Preliminary Data Synthesis Report: Lough Sheelin Environmental and Fish Monitoring

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Preliminary Data Synthesis Report: Lough Sheelin Environmental and Fish Monitoring - July 2025

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1. Background

IFI received a report of a fish kill in Captain's Bay, Lough Sheelin, Co. Cavan on the 16th of July (Fig. 1). IFI recovered 834 dead fish, mainly large wild brown trout (*Salmo trutta*), from Captain's Bay and the lower reaches of the Mountnugent River (just upstream of the lake), following the incident. IFI research was requested to compile data from high-frequency data loggers deployed in the catchment for the Climate Change Mitigation Research Programme and the OPW-funded Research Programme by IFI SHRBD for July 2025 to inform the ongoing fish kill investigation. This report synthesises the meteorological, environmental and fish tracking data collected from Lough Sheelin and the Mountnugent River in July 2025, with a focus on 14th to 18th July.

1.1 Introduction

As part of Inland Fisheries Ireland's Climate Change research programme, the Upper Inny and Lough Sheelin catchment was designated as a sentinel site in 2021 to investigate lake – catchment interactions under changing climatic and environmental conditions. The two main inflowing tributaries (Upper Inny and Mountnugent) and the Inny outflow (Finea) of Lough Sheelin were selected as dissolved oxygen (D.O.) and temperature monitoring sites to help assess the influence of tributaries and outflow conditions on overall lake dynamics. Such monitoring is fundamental for understanding how external inputs and water exchanges shape the lake's oxygen and temperature dynamics (oxythermal structure) and overall ecological resilience. In 2023, as part of the above projects, the Lough Sheelin Fish Tracking Project was initiated to build on this work, investigating fish behavioural responses to environmental and climate change within the lake and its tributaries during extreme events.

For brown trout, growth and feeding limitations occur at 18-19°C, metabolic stress is induced >20°C, and lethal water temperatures are 22-25°C with mortalities occurring at 26°C (Elliott & Elliott, 2010). As oxygen solubility declines with temperature, dissolved oxygen thresholds are also critical for cold-water fish. For brown trout, D.O. <7 mg L^{-1} induces mild stress, <5 mg L^{-1} moderate stress, and <3 mg L^{-1} severe or lethal stress (Kelly & Kelly, 2024). In eutrophic systems, daily algal cycles (photosynthesis and respiration) further amplify D.O. fluctuations, leading to supersaturation during daylight, followed by sharp nocturnal declines, heightening deoxygenation risk during warm, low-flow periods when oxygen demand is high (Kerins et al., 2007).

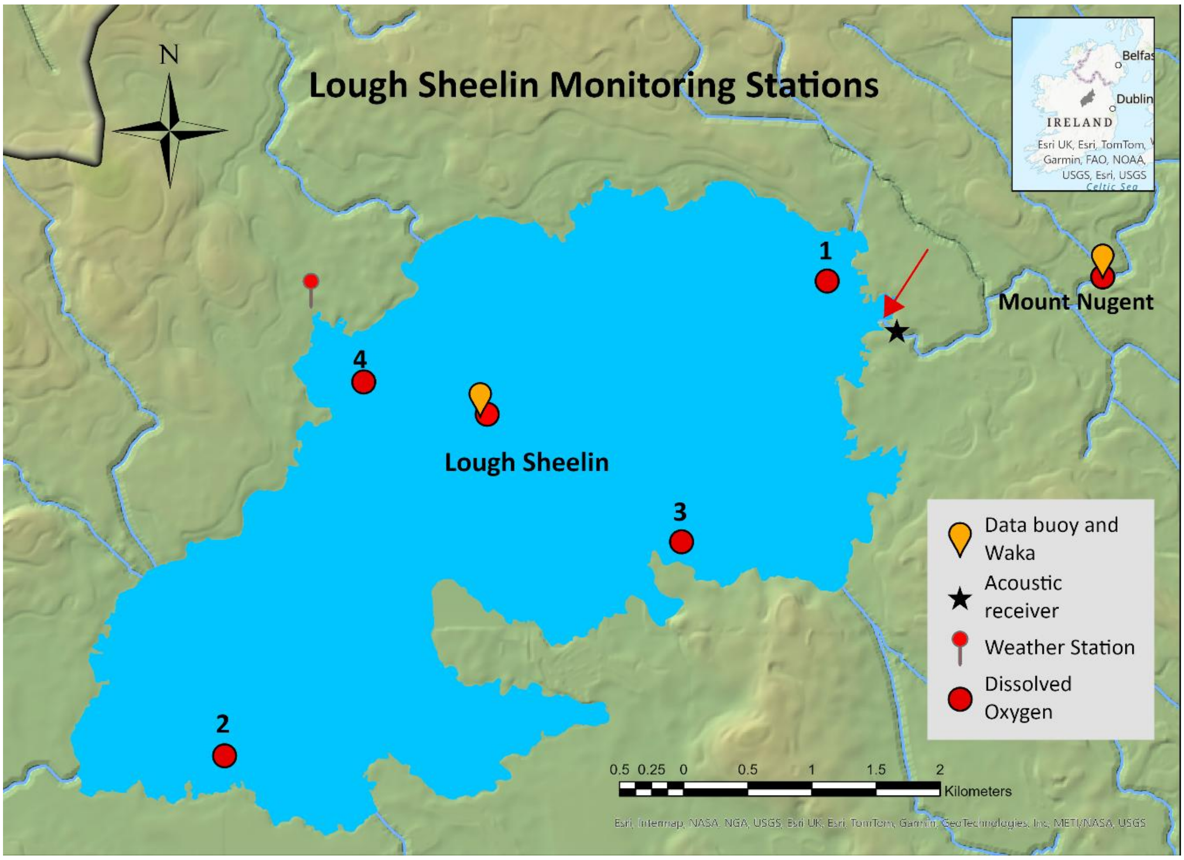


Fig. 1: Map of Lough Sheelin showing dissolved oxygen monitoring sites (red dots), the Mountnugent multiparameter IoT water quality device and data buoy (including multiparameter water quality meter)(orange balloon symbols), the Mountnugent acoustic receiver (black star), location of fish kill July 2025 (red arrow), and the IFI weather station (red pin).

2. Methodology

2.1 Study area

Lough Sheelin is a high alkalinity lake located in the Drumlin belt of the central-northern part of Ireland and situated on the upper reaches of the Inny River, a tributary of the River Shannon. The largest proportion of the catchment lies within Co. Cavan with the remainder divided between Co. Meath and Co. Westmeath. Low permeability gley soils, vulnerable to waterlogging and nutrient loss, predominate in the northern and western parts of the catchment. Deep, well-drained brown podzolics, grey-brown podzolics and brown earths are predominant in the eastern sub-catchments, while the soils closer to the lake shore around the Inny outlet are composed of blanket and basin peats.

