



LEGEND

- ◆ Reptile mats
- ▭ Site boundary



Project:
Broadwater Lake

Client:
Mace Group

Drawing Title:
Reptile refugia locations



Drawing No.:	Scale (@A3):
EBD_1969_DR001	1:2,000
Central Eastings, Northings:	Date Drawn:
504721, 189251	12/01/2022
Drawn by:	Approved by:
OH	LG

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LEGEND

-  Dormouse tubes
-  Site boundary

Location (1:75,000):



Project:

Broadwater Lake

Client:

Mace Group

Drawing Title:

Dormouse survey methods

Drawing No.:

EBD_1959_DR002

Scale (@A3):

1:2,000

Central Eastings, Northings:

504721, 189251

Date Drawn:

12/01/2022

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LEGEND

Bat Survey

- Point count
- Parking
- Static
- Bat transect
- Site boundary

Location (1:75,000):



Project:

Broadwater Lake

Client:

Mace Group

Drawing Title:

Bat survey methods

Drawing No.:

EBD_1959_DR003

Scale (@A3):

1:2,000

Central Eastings, Northings:

504744, 189233

Date Drawn:

12/01/2022

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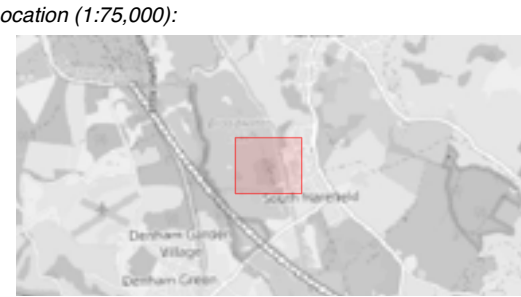
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- LEGEND
- Site Boundary
 - Quicksand out of bounds area
 - Inaccessible due to dense vegetation
 - Badger Latrine



Project:
Broadwater Lake

Client:
Mace Group

Drawing Title:
Badger Survey

Drawing No.:	Scale (@A3):
EBD_1969_DR001	1:2,000
Central Eastings, Northings:	Date Drawn:
504721, 189251	23/09/2022
Drawn by:	Approved by:
KP	LG

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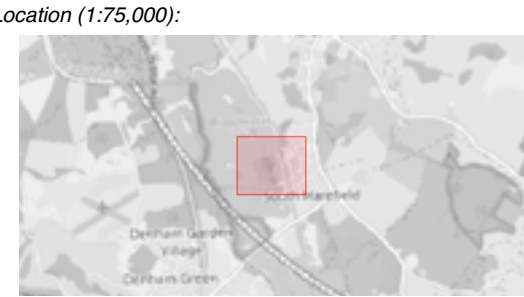
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- LEGEND
- Site Boundary
 - Quicksand out of bounds area
 - Crayfish remains
 - Potential otter spraint
 - Otter spraint
 - Inaccessible area due to vegetation



Project:
Broadwater Lake

Client:
Mace Group

Drawing Title:
Otter and Water Vole Survey

Drawing No.: EBD_1969_DR001	Scale (@A3): 1:2,071.912258
Central Eastings, Northings: 504744, 189235	Date Drawn: 23/09/2022
Drawn by: KP	Approved by: LG

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Appendix 2 – Enhancements



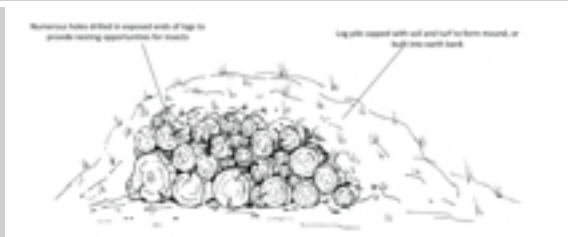
diagram taken from Langton, T.E.S., Beckett, C.L., and Foster, J.P. (2001), Great Crested Newt Conservation Handbook, Froglife, Halesworth.

Hibernacula

Dimensions: 0.5 m Deep x 1 m wide x 1 m tall

- 1) Remove turf around a 1 m x 1 m patch of soil
- 2) Excavate a 0.5 m deep hole and line the base with 100 mm of sharp sand for drainage
- 3) Fill the hole with an assortment of rubble, brash, and logs and pile to a height of 1m

Cover with topsoil and seed with wildflower grass mixture or patch over with the salvaged turf, leaving the south-western aspect uncovered.



