

Western Lakes – Mayfly (*Ephemera danica*) Habitat & Population Assessment

Ken Whelan, Ross Finlay, Martin McGarrigle and
Margaret McCaul

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The truth is that the mayfly, like all wild species, is subject to cycles of increase and diminution of which we know nothing. These revolutions take many years to work out: we see a slow death and we shake wise heads and assign our puny causes: but then again, we see a slow rebirth, and we have to invent new theories, till finally we realise that we are in touch with a great fact of nature, working itself out on lives unknown to us. And, at the moment, let us be of good cheer, for the curve is an ascending one. Hills, 1972

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“Mayfly Team, Lough Conn” – February 2024

Introduction

Ephemera danica is a mayfly of great importance to the angling communities of the Western Lakes. Hatches of *E. danica* on Loughs Conn, Mask and Corrib are world famous and provide a wildlife spectacle like no other. *E. danica* is also an important food source for brown trout. It is of major economic importance over the May / June period and a keystone species for the ecosystems of the Western Lakes. This species of burrowing mayfly is considered pollution intolerant and a Group A taxon under the EPA's Q Value monitoring index, its presence and abundance indicating waters free from significant organic pollution and eutrophication.

Anecdotally, a decline in the mayfly hatch has, in recent years, frequently been reported by seasonal anglers during LAWPRO engagement work with angling communities across the Western Lakes. The most recent population analysis of the mayfly on the Western Lakes was carried out in the 1970s by the Inland Fisheries Trust and University College Dublin. Overall, there are very limited data available for this species. Working with interest groups and local communities, the current project assessed the perceived changes in *E. danica* population abundance in the Western Lakes. The study examined the changes which have occurred in these loughs over recent decades and compared these changes with conditions in Lough Sheelin in the midlands, where mayfly populations have rebounded from a very low level in the mid to late 1970s.

The study assessed sites within Loughs Conn, Corrib and Mask. Loughs Sheelin and Carra were also included as reference sites. Sample sites were initially selected based on previous data from the 1970s (Whelan 1979, Whelan 1980, and Whelan 1981) and supplemented with additional information from the questionnaires and meetings with local interest groups.

This project was funded and actively supported by staff from LAWPRO, with assistance on methodology and reporting review from Buglife (<https://www.buglife.org.uk/>).

Phases of the Project

Work on the project commenced in late September 2023. Initially, a detailed online questionnaire was designed and circulated to key contacts familiar with each of the loughs. This was followed by personal contacts, to broaden out the sources of such information, so as to ensure that each area of the larger loughs was adequately covered. The completed questionnaires will be stored digitally, with all other relevant background material arising from the project, in a dedicated LAWPRO Mayfly Project Resources Folder.

A literature review was undertaken covering both burrowing mayfly biology in Europe and also in North America. Historical material on *E. danica* in Ireland was reviewed and the Inland Fisheries Trust Annual Reports (1953 to 1980), which contain a wealth of valuable information on the waters under study and on mayfly abundance over the decades, were reviewed. A detailed assessment of the data contained in one of the author's PhD Thesis (Whelan, 1980) was also carried out.

Field Studies

With support from colleagues at Dublin City University and the Environmental Protection Agency (Castlebar), mayfly nymph and sediment sampling commenced in late January 2024 and was completed in early May 2024. Initial sampling was focused on developing protocols for sampling the littoral / sub-littoral zones in each of the loughs and testing the efficacy of equipment on loan from the Environmental Protection Agency, Dublin City University and from University College Dublin. Following these trials, lake bed / sediment sampling was carried out using an Eckman Grab sampler (<https://aquaticbiotechnology.com/en/sediment-sampling/ekman-grab>), a Russian Corer (<https://www.vanwalt.com/equipment/russian-peat-corer-set/>) and standard FBA fauna nets (<https://www.nhbs.com/sweep-nets>).

Observations and results from the field visits were presented at an online Webinar, held on Thursday, 24th May. The webinar was recorded and is publicly available on YouTube (<https://www.youtube.com/watch?v=YcdH4teRzPA>). A summary of material provided by those who completed the mayfly questionnaires are presented below, in the form of a lough-by-lough summary of the current and past status of mayfly populations and perceived water quality/environmental conditions in each of the five chosen locations.

Table1: Field Study Visits (14) – January to May 2024

Site	Location	Date	Equipment	Snorkelling
L. Corrib	Devenish / Ard Point	25.1.24	Eckman / F.Net	No
L. Carra	Moorehall	25.1.24	F.Net	No
L. Sheelin	Arley / Orangefield Bays	29.1.24	Eckman / F.Net/ Corer	No
L. Conn	Castlehill / Victoria Bays	17.2.24	Eckman / F.Net/ Corer	No
L. Conn	Cloghans and Tolan's Bays	18.2.24	Eckman / F.Net/ Corer	No
L. Sheelin	Arley / Matthews / Horse Bays	14.3.24	Eckman / F.Net/ Corer	No
L. Mask	Carrig Dá Bhó / Scintilla Mór / Inishgorm	20.3.24	Eckman / F.Net/ Corer	No
L. Conn	Tolan's / Castlehill	3.4.24	Eckman / Corer	No
L. Corrib	Devenish	17.4.24	Eckman / F.Net	Yes
L. Conn	Tolan's / Castlehill	18.4.24	Eckman / F.Net	Yes
L. Sheelin	Arley / Matthews	24.4.24	Eckman / F.Net	Yes
L. Sheelin	Church / Derrysheridan / Finea	25.4.24	Eckman / F.Net	Yes
L. Conn	Brackwansha / Cloghans	01.5.24	Eckman / F.Net	Yes
L. Carra	Moorehall / Brownstown	02.5.24	Eckman / F.Net	Yes

Overview of Questionnaires

The questionnaire was circulated both as an on-line questionnaire and also in hard copy. A copy of the questionnaire is included in the LAWPRO online resources folder. All of the questionnaires received were from the online version. In addition, the resource area includes the background material collected during the course of the study: links to video material, a full set of the Inland Fisheries Trust reports (1953 to 1980) in digitised form, maps of all of the lakes covered by the study, a full set of references both popular and scientific collected over the course of the study, and a list of the interest groups who participated in the study and are keen to continue survey work on mayfly populations in their local loughs.

The questionnaire was very detailed, but the team were advised at the preliminary stakeholder meetings that those intending to complete the form were keen to provide an overview of all factors potentially affecting the abundance of the mayfly. In addition to the areas listed in the questionnaires for comment, those completing the questionnaire also generously provided offers of historical material, including: links to previous television programmes and news reports, offers of photographs, angling competition results, rod catch returns from angling diaries, etc.