The lake's trophic status has been well documented (e.g. Flanagan and Toner, 1975; Champ, 1991, 1993, 1998, 2003; Duggan and Champ, 1992; Kerins *et al*., 2007). The annual mean total phosphate value for Lough Sheelin over a 45-year period (1976 to 2022) was 0.29µg/l indicating the lake has been generally mesotrophic during the monitoring period. There were signs in the 80's (1982 to 1984 and 1987 to 1991 and late 90s (1993 to 2000) that the water quality in the lake was improving (possibly because of a slurry export scheme (1981-1984) and other mitigation measures); however between 2000 and 2022 (excluding 2017, 2018 and 2019) TP remained at ≥0.024 ug/l, indicating moderate status and no improvement in water quality. Overall, from 1976 to 2022, 60% of monitoring years equalled or exceeded the environmental standard for good water quality (0.025 ug/l P) and since 2001 the EQS for good status based on TP has been exceeded 16 times (73%) (de Eyto *et al*., 2024).

Additionally, in the most recent EPA Catchment Assessment (2024), water quality in the Upper Inny sub-catchment remains under pressure, with nutrient inputs, particularly phosphorus, continuing to drive eutrophication risk in Lough Sheelin.

2.2 Lough Sheelin Meteorological Data

Meteorological data (including air temperature and rainfall) are recorded at 15-minute intervals from an automated weather station (Davis Vantage Pro 2) at the Inland Fisheries Ireland base at Lough Sheelin (Plate 1). As the weather station is in a sheltered area, wind data was obtained from the Ballyhaise Met Éireann station (Met Éireann, 2025).

Plate 1: Weather station installed at Inland Fisheries Ireland Lough Sheelin base, transmitting meteorological data in near real-time.

2.3 Lough Sheelin Environmental Monitoring

A data buoy is located at the deepest point of the lake (Fig. 1 and Plate 2). This consists of a monitoring platform housing an internal datalogger and telemetry system that records and uploads measured data in near real-time. The system comprises a thermistor array with seven water temperature (Tw) loggers recording water temperature every 10 minutes at depths of 0.5, 2.5, 4.5, 6.5, 8.5, 10.5 and 12.5 metres (NexSens TS210). The buoy is fitted with a multiparameter water quality meter recording water temperature (°C), conductivity (uS/cm), dissolved oxygen (mg/L) and chlorophyll-*a* fluorescence (ug/L) at 0.5 m below the water surface every 10 minutes. Data is logged internally within the datalogger and transmitted via the same telemetry system as the water temperature data to a web portal, allowing visualisation of water quality parameter data (Plate 2). Calibrated (offline) D.O. loggers (HOBO U26-001) are deployed adjacent to the buoy, recording both D.O. and temperature every 10 minutes at three depths: surface (0.5 m), middle (6.5 m), and bottom (12.5 m). Identical D.O. logger setups are also deployed 0.5m below the surface in four shallow bays around the lake (HOBO U26-001 loggers): North (1. Captain's Bay), South (2. Sailors Garden), East (3.Curry Point - Inchacup,), and West (4. Chamber's Bay). This integrated monitoring network provides a high-resolution, spatial dataset on thermal and oxygen dynamics in Lough Sheelin and selected tributaries (Fig. 1).

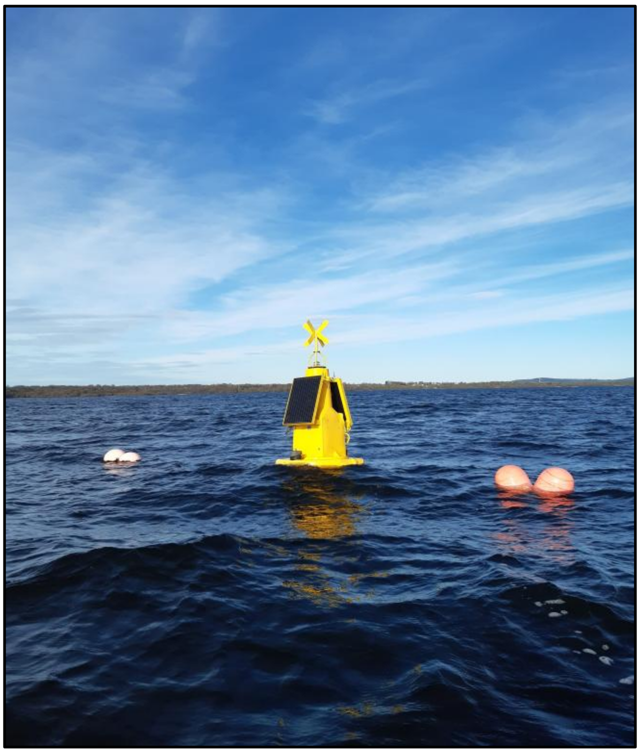


Plate 2: Data buoy platform installed on Lough Sheelin. Stored inside is a multi-depth thermistor chain surface to bottom (0.5, 2.5, 4.5, 6.5, 8.5, 10.5 and 12.5), and multi-parameter sonde at the surface (0.5m) recording temperature, dissolved oxygen, conductivity, and chlorophyll-a. Data transmits in near real time every 10 minutes to an online dashboard.

2.4 Mountnugent River– Environmental Monitoring

The Mountnugent River (MN) flows into the northeastern end of Lough Sheelin and is the primary inflow to the lake, with a catchment area of 95 km^2 and a mean discharge rate of 1.7 $m^3 s^{-1}$. The MN provides the largest spawning area in the Lough Sheelin sub-catchment and contributes approximately 60% to the overall lake brown trout adult stock in the lake (Delanty *et al*., 2020). Agriculture is the predominant land use category (>90%) in the Mountnnugent sub-catchment. The Moutnugent catchment is the largest inflow tributary and has the highest source of phosphorus to Lough Sheelin and has been assigned a “Poor” water quality status (EPA, 2021).

The IFI environmental monitoring station on the Mountnugent is located close to an Environmental Protection Agency (EPA) hydrometric station with established ratings curves and upstream of where dead fish were found (Fig. 1) (EPA, 2021). A calibrated U26-001 HOBO dissolved oxygen data logger with an anti-fouling guard in protective housing was deployed in 2021 at the site, recording D.O. and temperature every 10 minutes. A multi-parameter IoT water quality monitoring device (Plate 3) recording water temperature (°C), D.O. (mg/L), turbidity (NTU), and conductivity (uS), was deployed in summer 2024. During the summer period, the sensors on this device were cleaned every two weeks and swapped for a calibrated device every eight weeks. Stream flow data was obtained from the EPA online portal from the Mountnugent Bridge - Station number 26056 (EPA - WISKI Web Public). As part of the Fish Tracking project, water temperature from an acoustic receiver near the outflow of MN was also incorporated into the review of environmental parameters in July 2025.

Plate 3: Multi-parameter IoT device floating in the Mount Nugent. Sensors include temperature, dissolved oxygen, pH, turbidity, and conductivity. Data transmits to an online dashboard in near real time, every 15 minutes.

2.5 Fish tracking project

A fish tracking project was initiated on Lough Sheelin and its tributaries in April 2023 to investigate the impacts and extent of climate change, environmental change and extreme weather events on fish populations. In 2023, 12 acoustic receivers were deployed throughout the lake, along with two additional units in inflowing tributaries and one in the outflowing river. In 2024, seven additional acoustic receivers were added to improve spatial coverage (Fig. 2).