Buried Log Piles

Partially buried log piles provide valuable shelter and foraging resources to a range of invertebrates and other wildlife, particularly saproxylic species (associated with dead wood). Buried log piles are particularly beneficial when constructed from pre-existing dead wood taken from the site.

Wood from any broadleaved tree can be used but oak, beech and fruit trees support the richest invertebrate assemblages.





Habibat Bat Box

The Habibat Bat Box is a solid box made of insulating concrete with an internal roost space, which can be incorporated into the fabric of a building as it is built or renovated. A variety of facings can be fitted to suit any building. The box is suitable for Pipistrelle bats and other common UK species.

<https://www.nhbs.com/habibat-bat-box-plain-for-rendering>



Miramare Woodstone Bat Box

The Miramare is designed to mimic a hollow tree. It is a large bat box with four internal cavities and an external construction of woodcrete to be long-lasting and provide opportunities to large numbers of bats. The box is open to the bottom meaning that it is effectively self-cleaning.

<https://www.wildcare.co.uk/miramare-woodstone-bat-box-11268.html>



2F Schwegler Bat Box (or similar)

A standard bat box for smaller bats to be placed on a mature tree.

<http://www.nhbs.com/2f-schwegler-bat-box-general-purpose>

Appendix 3 – Site/Species Value

Species	Number of bats	Roosts/potential roosts nearby	Type and complexity of linear features
Common (2)	Individual bats (5)	None (1)	Absence of (other) linear features (1)
-	-	Small number (3)	Unvegetated fences and large field sizes (2)
Rarer (5)	Small number of bats (10)	Moderate number/Not known (4)	Walls, gappy or flailed hedgerows, isolated well- grown hedgerows, and moderate field sizes (3)
-	-	Large number of roosts, or close to a SSSI for the species (5)	Well-grown and well-connected hedgerows, small field sizes (4)
Rarest (20)	Large number of bats (20)	Close to or within a SAC for the species (20)	Complex network of mature well-established hedgerows, small fields and rivers/streams (5)

Species	Number of bats	Roosts/potential roosts nearby	Foraging habitat characteristics
Common (2)	Individual bats (5)	None (1)	Industrial or other site without established vegetation (1)
-	-	Small number (3)	Suburban areas or intensive arable land (2)
Rarer (5)	Small number of bats (10)	Moderate number/Not known (4)	Isolated woodland patches, less intensive arable and/or small towns and villages (3)
-	-	Large number of roosts, or close to a SSSI for the species (5)	Larger or connected woodland blocks, mixed agriculture, and small villages/hamlets (4)
Rarest (20)	Large number of bats (20)	Close to or within a SAC for the species (20)	Mosaic of pasture, woodlands and wetland areas (5)

Geographic reference	Score
International	>50
National	41-50
Regional	31-40
County	21-30
District/Local/Parish	11-20
Not Important	1-10

All Appendix 3 tables taken from Wray et al. (2010)



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2933 Broadwater Lake Aquatic Assessment Prepared for



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Document title - Broadwater Aquatic Assessment Report


Status - Draft

Project code - 2933

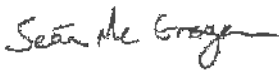
Client - Mace Group Ltd

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Internal QC approver - Jamie McCready

Signature 



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Executive Summary

Five Rivers Environmental Contracting Ltd (Five Rivers) was commissioned by Mace Group Ltd (Mace) to undertake fish and macro-invertebrate surveys on Broadwater Lake, near Harefield in the London Borough of Hillingdon.

The data gathered was used to provide commentary on key results and assesses whether species present may be affected by increased recreational activity on the lake due to the construction of a new water sports and outdoor activity facility.

Surveys were undertaken between the 10th and 12th October. Fish were surveyed using electric fishing, seine and fyke netting methods which aimed to target all species and life stages present. Macro-invertebrate samples were collected around the perimeter of the lake to represent the different habitats present.

A total of five fish species were recorded during the fish surveys across all methods; these were: pike (*Esox Lucius*), perch (*Perca fluviatilis*), tench (*Tinca tinca*), common carp (*Cyprinus carpio*) and three-spined stickleback (*Gasterosteus aculeatus*). The combined abundance of fish was 245 individuals with an estimated biomass of 10.2 kilograms. Perch were the most abundant species present, while pike had the highest biomass. Fish populations appeared to be low, however without intensive survey effort, this is impossible to confirm.

While undertaking fish surveys, 210 signal crayfish (*Pacifastacus leniusculus*), an Invasive Non-Native Species (INNS), were caught at multiple sites across Broadwater Lake.