Questionnaires were circulated to a wide range of contacts and individuals who have a detailed knowledge of current and previous mayfly abundances on the loughs in the study. Three stakeholder meetings were held with local interest groups in Foxford, County Mayo, in Partry, County Mayo, and in Ballyjamesduff, County Cavan. All of the meetings were very well attended and there was a keen interest amongst the local anglers and conservationists to become involved with the programme.

A total of 46 completed questionnaires were received. These included both individual and group submissions.

Lough Corrib

Lough Corrib is a large lough covering some 18,000 ha / 44,000 acres. It stretches over a length of some 56 km / 35 miles from Galway City in the south to the village of Cornamona in the north. It is renowned for its hatches of mayfly (*Ephemera dancia*) which, for well over 100 years, have supported an important peak in tourist angler visits to the area over the month of May. Concerns

expressed by anglers on Lough Corrib and the neighbouring western lakes that the hatches of mayflies had diminished in intensity was one of the primary factors motivating this study.

Detailed questionnaires were received from 14 anglers on Lough Corrib and the results are summarised below. This summary includes observations provided by the anglers on the perceived changes in mayfly abundance over past decades and other related issues including: overall insect hatches, weather patterns, water quality changes in lakeshore vegetation, changes in aquatic plant abundance / distribution, and their views on trout stocks / trout catches in Lough Corrib.

L. Corrib Questionnaires – summary of responses

The following summary responses include an overview of the scoring provided in the online questionnaires, the additional notes provided by respondents and also comments provided at stakeholder meetings.

The respondents agreed that there were two distinct hatches of mayflies on Lough Corrib: the main adult hatch in May / early June and also a supplementary, smaller hatch over the late July / early August period. They agreed that in the past, over the May / June period, the mayfly hatch varied between significant and very significant. There was also overall agreement that the second hatch of mayfly was sparse. This hatch was more localised and, in some cases, confined to more open water areas. The majority of respondents felt that the mayfly populations were now less abundant than in the past. They suggested that the decline happened between 2000 and 2013, and the majority were of the view that the decline took place around 2000 to 2003. In terms of significant changes to the lough itself, respondents felt that lake temperatures had increased in recent years.

Respondents expressed a broad range of different views regarding the factors that have affected mayfly abundance, including a drop in water quality, the spread of zebra mussel, and the occurrence of more frequent heat waves. The respondents felt there was a significant increase in water clarity in recent years, brought about by the spread of zebra mussel. Interesting comments were made in relation to bankside vegetation and a high proportion of the respondents were of the view that a reduction in lakeshore vegetation caused by increased development along the shores of the lough and increased removal of vegetation both on islands and on the lakeshore, may be causing a problem for adult

mayflies seeking out shelter. It was pointed out by one respondent that some of this loss of vegetation, at least in part, may be due to ash dieback.

As regards trout angling catches, the majority of anglers were of the view that the number of fish caught had decreased. The main cause for this decrease was attributed to a drop in mayfly hatches and changes in fish feeding behaviour. A number of respondents remarked on changes in weather patterns, with colder northeasterly winds predominating over the past decade during late April and into May, which they think may have affected the reproductive success of the mayfly adults. There was also quite a number of comments made in relation to decreasing water quality and increasing nutrients entering the lake, with the appearance, from time to time, of algal blooms and more green filamentous algae. There were also comments made in relation to the significant spread of native aquatic plants across specific bays in the lough (e.g. Greenfields area) and an overall drop in hatches of other insects of importance to anglers, particularly buzzer (chironomids) and sedges (caddis).

Lough Mask

I have never experienced a heavy hatch of mayfly on Lough Mask. (There were).... enough fly to get fish but nothing that would compare with other lakes such as Sheelin, Arrow, Derg, etc.

Lough Mask is a large limestone lough of 8,900 ha / 22,000 acres in area and, along with Lough Corrib, is one of the best-known brown trout fisheries in Ireland. It lies close to the town of Ballinrobe in County Mayo. Although it has a reputation for good hatches of mayfly, these are largely confined to the southern and southeastern portions of the lough. It is a much deeper lake than either Lough Corrib or neighbouring Lough Carra.

Detailed questionnaires were received from only 4 anglers on Lough Mask and the results are summarised below. low.

L. Mask Questionnaires – summary of responses

Two of the anglers were of the view that the lough had one main hatch of mayfly in late spring but no summer hatch of mayfly. The other respondents were of the view that the lough had two hatches of mayfly, a late spring emergence and a hatch over the late July / early August period. Three of the respondents agreed that the main late spring hatch was significant and that over the period since

2005 to 2010 the mayfly hatch had declined. Three of the respondents also agreed that lake temperatures were increasing in recent years. They suggested that the decline in mayfly abundance may have been connected with the increasing abundance of roach / hybrids and the spread of zebra mussel across the lough. They highlighted that the lough had become browner in recent years and some of the respondents felt there had been a drop in water quality. Two of the respondents were of the view that lake shore vegetation had decreased, while the other two respondents thought it had remained the same. Three of the anglers agreed that brown trout were less abundant in the lough. Concerns were expressed that other insect hatches have diminished in intensity over recent decades and concerns were also expressed regarding the dumping of waste engine oil and other waste materials around the shores of the lough and in the streams. Some of the respondents mentioned the issue of high-powered boat engines causing extreme damage to the ecosystem.

Lough Conn

Traditionally the lake provided free rising trout averaging some 250 g to 350 g (1/2 lb to 3/4 lb), however this changed in the 1990s, trout average size increased significantly, this is now declining back to historical sizes. Eel numbers collapsed in the 1990s and have not recovered.

Lough Conn, County Mayo, covers some 5,700 ha / 14,000 acres. It lies close to the market town of Crossmolina. With its immediate neighbour to the south, Lough Cullin, it is connected to the Atlantic by the River Moy. In the past Lough Conn supported very large hatches of mayfly, which attracted large numbers of anglers to the locality over the May / early June period.

Detailed questionnaires were received from 10 respondents on Lough Conn and the results are summarised below.

Lough Conn Questionnaires – summary of responses

The majority of the respondents agreed that Lough Conn historically hosted two hatches of mayflies: a main hatch that occurred in late spring and a hatch in late July / early August. The latter hatch could, at times, prove significant but was located in different areas to the main adult hatch. There was also agreement that in the past the lough hosted a significant, to a very significant, population of mayflies. Opinions in relation to the significance of the summer hatch differed

and it was seen by respondents as ranging from sparse to significant. As in the case of Lough Corrib, the summer hatch appeared to be localised and for that reason may not have been available to all of the anglers on the lough. More recently the mayfly hatch has, in some years, continued throughout the whole summer from May until late August.