To date, 88 fish have been sampled, comprising 74 brown trout (Salmo trutta) collected by rod-and-line angling, and 14 coarse fish (4 pike *Esox lucius* and 10 tench *Tinca tinca*) obtained via boom-boat electrofishing. Tagged fish have been implanted with acoustic transmitters since May 2023 on Lough Sheelin (Barry *et al.*, 2024). All tagging procedures were conducted in accordance with ethical guidelines and were approved by the Health Products Regulatory Authority of Ireland (Project number: AE19118/P011).

Fig. 2: Active Lough Sheelin acoustic receiver array in 2025.

3. Results

3.1 Lough Sheelin Meteorological data

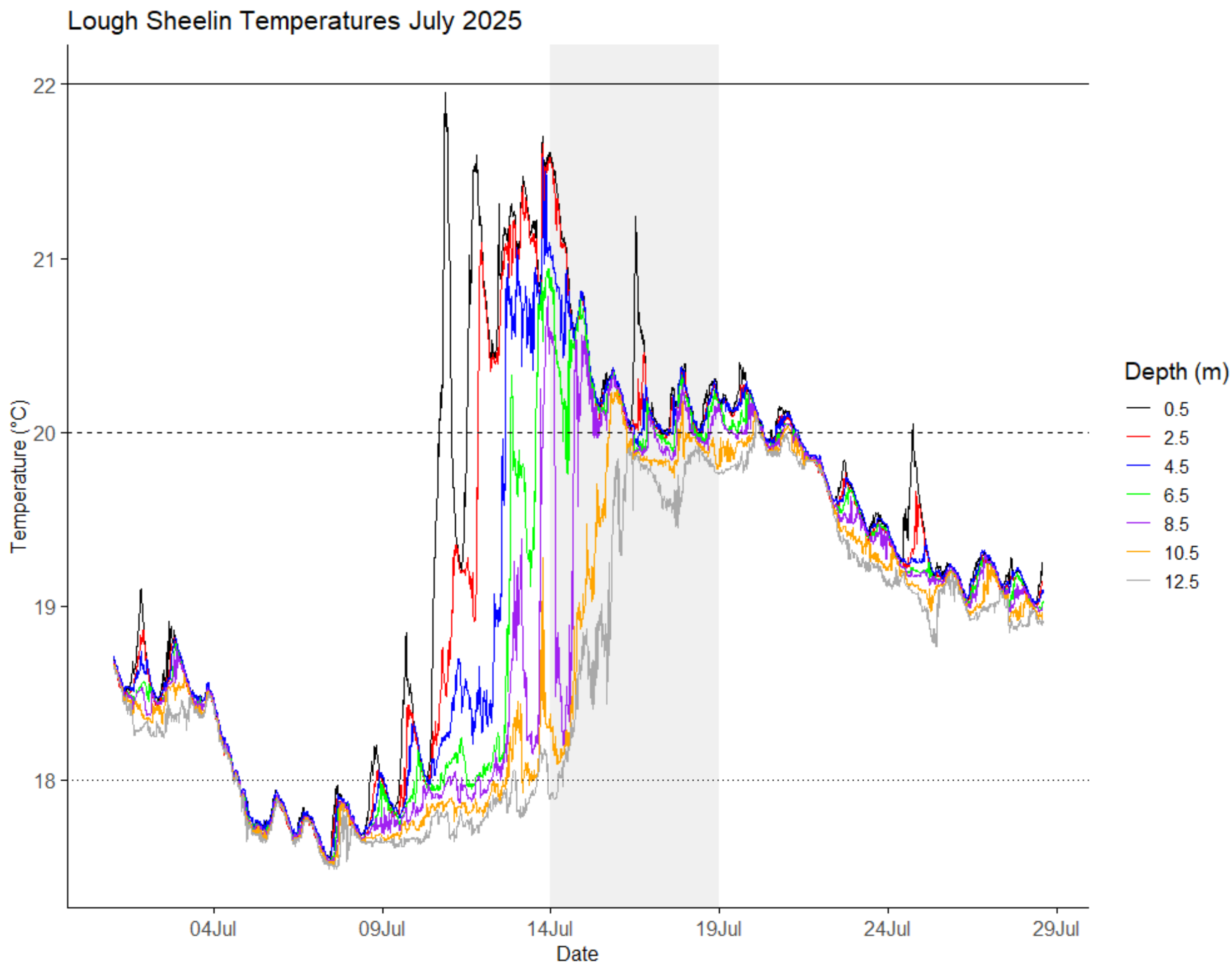
The lowest air temperature was 7.7°C recorded at 03:00 on the 3rd of July, after which conditions gradually warmed. The warmest day of the month was the 12th of July, air temperature exceeded 27°C for more than six consecutive hours (12:00-19:00), with a maximum temperature of 29.3°C at 15:00. A subsequent cool period occurred on the 16th, when air temperature dropped to 8.6°C in the early morning. Solar radiation follows a diurnal pattern, with values typically peaking around midday. The maximum solar radiation was 831.25 (W/m^2) at 12:00 on the 10th of July. Hot and sunny conditions dominated in early July, whereas both air temperature and solar radiation were suppressed during mid-July, reflecting a spell of cloudier and unsettled weather.

A rainfall event occurred on the 15th of July, with 21.8 mm recorded at the IFI Lough Sheelin weather station. This coincided with marked hydrological and D.O. changes in the river and lake (Fig. 5 and Fig. 8). Wind data from the Ballyhaise station show variable wind speeds throughout July, with frequent gusts above 8 m/s in the first half of the month and a general decline towards late July. Wind direction was predominantly from the west and southwest, often exceeding 6 m/s, which likely enhanced surface mixing during and after rainfall.

3.2 Lough Sheelin Environmental Monitoring

Middle Lake

In early July 2025, water temperatures throughout the Lough Sheelin water column were relatively uniform, indicating an isothermal lake. From the 12–16th of July, thermal stratification developed, with surface water temperatures exceeding 21°C while bottom temperatures remained near 18°C. A full water column overturn began on the 14th of July, and by the 16th the lake was again relatively uniform at 20°. Minor fluctuations observed later in the month reflect daily heating and cooling cycles, but no further sustained stratification occurred (Fig. 3). Surface (black and red lines) temperatures showed a steady increase to a mid-month water temperature peak (21.95°C), while the middle and bottom layers warmed more gradually (Fig.3).



Chlorophyll-a fluorescence (RFU) at the Sheelin data buoy (Fig. 4) showed an initial peak at the start of the month, followed by relatively stable conditions. This was interrupted by pronounced increases >35 RFU, on the 10th, 13th and 14th of July coinciding with surface warming, elevated air temperature, and increased solar radiation. After the 15th, chlorophyll-a levels declined gradually and stabilised to 12-20 RFU, tracking the change in weather conditions and breakdown of stratification.

