Integrated Pest Management approaches to leatherjacket mitigation in Fermanagh, Northern Ireland

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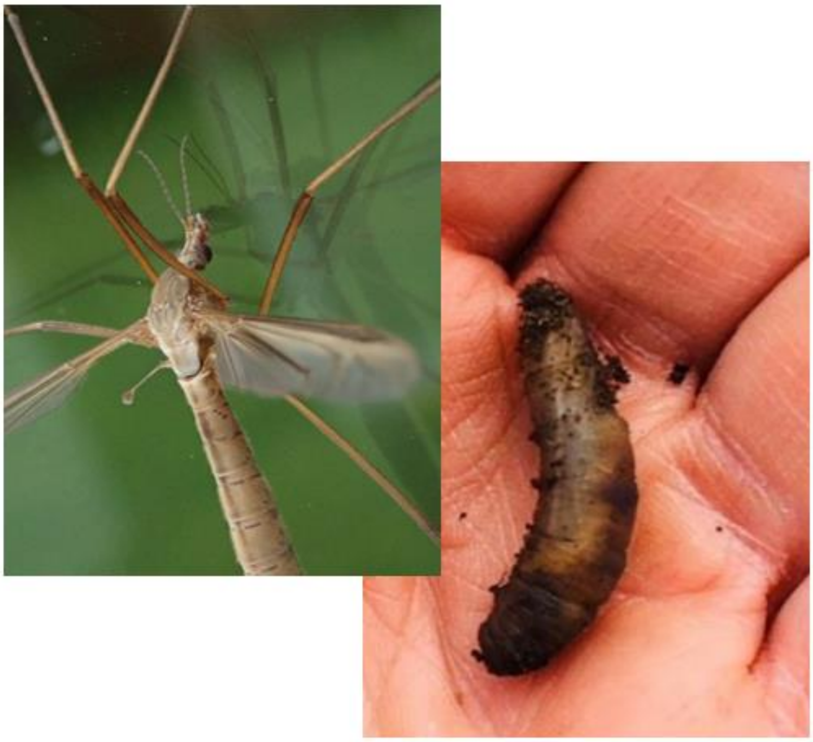

Operational Group: Leatherjacket Mitigation Strategies Group

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Project Website: www.agrisearch.org/eip/leatherjacket-mitigation-strategies

Project Commenced: November 2020

Project Concluded: June 2023

Report Published: August 2023

Department of Agriculture, Environment and Rural Affairs
www.daera-ni.gov.uk

'The European Agricultural Fund for Rural Development: Europe investing in rural areas'.

rural Development Programme

Abstract

Leatherjackets are the larvae of the crane fly, or daddy long-legs; in Northern Ireland this is predominantly *Tipula paludosa* (Tipulidae: Diptera) but *Tipula oleracea* is also present. Leatherjackets feed on the roots and stems of grass or cereal plants and can cause significant damage from loss of yield and the presence of large bare patches.

Grassland covers 92% of the utilised agricultural area in Northern Ireland and is the principal and cheapest feed for the ruminant livestock sector. The destruction of grass by leatherjackets can therefore have a significant effect on the profitability of dairy, beef, and sheep farms. For the past 40 years, leatherjackets were controlled by agrochemicals containing chlorpyrifos (e.g. Dursban). However, approval for use of products containing this active ingredient in grassland was withdrawn in 2016 because of potential genotoxic and neurological effects on humans, particularly unborn children.

This project aimed to determine the leatherjacket problem within an area of Northern Ireland (Fermanagh) and the factors that influence their prevalence, from which alternative mitigation strategies can be proposed to aid decision making on farm. During the three years of the study, 73 sampling events took place. The highest population of leatherjackets was estimated at 5.5 Million per ha, with 23% and 35% of fields found to have populations above the economic threshold of 1 Million per ha in 2022 and 2023, respectively. These figures are in the upper range of those found in the 1965-1982 annual leatherjacket surveys previously conducted in Northern Ireland.

The results of an online survey found 67% of respondents (the majority in Fermanagh and Tyrone) to have experienced leatherjacket presence in grassland with 74% of those experiencing associated reductions in grass growth and availability on farm. There is a clear necessity for leatherjacket research to identify and communicate measures to mitigate infestation risk and the resulting reduction in grassland availability associated with leatherjacket presence.

Review of the literature, ongoing discussions within the EIP operational group members and farmer feedback from webinars and events enabled the construction of an integrated pest management (IPM) strategy. Such an IPM approach is common with other crop sectors and is a requirement of DAERA and the EU via the Sustainable Use of Pesticides Directive. This strategy is based on a long-term multi-season management approach, quite different from reactive insecticide application. IPM seeks to incrementally reduce leatherjacket populations through a series of complementary measures. Most of the IPM recommendations are good grass husbandry, and include drainage, liming, regular reseeding, and regular monitoring of fields to detect potential leatherjacket problems at an early stage. Brassica break crops and multi-species swards should also be considered. Along with these actions, a change to sward management seemed the most acceptable measure to farmers. There was tentative evidence that close grazing in late summer / autumn can reduce leatherjacket populations. However, because of the previous reliance on insecticide control, there is currently little experimental data available on alternative management approaches for leatherjackets.

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Project Aims

Farmers in Northern Ireland (NI) are increasingly facing financial, production and environmental challenges. Low profitability in particular is a real threat and maintaining livestock performance from grassland is critical to sustaining farm businesses and the wider industry for the future.

Grassland covers 92% of the utilised agricultural area in Northern Ireland and is the principal and cheapest feed for the ruminant livestock sector. The destruction of grass by leatherjackets can therefore have a significant effect on the profitability of dairy, beef, and sheep farms. For the past 40 years, leatherjackets were controlled by agrochemicals containing chlorpyrifos (e.g. Dursban). However, approval for use of products containing this active substance in grassland was withdrawn in 2016.

Leatherjackets are the larvae of the crane fly, or daddy long-legs; in Northern Ireland this is predominantly *Tipula paludosa* (Tipulidae: Diptera) but *T. oleracea* is also prevalent. Having laid their eggs in late summer / early autumn, the larvae (leatherjackets) then develop over the winter months, reaching maturity in the spring, before pupating during the summer. Leatherjackets feed on the roots and stems of grass or cereal plants and can cause significant damage from loss of yield and the presence of large bare patches. In particular, grass reseeds and new leys can be devastated if leatherjackets are not controlled.

As leatherjackets eat the roots, farmers might not know they have an infestation until stunted crop growth is evident. Chlorpyrifos was used to kill grubs late in their lifecycle which means land managers are accustomed to spraying in response to infestations, which are usually identified in the spring. A move to pre-emptive mitigation strategies is required but there is very little known about this or its effectiveness.

This project aimed to determine the leatherjacket problem within an area of Northern Ireland (Fermanagh) and the factors that influence their prevalence, from which alternative mitigation approaches could be proposed to aid decision making on farm. If substantiated, these mitigating approaches could be combined to form the basis of an innovative integrated pest management (IPM) strategy that will incorporate agronomic methods to minimise dependence on agrochemicals.

The core objectives of the project were to:

- Determine the number and species of leatherjacket present within the study areas.
- Assess impact of leatherjackets within the study areas
- Assess the correlation between influencing factors and leatherjacket prevalence
- Identify feasible and practical mitigation strategies
- Validate a Predictive Model
- Disseminate project activity and results

The Operational Group

The Leatherjacket Mitigation Strategies Operational Group was formed as a result of concerns raised by farmers in Fermanagh regarding the general lack of information and advice available on leatherjackets in Northern Ireland and the lack of available control mechanisms following the removal of the chemical chlorpyrifos (e.g. Dursban) from the market in 2016.

AgriSearch brought together four grassland focused farmers from Fermanagh, alongside expertise from the Agri-Food and Biosciences Institute (AFBI) entomology and livestock teams to apply for European Innovation Partnership funding to undertake a project to bridge the observed knowledge gap.

The four farmer members of the operational group were:

- Albert Foster - Derrylin, Co. Fermanagh
- Ian Brown - Macken, Co. Fermanagh
- Geoffrey Read - Lisnaskea, Co Fermanagh
- John Egerton - Rosslea, Co Fermanagh

Additional group members were:

- Dr Archie Murchie (AFBI)
- Dr Stephen Jess (AFBI)
- Dr Francis Lively (AFBI)
- Jason Rankin (AgriSearch) – Project Lead

Entomologists Dr Archie Murchie and Dr Stephen Jess (AFBI) took on the role of scientific leads in the project having previous experience of crop protection, pesticides, sustainable agriculture, and targeted control research. Dr Francis Lively (AFBI) provided oversight from a livestock perspective being experienced in on-farm ruminant research.

The group was administered by AgriSearch who took on the role of project lead and provided an innovation broker to support the delivery of the project aims and objectives. AgriSearch also led on all dissemination activity for the project.