All the respondents agreed that the mayfly was now less abundant than in the past. Respondents identified the decline as having taken place within a number of differing time periods; however, all respondents agreed that the decline occurred between 2000 and 2015. It was noted that lake temperatures were increasing in recent years and respondents also felt that strong winds were an issue at times over recent years. The respondents reported that the spread of zebra mussel and roach/hybrids were, in their view, linked to the decline in mayfly abundance, as was a drop in water quality and the occurrence of algal blooms. They expressed the view that changes in water quality were also linked to reduced hatches of other invertebrates, particularly key angling species of caddis (sedges) and chironomids (duckfly). Comments were also provided on weather conditions, and it was noted that it has been many years since anglers “broke ice” on the lake to launch boats on the 15th of February, the opening day of the angling season. They also noted that the frequency of snowfall during the early season has greatly decreased. In more recent years, wind patterns seem to lock into a given direction for longer periods, making fishing impossible for many weeks at a time, over the key mayfly period.

Due to the presence of large concentrations of filter feeding zebra mussel, the lake appeared clearer at times, but this was in stark contrast with intense algal blooms that appeared from time to time on the lough. There were also significant problems reported in the questionnaires with discolouration in the lough following heavy rain. Anglers reported that both the abundance of brown trout and their average size had decreased in recent years. They assigned poor angling catches to less abundant mayfly hatches and an overall drop in the abundance of brown trout. They were also of the view that fish feeding behaviour had changed in the lough and this may have impacted trout rod catch returns.

Very detailed information was provided, both verbally and in the questionnaires, on the spread of aquatic plants in particular bays: Cloghans Bay and, in part, Castlehill Bay. This in turn has changed the bed of the lake and anglers linked this with the disappearance of the mayfly from these areas.



Marl grab sample from Tolans Bay, Lough Conn and a sample from Cloghans Bay, Lough Conn, where the marl has been overlaid by finer sediment, arising from the spread of dense swards of macrophytes across the bay.



Fine sediment sample from Cloghans Bay, in an area traditionally associated with intense hatches of mayfly.

Lough Carra

(In 2023) I fished a (trout fishing) competition on the 12th of May, and throughout the whole of the day I saw a single mayfly!

Lough Carra lies to the northeast of the town of Ballinrobe, in County Mayo and is connected to Lough Mask by the Keel Canal / River. It has a surface area of 1,600 ha / 4,000 acres and is far smaller than the other western lakes. It is a shallow, once crystal clear, marl lough (<https://en.wikipedia.org/wiki/Marl> and http://culturalecology.info/wetland_combi/Marllakes.html), with an average depth of just 1.8 m, and a maximum depth of 18 m.

Over the decades, Lough Carra has been impacted by nutrient pollution, primarily due to agricultural intensification. Over time, approximately 25% of the catchment area has been converted from natural or semi-natural vegetation to improved grassland, resulting in nutrient runoff into the lake. The eutrophication problems that currently exist in the lough threaten its delicate ecosystem and have had profound impacts on the invertebrate populations and the populations of native brown trout. To address these issues the EU-funded, Lough Carra LIFE Project, aims to improve ecosystem resilience and reduce nutrient pollution. The project began in January 2022 and will run until 2026 (<https://www.loughcarralife.ie/>).

Detailed questionnaires were received from 10 anglers on Lough Carra and the results are summarised below.

Lough Carra Questionnaires – summary of responses

The respondents agreed that traditionally Lough Carra had a mayfly hatch which spread over two periods: late spring – April / May, and a summer hatch over the period late July and August. The majority of the anglers were of the view that although the summer hatch was present it was at times sparse. Others felt it was of significance in angling terms. However, as in the case of Lough Corrib, the summer hatch may be confined to specific areas. The respondents reported that mayfly populations collapsed over the period 2000 to 2010 but one angler, who had been fishing the lake since the 1970s, felt that mayfly populations had declined since the 1990s. There was also an interesting comment about the timing of the spring hatch on Lough Carra, stating that the hatch traditionally started during the last week of April and peaked during the first week of May.

The respondents considered that increasing lake temperatures and more frequent storms were associated with the serious decline in mayfly populations but predominantly they were of the opinion that it was a drop in water quality and an increase in strong algal blooms, which resulted in water discoloration, that were the main causes of the collapse in mayfly populations. The respondents reported an overall increase in lakeside vegetation. In addition to a drop in the abundance of mayfly, anglers also noted an overall significant drop in the abundance of other invertebrates of importance to anglers: sedges (caddis), other mayfly species (lake olives – *Cloeon* spp.), and duckfly (chironomids). They noted much milder winters over recent years and the presence of persistent, cold northeast winds over the mayfly period, at times accompanied by frost. A spread of aquatic plants was noted, and in particular, the replacement of the once-extensive reed beds with the strong stems of bull rushes. Over the past five years in particular very large reed beds have disappeared from the lough.

The respondents reported a significant drop in both brown trout abundance and brown trout catches. They were of the view that the average size of brown trout caught on the lough had increased. They expressed serious concern over the collapse of the brown trout population, with much fewer anglers now fishing the lough. One angler was of the view that Lough Carra now barely survives as a viable trout fishery. This is in stark contrast with the 90s when according to one of the respondents, in the early 90s, Lough Carra was:

without a doubt the best mayfly lake in the West of Ireland. He also commented:..... all IFI survey results over the past 15 years point to an ongoing rapid decline in trout stocks. Poor trout stocks, taken together with the massive decline in mayfly, results in a situation whereby catching a single trout in a day's fishing could now be deemed a success.

Lough Sheelin

Lough Sheelin is a little more than 6 km (4 miles) long and over 1.6 km (1 mile) wide. It has an area of approximately 1,860 ha / 4,600 acres. The greater proportion of the lake is less than 6 m deep and the deepest point is 14 m. The lough is situated in the north midlands on the borders of counties Cavan, Meath and Westmeath and is part of the River Inny system. This is a rich limestone lough with a capacity to produce and maintain a population of large brown trout. The trout average approximately 1 kg in weight.

Lough Sheelin has faced serious pollution challenges over the years. The environmental problems initially stemmed from intensive pig fattening in its catchment area. Pig places increased from 9,000 in 1968 to 19,000 in 1971. In the late 1960s water quality deteriorated leading to severe algal blooms. By 1979 the situation reached crisis point, prompting concerns about the lough's viability as a trout fishery. Over that time the mayfly populations plummeted and had, by the mid-70s, all but disappeared. Fortunately, recent efforts have helped control pollution, and Lough Sheelin has shown a remarkable resilience in recovering from its troubled past. More recently concerns regarding green and blue-green algae persist amongst local interest groups, who maintain that the spread of filter-feeding zebra mussel in the lough over the last two decades has helped maintain its clarity and its reputation as a prime angling water.