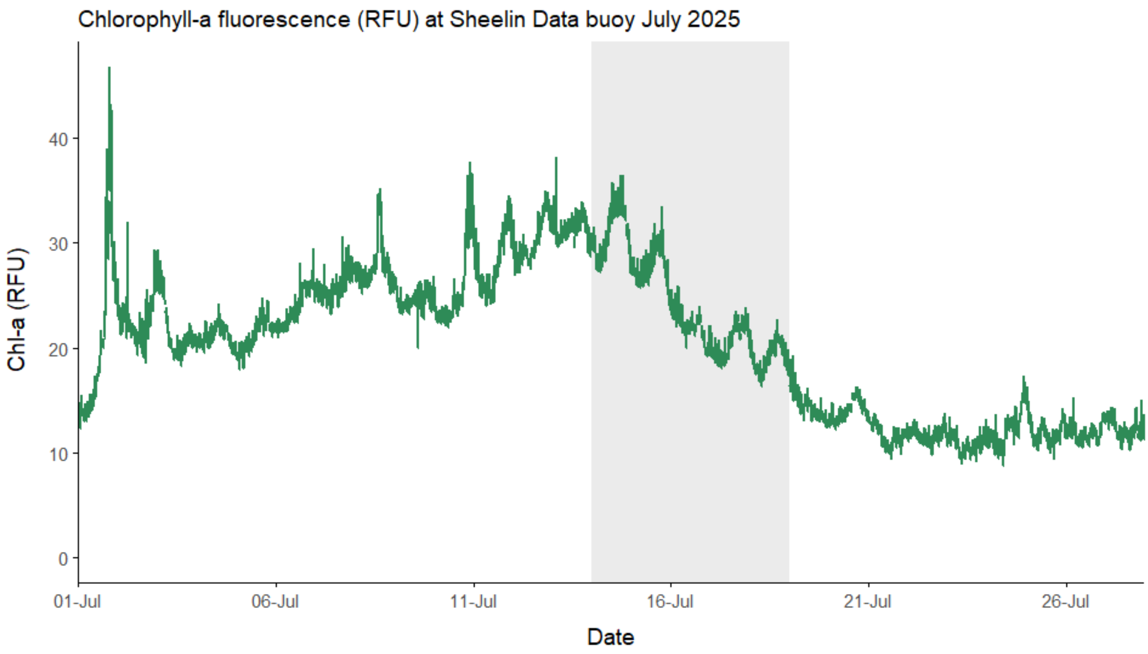


Fig.4: Lough Sheelin data buoy Chlorophyll-a fluorescence (RFU) for July 2025 (sensor is located 0.5m from the lake surface and records every 10 minutes). The grey shaded area highlights the period 14/07-18/07.

D.O. remained relatively high and stable in the surface and middle layers, with some regular short-term declines, likely associated with diurnal biological activity. However, on the 16th of July, D.O. in the middle layer dropped below 3mg/L, reaching a minimum of 2.1mg/L at 10:00, recovering to above 7mg/L within two hours, suggesting a short-lived but potentially stressful low-oxygen event (Fig. 5).

The bottom D.O. logger (Fig. 5. Lower panel - blue) recorded sustained 0mg/L readings from the 4–15th of July. These values are probably due to the sensor settling into sediment during low lake levels rather than remaining suspended in the water column, affecting the accuracy of the bottom measurements and have therefore been removed from Fig. 5.

Fig.5: Lough Sheelin dissolved oxygen (mg/L), recorded at 0.5m (Sheelin_upper, blue), 6.5m (Sheelin_middle, green), and 12.5m (Sheelin_bottom, red) from the lake surface for July 2025. The horizontal lines denote 7mg/L, 5mg/L, and 3mg/L. The grey shaded area highlights the period 14/07-18/07.

Lough Sheelin Bays

Temperature and D.O. dynamics in the bays mirrored middle-lake patterns, but with greater spatial variability. All bays warmed steadily during early July, peaking between the 11–15th of July. The north, west, and south bays briefly exceeded 22°C, particularly on the 13th and 14th while the east bay remained cooler and did not surpass 22°C. After July 16th, water temperatures declined slightly across all bays and stabilised around 20°C, consistent with the breakdown of stratification (Fig. 6).

D.O. was generally high but showed short-term variability, especially from the 14–18th of July. The north bay exhibited much larger D.O. fluctuations, with occasional drops below 5mg/L. The south bay showed a stronger diurnal signal, with peaks to 15mg/L, but also occasional drops to below 7mg/L during early mornings. The east and west bays maintained more stable D.O. levels, generally above 7mg/L, however, all sites experienced a drop in D.O. on the 16th and 19th of July (Fig. 6).