Macro-invertebrate communities were relatively diverse and were indicative of moderate water quality. No protected species were found in the samples.

Overall, an increase in recreational activity would have no significant effect on the fish or macro-invertebrate communities.

Recommendations for improving fish and macro-invertebrate populations and habitat have been provided.

1. Introduction

1.1 Project Background

Five Rivers Environmental Contracting Ltd (Five Rivers) was commissioned by Mace Group Ltd (Mace) to undertake a suite of aquatic ecology surveys on Broadwater Lake (hereafter referred to as 'Broadwater'), near Harefield in the London Borough of Hillingdon, to determine the potential effects of proposed increased recreational activity in relation to a proposed new water sports and outdoor activity facility near the southeast bank of Broadwater.

Alongside the development will be habitat improvements works on Broadwater for wading birds including the creation of islands on the northeast side for nesting and the maintenance of a shallow wading area, for feeding, in the southwest corner.

Broadwater is a 19-hectare (Ha) body of water located near the village of Harefield, Middlesex. The lake, alongside several others within the Colne Valley, is designated as Site of Scientific Special Interest (SSSI) and is recognised as an important area for wintering wading birds.

To the east of the lake is the Grand Union Canal (GUC) and to the west is the River Colne. The lake is a gravel pit and has a maximum depth of approximately 4 metres (m). The southwest extent is relatively shallow while the northern parts of the lake are the deepest.

The majority of the lake is surrounded by dense tree cover, with willow (*Salix spp.*) being dominant along much of the perimeter.

Broadwater Sailing Club (BSC) is situated on the northern bank of the lake, and there are several pontoons and slipways.

1.2 Brief and Objectives

The aim of the surveys was to gather information and report to fulfil the brief which was:

- To assess the potential effects of increased recreational use of Broadwater on fish stocks and macro-invertebrate communities present.
- To provide mitigation, if any is required, for potential effects caused by increased recreational activity.
- To provide recommendations to improve habitat for fish and macro-invertebrate communities.

2. Methodology

2.1 Fish Survey

Fish surveys were undertaken on Broadwater between the 10th and 12th of October 2022, by a team of suitably qualified and experienced aquatic/fisheries ecologists. Weather conditions were calm and generally sunny.

The fish community of Broadwater was surveyed using three different methods, designed to target all potential species, as well as all life stages. The locations of all the fish surveys are presented in **Error! Reference source not found.** located in Appendix A. Survey Map.

Electric fishing methods were used in the marginal habitat of the lake to target juvenile life stages. Two 400-millimetre (mm) anodes were fished from a 3.5m rigid inflatable boat (RIB) powered by a 6 horsepower (hp) outboard operated by a Royal Yachting Association (RYA) Powerboat Level 2 certified operative. Electric fishing settings/output were selected based on conductivity (Table D-1 in Appendix D. Fisheries Data) measured using a calibrated hand-held YSI Pro-Plus probe. For electric fishing operations, a frequency of 50 hertz (Hz) was used at a current of 3 amps. All electric fishing complied with British Standard BS EN 14011:2003-BS 6068-5.32:2003 (Water quality. Sampling of fish with electricity) (British Standards Institution, 2003).

Seine netting was used to target adult life stages. A 51m by 4m, 14/17mm mesh seine net was set via boat. A total of six nets were set and retrieved by operatives towards the bank, ensuring the buoyant floats remained on the water's surface, and the lead-line at the net's bottom remained on the lakebed, preventing fish from escaping.

Fyke netting was used to target benthic (bottom dwelling) species including European eel (*Anguilla anguilla*).

Fyke nets were set on the lakebed and held in place with two mud weights marked with buoys. A fyke net consists of two cylindrical nets called ends which are separated by a leader. Each end has a series of openings called inscales which decrease in size, trapping fish as they enter further into the net. Fish are held in the final chamber, called the cod end, until the fyke net is emptied. Fyke nets were double ended (two cod ends per trap) 50cm diameter knotless nets with 8m leaders, with 85mm otter guards fitted. The nets complied with the EA Operational Instruction 25_07 – Fyke Netting for Fish Monitoring (Environment Agency, 2010).

A total of 15 fyke nets were deployed and left overnight before being retrieved the following morning. Fish were removed from the nets and processed before the fyke nets were redeployed. The 15 nets were deployed, checked and redeployed over both nights that operatives were onsite.