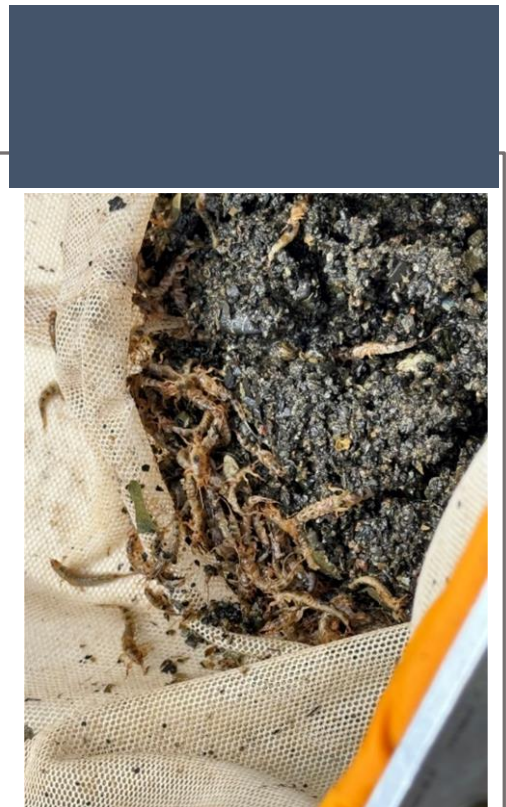
Lough Sheelin Questionnaires – summary of responses

The respondents from Lough Sheelin reported a significant hatch of mayfly from early May to early June, with a sparse to, at times, significant (but very localised) hatch of adult mayflies in late July / early August. Anglers were of the view that even before 2010 the main spring hatch was significant to very significant. Few of those responding to the questionnaire would have fished the lake around the time of the adult mayfly collapse from the early 70s to the mid 80s.

The general consensus of those anglers who were interviewed at stakeholder events and from comments received in the questionnaires, is that mayfly numbers have significantly and consistently increased since 2010. Anglers also observed the occurrence of more frequent storms and calmer conditions over the mayfly period.

Views were spread across a wide range of factors that might be involved in the changing abundance of mayfly on Lough Sheelin. Amongst the main changes they highlighted from the lough was the appearance and spread of the zebra mussel, the appearance of algal blooms, and concerns over more frequent heat waves in recent years. Not surprisingly, given the densities of zebra mussel in the lough, anglers reported that, apart from periods where algal blooms were present, transparency in the lough had greatly improved over recent years. In the view of the respondents, lakeshore vegetation had largely remained unchanged.

The majority of anglers reported catching more and larger trout. Angling pressure has greatly increased with anglers fishing a wide range of new techniques, particularly targeting trout feeding on mayfly nymphs. They also reported that fish feeding behaviour had changed and catches have increased due to more intense hatches and a greater abundance of mayfly. As was the case from Lough Corrib, the anglers reported that trout were, in recent years, feeding on a range of insects during the mayfly period. In addition to mayfly adults and nymphs the trout are feeding on sedges (caddis) and buzzer (chironomids). The respondents noted that weather conditions have been ideal over the mayfly period for the past number of years, and this may have helped boost catches of brown trout.



Dense concentrations of mayfly nymphs from a grab sample in Lough Sheelin

Water Chemistry – Summary of Results

A detailed assessment of water chemistry and surface water temperature historical trends in all five of the loughs in the study was undertaken. The results are based on lake sampling carried out by the Environmental Protection Agency and the Local Authorities to assess the status of each of the loughs, in accordance with the Water Framework Directive (WFD). The WFD comprises a five-class scale (High, Good, Moderate, Poor and Bad ecological status). Once Member States of the EU have determined the ecological status of their water bodies, ongoing monitoring can be used to track changes in the status of each water body and to make recommendations for improvement.

The parameters included in the trend analysis for the individual lakes were chlorophyll and total phosphorus. A combined lake analysis for temperature trends is also included. Data are available for some of these lakes as far back as 1975, but the most recent datasets cover the period 2007 to 2023. The analysis primarily targeted this 17-year period, as it was judged to be the most relevant to the status of mayfly populations in the loughs under study.

The OECD (1982) fixed boundary system for measuring eutrophication or lake enrichment caused by excess nutrients, recommends the boundary levels for chlorophyll and phosphorus shown in the table below. The “*indicative quality guide*” set by the EPA for chlorophyll concentrations in these lakes is in the range of 5 to 6.3 mg/m³. In the case of total phosphorus, the EPA has set national legal standards for total phosphorus in lakes: 0.01 mg/l P for High Status lakes and 0.025 mg/l P for Good Status lakes. Concentrations above these thresholds designate a lake as in Moderate, Poor or Bad Status.

The OECD fixed boundary system for eutrophication (chlorophyll and total phosphorus).

Trophic Category	Mean Annual Chlorophyll (mg/m³)	Maximum Annual Chlorophyll (mg/m³)	Mean Total Phosphorus (mg/l P)
Ultra-oligotrophic	≤ 1	≤ 2.5	≤ 0.004
Oligotrophic	≤ 2.5	≤ 8	≤ 0.01
Mesotrophic	2.5–8	8–25	0.01–0.035
Eutrophic	8–25	25–75	0.035–0.10
Hypertrophic	≥ 25	≥ 75	≥ 0.10

Lough Corrib

Status

Under the WFD Lower Lough Corrib is classified as being at Good ecological status. Most quality elements are at High, but fish and hydromorphology bring the overall assessment down to Good status. Similarly, with Lough Corrib Upper, most elements are High but again fish at Good and hydromorphology at Good reduce the status to an overall Good categorisation.

Trends

Chlorophyll

Chlorophyll shows an apparent downward trend in both upper and lower Lough Corrib. It should be noted that the laboratory limit of detection (LOD) was lowered in 2017, and this has emphasised the downward trend. Some 20% of measurements are below the LOD.

Total Phosphorus

Total Phosphorus (TP) concentrations are very low in both basins of Lough Corrib. There is an indication of a downward trend but, with over 70% of measurements being below the limit of detection (LOD) of 0.005 mg/l P, this trend may not be that reliable. The data dashboard, on *Catchments.ie* for Lough Corrib, does record a downward trend for annual mean TP concentration for 2013 to 2018, albeit not statistically significant.

Lough Mask

Status

The overall ecological status is Good. While most quality elements are rated as High, aquatic plants and hydromorphology are rated as Good and these decide the final one-out all-out status – Good.