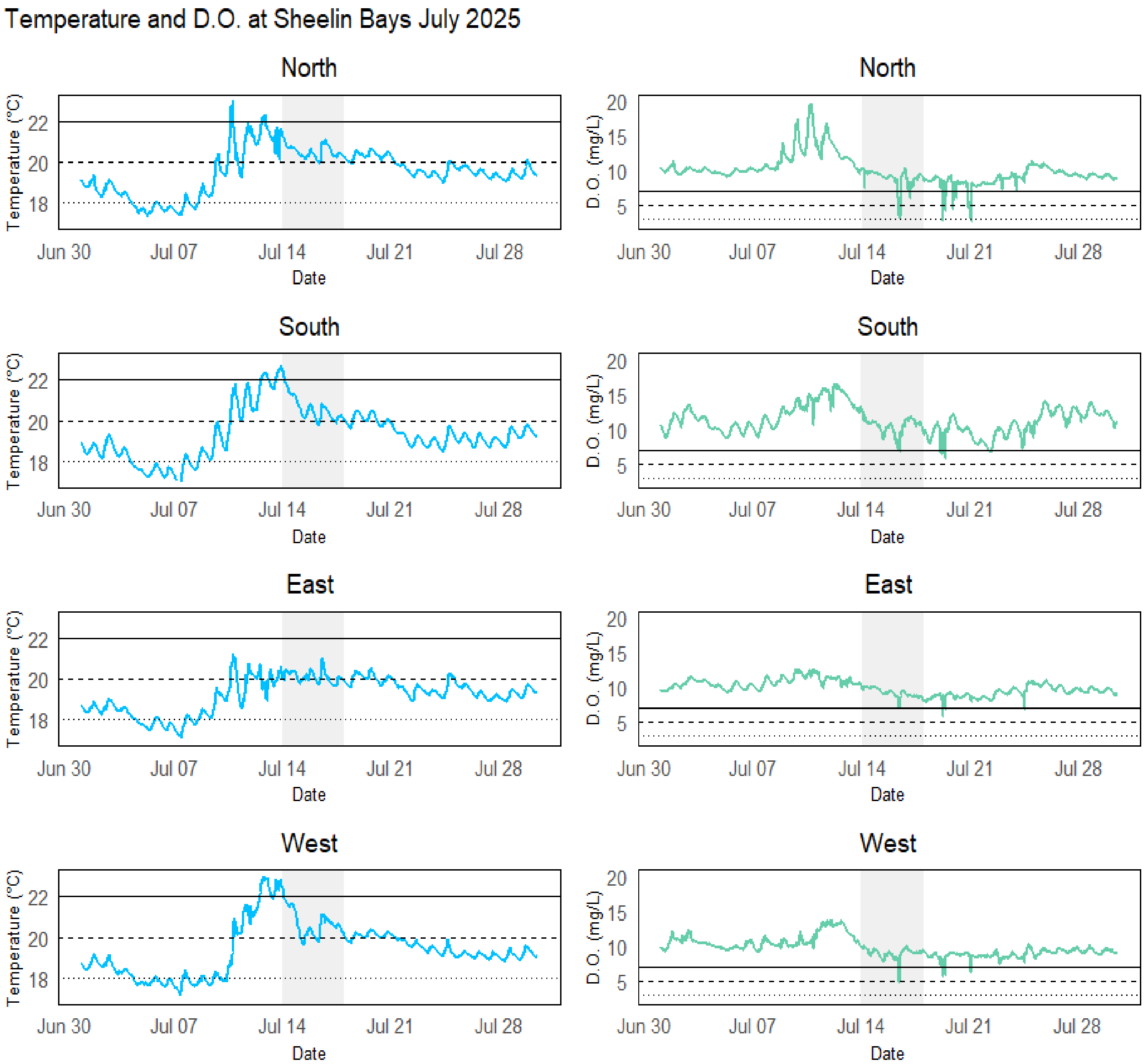


Fig.6: Dissolved oxygen (mg/L) and water temperature (°C) at Sheelin bays (north, south, east, west) during July 2025. Grey shaded area marks the period 14/07–18/07. The horizontal lines mark 18, 20, and 22°C (water temperature), and 7, 5, and 3mg/L (D.O.).

In the North Bay (1. Captain's Bay), the maximum D.O. of 21mg/L on the 10th of July coincided with the maximum solar radiation for the month. D.O. dropped to 2.9mg/L at 10:00 on the 16th of July, recovering to 7mg/L by 12:00, while water temperatures remained above 20°C (Fig. 7). Early morning declines continued at this site reaching 2.4mg/L on the 19th and 2.6mg/L on the 20th, until water temperatures cooled to below 20°C. This pattern closely matched the mid-layer decline in the middle lake (Fig. 6).

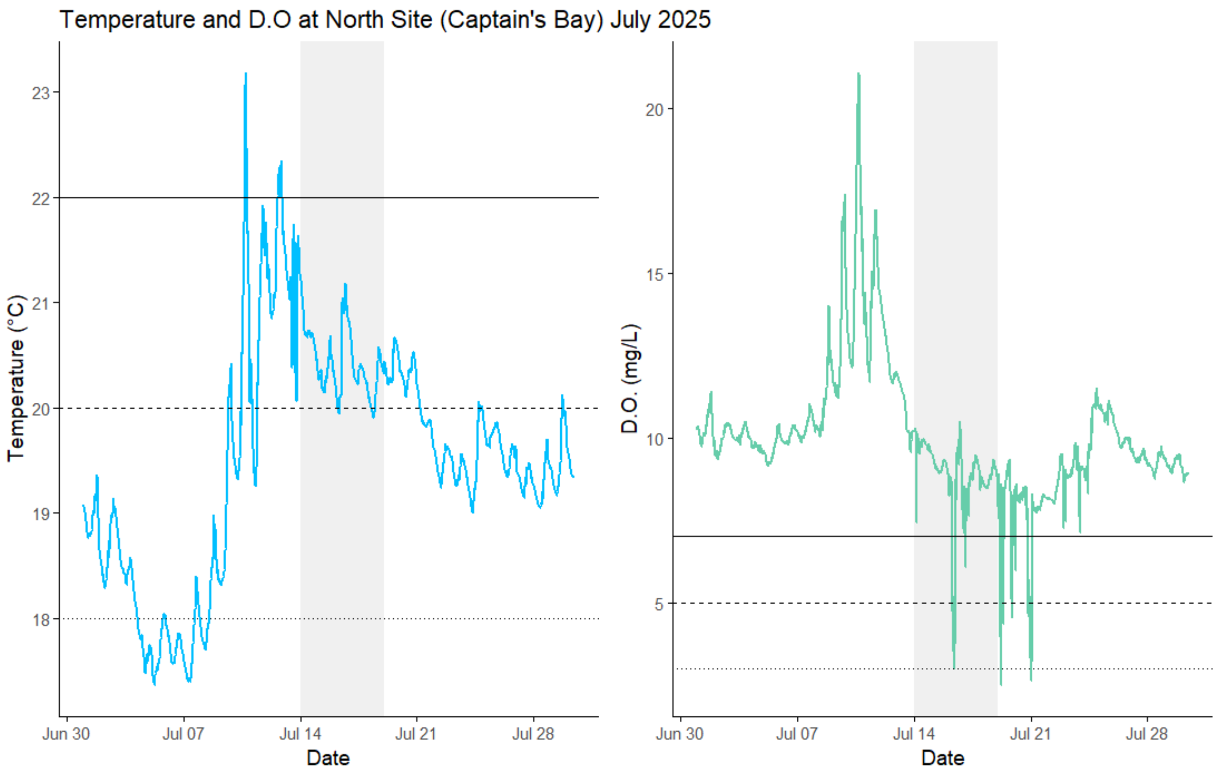


Fig.7: Water temperature (°C, blue) and dissolved oxygen (mg/L, green) at the north bay in Lough Sheelin, July 2025. Grey shaded area marks the period 14/07–18/07. The horizontal lines mark 18, 20, and 22°C (water temperature) and 7, 5, and 3mg/l (D.O.).

3.3 Mountnugent River Environmental Monitoring

The Mountnugent River, which flows into Captain's Bay, experienced pronounced fluctuations in environmental conditions in July (Fig. 8). Water temperatures peaked at 22°C on the 14th of July, then dropped below 18°C between the 15–18th of July. Over 25mm of rain on the 15th July increased flow from <0.18m³/s to >0.7m³/s and coincided with a drop in pH, increase in turbidity, and a sharp D.O. decline to 2.9mg/L at 01:00 on the 16th July (Fig. 8).