Members signed a partnership agreement declaring their intentions to work cohesively to deliver the objectives listed in the project action plan. Each member contributed to the compilation of the action plan and its delivery. The group met on a regular basis to discuss progress and make decisions on any matters arising, often via online platforms for ease of attendance. A WhatsApp group was also established to encourage communication between meetings and to allow sharing of photos, videos, and results. Further guidance was also sought when required from an appointed CAFRE advisor.

Project Details

To meet the aims of the project a number of actions were planned and undertaken for the delivery of individual objectives.

Training Workshop

A training workshop was delivered by the entomology team at AFBI for all operational group members in January 2021. The training covered the topics of leatherjacket biology, lifecycle, their impact on grasslands and population sampling methods. The aim of the training was to ensure all operational group members had the same base level of knowledge on the topic being studied and to set the scene for planned on-farm activity within the project. The workshop was conducted via an online platform due to COVID-19 restrictions at the time.

Online Survey

Being the first study to address leatherjackets in grassland within Northern Ireland for many years a number of assumptions were made based on historical research and anecdotal information when designing the project plan. To better understand the current leatherjacket challenge in Northern Ireland, a farmer survey was undertaken to examine the geographic spread of leatherjacket presence in Northern Ireland and identify potential factors that may increase the likelihood of leatherjacket presence.

For ease of data collection across the province, the survey was created and issued using an online platform. To ensure a high response rate the online survey was designed with ease of completion at the forefront and could be completed in a maximum of 10 minutes. A range of open-ended, closed, single and multiple choice questions were used as appropriate. The online survey was made available via an online link on the AgriSearch website and was publicised regularly via AgriSearch social media channels, the Northern Ireland farming press and via CAFRE circulation to Business Development Group members. Its intended respondents were Northern Ireland grassland farmers. The online survey was launched in July 2021 and closed in October 2021.

Leatherjacket Sampling on Farm

Leatherjacket populations were sampled on the participant farms three times over the course of the project in spring 2021, 2022 and 2023. In 2021 five fields were selected from each farm at random with the results forming a 'baseline'. In 2022 targeted selection was undertaken with fields chosen based on their risk and likeliness to have potential leatherjacket issues. Where possible, the fields sampled in 2022 were revisited in 2023 and sampled again. Sampling of leatherjacket populations on participant farms was conducted by individuals from AFBI.

Four additional farms were sampled in May 2022. The additional farms sampled had indicated that they had significant leatherjacket problems in the online survey and were happy to be contacted for further questioning. Two fields which were believed to have leatherjacket presence were sampled at each of the additional farms. The additional sampling was conducted by individuals from AgriSearch following training from AFBI.

Leatherjacket Species Prevalence

According to the literature, the predominant leatherjacket species present in Northern Ireland is *Tipula paludosa* (Tipulidae: Diptera) but *Tipula oleracea* is also prevalent. The life cycle of each differs and can therefore impact the timing of any IPM strategy implementation. Species identification was undertaken at the time of sampling in year one (2021) to determine if the assumption that *T. paludosa* is the main pest of grassland in Northern Ireland remains correct.

Population Sampling Methodologies

Leatherjacket population sampling can be conducted via a timely but accurate soil core methodology or via a simpler extrapolation method. Both methods were undertaken when sampling in year one (2021) to determine if the simpler method is more accessible but still representative for the purposes of this study and for future on-farm sampling efforts.

Collation of on-farm data

A selection of information was collected and collated from the participant farms over the course of the project to allow for correlation between influencing factors and leatherjacket prevalence to be studied. This information also contributed to assessments of the impact of leatherjackets and the identification of practical mitigation strategies.

Information gathered included farm maps and individual field details including soil type and characteristics, grazing regimes, grass management strategies, seasonal grass yields and anecdotal information regarding past leatherjacket problems and any prior mitigation methods implemented.

To further records already held on farm soil sampling and analysis was carried out in January 2022 on the fields selected for year two sampling (targeted for known current or past leatherjacket issues). Analysis included standard pH, P and K alongside a broader suite of trace elements. Twenty fields were soil sampled in total to determine soil chemical analysis, soil textural classification and soil microbial index. Leatherjacket population results from the same fields were then analysed to determine if any significant relationships or patterns emerged.

Climate and weather data was also collected. To do so two weather stations were installed and a further existing weather station utilised alongside historic weather information for Fermanagh from AgriSearch GrassCheck records.

Validation of Predictive Model

A validation exercise of an historical climate model was undertaken with the intent of providing Northern Ireland farmers with an annual prediction of leatherjacket severity risk to aid them in their IPM planning and sward management decisions. The model was obtained, and current and historical weather information used alongside known lifecycle and population dynamics to validate its effectiveness and accuracy.

IPM Strategy Planning

As a result of actions undertaken and information collected, a suite of possible mitigation strategies that would fit within an IPM strategy was drafted. From this a core suit of options were pulled together based on feasibility, practicality, cost-benefit, and likely effectiveness. Options were discussed and debated at both internal group meetings and public discussions with wider groups of farmers.

Dissemination Activity

A suite of dissemination activity was planned and undertaken throughout the course of the project to share both generalist information on leatherjackets as well as project activity and outcomes as they arose.

Project Funding

The delivery of this project was supported via the European Innovation Partnership (EIP) Scheme in Northern Ireland which is jointly funded by the European Agricultural Fund for Rural Development (EAFRD) and the Department of Agriculture, Environment and Rural Affairs (DAERA).

Each project had a maximum budget of £120,000 available for the delivery of planned activity over the duration of the project. This project did not exceed the amount of funding available.

Total budgeted and claimed costs – £79059 (TBC)

Approximately 17% of funding was allocated to project dissemination and promotion and 20% allocated to project administration. The remainder was allocated to direct activity in the delivery of the project.

No capital funding was obtained for this EIP project via the available channels.

Any additional or ineligible activity was funded by AgriSearch, the lead partner within the Leatherjacket Mitigation Strategies Operational Group.

Project Results and Outcomes

Online Survey

In total, 335 online survey responses were collected. A full report of the findings is available in *appendix 4*. In summary the main findings from the survey were as follows:

- Of the 335 respondents to the Leatherjacket survey, 226 (67%) had experienced leatherjacket presence within grassland.
- Of those who experienced leatherjacket presence, 110 (52%) of respondents experienced presence annually, a further 37% experienced leatherjacket presence every few years.
- However, of those who observed leatherjacket presence on farm, only 29% experienced presence across the majority of the farm.
- 74% of farmers who experienced leatherjacket presence observed significant reduction in grass growth and availability on farm.
- The problem of leatherjacket presence has increased in the past 5 years, with 60% of farmers observing increased leatherjacket levels.
- Leatherjackets are a significant problem in the west of the province, with a leatherjacket incidence rate of 92% in Fermanagh and 74% in Tyrone in those surveyed
- 60% of the leatherjacket incidences in Fermanagh occurred annually, and 52% in Tyrone.
- While many farmers experienced leatherjacket infestations across a mixture of fields, common factors that were observed included infestations being mainly on wetter ground or through arable reseeds.
- Common methods to control leatherjacket populations included using spray (in the past), rolling and grassland management, however a large proportion of farmers are taking little or no action to mitigate against the impact of leatherjackets.

The results of this online survey clearly indicated the necessity for further leatherjacket research to identify and encourage uptake of measures to mitigate infestation risk and the resulting reduction in grassland availability associated with leatherjacket presence.

Population Sampling Methodologies

In 2021 two sampling methods were used to determine leatherjacket density within fields. The first method was soil core sampling which occurred in every field within the core study area and followed methods outlined in Blackshaw & Coll (1999). Ten soil core samples (taken using a 10 cm diameter soil corer to a depth of 5 cm) were collected per field and analysed through a laboratory washing and sieving process. A jet of water is used to break down and wash through a soil core sitting on a 5 mm sieve, with a 2 mm below. Contents of the sieves are floated off in saturated brine.

The second method was brine flotation sampling (Stewart & Kozicki 1987) where a saturated salt solution was placed in 10 cm diameter plastic pipe inserted into the ground for c. 20 minutes. This method was used in a subset of farm fields. Leatherjackets were sampled during March-April 2021. Once the number of leatherjackets per sample was determined, the estimated density of leatherjackets on average per hectare were calculated using standard methodology.

There were 10 fields in which both the brine flotation method and soil core sampling methods were simultaneously deployed. Both methods were highly and significantly correlated ($r_s = 0.746$, $P = 0.0107$) as illustrated in *figure 1*.