Trends

Chlorophyll

There appears to be a downward trend in chlorophyll concentrations since 2007, even allowing for the lowering of the limit of detection after 2015. Inland Fisheries Ireland confirmed the presence of zebra mussel in Lough Mask in 2008 and this may account for the downward trend in chlorophyll concentration. Biodiversity Ireland's latest distribution map for zebra mussel, however, does not currently show a widespread occurrence of zebra mussel in Lough Mask. Some of the replies to the Mask questionnaire mentioned the spread of zebra mussel across the lake. The full extent of zebra mussel colonisation in Lough Mask remains to be confirmed.

Total Phosphorus

There appears to be a slight upward trend over time in phosphorous concentrations. For many years, the median concentration was effectively at the lower limit of detection. The limit of detection at 0.01 mg/l has not changed since 2008. The annual average concentration has exceeded 0.01 mg/l P just once, in 2021 – at 0.011 mg/l P. The number of total phosphorus samples taken from the lake each year increased, from an average of 28 per annum for the period 2007 to 2014, to over 80 during the period 2016 to 2021. This may have a bearing on the apparent trend – i.e. being a function of improved sampling that gives a better understanding of the true mean concentrations, with fewer samples below the limit of detection.

Lough Conn

Status

Lough Conn is at Good ecological status. While most quality elements are High status, its macrophytes and hydromorphological conditions are at Good status and this brings the overall assessment down from potentially High status to Good status.

Trends

Chlorophyll

Chlorophyll concentrations show a clear decrease over time. This decrease is likely to be in part due to the introduction of zebra mussel to Lough Conn from as far back as 2006. Note the step change between 2015 and 2016 is due to the improvement in the laboratory technique allowing for a lower limit of detection. This obviously strengthens the apparent downward trend in concentration. The chlorophyll levels are nonetheless quite low, which places Lough Conn into the oligotrophic category, based on average chlorophyll concentration.

Total Phosphorus

Phosphorus levels in Lough Conn are low, albeit with an apparent upward trend. Average concentrations are less than 0.01 mg/l, and this places the lough into the OECD oligotrophic category and classified as High, against the national standard. Current phosphorus concentrations are significantly lower than recorded over the period 1987 to 1999, when the mean concentration was 0.015 mg/l.

Lough Carra

Status

Lough Carra is at Good ecological status. Most of the quality elements are assessed as being at High status but its hydromorphological condition and fish status are classified as Good status. The one-out-all-out principle brings the final assessment to Good ecological status.

Trends

Chlorophyll

Chlorophyll in Lough Carra appears to be on a downward trend in recent years. To date zebra mussel have not colonised Lough Carra and this trend is likely to be an actual trend, unaffected by zebra mussel filtration.

Total Phosphorus

Total phosphorus appears to be increasing over time. Concentrations remain low, however, and the lake is classified as High status for phosphorus.

Lough Sheelin

Status

A range of ecological quality elements are assessed for Lough Sheelin, to give an overall status of Moderate. While all the biological quality elements achieve Good status, oxygen and nutrient conditions (total phosphorus) are assessed as Moderate, and this brings the overall status down to Moderate.

Trends

Chlorophyll

Chlorophyll has a general downward trend from 2017 to 2022, albeit somewhat variable over earlier years. Zebra mussel are present in the lough, with large populations noted since 2004. Chlorophyll levels in Lough Sheelin are significantly higher than in all the other lakes included in this study.

Total Phosphorus

Phosphorus concentrations appear to be on an upward trend in Lough Sheelin since 2014, with average concentrations above the Good/Moderate boundary value of 0.025 mg/l since 2019. Concentrations over the period 2007/2008, were, however, higher than those in recent years. As is the case with chlorophyll, total phosphorus concentrations are significantly higher in Lough Sheelin than in the other lakes in this study.

Temperature

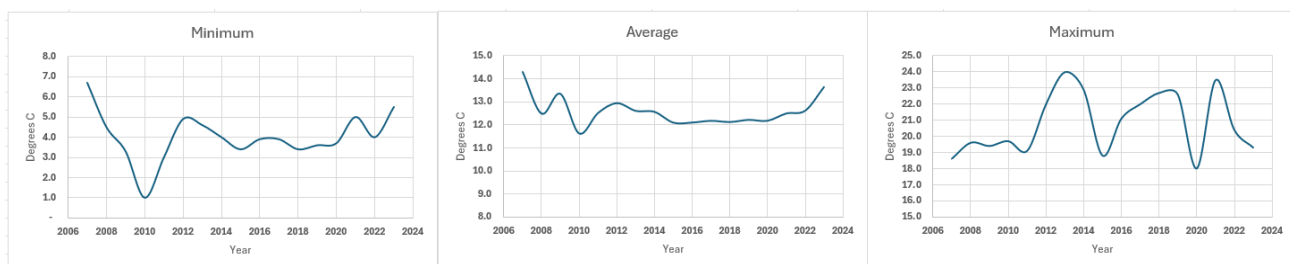
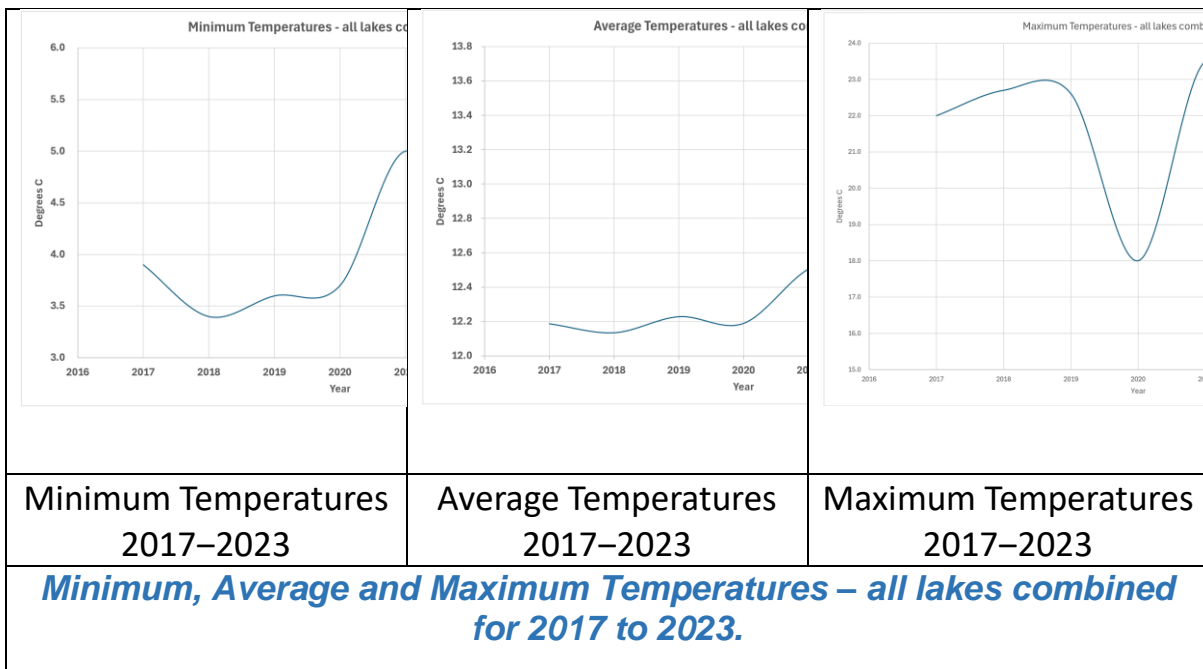
With climate change progressing steadily, as atmospheric carbon dioxide levels reach almost 420 ppm, the world is warming. It can be expected that water temperatures will reflect this. Temperature is an important predictor of the length of the nymphal stage of the mayfly and when the adults are likely to emerge from the bed of the lough. Increasing water temperature, in combination with extended periods of calm weather, could lead to stratification of the deeper areas of Irish loughs. Lake stratification is the tendency of lakes to form separate and distinct thermal layers during warm weather. Typically, stratified lakes show three distinct layers: the epilimnion, comprising the top warm layer; the thermocline, the middle layer, whose depth may change throughout the day; and the colder hypolimnion, extending to the floor of the lake. Such conditions could potentially adversely affect fish, invertebrate and floral communities in our ordinarily windswept and well oxygenated Irish loughs.