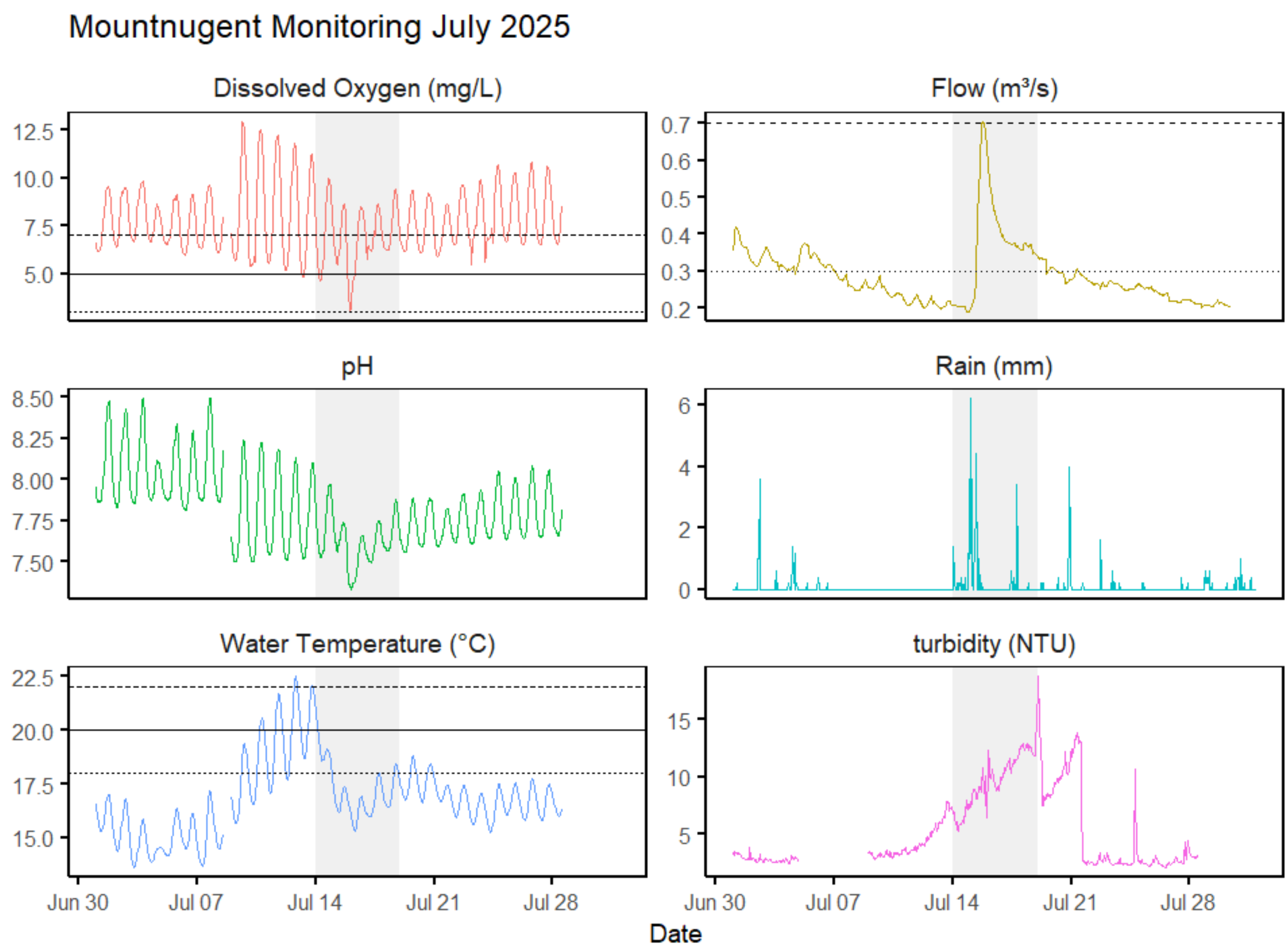


Fig.8: Mountnugent River monitoring during July 2025, showing dissolved oxygen (mg/L), flow (m^3/s), pH, rainfall (mm), and water temperature (°C). The grey shaded area highlights between the 14/07–18/07. The horizontal lines mark 3, 5, and 7mg/L (D.O.), 18, 20, and 22°C (water temperature), and 0.3 and 0.7 m^3/s (Q95 and Q50 estimated percentile flow). Hourly averages were calculated for each variable to ensure consistency across the dataset. *Flow data was derived from the EPA online data portal (EPA - WISKI Web Public).

3.4 Lake vs River water temperatures

Comparison of river and lake surface water temperatures (Fig. 9) showed that in early July, river water temperatures were consistently cooler than the lake. By mid-month, both river and lake surface water temperatures warmed to >21°C, with the north bay recording the highest temperature of 23.1°C on the 10th of July. Following rainfall and an increase in flow, water temperature declined at the Mountnugent monitoring sites, while the lake remained over 20°C (Fig.9).

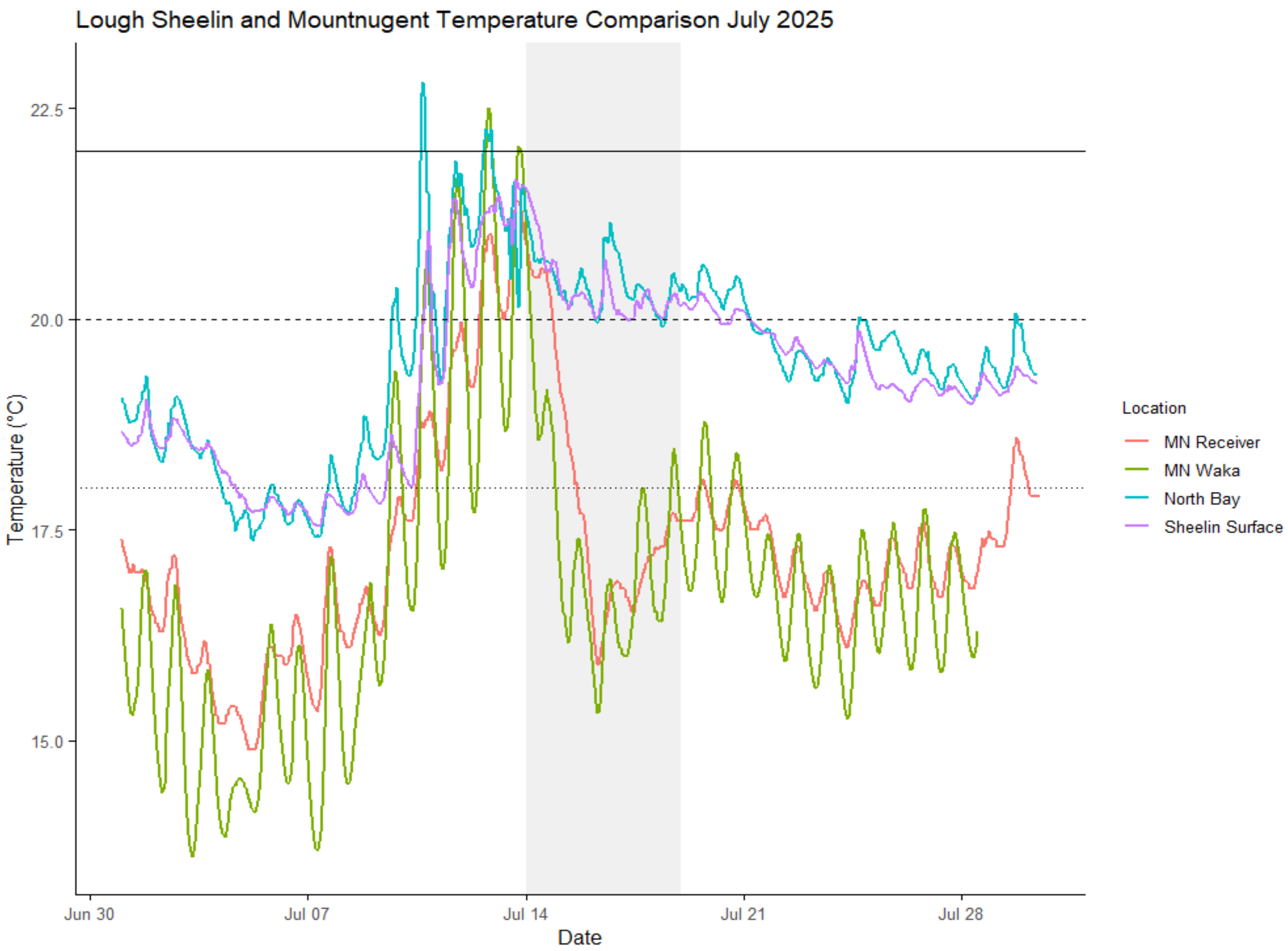


Fig.9: Water temperature comparison between the Mountnugent River (Upper [MN Waka, Green], and Lower [MN Receiver, Red]) and Lough Sheelin (North Bay [Blue] and Sheelin Surface at Databuoy [Purple]) for July 2025. The grey shaded area highlights the period 14/07–18/07. Horizontal lines mark 18, 20, and 22°C.