On completion of sampling, individual fish were identified to species level, measured to fork length (mm), and returned to the lake. Digital georeferenced photographs were taken of each species.

All invasive non-native species (INNS) captured during survey were retained and humanely euthanised and responsibly disposed of in line with guidance from the Non-native Species Secretariat (NNSS, 2022).

2.2 Data Analysis

Several different metrics were produced to provide interpretation of the fish population within Broadwater:

- **Abundance:** the total number of individuals caught by species.
- **Estimated weight:** the total weight of fish caught by species calculated using Environment Agency length-weight relationships¹.
- **Species composition:** a breakdown by species of the number of fish caught and presented in pie charts.
- **Estimated biomass:** a breakdown by species of total weight of species caught and presented in pie charts.
- **Population structure:** the number of fish by species caught within certain size bands presented in length frequency histograms.

¹ Individual fish lengths were used to calculate estimated weights using standard Environment Agency length-weight relationships.

2.3 Macro-invertebrate Surveys

Macro-invertebrate surveys were undertaken by a suitably experienced and qualified aquatic ecologist on the 12th of October 2022.

Samples were collected from the littoral zones of the lake, with sample sites chosen to target the different habitats present. These were collected on the south, east and west sides of the lake (**Error! Reference source not found.** in Appendix A. Survey Map).

Sampling was undertaken using a standardised 3-minute kick sample, using a 1mm mesh net, followed by a 1-minute timed manual search following the Environment Agency (2017) procedure, which conforms to BS EN ISO 10870:2012 Water Quality – Guidelines for the selection of sampling methods and devices for benthic macro-invertebrates in fresh waters (BSI, 2012).

A standardised field sheet was completed to provide information about the waterbody, including substrates, depths, and riparian land use.

Samples were preserved with Industrial Denatured Alcohol (IDA) on site and transported back to the laboratory for sorting and analysis to Taxonomic Level 5 (TL5) in adherence with the Environment Agency (2014) procedure.

Sorting and analysis of samples was undertaken by a suitably experience and qualified freshwater taxonomist.

2.4 Data Analysis

The identification of macro-invertebrates to TL5 species level allowed the use of specific metrics to determine ecological values of the communities and individual species present at each site. These can be combined to give an overall picture of the communities within the lake.

The metrics used are listed below and defined in Appendix E. Macro-invertebrate Data:

- **BMWP** (Biological Monitoring Working Party)
- **NTAXA** (Number of Taxa)
- **ASPT** (Average Score Per Taxa)
- **CCI** (Community Conservation Index)
- **CS** (Conservation Score)

2.5 Limitations

Five Rivers stored their boat alongside the trailer within the Broadwater compound each evening post-survey. Unfortunately, the boat was stolen on the final evening. This resulted in a delay the following day as surveyors had to return to base to obtain a new boat. Therefore, only the east and north banks were electric fished due to time constraints.

Although the dense willow cover along the perimeter of Broadwater provided good cover for fish, it made electric fishing difficult, as surveyors found it difficult to position their anodes and nets between branches and trees, meaning multiple fish were missed.

3. Results

3.1 Fish Survey

A total of five fish species were recorded during the fish survey, across all sampling methods, these were pike (*Esox Lucius*), perch (*Perca fluviatilis*), tench (*Tinca tinca*), common carp (*Cyprinus carpio*) and three-spined stickleback (*Gasterosteus aculeatus*). A summary of the catch data is provided in Table 3-1.

Species abundance and biomass composition charts for the catch are presented in Figure 3-1 and Figure 3-2. Length frequency histograms for all species are provided in Figure 3-3.

Catch information is presented in Table D-2, Table D-3, Table D-5 and Table D-7 located in Appendix D. Fisheries Data.

Table 3-1. Fish species list with abundances and estimated biomass.

Common Name	Scientific Name	Abundance	Estimated Weight (g)
Pike	<i>Esox lucius</i>	4	6172.46
Perch	<i>Perca fluviatilis</i>	200	3579.94
Tench	<i>Tinca tinca</i>	8	416.00
Common Carp	<i>Cyprinus carpio</i>	1	27.56
Three-Spined Stickleback	<i>Gasterosteus aculeatus</i>	32	32.61
Total		245	10228.56