The tables below show the temperature range (2007 to 2023) for the individual loughs, including the minimum, average and maximum temperatures for all loughs combined, and also the dataset from 2017 to 2023. No obvious trends are apparent when the full set is graphed collectively; however, separating out the data for the period 2017 to 2023 shows an apparent upward trend, particularly for average temperature across all lakes combined. The year 2020 appears anomalous in the maximum temperature graph but this may be due to a generally cooler year in 2020, based on Met Eireann monthly air temperatures at Claremorris.

These temperature measurements are, however, spot measurements made by the various agencies when taking water samples and are all daytime measurements. *In situ*, continuous temperature measurements would give a far more accurate measure of trends, especially as climate change progresses and further impacts the bays and open water areas of our loughs and ponds.



A view over Castlehill Bay, Lough Conn, towards Nephin Mountain.



Minimum, Average and Maximum Temperatures for all lakes combined over the full period from 2007 to 2023.

Lake Sediments

Over the course of the project the opportunity was taken to collect samples of lakebed sediment types from several of the lakes under study. Analysis of these samples is under way in Dublin City University, and it is hoped that the results from this preliminary physico-chemical assessment will form the basis for seeking funds to support future postgraduate research.

This type of analysis is used to assess the environmental stressors that can adversely affect the early life stages of aquatic biota. It can identify which of the stressors has potentially the greatest effect on a particular species or range of species and under what conditions it can have the greatest impact. It may also demonstrate if, and how, the populations are adapting to changes in the surrounding aquatic environment.

Particle analysis of the sediment samples will provide additional data on the sediment types most frequently used by *E. danica* nymphs when forming their burrows and it is hoped will quantify what are the limiting physical factors which preclude mayfly nymphs from forming burrows outside of areas containing their preferred sediment types.

Discussion and Recommendations

Discussion

Studies across Europe and North America have clearly shown the cyclical nature of *E. danica* emergence patterns. In Irish loughs other fauna, such as caddis flies, also show similar patterns of dearth and abundance. As was the case with the original studies in the 1970s, there are strong parallels between what has been noted from loughs in Ireland and fluctuations in the abundance of burrowing *Hexagenia* species throughout North America. Material listed in the literature review demonstrates these similarities.

Overlaid on such natural patterns of emergence are the significant changes which have taken place, and are continuing to take place, within these large water bodies. In the past, Loughs Sheelin, Conn and Carra were impacted by eutrophication and other anthropomorphic changes to water quality. The loughs in this study are impacted by invasive species and by the overall impacts of climate change, primarily seen as an increasing trend in surface water temperatures and changes in weather patterns, particularly milder winters and more extreme water levels resulting from exceptionally wet periods (e.g. July '23 to May '24). Such wet periods are countered, at times, by severe droughts. The loughs in the present study are all large bodies of water and can vary greatly in their response to stressors and to environmental changes within the water bodies themselves. For example, Lough Corrib has a surface area of 18,000 ha and is in many ways equivalent to a very large marine bay, with the upper and lower loughs reacting in a very different manner to such changes.

Other factors which may affect the abundance of mayfly nymphs, and which may not be immediately obvious include predation and the effects of large arterial drainage schemes or river maintenance schemes which raise the sediment levels in inflowing rivers. The Inland Fisheries Trust reports (1952 to 1980) record heavy predation of mayfly nymphs, at times, by perch shoals and by juvenile pike of less than 1 kg. Due to a drop in overall trout abundance in Lough Sheelin in the mid-70s, very large numbers of juvenile trout were stocked into the lough, boosting its population to a peak of some 98,000 trout of over 20 cm in 1978. It was calculated at the time that almost half of this population could be accounted for by the additional stocked trout. Heavy stocking of juvenile brown has also occurred in Lough Carra in the past. While active, these stocking measures will have significantly increased predation pressure on the populations of mayfly

nymphs in both loughs. Invasive cyprinid species such as roach and roach hybrids are also invertebrate feeders and may well crop a significant proportion of the mayfly nymphs from the loughs hosting expanding populations of these fish species.

Another relevant factor which may influence burrowing mayfly abundance is the effect of sediment loadings, arising, for example, from large arterial drainage schemes or maintenance programmes. The Inland Fisheries Trust reports clearly outline the effects of drainage works on the inflowing river Inny and how a drop in water clarity, brought about by heavy sediment concentrations in the water column, severely impacted trout angling in Lough Sheelin for several seasons. During the course of this study, concerns were raised regarding intense, localised discolouration of specific bays in Lough Conn following high rainfall at locations adjacent to hillside forestry works.

The snorkelling survey demonstrated just how complex the bottom types are in these loughs and how quickly the habitat may alter. The variation in bottom habitat types was far more complex than had initially been envisaged and showed the challenges in quantifying the abundance of burrowing mayfly nymphs. Clearly, any future efforts to quantify the abundance of burrowing mayfly nymphs needs to concentrate on specific, well-defined areas, where efforts are made to assess in detail fluctuations in the abundance of nymphs and to relate such changes to characterised habitat types and to physio-chemical changes in the surrounding water body and sediment. This type of approach lends itself to the involvement of local citizen science groups. The feedback received from those volunteers involved with the current study is that they would welcome training and also welcome the provision of equipment to examine selected areas of their local loughs in detail.