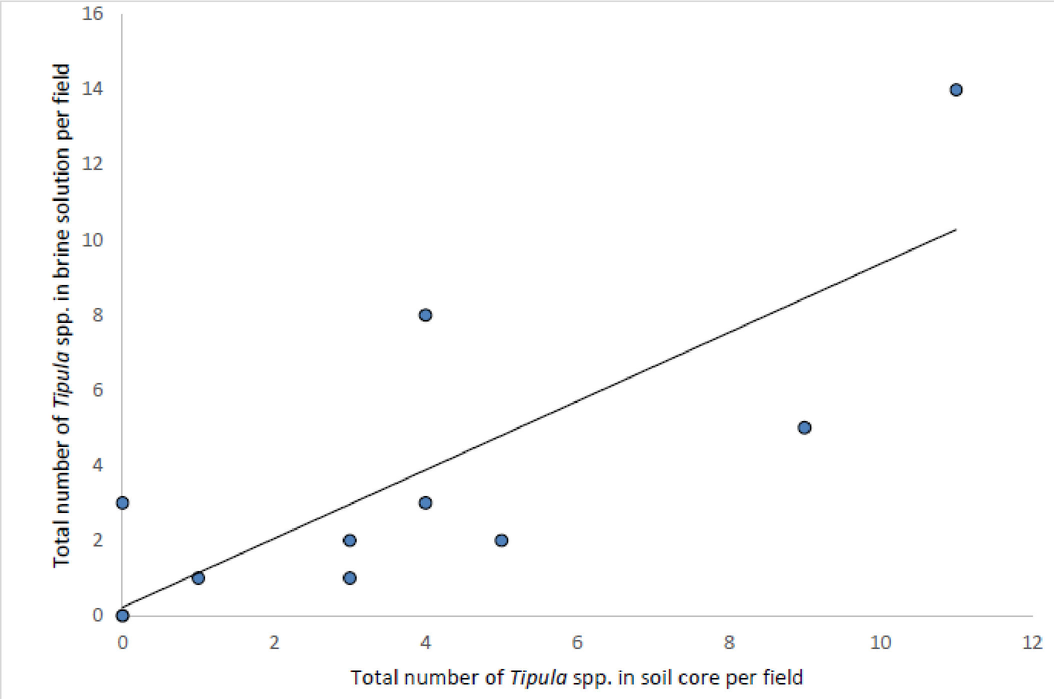

Figure 1 – Scatterplot with trendline comparing the number of leatherjackets collected from soil cores and brine flotation methods

Although the sample size was small, the significant correlation between the soil core and brine flotation sampling method infers that brine sampling is a reliable means of assessing leatherjacket density, comparative to soil cores. It can be readily deployed and used by farmers to assess population density of *Tipula* spp. and provide thresholds for assessing leatherjacket impact on grassland fields. In their more extensive test of this method, Stewart & Kozicki (1987) found that the brine sampling method was 94% similar to figures obtained by heat extraction.

Leatherjacket Species Prevalence

Ten soil core samples were collected per field in 2021 (22 fields) and analysed through a laboratory washing and sieving process which collected individual leatherjackets that were then stored in ethanol, counted, and analysed microscopically to identify species. The identification of *Tipula* species was done morphologically based on the shape of the anal papillae (Brindle 1959).

All leatherjackets recovered from the soil cores were *T. paludosa*. This agrees with the findings of Humphreys et al. (1993), who found that *T. paludosa* predominated in NI, with only one field out of 75 having *T. oleracea*. However, adult tipulids were observed on the wing in an additional heavily infested field sampled in 2021 and, given the time of year, these were almost certainly *T. oleracea*.

Leatherjacket Abundance on Farm

<u>2021</u>

In year one for each participant farm, a random selection of five individual farm fields were selected based on farm and field data provided to determine the abundance of *Tipula* spp. One additional farm requested a survey, and two highly infested fields were investigated (not randomly selected) for leatherjacket burden. Therefore, a total of 22 fields were sampled.

In the 20 fields randomly selected the leatherjacket populations ranged from 0 to 1.4 million on average per hectare but with the majority of the fields (90%) having an estimated less than 500,000 leatherjackets on average per hectare. For leatherjackets to markedly reduce grass growth in established pasture an estimated population density of 1 million leatherjackets per hectare is required.

In the two additional fields that were investigated, fields were identified on the basis of having a high level of damage caused by leatherjackets, and in one of these fields, there were an estimated 3.3 million leatherjackets per hectare, with a neighbouring field having an estimated 700,000 leatherjackets per hectare.

2022

During spring 2022, leatherjacket populations were sampled using the brine extraction method. A total of seven farms were sampled which included the four farms involved directly in the EIP project and three additional farms in the locality. Two to eight fields were sampled per farm, giving a total of 31 fields sampled. Fields were selected based on known or suspected past or current issues with leatherjackets.

Seven fields (23%) were above the 1 million leatherjackets per ha threshold where control would be economically justified, as illustrated in *Figure 2*, and 16 (52%) were above the 500,000 leatherjackets per ha where economic damage is starting to occur. Two farms had no leatherjacket problems, and two had significant leatherjacket problems on several fields. The highest level of infestation was a field with an estimated 4.5 million leatherjackets per ha which represents a significant risk to the sward.

2023

In 2023 sampling took place only on the four operational group member farms, in the same fields as had been sampled in 2022. Twenty fields in total were sampled. Seven fields (35%) were above the economic threshold, as illustrated in *figure 3*, and 12 (60%) above 500,000 leatherjackets per ha. The greatest estimated leatherjacket population was 5.5 M per ha, which was the highest recorded in the study.

There is a suggestion that leatherjacket numbers may be building up year-upon-year in the absence of control measures. The idea being that chlorpyrifos not only provided local control but also had a regional damping effect on leatherjackets and subsequently adult craneflies. The lack of chemical control coupled with milder wetter winters, could possibly increase regional leatherjacket problems unless alternative management steps are implemented. The 2022 and 2023 samples were taken largely from the same fields, and there was no evidence of a statistically significant increase in leatherjacket populations between the two years. For example, the highest leatherjacket population in 2022 was in a field with 4.5 M per ha which dropped to 510,000 in 2023. Conversely, the highest field in 2023 was 5.5 M per ha but had previously been an unremarkable 510,000 in 2022. This highlights the sporadic nature of leatherjacket infestations on individual fields, which may be associated with local topography and wind deposition of egg-laying females.

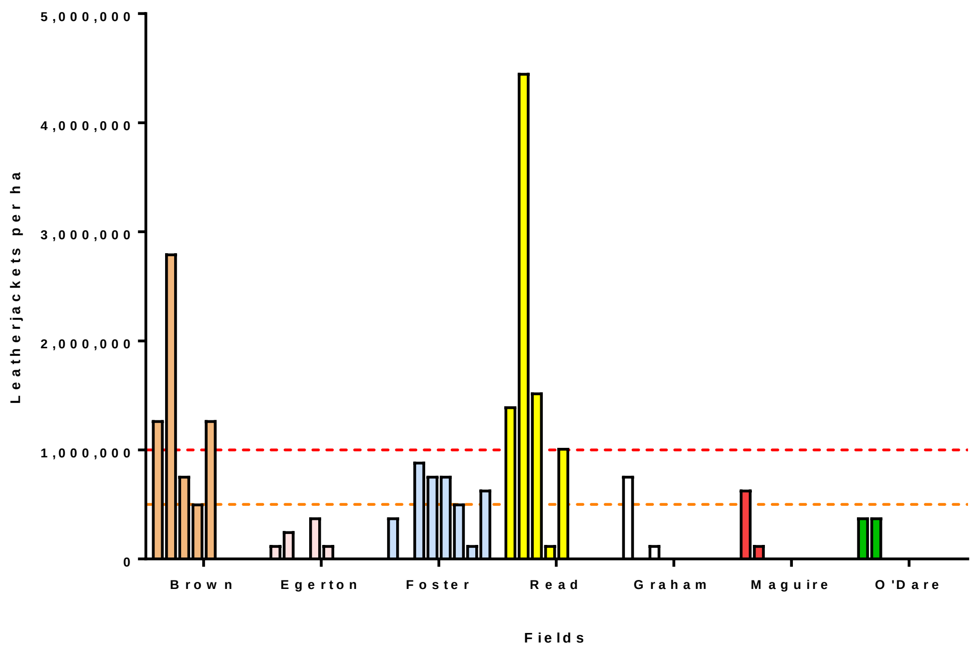

Figure 2 – 2022 leatherjacket counts derived from brine-pipe sampling Fermanagh fields and extrapolated to millions per hectare. Farm name is on the y-axis, with fields on the same farm grouped by colour. Red dashed line = 1 M and orange = 500,000 leatherjackets per ha.