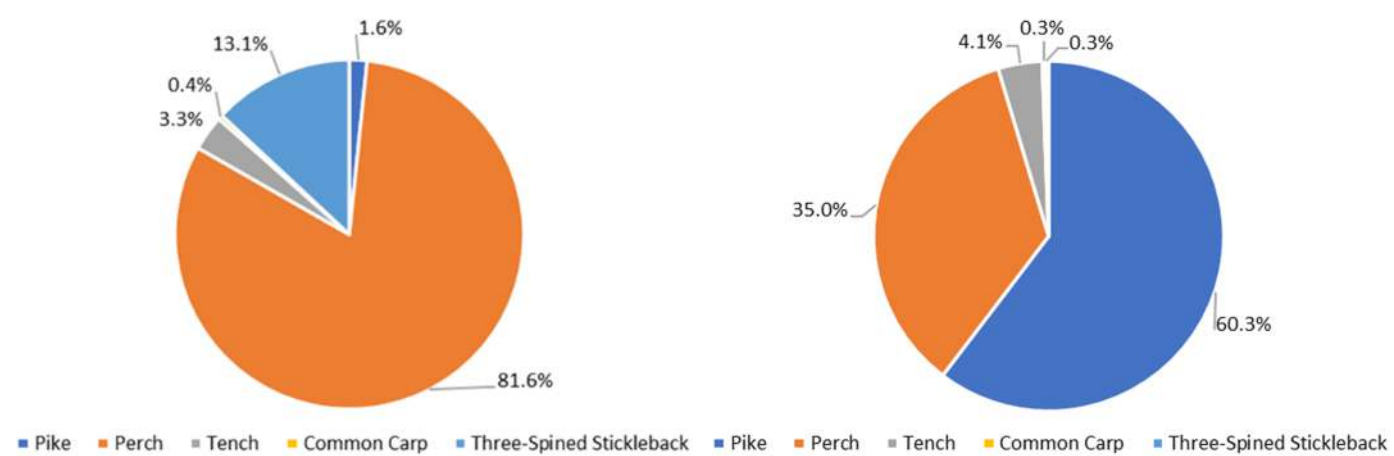


Figure 3-1. Species composition of all fish caught. Fish total = 245.

Figure 3-2. Biomass of all fish caught. Biomass total = 10.22kg.

Several North American Signal Crayfish (*Pacifastacus leniusculus*), which is an INNS were caught in multiple fyke and seine nets across Broadwater.