Data from this study clearly show the limitations in terms of the distribution of mayfly nymphs across the bed of the lakes examined. Only areas of less than six metres deep contain significant concentrations of mayfly nymphs. High numbers of nymphs are only found in depths of less than 4.5 m and in most cases the bulk of the mayflies are in areas less than 4 m deep. In some of the shallower loughs, such as Lough Sheelin, where the bulk of the lough is less than 6 m deep and only 14 m at its deepest, a very significant proportion of the bed of the lake is potentially available to colonisation by mayfly nymphs, provided a suitable burrowing habitat is present.

The highly clumped nature of the mayfly nymphs across the bed of each lough and their adaptability provide challenges when attempting to quantify the abundance of the nymphs in specific locations. In addition to the more open, marl-based substratum, nymphs are also to be found in concentrated pockets between larger rocks or on the edge of very soft sediments. Very high-water levels (July '23 to May '24) during the study period appear to have facilitated the spread of nymphs in large numbers into areas that would, under normal conditions, be above the shoreline, demonstrating the mobile nature of mayfly nymphs in response to changing environmental conditions.



Mound of empty zebra mussel shells from the bed of Lough Sheelin

Surveys (2014/2015), near Lusty Beg Island on Lough Erne, in Northern Ireland, have shown the ability of *Ephemera dancia* to adapt to novel habitats. Here, mayfly nymphs were found living amongst empty zebra mussel shells and also in the empty shells themselves – using them as a convenient habitat – squeezing down between the interstices of the mounds of empty shells or utilising still intact empty shells. In Lough Conn mayfly nymphs were also located living in abundance amongst nodules of calcified peat. The accompanying video shows nymphs living in both of these novel habitats in Loughs Sheelin and Conn.



Calcified Peat Nodules – Lough Conn

Although it did not prove possible to quantify the abundance of nymphs in the loughs surveyed in this study, some qualitative results regarding the size of the nymphs encountered on each lough did prove very interesting. In the past the size range of nymphs encountered indicated a very distinctive two-year life cycle from the midland lakes, such as Lough Sheelin, whereas in the western lakes, and particularly in Lough Carra, the life cycle options were far more complex ranging from nine months to two years. Research in both Ireland and in the UK at the time clearly showed that water temperature was a major determinant in regulating the growth rate of the nymphs and the timing/phenology of adult emergence.



A sample of mayfly nymphs of varying sizes from Lough Sheelin

During the present study a broad range of nymph sizes were recorded from all of the loughs. This may perhaps indicate that there are changes not just in the abundance of the mayfly but also in their maturation and hatching patterns. It

was noted this past summer (2024) that there was a far more extended hatch of mayfly on Lough Corrib and there are reports coming through of consistent mayfly fishing from May until early August. This is a clear indication that the pattern of emergence and abundance may be changing, with a more staggered hatch of mayfly adults spread out over the late spring and summer months.

Previous studies on Lough Carra indicated that the autumn-laid eggs may over-winter in the egg stage or as first instar nymphs. Tolan's Bay on Lough Conn was sampled on the 18th of February and again on the 3rd of April 2024. During the second sampling of the bay, what appeared to be a mass emergence of tiny (2 mm to 3 mm) mayfly nymphs was recorded, providing additional evidence that delayed development over the colder winter period may be a feature of the mayfly's biology.

Respondents to the questionnaires and local interest groups were also very concerned regarding the long-term impacts of invasive species on the abundance of mayfly nymphs. They highlighted issues relating to direct predation by shoals of roach and roach hybrids on mayfly nymphs and also the indirect effects that the invasive species may have on the abundance of other predators such as perch and pike.

However, respondents were primarily concerned with the impact of zebra mussel on the overall ecology of the loughs. The survey confirmed the presence of very high concentrations of zebra mussel in Loughs Conn, Corrib and Sheelin. Zebra mussels were less abundant in Lough Mask and have not, to date, being confirmed as present in Lough Carra. The most obvious effect of zebra mussel colonisation is an increase in water clarity. Interest groups were concerned regarding the effects this might have on increasing the growth of macrophytes and also the difficulties that anglers are encountering in fly fishing for trout in such clear water. There was also concern expressed regarding the long-term effects of water filtration by the mussel and how a potential overall drop in productivity in the loughs may affect mayfly and associated invertebrate populations into the future.

As shown in the video clips, the densities of zebra mussel are particularly apparent in areas where a hard, rock-based substrate is present in the loughs. The closely related quagga mussel is present in Lough Ree, in the Irish midlands, and during the survey some, as yet unconfirmed, evidence for the presence of quagga mussel was discovered in Lough Sheelin. The biology of these recent invaders is quite different to the zebra mussel, as they colonise softer sediments,

where the mayfly is potentially more abundant. Following the progress of this invasive species as it spreads across other loughs in Ireland over the coming years is of the utmost importance.

As outlined previously, respondents from Loughs Conn and Corrib were also concerned about the spread in recent years, and across specific bays, of native plant species. The survey identified changes in sediment types which may be associated with the spread of these plants and the absence of mayfly nymphs from areas where these finer sediments have accumulated.

The chemical monitoring data examined has shown that the overall levels of total phosphorus are currently low in all waters, except for Lough Sheelin. The mean concentration is below 0.01 mg/l P in five of the lakes, placing them at potentially High status and as oligotrophic under the OECD scheme, and at High status under national standards. Lough Sheelin is the exception with a mean TP of 0.026 mg/l P – slightly above the Good/Moderate mean Environmental Quality Standard (EQS) and putting it into the OECD mesotrophic category for phosphorus.

In general, chlorophyll concentrations show declines in recent years. It should be noted that there is a steep change in the lowest concentrations measured between 2015 and 2016 – this is due to a change in the laboratory limit of detection rather than a change in the lakes. The change in some cases is due to zebra mussel filtering phytoplankton from the water. As the numbers of this invasive species increase in a lake, they can have a dramatic impact on the phytoplankton as well as the water clarity, as outlined above. To date, zebra mussel have not been found in Lough Carra, so the trend of reducing chlorophyll there appears to have another cause.

Significant eutrophication initially occurred in Lough Sheelin in the 70s as a result of over enrichment from pig farm effluent. The near disappearance of the mayfly at that time was, in part, assigned to enrichment of the lough. Surprisingly, this study has shown that there are exceptional densities of *Ephemera danica* nymphs in Lough Sheelin at present, even though it is the only lake currently showing obvious signs of continuing eutrophication. In contrast, there is a perception that mayfly numbers have declined or that the pattern of emergence has changed over recent decades in the loughs in this study where water quality appears largely stable. This clearly indicates that unravelling the causes for the fluctuations in mayfly emergence patterns and the cause(s) for their dynamic cycles of dearth and abundance is particularly complex.

