our economy, health and aspects of daily life (Aldridge, 2013))

After initial investigations this report can confirm, in conjunction with previous evidence, the presence of the following INNS at Broadwater lake:

Demon Shrimp: *Dikerogammarus haemobaphes* (within kick samples from the littoral zones)

Preserved samples of this species were first found in 2012 from the River Severn (Aldridge, 2013) and now there is widespread distribution across England indicating that it is surviving and reproducing. The “Demon Shrimp” is considered to share a similar trophic level with the “Killer Shrimp” (*Dikerogammurus villosus*). It is a dietary generalist and it’s predation on food sources such as chironomids, oligochaetes, crustaceans and mayflies increases in when water temperatures are high (van der Velde et al., 2009). Cannibalism is higher within this species than other European gammarid species (Kinzler et al 2009) Research on the ecological effects of *D. haemobaphes* is limited and diverse and varied communities have been observed when they are the dominant species however much of the research focussed on *D. villosus* has shown there is potential for significant ecological consequences but community dynamics in natural setting are limited and most research has taken place under laboratory conditions (Mathers et al, 2023). There is the potential for community dominance (Jazdzewski et al 2004)

It is found in a range of different aquatic conditions although is noted to prefer solid substrates, macrophytes and algae in rivers and lakes. They also share a strong preference for beds of the Zebra Mussel (Kobak et al., 2009) of which evidence was found in Broadwater although may have been transported from the adjacent canal. The spread of the species within flowing water is possibly attributed to drift although some important overland vectors may include fishing gear (such as keep nest), waders and also via outboard engines and boats (Musko, 1990).

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Zebra Mussel: *Dreissena polymorpha* (within a kick sample from the littoral zone although evidence of shell only)

The Zebra mussel can be described as one of the biggest invasive pests in the world's freshwaters (Aldridge et al., 2004) and it has the ability to cause trophic level changes in the ecology of freshwater environments often functioning as keystone fauna (MacIsaac, 1996). They have been reported to reach densities as high as 750 000 individuals per m² and each individual can filter between 1-2 litres of water daily, causing shifts in planktonic communities (Readers et al., 1989).

As previously noted some gammarid shrimps can benefit from the increased habitat formed by the zebra mussels and increased water clarity, resulting from the decline in phytoplankton, can further encourage the establishment of macrophytic vegetation. While this can create further

habitats for invertebrates such as Trichoptera (caddis fly larvae) and Turbellaria (Flatworms), it can impose increased competition on suspension living species. (Strayer et al., 1998), While the presence of the zebra mussel could be of benefit to some molluscivorous wildfowl and fish it is important to consider the deleterious effects of this INNS and sites with a high conservation importance should be closely monitored (Aldridge et al., 2004) While population numbers in UK were seen to decline during 1980s, there has been a rapid increase since 1999 throughout much of southern and eastern England. The mussel larvae can drift downstream for up to 4 weeks but most of the introduction to new areas is due to anthropogenic transport in fish and bait wells as well as shipping. (NNSS, 2016)

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Red Signal Crayfish: *Pacifastacus leniusculus* (evidence of specimens at sample points)

The signal crayfish (*Pacifastacus leniusculus*) is North American in origin, introduced to the south of England in the 1979 for cultivation purposes. (Lowery and Holdich, 1988, Holdich and Reeve, 1991) Signal Crayfish are known to carry *Aphanomyces astaci*, crayfish plague, which is lethal to native populations (James et al., 2017). They are large omnivorous invertebrates and can impact benthic food webs through both predation and competition as well as modification of habitats. Signal Crayfish are known to burrow into riverbanks (e.g. Faller et al., 2016) transferring sediment directly into the water body as well as reports of increased bank erosion (West, 2010). The presence of these non-native crayfish will have an impact on the lake biodiversity particularly the macro invertebrate community especially the larger less mobile species (e.g. trichoptera and molluscs) as well as potentially fish eggs and small fry, by predated and outcompeting native species (Guan and Wiles, 1997).

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