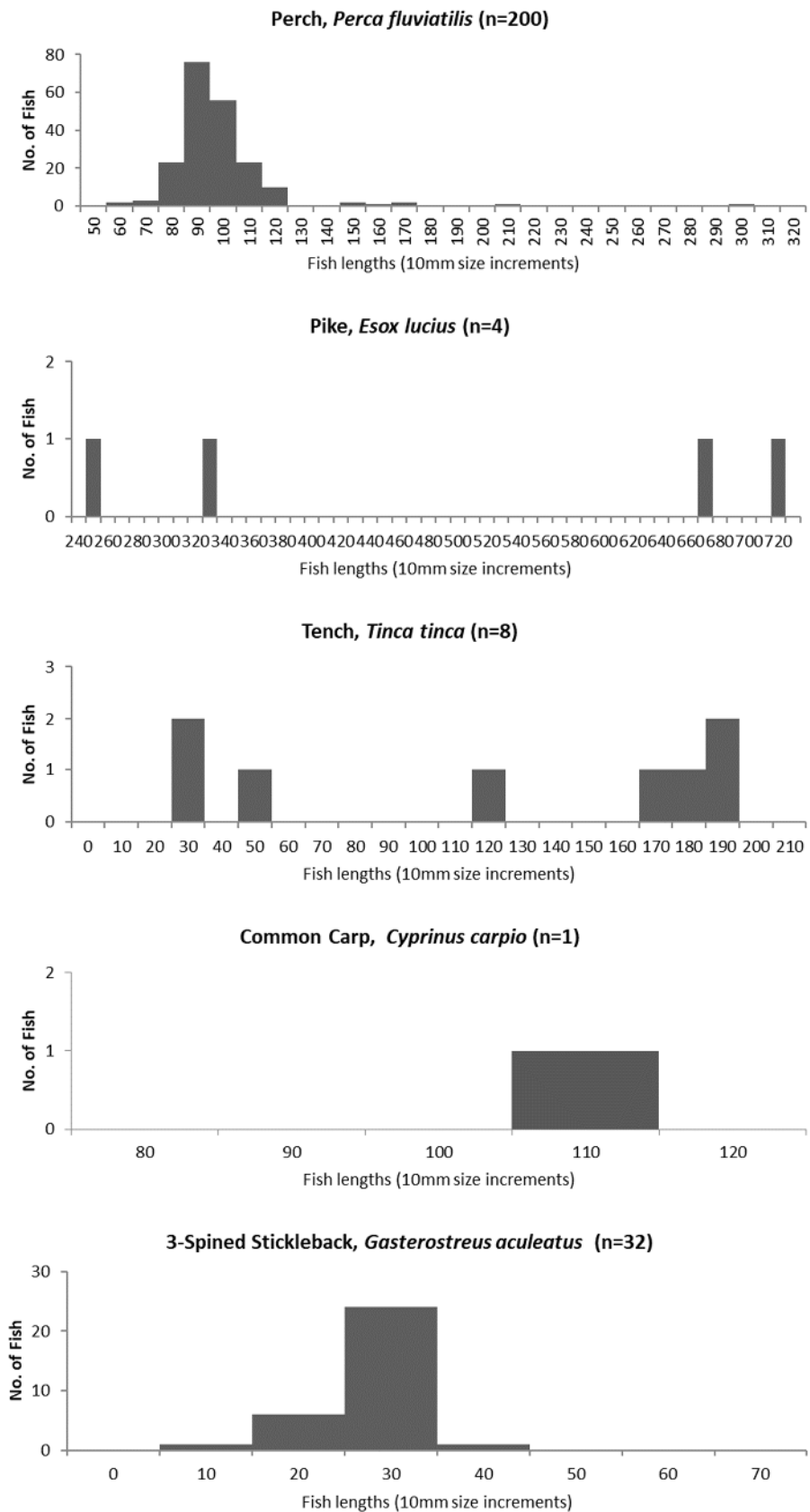


Figure 3-3. Length frequencies of all fish species caught.

3.1 Macro-invertebrate Surveys

Macro-invertebrate metric scores are presented in Table 3-2. A taxa list for each sample is provided in Table E-3 located in Appendix E. Macro-invertebrate Data).

The south bank had the greatest BMWP and NTAXA scores of 101 and 22, respectively while the west bank had the highest ASPT score 4.88.

CCI scores at ranged between 9.81 and 22.50. All species with a CS of five and greater, representing species of Local Conservation or higher, have been shown in Table 3-3

Table 3-3. Macro-invertebrate species with a CS Score of 5 or greater.

Area	Species	CS Score	CS Definition	IUCN Conservation Status
South bank	<i>Cymatia coleoptrata</i>	5	Local	Least Concern
	<i>Anax parthenope</i>	6	Regionally notable	Lower risk – Least Concern
	<i>Corixa panzeri</i>	5	Local	Least Concern
West bank	<i>Leptocerus lusitanicus</i>	8	Red Data Book 3 (Rare)	Least Concern
East bank	<i>Corixa panzeri</i>	5	Local	Least Concern
	<i>Cymatia coleoptrata</i>	5	Local	Least Concern
	<i>Ecnomus tenellus</i>	5	Local	Least Concern

No species had an International Union for Conservation of Nature (IUCN) status of greater than Least Concern. The highest CS score was present in the Westbank sample and was the caddisfly *Leptocerus lusitanicus*.

Table 3-2. Macro-invertebrate metric scores.

Metrics	South bank	West bank	East bank
BMWP (TL1)	101	78	83
NTAXA (TL1)	22	16	20
ASPT (TL1)	4.59	4.88	4.15
CCI (TL5)	12.00	22.50	9.81

Table 3-3. Macro-invertebrate species with a CS Score of 5 or greater.

Area	Species	CS Score	CS Definition	IUCN Conservation Status
South bank	<i>Cymatia coleoptrata</i>	5	Local	Least Concern
	<i>Anax parthenope</i>	6	Regionally notable	Lower risk – Least Concern
	<i>Corixa panzeri</i>	5	Local	Least Concern
West bank	<i>Leptocerus lusitanicus</i>	8	Red Data Book 3 (Rare)	Least Concern
East bank	<i>Corixa panzeri</i>	5	Local	Least Concern
	<i>Cymatia coleoptrata</i>	5	Local	Least Concern
	<i>Ecnomus tenellus</i>	5	Local	Least Concern

4. Discussion & Conclusion

4.1 Fish Surveys

A total of 245 fish were caught across the three sampling methodologies. All fish species caught were native to Britain. Fyke nets caught the greatest abundances of fish (three species, 193 individuals with a biomass of 3,893.43 grams), while electric fishing caught the most diverse range of species and the most biomass (four species, 13 individuals with a biomass of 6,254.84 grams).