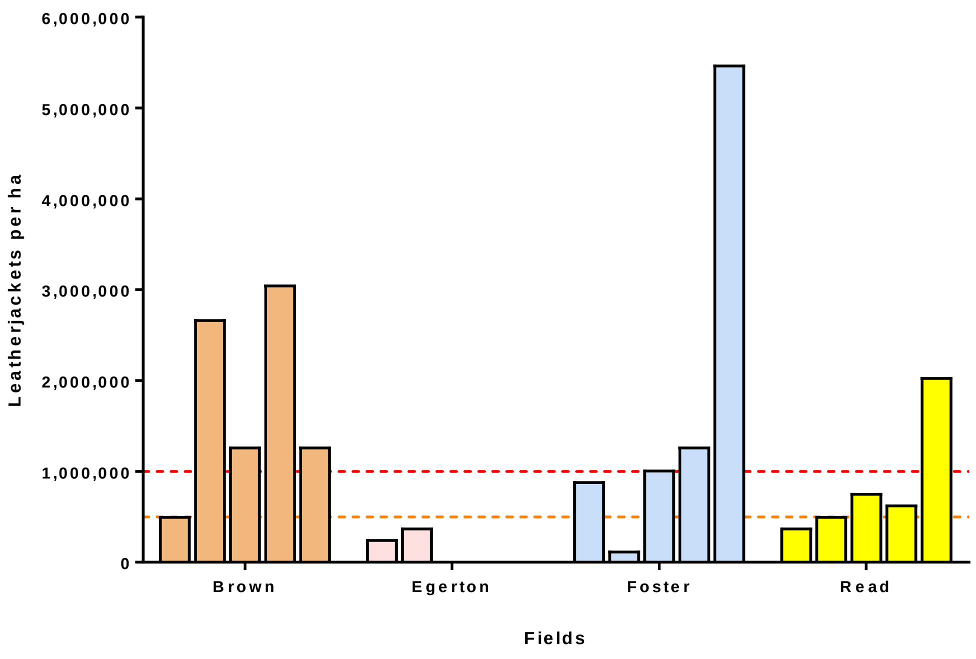

Figure 3 – 2023 estimated leatherjacket populations per ha derived from brine-pipe sampling Fermanagh fields. Farm name is on the y-axis, with fields on the same farm grouped by colour. Red dashed line = 1 M and orange = 500,000 leatherjackets per ha.

The mean number of leatherjackets per year over the four farms was in 2021 = 470 K, in 2022 = 930 K and in 2023 = 1.1 M (*Table 1*). The mean leatherjacket population in NI from 1965 to 1982 was 520 K per ha (Blackshaw 1983). This could infer that leatherjacket populations are increasing; however, our study does not constitute a random sample in the years 2022 and 2023, so this cannot be verified without future work. Nevertheless, the relatively high proportion of fields with leatherjacket populations above the 1 M per ha threshold (23% in 2022, 35% in 2023) puts the results from this study in the upper range of those populations estimated by Blackshaw (1983) over the period 1965-82.

Table 1. Estimated mean leatherjacket populations per ha for each farm and each year, as derived from brine-pipe sampling.

Farm	2021	2022	2023
Brown	891,723	1,324,846	1,757,968
Egerton	127,389	148,621	127,389
Foster	700,640	552,019	1,757,968
Read	152,867	1,707,013	866,245
Mean	**468,155**	**933,124**	**1,127,393**
Grand mean			**842,891**

Correlation with Soil Characteristics

Although the sample size was small and one data point was excluded, there was some evidence of soil characteristic effects, as illustrated in *figure 4*. Fewer leatherjackets were recovered in fields with a pH approaching neutrality ($F=10.57$, d.f.=1,15, $P<0.01$). Leatherjacket counts were positively related to phosphate and potassium levels ($F=6.95$, d.f.=1,15, $P<0.05$ and $F=4.60$, d.f.=1,15, $P<0.05$, respectively), whilst there was no relationship with magnesium levels.

The relationships between soil characteristics and leatherjacket counts presented here requires some caution and further analyses because there are likely to be interacting factors involved. Nevertheless, the relationship between soil pH and leatherjackets is supported by anecdotal evidence from farmers who found leatherjackets more abundant in slightly acidic soils. The apparent positive relationship with phosphate and potassium levels and leatherjacket counts has not been seen before and requires more investigation.

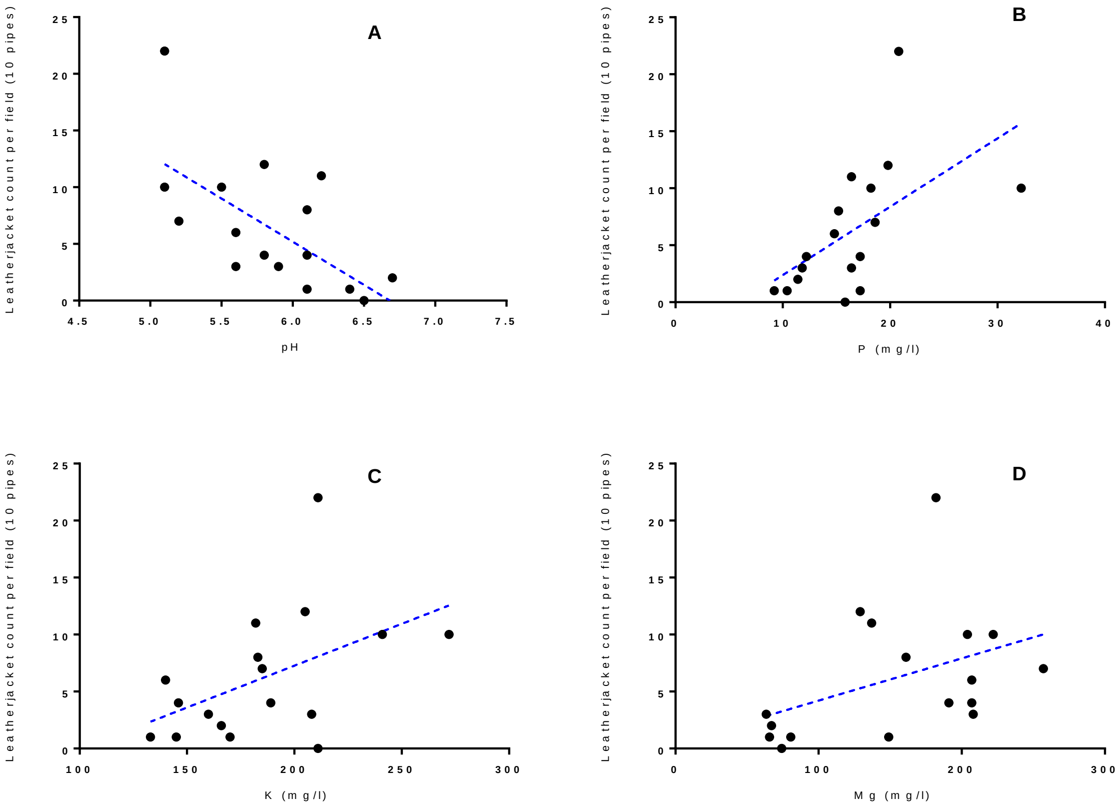

Figure 4 - Relationship between soil characteristics and leatherjacket counts in grassland fields. One point (leatherjacket count =35) is excluded as an outlier. Trend line (dotted) is fitted by linear regression.

Economic Impact

Economic thresholds are a measure of the economic significance of pest numbers within a crop. They are a cost / benefit analysis of the value to be had in enacting control measures. Normally measured in counts of pests per area or pests per plant, a count above the economic threshold justifies intervention, whereas one below the threshold indicates that control measures are not economically viable. Economic thresholds are therefore comprised of two factors: the damage caused to the crop's value by the pest; and the cost of control. In theory, economic thresholds should be flexible and reflect changing market prices of the crop and cost of control, but in reality, they are effectively fixed.

The economic threshold for leatherjackets in grassland is generally accepted as 1,000,000 per ha (Blackshaw & Coll 1999), although there are a range of thresholds given in the literature (summarised by Moffat 2022). Working in Fermanagh, Blackshaw (1984) used insecticide treated plots to determine the yield loss caused by leatherjackets. He gave the estimate of 50 kg DM loss per 125,000 leatherjackets per ha, if controlled in March. However, if controlled in September the yield loss estimate is increased by a factor of 2.72. This gives an expected yield loss of 1.09 g DM per leatherjacket (Blackshaw 1985). Using the average leatherjacket population per field of 520, 130 per ha in Northern Ireland, this gave a herbage DM loss of 566 kg per ha (allowing for rounding errors). Blackshaw (1985) used these figures to give an estimated economic cost to Northern Ireland of £15 million, assuming a herbage cost of 3.5p/Kg DM.

Herbage costs and values have increased substantially since 1985. Using an inflationary uplift from Blackshaw's original estimate, the current cost is 10p/kg, whilst Barenbrug estimated that grass has a DM value of 14p/kg and Douglas Green Consulting Limited give a cost of 17p/kg. We have chosen

14p/kg as the DM value and used this to estimate the cost of leatherjacket herbivory at different pest densities, set out in *table 2*.

There are considerable caveats with this approach. The population estimates are huge extrapolations from cm^2 to ha, and there may be much variability in spatial distribution of leatherjackets throughout the field. Likewise, the estimates of leatherjacket herbivory could easily vary dependent on field characteristics. Lastly, even the estimate of grass DM value is subjective and reliant on yield, cost of inputs and other factors that will vary between intensive and extensive production system. Other advisory pamphlets have given greater impacts of leatherjackets. Buckingham et al. (2013) gave a population of 1,000,000 leatherjackets/ha as causing 2.5 tonnes DM lost and costing £753 to replace lost crop energy with concentrates.