3.5 Fish tracking project -Fish behaviour

Six tagged brown trout were detected within the acoustic telemetry array during July 2025. Fish movement was summarised using a daily temperature–depth heatmap (0–12.5m; data buoy thermistor) overlaid with mean depth and activity of tagged fish active in the array (mean number of stations detected per day as proxy for activity) (Fig.10). Prior to the mid-July thermal peak (13–14th July), trout predominantly occupied depths of approximately 2–3m across the lake. As surface waters warmed and the oxy-thermal habitat compressed, fish shifted to deeper depths (~6–7m). Fish returned to shallower layers (~2–3m) on the 15th of July (Fig. 10).

Daily activity, expressed as the mean number of stations visited, declined during the mid-July thermal event (from >2 to <2), suggesting reduced movement and/or spatial constriction of home ranges under thermal stress. Individual movement trajectories revealed heterogeneous responses, with three of the six trout entering the lower Mountnugent tributary on 3rd, 13th, and 14th July (see Appendix for example track; Fish 2555). One fish exhibited extended residence within Captain's Bay during the 14th-18th July.

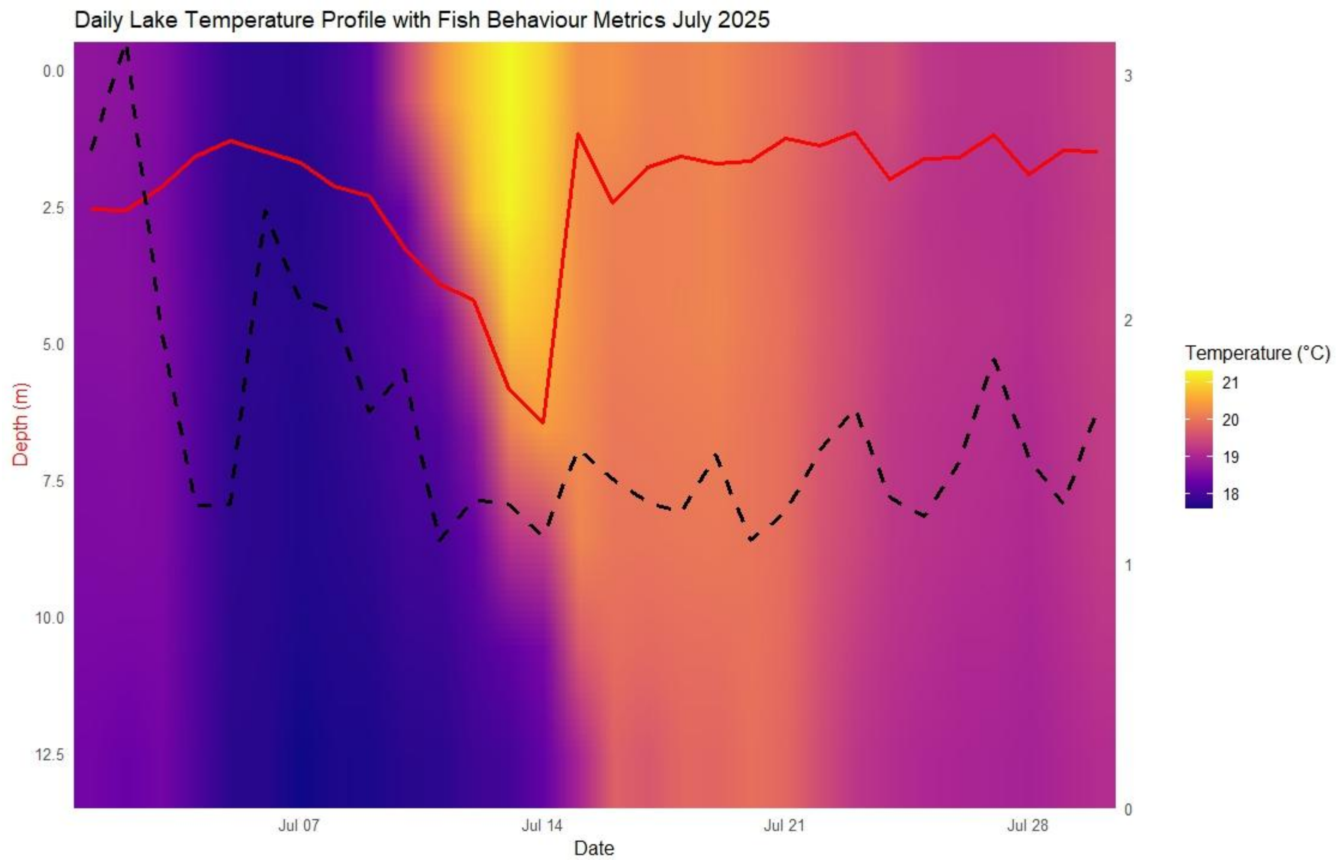


Fig. 10: Daily lake water temperature profile for July 2025 (heatmap; warmer colours = warmer water, 0–12.5m *data buoy). Overlaid are mean fish depth (m) (red line, left axis) and mean activity – number of stations detected on (black dashed line).

4. Summary

In July 2025, Lough Sheelin exhibited marked changes in its oxythermal environment, which were recorded by high-frequency monitoring. A brief mid-July stratification event altered the thermal and dissolved oxygen structure in the lake, leading to stressful conditions for fish (Elliot 2000; Elliot and Elliot 2010). This event was preceded by a period of hot, sunny weather, during which elevated air temperature and solar radiation coincided with peak D.O. concentrations in the North Bay (1. Captain's Bay; Fig.1). A spike in chlorophyll-a also aligned with the strongest surface warming in the middle of the lake (Data buoy; Fig.1) and the onset of stratification, conditions that likely promoted algal growth. The sequence of high temperatures and algal growth may have promoted the observed high daytime oxygen supersaturation through enhanced photosynthetic activity. This elevated productivity may have contributed to a sharp but brief decline in D.O. in the middle layer on the 16th of July, as heightened algal respiration and decomposition can create short-lived oxygen stress during stratified periods. However, a period of cooler, windier weather and 21.8mm of rain on the 15th of July affected the lake and river environment by breaking stratification and creating mixed, isothermal conditions throughout the water column, and increasing discharge from inflowing tributaries. The mixing potentially redistributed low-oxygen waters from the lake bottom, thereby increasing respiration-driven oxygen demand (Jennings *et al*., 2012).