The biomass from the electric fishing was mostly made up of the three pike caught weighing 6061.07 grams. Seine netting had the second lowest catch abundance and the lowest biomass of the three methods used (three species, 39 individuals with a biomass of 80.3 grams).

Perch were the most abundant species of fish caught using the three sampling methodologies composing 81.6% of the total abundance caught.

Pike abundance was small at 1.6% of the total composition, however, due to the size of the individuals caught, (ranging from 251mm to 730mm with estimated biomasses of 111.39 and 3266.01 grams respectively) they composed 60.3% of the biomass caught.

Abundances of three-spined stickleback made up 13.1% of the total abundance composition but only 0.3% of the total biomass. Tench and common carp abundances were low as was their total biomass compositions.

Most of the fish caught were young/juvenile age classes with some of the large pike and perch being the exceptions to this, indicating limited successful recruitment was occurring.

Anecdotal evidence from local anglers reported that there are carp close to 20kg in the lake. Common bream (*Abramis brama*) and eels were also said to be present, however none were caught in the surveys. There was also anecdotal evidence of large eels present, however none were caught, indicating that if they were present then they would have been in low abundances. European eel are a Priority Species under Section 41 of the Natural Environment and Rural Communities Act 2006 (England)², listed as critically endangered on the global IUCN Red List of threatened species³ and protected in England under specific legislation; The Eels (England and Wales) Regulations 2009⁴.

Overall densities of fish appeared to be low, although without intensive surveys, an accurate assessment of the fish population in the lake cannot be given. Coarse fish species including roach (*Rutilus rutilus*), rudd (*Scardinius erythrophthalmus*) and common bream (*Abramis brama*) were not caught in the surveys indicating that they were not present or were in very low abundances. These are common prey items for wading piscivorous birds.

Generally, the habitat in Broadwater appeared to be lacking for juvenile fish. Most of the cover was provided by overhanging branches from the large willow trees around the perimeter of the lake. There was also the occasional bed of branched bur-reed (*Sparganium erectum*). Other than this cover was lacking; this was particularly the case in the limnetic zones. Limited macrophytes and other cover meant that the amount of spawning medium which could be utilised by fish was low. The lack of cover present meant that fish were more vulnerable to predators such as piscivorous fish or birds such as cormorants, most likely resulting in low juvenile survival rates.

The planned creation of the deep lagoon along the southeast quadrant of the lake and the protection of the shallow area along the southwest quadrant, could help to create more diverse habitat which will be beneficial for fish populations, increasing habitat availability for both adult and juvenile life stages.

Recommendations on how to potentially improve fish habitat is summarised in the Recommendation section.

Overall, increased recreational activity will likely not have a significant effect on the fish populations present within Broadwater.

² Available from: <https://www.legislation.gov.uk/ukpga/2006/16/section/41> [accessed 20/12/2022]

³ Available from: <https://www.iucnredlist.org/species/60344/152845178> [accessed 20/12/2022]

⁴ Available from: <https://www.legislation.gov.uk/uksi/2009/3344/made> [accessed 20/12/2022]

4.2 Macro-invertebrate Surveys

The east bank had the lowest CCI score of all three macro-invertebrate samples of 9.81, which gave it a Moderate conservation value. South bank and West bank had CCI scores of 12.00 and 22.50 respectively yielding conservation values of Fairly High and Very High respectively.

The Very High conservation value associated with the west bank is predominantly due to the presence of the caddisfly *Leptocerus lusitanicus*, which has a CS score of 8. Although this was a RDB3 species, the IUCN status has downgraded it to a species of Least Concern (Natural England, 2016).

BMWP scores varied between 78 and 101 across the three sites, while ASPT was between 4.15 and 4.88. This indicated that the macro-invertebrate communities present had moderate tolerances to organic pollution indicating that general water quality was moderate.

South bank and east bank had communities with relatively high diversity with NTAXA scores of 22 and 20 respectively. The West bank had slightly less diversity with 16 different taxa present.

The littoral zones are usually the best areas for aquatic macro-invertebrates particularly areas with gravel substrate or dense macrophyte cover. Much of the substrate within the sampling areas were a mix of gravel and pebble, which provides excellent habitat for macro-invertebrate communities (EA, 2007).

Although there was some submerged macrophytes present (*Elodea sp.*), overall, the marginal/emergent vegetation was poor. The littoral zone also appeared to be very homogenous which may potentially limit the diversity of the macro-invertebrate community.