Table 2. Leatherjacket counts in brine pipes extrapolated to leatherjackets per ha. Text in red denotes the economic threshold of 1 million leatherjackets per ha

Leatherjackets per 10 brine pipes	Leatherjackets per ha	DM loss (kg/ha) assuming 1.09 g /leatherjacket	Cost (£) assuming grass DM costed at 14p/kg
1	127,389	139	19.44
2	254,778	278	38.88
3	382,167	417	58.32
4	509,556	555	77.76
5	636,945	694	97.20
6	764,334	833	116.64
7	891,723	972	136.08
8	1,019,112	1,111	155.52
9	1,146,501	1,250	174.96
10	1,273,890	1,389	194.40
20	2,547,780	2,777	388.79
30	3,821,670	4,166	583.19
40	5,095,560	5,554	777.58

Predictive Model

It was proposed at the beginning of this project that a climate model could be used to predict leatherjacket severity in a given year to aid on farm decision making.

Annual surveys of leatherjacket prevalence were previously conducted in Northern Ireland (Blackshaw 1983). This entailed sampling c. 20 to 60 fields in November to February. Twenty soil cores were collected from each field and taken back to the laboratory for sieving and washing to extract leatherjackets. Data collected from the leatherjacket surveys 1970 to 1984 were used to construct a climate-based leatherjacket model (Blackshaw 1990; Blackshaw & Perry 1994). Because of this model, the annual leatherjacket surveys were discontinued. It was proposed that the model could give a sufficiently accurate forecast of the mean annual populations to enable pest management decisions to be informed, without the cost of annual surveys.

The model is a multiple regression model as follows.

Variable	Regression coefficient	t-value
Constant	-3780.1	-3.07
March rainfall (mm)	3.3	2.3
July rainfall (mm)	-3.17	-2.9
Winter rainfall* (mm)	-2.49	-3.93
February chill*	1.78	2.56
October temperature (°C)	-46.16	-3.7
December humidity	53.13	4.45

*Winter rainfall = November + December rainfall. Chill factor = ((Wind speed x humidity x 35) x air temperature).

An attempt was made to re-validate the model using weather data from Aldergrove during 1986-87, as was used in the original paper (Blackshaw 1990). However, a number of issues arose in the calculations. First, there is discrepancy in the 'chill factor' calculation which is given as:

Chill factor = ((Wind speed x humidity x 35) - air temperature) (Blackshaw 1990)

and

Chill factor = ((Wind speed x humidity x 35) x air temperature) (Blackshaw & Perry 1994)

Second, the units for wind speed and humidity are not given. Using the second chill factor equation and giving windspeed as km/h and humidity as % gave a leatherjacket population of 251, 998 compared to 459, 652 in the original paper. These calculations were checked by AFBI's in-house statistician and by the author of the original paper Dr Rod Blackshaw. Given that the papers are essentially scientific summaries of the work, not detailed worksheets and that the original calculations are no longer available after 33 years, it is difficult to determine where the discrepancies lie. It is either that the weather data used are different to the original or that the equation has been interpreted incorrectly. Nevertheless, without a clear step-by-step process to reconstruct the model, it was not possible or appropriate to use it with current weather data to estimate leatherjacket populations in the EIP study.

Leatherjacket Mitigation - IPM Framework

Following discussions within the EIP group and feedback from the webinars, a draft IPM framework was constructed (see *appendix 5)*.

Unlike insecticidal control, which can be viewed as a 'quick-fix', the IPM framework proposed is a multi-season approach, which seeks to reduce and maintain the tipulid populations at economically non-damaging levels; whilst at the same time protecting soil health, especially macro- and micro-arthropods (e.g. Collembola and soil mites) which would be killed by insecticide application. Limited leatherjacket populations may even have beneficial aspects as a food item for farmland birds (McCracken et al. 1995) and because their burrows aid water infiltration (Holden & Gell 2009).

For the framework to be successful, there is also a spatial component. As tipulids can fly and lay their eggs in surrounding fields, the framework must be enacted at a farm level and not for individual fields. It is even preferable that a regional (also termed areawide) approach is taken to manage tipulid populations as has been used for other insect pests (e.g. cotton boll weevil in the US) (Faust 2008); however, this is out with the control of individual farmers.

Recognising that there will be no silver-bullet replacement to chlorpyrifos, the framework proposed includes a combination of standard agronomic approaches (drainage, reseeding, liming) coupled with tight autumn grazing and regular monitoring of leatherjacket counts. A number of factors (e.g. slurry application, silage cuts, rush control, natural enemies, multi-species swards) that have an influence on leatherjacket populations are factored in for further study. It employs a multi-season management approach as illustrated in *Table 3*.

Table 3 – Proposed mitigation options within a multi-season IPM approach

Implementation Timeframe	Mitigation Options
Long-Term (10 seasons)	• Drainage • Re-Seeding • Soil pH • Monitoring
Medium-Term (2-3 seasons	• Establishing a brassica break crop • Multi-species Swards • Encouraging natural enemies
Short-Term (annual)	• Sward Management • Insecticides • Biopesticides

Drainage

The family Tipulidae has a large number of species which are aquatic or semi-aquatic in the larval stage, including Tipula (*Yamatotipula*) aino which is an aquatic pest of rice seedlings (Jong et al. 2007). Correspondingly, terrestrial species such as *T. paludosa* are adapted to moist soil conditions. Tendency of a field to waterlogging was a factor contributing to leatherjacket prevalence in Scotland (McCracken et al. 1995) and feedback from farmers and contractors in this study suggests that well-drained fields have fewer leatherjacket problems. However, Blackshaw & Coll (1999) suggests that soil moisture is unlikely to be a limiting factor in leatherjacket survival in Northern Ireland and drainage of fields could exacerbate the problem, as high rainfall and flooding could drown leatherjackets (Blackshaw 1983; Blackshaw 1990). The only study on this topic was inconclusive (Blackshaw & Coll 1999). On balance, we suggest that drainage, as part of good grassland agronomy, is likely to be beneficial in limiting excessive leatherjacket populations. However, we are cognisant of the negative impact of flooding on leatherjackets at different life-stages, and also the uncertainties as to how this relates to changing weather patterns under climate change.

Reseeding

Reseeding of swards is dependent on the intensity of grassland utilisation. For intensive dairy farms, reseeds could be every 8-10 years, or more frequently where a crop rotation is in place. Whereas for extensive beef or sheep systems, swards may never be reseeded. A traditional approach is to reseed when the proportion of sown species is less than 50% in the sward (D. Patterson, pers comm.). It is estimated that 10% of intensive grassland should be reseeded annually. Reseeding impacts on leatherjackets because cultivation kills the larvae in the soil or exposes them to bird predation and disrupts the availability of a host crop. Leatherjackets may also show a preference for weed grasses such as couch grass (*Elymus repens*). Earlier in this study, we provided some tentative evidence that grassland fields reseeded after 2010 had lower leatherjacket populations than those reseeded earlier or not at all. This supports the contention of Kell (1988) that following reseeding leatherjacket populations can take 7-10 years to recover (Blackshaw & Coll 1999). The timing of reseeding during the year may also impact on leatherjackets. Most grassland reseeding takes place in the autumn August / September, with about one-third of drilling occurring in late spring April / May. Spring reseeding and cultivation may have the advantage of killing leatherjackets when they are large and vulnerable to damage and predation. Summer cultivation with a fallow period before reseeding in autumn will have a similar effect. Blackshaw & Coll (1999) considered autumn reseeding to have most impact on leatherjackets, as long as cultivation disrupted cranefly emergence, flight, and egg-laying. To be effective, reseeding must disrupt the soil. Direct-drilled or minimum-tilled reseeds are likely to be vulnerable to leatherjacket herbivory if larvae are not killed.

Soil pH

This study showed a negative relationship between leatherjacket counts and soil pH, suggesting that leatherjacket problems are more likely in acidic soils in Fermanagh. In a more extensive study in the RoI and Scotland, Moffat (2022) found no explicit relationship with pH but did with a range of soil micronutrients. Manganese and iron content had a negative relationship with leatherjacket counts, whereas aluminium had a positive one. Manganese and iron become more available in acid soils, which would suggest the opposite to what we found in Fermanagh and that soils approaching neutrality are more suitable for leatherjackets. Conversely, aluminium becomes more soluble in acid soils, which can inhibit plant growth. Moffat (2022) explained the positive relationship between aluminium and leatherjackets by suggesting that aluminium toxicity may stress the plants and make them more susceptible to leatherjacket herbivory. Clearly there are complex interactions amongst soil organic matter, soil moisture, micronutrient availability, plant health and pH. Similar, to the advice for drainage, whilst acknowledging the contradictory findings in the literature, we would recommend liming acidic soils to promote good grass growth and inhibit leatherjacket damage.

Monitoring

Monitoring on farm leatherjacket numbers is fundamental to an integrated pest management approach. To take appropriate action against pests, it is necessary to assess pest densities within the crop and whether they are at a level that is causing, or likely to cause, damage. In addition, regular monitoring can help to identify problem fields and benchmark progress when applying mitigation measures.