The monitoring data examined from the five loughs in this study were based on spot measurements, taken in conjunction with water samples. The data used were from daytime measurements and do not account for fluctuations in temperature over a twenty-four-hour period. As shown in Appendix 2, no obvious trends in water temperature are apparent when the full data set 2007 to 2023 is examined. However, over the period 2017 to 2023, there is an apparent upward trend, particularly for average temperature across all lakes combined. A high number of questionnaires also assigned the changes in the mayfly abundance and emergence patterns to increasing water temperatures in the five loughs. As outlined above there is, from the literature, a very strong correlation between cumulative degree days and the length of the nymphal life cycle of *E. danica*. Such a relationship has also been shown for the North American burrowing mayfly *Hexagenia* spp.

The present study was limited to an initial assessment of the status of mayfly nymphs and did not include a review of factors affecting the adult population. Past studies, and data from the Inland Fisheries Trust Annual Reports, clearly relate the strength of mayfly hatches in a given year to factors affecting the success of egg laying by adult mayflies in previous years. The starkest example of such effects is the series of May storms encountered on Lough Sheelin over several years in the early 70s (1972 to 1974) which disrupted the success of mating and egg laying. Tragically, these natural events coincided with increased pollution of the lake and heavy siltation arising from a major arterial drainage scheme on the inflowing River Inny, which feeds the lough. A combination of these factors resulted in the almost complete absence of *E. danica* nymphs from the lough by the time scientific studies on the status of the mayfly commenced in summer 1975.

In the past, fluctuations in the abundance of *E. danica* encouraged a number of large-scale efforts to transplant adult mayflies from one lough to another. Several such initiatives are recorded in the Inland Fisheries Trust reports. One of the most extensive restocking programmes of this nature was undertaken in 1991, long after the dissolution of the Inland Fisheries Trust in 1980. The Central Fisheries Board Inspector, who managed this mayfly restocking programme, provided information to the project describing the transportation of large numbers of adult mayfly in tea chests, loaded with gauze, to Lough Sheelin from Loughs Arrow, Key, and Cavetown Lakes in Counties Sligo and Roscommon.

The experimental research programme carried out in the mid to late 70s included the refinement of techniques originally developed on the River Test in Hampshire, to strip mayfly females of eggs at a trout hatchery in Mullingar, County Westmeath, and the restocking of Lough Sheelin and Pallas Lake, County Offaly, with their progeny. The stocking programme successfully established a hatch of adult mayflies, over a two-year period on Pallas Lake, which was originally devoid of mayfly nymphs. Given the differences in physical features of the various mayfly populations (e.g. overall body length, colouration, etc.) and differences in the timing and emergence patterns of mayfly nymphs from various waters, it is important to ensure that any future efforts to transplant or restock mayflies from one water to another are accompanied by appropriate genetic studies. Such studies are required to assess if there are discernible genetic differences between mayfly populations and if such transportation programmes are appropriate.

Previous preliminary work on *E. danica* river populations in Ireland has also shown apparent differences in physical characteristics, with some exceptionally large nymphs of 35 mm+ in some of the samples. This may indicate an even longer life cycle in flowing water systems or the availability of prime habitat for growth and maturation.

Recommendations

Given the remaining gaps in our knowledge of the biology of *E. danica*, there is a need for a more detailed and focused assessment of prime mayfly production areas. The programme also needs to be extended to include an assessment of the adult stages of the mayfly. Given the clumped and at times localised distribution of mayfly burrowing habitats there is a role for both Citizen Science projects and more detailed scientific programmes.

Citizen Science

Several of the interest groups who facilitated this project are keen to engage in further Citizen Science programmes which would help to assess and understand the factors involved in the fluctuations in mayfly abundance and the changes taking place in adult mayfly emergence patterns. With the provision of training and appropriate equipment, local teams could assess some or all of the following parameters in selected locations, on an ongoing basis:

- Monitor water temperature and light intensity using in-situ meters (similar to ongoing Citizen Science programme on Lough Carra – <https://www.onsetcomp.com/products/data-loggers/utbi-001>).
- Monitor water clarity (regular Secchi disk readings at chosen locations – https://en.wikipedia.org/wiki/Secchi_disk).
- Collection of skins (exuviae) and hatching nymphs – using appropriate mesh sized nets, volunteers could tow these across the surface, using a predetermined, stratified sampling protocol.
- Nymphs – (calculate length-frequency distribution of mayfly nymphs across the year).
- Monitor Data from Mini Meteorological Stations – wind / temp / rainfall / sunshine, etc. (<https://www.climemet.com/collections/weather-stations>).
- Assess the extent of concentrations of mating swarms of adult mayflies, using a predetermined, stratified sampling protocol.
- Collection of shoreline and near shore water samples, plankton and chlorophyll samples for scientific analysis by the appropriate authorities.

Scientific Research

In addition to the Citizen Science programmes scientific research is required in the following areas:

- Floral Survey – mapping and identification of the flora in selected bays of key loughs.
- Mapping of the lakebed and substratum in selected areas.
- Development of quantitative sampling techniques to assess the densities of mayfly nymphs out to a depth of 6 m.
- Sediment surveys in selected areas and particle size / composition analysis, of the material(s) used by *E. danica* nymphs in constructing their burrows. What factors are limiting the use of different sediment types in the construction of mayfly burrows?
- Genetic studies to assess if discrete genetic populations of mayflies are to be found in chosen locations across Ireland.
- Surveys to follow the colonisation of the softer sediments by quagga mussel and how this may affect the distribution and abundance of mayfly nymphs.
- Extend the current initial qualitative / questionnaire survey to cover additional waters, including both loughs and river systems.
- Funding of studentships to review additional risk factors to mayfly populations: e.g. parasite infestations / effects of trace levels of toxic chemicals (cypermethrin, etc.).
- Project to assess emerging AI-based, sensor / satellite technologies to support the above programmes.

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Videos Links

Burrowing mayfly:

<https://www.facebook.com/AustinWatershed/videos/409671504696801/>

Swarming Mayfly: <https://www.youtube.com/watch?v=fxMx3QFK7X8>

Life Cycle of the Mayfly:

<https://www.bing.com/videos/search?q=videos+burrowing+mayflies&view=detail&mid=01504051CA6672A00E6F01504051CA6672A00E6F&FORM=VIRE>

Life Cycle of the Mayfly (2):

<https://www.bing.com/videos/search?q=videos+burrowing+mayflies&docid=603541642134553290&mid=F9B73F916B2B55EAD619F9B73F916B2B55EAD619&view=detail&FORM=VIRE>

Life Cycle of the Mayfly (3): <https://www.youtube.com/watch?v=PBHBfck67D8>

Life Cycle of the Mayfly (4): <https://www.youtube.com/watch?v=4UjIT7fqJ1s>

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