Recommendations to improve the macro-invertebrate communities are similar to recommendations to improve fish populations; these suggestions have been combined together in the Recommendations section.

Overall, increased recreational activity will likely not have a significant effect on the macro-invertebrate populations present within Broadwater Lake.

4.3 Invasive Non-Native Species (INNS)

A total of 210 North American signal crayfish were caught whilst fyke and seine netting.

North American signal crayfish are a highly invasive species which are proven to have a detrimental effect on native fish and macro-invertebrate populations. Once they become established in a waterbody, eradication is almost impossible.

Increased recreational activity could increase the likelihood of other invasive species being introduced unintentionally from other waterbodies into Broadwater and consequently, there is potential to negatively affect the aquatic ecology of the lake.

INNS can be transported through many means in the form of seeds, plant fragments, eggs, or even adult individuals. Increased recreational activity may raise the possibility that they are spread through various recreational activities such as; water sport clothing (i.e. wetsuits, drysuits or waders), boats (bilge water or other areas that remain damp during transport from one waterbody to another) or other sporting equipment which has been used in multiple watercourses.

To prevent further spread of INNS into other waterbodies from Broadwater and to prevent additional INNS being introduced, biosecurity measures should be implemented which are briefly covered in the Recommendation section.

5. Recommendations

Table 5-1. Recommendations.

Description of Works	Benefits
Planting of marginal aquatic plants to increase habitat availability for fish and macro-invertebrates. Additional planting can be undertaken around the planned new islands.	<ul style="list-style-type: none"> • Creation of cover for juvenile fish species • Increased spawning media for mature fish • Creation of habitat for macro-invertebrates
Creation of structures in the limnetic zone.	<ul style="list-style-type: none"> • Creation of cover for juvenile fish species • Increased spawning media for mature fish
<p>The creation of a Biosecurity Management Plan, which promotes good biosecurity measures for recreational users of the lake.</p> <p>This would promote “check, clean and dry” procedures for all recreational users. It would also provide information to the key stakeholders of Broadwater Lake educating them on the importance of good biosecurity practice. Please see the Non-Native Species Secretariat for more information on biosecurity and invasive species Home » NNSS (nonnativespecies.org).</p>	<ul style="list-style-type: none"> • Reduced risk of the transfer of INNS, which could have significant impacts on fish and macro-invertebrate communities
Provide contractors undertaking improvement works; a toolbox talk on the ecology of the species present and how to prevent accidental introductions of INNS into Broadwater whilst undertaking the planned work.	<ul style="list-style-type: none"> • Reduced risk of the transfer of INNS, which could have significant impacts on fish and macro-invertebrate communities
Future monitoring once habitat improvement works have been undertaken.	<ul style="list-style-type: none"> • Monitor the success of any habitat improvement works implemented • Monitor the recruitment success of fish populations • Assess key changes in macro-invertebrate communities • Monitor changes to invasive species populations and assess the success of a stringent Biosecurity Management Plan

6. References

- British Standards Institution (2003) BS EN 14011:2003, BS 6068-5.32:2003: *Water quality. Sampling of fish with electricity*, London: BSI.
- British Standards Institution (2012). BS EN ISO 10870:2012 Water Quality – Guidelines for the selection of sampling methods and devices for benthic macroinvertebrates in fresh waters. London. BSI.
- Chadd, R. and Extence, C. (2004). The conservation of freshwater macroinvertebrate populations: a community-based classification scheme. *Aquatic Conservation: Marine and Freshwater Ecosystems* 14: 597–624.
- Environment Agency (2007). Lake benthic macroinvertebrates I: improving sampling methodology. Environment Agency, Bristol.
- Environment Agency (2010). Fyke netting for monitoring fish. Operation Instruction 25_07. Issued 13/01/2010.
- Environment Agency (2014). Freshwater macroinvertebrate analysis of riverine samples: Operational Instruction 024_08. Issued 28/01/14. Environment Agency, Bristol.
- Environment Agency (2017). Freshwater macroinvertebrate sampling in rivers: Operational Instruction 018 08. Issued 01/03/17. Environment Agency, Bristol.
- Natural England (2016). A review of the status of the caddis flies (Trichoptera) of Great Britain. Natural England Commissioned Report NECR191
- Non-Native Species Secretariat. <http://www.nonnativespecies.org/home/index.cfm>. Accessed 29/11/2022

Appendix A. Survey Map