The most accurate measurement of leatherjacket prevalence is to take soil cores and extract larvae in the laboratory through soil washing or heat extraction. Soil washing of cores was done earlier in the project and although accurate, is time-consuming and cannot be done on farm. The use of brine pipes was developed as a DIY method of assessing leatherjacket numbers and was adopted by Dow Agrochemicals as the method in their Dursban 4® Leatherjacket Testing Kit. The efficiency of brine pipes calculated as 88%, compared to 97% for heat extraction (Stewart & Kozicki 1987). In our study, the counts derived from the brine tubes sampling was 95% of the soil washed cores, albeit at a time of year when larvae are large and noticeable. An even simpler method is to dig up turf with a spade and sort through by hand (Buckingham et al. 2013).

Brassica Break Crop

The principle of a break crop is to remove the preferred host plant of the pest species and therefore 'break' the generational cycle of the pest. Break crops work best with a monophagous pest. Leatherjackets are polyphagous and have been recorded as feeding on a range of crops, including brassicas (Blackshaw & Coll 1999). Nevertheless, brassicas have been suggested as a potential break crop to manage leatherjackets (Buckingham et al. 2013; Soil Association Scotland 2017). The rationale behind this is that whilst leatherjackets may feed on brassicas, it is unlikely that they are the preferred host crop. Brassicas contain secondary plant metabolites called glucosinolates which break down to produce compounds such as isothiocyantes when the plant is damaged. These compounds give brassicas their sharp sulphurous taste and act as a defence against herbivory. Most pests of brassicas are specialists which are adapted to feed on glucosinolate containing plants. Planting a brassica crop in a grass rotation could therefore limit leatherjacket populations but this has not been experimentally tested.

The choice of brassica break crop would need to be considered carefully, as Blackshaw & Coll (1999) found that *Tipula oleracea* leatherjacket attacks on cereals were worsened if the preceding crop was oilseed rape. They considered that the dense rape canopy prevented natural dispersal of adult craneflies and concentrated their egg-laying in the same location. Whether the same issue would occur with *T. paludosa* in a pasture system is unknown but is perhaps less likely as the biologies of the two pest leatherjacket species are different, with *T. oleracea* having two generations compared to *T. paludosa's* one. Forage rape (*Brassica napus*) or Redstart, a hybrid between forage rape and kale, which can provide alternative grazing for cattle and sheep, would be a good choice as a break crop.

<u>Multi-Species Swards</u>

Multi-species swards typically include a mixture of grasses (perennial ryegrass, timothy), legumes (clovers) and herb species (chicory, plantains). There is increasing interest in the utilisation of multi-species swards in Northern Irish pasture systems, as they have several benefits. They are more nitrogen efficient, requiring less inorganic nitrogen input. There are agronomic benefits as the deeper-rooted herb species improve soil structure and mitigate against drought conditions. Multi-species swards also have greater earthworm densities and there are likely to be above-ground biodiversity benefits as well, e.g. pollinators will benefit from the presence of clover. Multi-species swards are a good source of herbage during the summer and there is some evidence that they help reduce parasite burden in livestock.

In general, greater plant diversity within a crop benefits pest management. There are two hypotheses why this might be so. First, the mixed crop presents a range of palatable and less palatable plants to the pest, along with mixed cues for attraction and oviposition. This can disrupt the pest's normal feeding behaviour. Second, greater plant diversity may support more natural enemies of pests compared to a monoculture. The only work on the impact of multi-species swards on leatherjackets is that of Aisling Moffat for her PhD studies (Moffat 2022). In a series of glasshouse studies, she inoculated single species (ryegrass, timothy, red clover, white clover, chicory, plantain) and a mixed species (all of the aforementioned single species together) pots with leatherjacket larvae. Similar to other findings in the literature, in single species pots white clover was most affected by leatherjacket herbivory with a significant reduction in shoot and root biomass. Comparing the performance of species within a multi-species plot, leatherjacket herbivory reduced overall shoot biomass but this was only significant for the ryegrass (albeit this made up the largest proportion of the shoot biomass). However, in one study leatherjacket herbivory increased root dry weight, possibly due to an increase in chicory and plantain root weight. Differential herbivory by leatherjackets could therefore increase the persistence of the multi-species sward by preventing domination by grasses. There was also some evidence of limited leatherjacket herbivory stimulating compensatory plant growth. The outcomes of this study are therefore not straightforward and different experiments gave different results, suggesting a complexity of interactions that need to be further teased apart. Nevertheless, the potential of multi-species swards to tolerate leatherjacket herbivory compared to single species swards could make them an important component of an IPM strategy.

Natural Enemies

There is a level of natural control of pests within the environment provided by predators, parasites, and pathogens. One of the tenets of IPM is to safeguard and enhance natural control, which can often be under-utilised by farmers as it is unrecognised. Blackshaw & Coll (1999) summarises the natural enemies attacking leatherjackets. These include birds such as starling and rooks, which by their feeding can indicate that a significant leatherjacket population is present. The RSPB reserve on Islay actively manages grassland to maximise leatherjacket-feeding by choughs (*Pyrrhocorax pyrrhocorax*) (Trask et al. 2020), as they are such a crucial component of the birds' diet (McCracken et al. 1992; Reid et al. 2008). More cryptic natural enemies are the insect predators, insect parasitoids and pathogens. Predatory ground beetles of the family Carabidae are important generalist predators in agriculture and have been found to attack and eat leatherjackets (Chapman 1994) but, as with many natural enemies, their impact at the population level has not been assessed in the field. A minute parasitic wasp *Anaphes* sp. (Hymenoptera: Mymaridae) as yet unidentified to species, was reared from *T. paludosa* eggs (Blackshaw & Coll 1999). In eggs collected in Northern Ireland, this parasitic wasp was reared from 44% of them; however, the extent to which this ultimately impacts on leatherjacket population levels is unknown. Another potentially important natural enemy is Tipula iridescent virus, which is common in field populations but it seems limited in its ability to cause epizootics to reduce populations. Blackshaw (1990) commented that there was disparity between the distribution of leatherjacket populations and the presence of an insect parasitic nematode, *Neoaplectana bibionis*, in Northern Ireland. Again, there is no substantiated evidence of a meaningful impact on populations but tantalising field observations. Clearly, more needs to be knowns about the role of naturally existing predators and parasites in leatherjacket life history dynamics. Even if each natural enemy is only reducing the leatherjacket population by a small percentage the cumulative impact of several at different life stages can be an important component of an IPM approach.

Sward Management

Stocking levels and grazing intensity can have significant effects on grassland invertebrates (Helden et al. 2015; Purvis & Curry 1981). Most of the recent work on grassland management in Europe has examined this from a conservation of biodiversity perspective (Bell et al. 2006; Blake et al. 2011; Dicks et al. 2020; Torma et al. 2023; Woodcock et al. 2005). However in the 1980s in New Zealand, there were studies on using grazing animals as a means of pest management, stimulated by the withdrawal of cheap organochlorine insecticides – a situation somewhat similar to the withdrawal of chlorpyrifos for leatherjacket control. East & Pottinger (1983) gives an overview of the use of grazing animals to manage pests, with the general consensus that increases in stocking rate, or the intensity of defoliation reduces populations of phytophagous grassland insects. They list several reasons why this may be so: 1) direct mortality through grazing or trampling; 2) removal of living space, i.e. changes to the physical habitat of the pasture; 3) effects on microclimate of the sward, which may expose eggs or early instar larvae to high temperatures and/or desiccation; 4) changes in pasture productivity. There are some examples of soil pest management using livestock. Grey field slug (*Deroceras reticulatum*) in New Zealand were reduced by 68% by stocking plots with the equivalent of 500 hoggets per ha for two nights. Similarly, chafers (Scarabaeidae) biomass was affected by sheep stocking density but the relationship was quadratic (curved), with a slight increase in chafer biomass with a moderate stocking density level but declining substantially at higher levels (Roberts & Morton 1985).

There is strong anecdotal evidence that sward management, in particular close grazing in late summer and autumn can reduce leatherjacket prevalence. This has been put forward by farmers in the discussion groups and was also hinted at in the literature. The reasons suggested for this are two-fold. First, close grazing during the egg-laying period could reduce adult cranefly mating, settling and oviposition sites. It is considered that clumps of grass form suitable oviposition sites (Jones & Jones

1984; Soil Association Scotland 2017). This may also be the reason why leatherjacket populations were lower in a field treated with herbicide (Agritox MCPA) for rush control compared to an immediately adjacent field. The second reason could be that close grazing opens up the sward and alters the soil microhabitat at a crucial time for early instar larval survival. Close grazing for leatherjacket control has not been investigated experimentally but would seem a potentially key strategy for IPM as it is compliant with existing farm practices. In a similar way, the number of silage cuts could also impact on leatherjacket prevalence. However, how this interacts with leatherjacket populations is not clear. McCracken et al. (1995) found that fields with more than one cut of silage had lower leatherjacket numbers. However, Moffat (2022) found that 5 silage cuts was positively correlated with leatherjacket counts. It would seem that the height of the sward during the oviposition period and early leatherjacket instars is crucial.