After the rainfall event, decreases in both temperature and pH were observed, followed by the lowest D.O. concentration (2.9mg/L) recorded in July at the Mountnugent River monitoring site (upstream of the area where dead fish were found). This subsequently corresponded to low D.O. levels being observed in Captain's Bay (inflow area of Mountnugent river; Fig.1). D.O. concentrations below 3mg/L were recorded in the river and lake environment. Even for short durations, D.O. at these levels are known to cause physiological stress for brown trout (Elliott & Elliott 2010). It is important to note that in productive systems, early morning declines in D.O. are commonly observed due to diurnal photosynthesis–respiration cycles, particularly under high nutrient conditions (Mulholland *et al*., 2005), and this pattern was evident in the present data (Figure 8; Mountnugent river, top left). Such dynamics can reduce the availability of suitable habitat for fish during warm summer periods, when both temperature and oxygen may become limiting. The cascade of processes outlined could have contributed to acute deoxygenation events in the Mountnugent inflow to Lough Sheelin.

Only six trout were active in the array during July 2025, comprising three individuals tagged in 2025 and three from the 2024 tagging cohort, whose tag batteries were nearing depletion by late August 2025. While this small sample size represents a caveat and limits the broader inference of population-level responses, it nevertheless provides a valuable opportunity to observe fine-scale behavioural patterns of individual fish during the period of interest. Thermal stress and stratification during mid-July 2025 induced pronounced behavioural shifts in tagged trout, notably vertical relocation from shallow (~1–2.5m) to deeper (~4-6.5 m) waters as surface layers warmed. Such movement aligns with the common behaviour of cold-water fish tracking more favourable oxygen-temperature conditions under habitat compression. Similar adaptive shifts in depth to maintain optimal environmental conditions have been documented in temperate lakes experiencing thermal habitat loss (Kraemer *et al*., 2021). The observed decline in activity suggests a contraction of space use and perhaps energy-saving strategies during periods of thermal and hypoxic stress. When temperatures or hypoxia exceed tolerable thresholds, brown trout often suppress activity, likely as a compensatory adaptation to reduced oxygen requirements and to avoid critical metabolic stress. Activity declines are typically observed when water temperatures rise above ~18–20°C or when dissolved oxygen falls below ~5–6 mg/L (optimum >7 mg/L) (Elliott, 2000; Ojanguren & Brana, 2003, Elliott & Elliott, 2010).

Individual variability ranging from tributary entry (n = 3) to local holding and mid-lake refuge use (n = 3) reveals a high degree of behavioural plasticity that may be critical for survival during heatwave events provided suitable refuge habitat remains available. Similar patterns have been reported in other salmonids, such as steelhead trout (*Oncorhynchus mykiss*), which often exploit tributary confluence zones as thermal refuges, highlighting the importance of these buffered environments (Wang et al., 2019). However, in this instance, trout that entered the tributary likely experienced dissolved oxygen levels close to lethal limits, indicating that behavioural adaptations to thermal stress (tributary entry) can become ineffective once environmental thresholds are surpassed. The vertical relocation to deeper waters and reduced activity observed in tagged trout during peak thermal stress emphasise how acutely sensitive salmonids are to short-term habitat compression, a response likely to become increasingly common under intensifying extreme weather and climate-driven heat events.

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Appendix

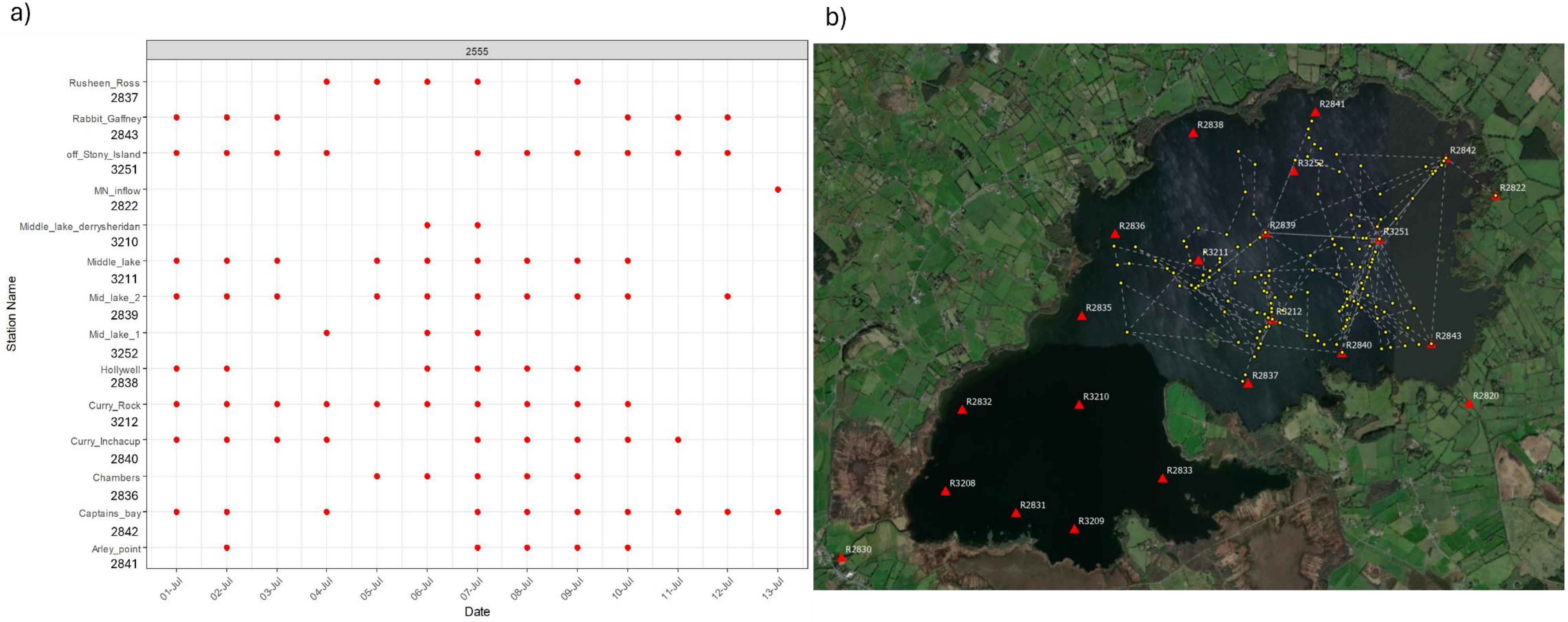

Fig. A1 Example track of tagged fish. Tag 2555 – 52cm (1st- 13rd July). a) Abacus plot of daily presence at each receiver station, with stations identified by local name. b) Interpolated track based on hourly Centre of Activity Locations between 1-13th July; fish entered Mount Nugent inflow at 04:00am on 13th July and was not redetected on the lake array* (*as of August 10th download 2025).