Slurry Application

Leatherjacket sward destruction in Northern Ireland has been associated with shallow rooting soils and heavy applications of slurry in the autumn. Under these conditions, plants are stressed and find it difficult to recover from attack (Blackshaw & Coll 1999). Soils with a high level of organic matter (especially those with a discrete surface horizon) are good at retaining water (Curry 1987a), and McCracken et al. (1995) found the use of organic fertiliser to have a positive effect on leatherjacket numbers. However, no relationship was found between leatherjacket numbers and soil percentage loss on ignition (a measure of organic matter content), and therefore the use of organic fertiliser was probably influencing leatherjacket numbers through an effect on sward productivity and nutrient content. It is known that grassland soil invertebrate populations generally benefit from moderate applications of organic manure, and such relationships with sward nutritional quality have been found for earthworms and other herbivores (Curry 1987a; Curry 1987b).

Insecticides

Subsequent to the withdrawal of approval for use and storage of chlorpyrifos in 2016, there are no recommended chemical controls for leatherjacket infestation in agricultural grassland.

Chlorantraniprole, a broad-spectrum insecticide has been approved for the control of leatherjackets in sports pitches, golf courses, racecourses, bowling greens, airfields, and professional application to commercial and residential lawns, subject to specific restrictions on the percentage of the area being treated. This is not suitable in an agricultural context nor is it economically viable.

Biopesticides - garlic compounds

Garlic *Allium sativum* L. juices and extracts form the basis of several commercially available pest control products, but the performance of these products is variable, possibly due to lack of quality control upon batches of materials in the manufacturing process (Prowse et al. 2006). A commercially produced food grade garlic juice did have a toxic effect on two target dipteran pests, cabbage root fly (*Delia radicum* (L.)) and housefly (*Musca domestica* L.). The magnitude of the effect was dependent on the life stage considered, with the egg and adult stages most susceptible.

Under glasshouse conditions, a targeted soil application of Ecoguard garlic granules killed cabbage root fly larvae (Jukes et al. 2005). At the dose equivalent to the rate (0.12g product/plant) recommended for field application, insect numbers were reduced by almost 60%. Unfortunately, the insecticidal effect produced by the garlic under glasshouse conditions was not reproduced under field conditions. It appears that the active ingredient is too soluble to be effective in the field. Hence, if placed into the soil in the optimum zone for killing cabbage root fly larvae, it would soon be "leached" from this zone by rain and/or irrigation.

A field experiment in Scotland, using a garlic juice product Rigel G, conducted by the Soil Association concluded that autumn spraying of garlic compounds could be an effective strategy for leatherjacket population control (Soil Association Scotland 2018). The effect of spring spraying was indeterminable, which suggests a reduced efficacy of Rigel G on older larvae. This means that garlic spraying could be suitable for farmers who identify a high number of leatherjackets in autumn surveys, or as a preventative measure on high-value crops. Similar to biopesticides, Rigel G would be an expensive preventative measure, and might not be effective when used on mature leatherjackets. Further work is required to understand the insecticidal effects of garlic compounds more fully.

Biopesticides – nematodes and microbes

Entomopathogenic nematodes belonging to genera *Steinernema* and *Heterorhabditis* together with their symbiotic bacteria *Xenorhabdus* and *Photorhabdus*, respectively, and slug-parasitic nematodes *Phasmarhabditis* with its symbiotic bacteria *Moraxella* have been considered as promising biocontrol agents for the management of crop insect pests and slugs. These nematodes have short life cycle, wide host range, and may survive unfavourable conditions and environmental extremes. Survival and pathogenicity of these nematodes vary from 5°C to 35°C. They can be mass produced under both *in vivo* and *in vitro* conditions (Askary 2010; Ehlers 2003).

The controlling effects of two *Steinernema* species, *S. carpocapsae* and *S. feltiae*, on *Tipula paludosa* have been investigated (Oestergaard et al. 2006). Results indicated that the early instars of the insect are most susceptible to nematodes. *S. carpocapsae* provided more effective control (>80%) compared to *S. feltiae* (<50%). However, the potential of *S. carpocapsae* might be limited by soil temperatures below 12 °C.

Currently, *S. feltiae* is used for leatherjacket control in garden lawns, but the costs for use in agricultural grassland would be prohibitive at approximately £1,700 per hectare. In addition, the timing of application would require considerable precision to ensure susceptible life stage of the pest and optimum soil temperature for nematode efficacy. In addition, later application of nematodes would require significantly increased application rates to ensure effective control of leatherjackets.

Previously, the use of microbial control agents in grassland has been limited due to the availability and efficacy of synthetic insecticides. The entomopathogenic fungi *Metarhizium spp.* and *Beauveria bassiana* are available for the control of surface and subterranean feeding insects, but limited efficacy data is available (Koppenhöfer & Wu 2017).

In greenhouse tests, a number of species and strains of entomopathogenic fungi were evaluated for the control of *T.paludosa*. *Metarhizium robertsii* strain V1005 was the most virulent, causing 100% larval mortality 4 weeks post-inoculation. Eight other *M. robertsii* strains and *M. brunneum* (ARSEF 3297) caused mortality ranging between 0 and 60%, whereas strains of *Beauveria bassiana*, *Isaria fumosorosea* and *Lecanicillium longisporum* were non-pathogenic to *T. paludosa* (Ansari & Butt 2012). Laboratory experiments showed that 17 strains of entomopathogenic fungi tested varied greatly in their virulence to all developmental stages of *T. paludosa*; strain V1005 of *M. robertsii* was the most virulent of the tested strains. This strain was originally isolated from naturally infected larvae of *T. paludosa*. Other strains/species of fungi tested are known to be virulent for their respective hosts but were not pathogenic towards *T. paludosa*.

In the early 1990's, laboratory assays demonstrated that *T. oleracea* and *T. paludosa* were sensitive to the entomopathogenic bacterium *Bacillus thuringiensis* subsp. *Israeliensis* (Bti) (Smits et al. 1993). However, older larvae become less sensitive to Bti. Subsequent field experiments demonstrated that first instar larvae can be controlled effectively with relatively high dosages of commercially available

Bti products. Both application timing and dosage were considered unfavourable for large-scale practical use, with possible exception for sports fields or lawns. Further laboratory and greenhouse experiments using bait formulations with lower doses of Bti demonstrated reasonable control of third instar larvae.

Oestergaard et al. (2006) also demonstrated that results with Bti were strongly influenced by the larval stage and concentration. Against early instars in autumn between 74 and 83% control was achieved with 13 kg ha^{-1} Bti of 5,700 International Toxic Units (ITUs) and 20 kg ha^{-1} of 3,000 ITUs. Applications in spring against third and fourth instars achieved between 0 and 32% reduction. The results indicate that application of Bti and nematodes will only be successful and economically feasible during the early instars.

Despite the pressure to develop alternative plant protection products, particularly considering the continual decline of approved synthetic chemicals, there are currently no reliable alternative biological control products available for the control of grassland pests, and in particular, leatherjackets.

IPM readiness

Due to the previous reliance on insecticide control, there is a lack of empirical data on alternative control measures for leatherjackets. Whilst most of the measures recommended above are good practice for grassland management (e.g. drainage, liming, reseeding) or have accepted agronomic benefits (break crops, multi-species swards, grazing and stocking management), hence can be applied immediately, their interactive impact on leatherjacket populations are largely unknown. There are likely to be trade-offs between different measures, for example, between enhancing natural enemies and close grazing of swards. It is possible that novel synthetic insecticides or biopesticides will be developed for grassland control of leatherjackets, as these are currently available for amenity grass turf. However, given the economic cost of registering insecticides and the risk of environmental or health restrictions, an IPM strategy (which may include insecticide control) is a more sustainable approach. Readiness level is indicated within the draft IPM Framework (*Appendix 6*) using the colours red, amber, green. Green boxes represent controls appropriate for Fermanagh grassland, red are inappropriate and amber are possibilities. Boxes marked with a question-mark require further review and study.

Building bridges between farmers, the research and development community and others supporting the agriculture sector

Operational Group

The membership of the Leatherjacket Mitigation Strategies Operational Group was designed specifically to bring together complementary expertise to deliver the objectives of the project.

Farmer participation was key to the project and the project itself was focused upon addressing a farmer identified knowledge gap. Each farmer selected for membership of the Operational Group was an experienced ruminant livestock farmer, focused on maximising productivity from grassland who had experience of problems with leatherjackets and was based in the core project area of County Fermanagh, Northern Ireland. A number of the farmer members of the Operational Group participate in their local Business Development Groups and/or had participated in on-farm research in the past. They therefore had prior experience of sharing their farm information and experiences and were clearly willing to consider and make changes where necessary to improve their farming business.

Working directly with farmers in the delivery of a project is relatively uncommon for the Entomology research team at AFBI and so some adjustments had to be made to regular research procedures. The sharing of knowledge between researchers and practitioners on the ground did, however, prove to be invaluable and of great benefit to both groups; providing the wider context for research activity and ideas for additional associated research to benefit the agriculture sector.

AgriSearch, who are experienced in on-farm research facilitation acted in the coordination role to bring together the different members of the group. Initial meetings focused on knowledge exchange and the sharing of expertise to create a good foundation for activity. Bridges were built as a result of the shared interest in tacking the leatherjacket challenge being addressed by the project. On-farm sampling and activity also allowed for meetings and discussion on a 1:1 basis which further encouraged cooperation and shared learning.

Additionally, expertise has been gained from other EIP projects across the topics of project delivery and dissemination via information shared at regular EIP forum events. Such events and knowledge exchange definitely helped to ensure success across all projects.

Project Dissemination

In addition to encouraging knowledge exchange between Operational Group members, a core objective of the project was to share the aims, objectives and any outcomes with the wider agricultural sector in Northern Ireland.

Dissemination activity included the organisation and delivery of events, general media communication, direct communication with stakeholders and the production and distribution of resources.

Events included two webinars and an in-person presentation to the members of the Fermanagh Grassland Club. The first webinar took place a year into the project and focused upon an introduction to leatherjackets and their impact as well as an introduction to the project and what it hoped to achieve. The second webinar took place at the end of the project focusing on project outcomes and took place in collaboration with Teagasc (the webinar host), broadening the reach of project dissemination to farmers within the Republic of Ireland as well as Northern Ireland. Due to the COVID-19 pandemic webinars had become more prominent and familiar to farmers and industry professionals allowing this project to avail of the wider attendee reach they can provide. The webinar format also allowed speakers from England and the Republic of Ireland to present alongside those from Northern Ireland without the need to travel, maximising the benefit for attendees. A recording of the webinar was made available to view after the event on the AgriSearch YouTube channel. Having a lasting resource is another benefit of the webinar format and has led to additional views since the live event took place.

Feedback was sought from attendees following the AgriSearch organised webinar with 93% agreeing or strongly agreeing that the event met their expectations and 93% agreeing that the topics were explained in 'about right' detail'. Regarding the attendees 80% were farmers, 17% advisory or consultants and 3% trade. Written feedback included noting a preference of hearing from the farmer speaker and commenting on the need for more research in this area. One respondent commented that they had had little knowledge of leatherjackets so found the webinar extremely informative. Another respondent also highlighted that the webinar was very welcome on an important and recently neglected subject area.

The project was also invited to present the aims of the project and it's outcomes at an open meeting of the Fermanagh Grassland Club. IPM approaches being suggested by the project were discussed alongside findings of a PhD study carried out in the Republic of Ireland which had some complimentary and supplementary findings. The event promoted a good Q&A session with feedback from a wider range of farmers within the project focus area being obtained. Feedback from the Club Secretary was that the event attracted the greatest number of members all season which showed the level of interest in the topic from grassland focused farmers in Fermanagh across the beef, sheep and dairy sectors.

General media communication included the issue of Press Releases to local farming media on a regular basis to both promote the project and highlight key activity and findings as it arose, as well as the promotion of planned events. Pick-up of press releases was high across the three primary agricultural publications. AgriSearch also consistently promoted the project across its social media channels and website broadening the reach.

On-fam leatherjacket population sampling methods and IPM approaches to mitigate against infestation were directly communicated to farmers via representation at a trade stand at the AFBI Grassland Open Day event at AFBI, Loughgall. One-to-one conversations were supplemented with a Poster, take home leaflets and an article in the wider event brochure. Footfall on the day was consistent, with a number of farmers communicating their surprise at the impact on grass production a leatherjacket infestation can have and commenting that they would like to try the on-farm sampling method.

From online searches undertaken at the beginning of the project the amount of information available on leatherjackets in grassland is extremely limited with the majority limited to the arable sector in GB and further afield. The project has therefore created a number of resources available online via the AgriSearch website ranging from an introduction to leatherjackets, suggested IPM approaches and a short video explaining on-farm leatherjacket population sampling. The full report from this project and any other supplementary information arising from the project will also be added as an open informational resource for all farmers and wider agricultural stakeholders.

Additional benefits or unintended negative consequences that have arisen from the delivery of the project

An additional benefit that arose as a result of the EIP project was that the webinars and events scheduled by this project were able to provide a platform for the presentation of results from a University of Edinburgh/Teagasc PhD student. This creation of connections between researchers in Northern Ireland and the Republic of Ireland was most welcome and in return resulted the outcomes of this project being shared to a wider audience, outside the existing networks of the operational group members. The sharing of complimentary and additional findings encouraged the EIP organisational group and have strengthened research networks in the topic area.

In contrast one negative of the EIP project could be that by sharing information on Leatherjackets more farms may now be aware that they have an issue. The project also made clear that no new chemical solutions or derogations for chemical solutions previously available are forthcoming and so a move to IPM strategies is the only way forward. This was not what many farmers wished to hear.

Conclusions

Through the actions undertaken in this EIP project the original concerns raised by farmers in Fermanagh regarding leatherjackets have been found to be justified. An online survey confirmed that leatherjackets are more prevalent in the western counties of Northern Ireland and the withdrawal of chlorpyrifos has left farmers with a serious lack of options for leatherjacket control.

Across 73 sampling events carried out in Fermanagh as part of this project the highest population of leatherjackets was estimated at 5.5 Million per ha, with 23% and 35% fields found to have populations above the economic threshold of 1 Million per ha in 2022 and 2023, respectively. The associated yield losses in cases such as this will be significant. These figures are in the upper range of those found in the 1965-1982 annual leatherjacket surveys previously conducted in Northern Ireland.

Owing to the permanent nature of grassland, with no natural breaks in cropping, or interim cultivation, pest control is complex. Review of the literature, ongoing discussions within the EIP operational group members and farmer feedback from webinars and events enabled the construction of an integrated pest management (IPM) strategy. Such an IPM approach is common with other crop sectors and is a requirement of DAERA and the EU via the Sustainable Use of Pesticides Directive. This strategy is based on a long-term multi-season management approach, quite different from reactive insecticide application.

IPM seeks to incrementally reduce leatherjacket populations through a series of complementary measures and most of the IPM recommendations made within this project are good grass husbandry, and include drainage, liming, regular reseeding and regular monitoring of fields to detect potential leatherjacket problems at an early stage. Brassica break crops and multi-species swards should also be considered but a change to sward management seemed the most acceptable measure to farmers with tentative evidence suggesting that close grazing in late summer / autumn can reduce leatherjacket populations. Improved sward management can not only reduce the likelihood of a leatherjacket infestation but also ensure better utilisation of the valuable grass resource already on farm reducing the impact any infestation might have.

Pest monitoring is an important, integral element of integrated pest management but regular independent sampling of leatherjackets in Northern Ireland ceased many years ago. This project has shown the simple brine sampling method to be a reliable means of assessing leatherjacket density. It is able to be carried easily by farmers or advisors to provide thresholds for assessing leatherjacket impact on grassland fields. Enhanced uptake and sharing of survey results can only help with decision making on farm and mitigation efforts in general.

IPM approaches require a different mind-set and longer term planning than insecticidal control and farmer education will be essential to communicate the benefits of an IPM approach and how they can be integrated on farm to tackle leatherjacket problems or prevent them arising in the future. It was very clear in discussion with farmers that not only are options for chemical control lacking, information currently available to farmers on leatherjackets and their control is also lacking.

In undertaking this project, the Leatherjacket Mitigation Strategies Operational Group has raised the profile of leatherjackets and their impact in Northern Ireland, highlighted the knowledge gap that has existed since the removal of chemical control methods from the market and taken the first steps in providing famers with simple actions that can be undertaken on farm to both understand current leatherjacket problems and mitigate against the risk of an economically damaging infestation.

Recommendations

This EIP project in its short duration was only able to scratch the surface of the leatherjacket problem in Northern Ireland and possible mitigation control measures. Further research is required on the effects of sward management (stocking levels, grazing intensity, silage cuts) on leatherjacket populations. There is anecdotal evidence to suggest their impact but because of the previous reliance on insecticide control, no experimental studies have been conducted on alternative management approaches for leatherjackets.

Also requiring further investigation is the prevalence, distribution, and impact of natural enemies of leatherjackets as well as the impact of multi-species swards and the use of grasses other than perennial ryegrass (Lolium perenne). Results from a recent PhD study suggest diversity in rooting systems within a sward can reduce the leatherjacket impact risk.

Integrated pest management is part of the Sustainable Use Directive and farmers should therefore be provided with guidance on the principles and approaches used. This is more difficult with a pasture based grassland system, where there are less insect pest problems compared to arable systems, but the leatherjacket problem is a good example of where IPM can compensate from loss of a synthetic insecticide.

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