An Investigation into Aquatic Invertebrates, Saline Influence and other factors associated with Management of Ballyvergan Marsh, Youghal, Co. Cork.

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BL4001 Research Project

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CARL
COMMUNITY - ACADEMIC
RESEARCH LINKS
University College Cork, Ireland

Youghal Tidy Towns

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- provide their services on an affordable basis;
- promote and support public access to and influence on science and technology;
- create equitable and supportive partnerships with civil society organisations;
- enhance understanding among policymakers and education and research institutions of the research and education needs of civil society, and
- enhance the transferrable skills and knowledge of students, community representatives and researchers (www.livingknowledge.org).

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How do I reference this report?

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Abstract:

The main aim of this project was to investigate aquatic invertebrate communities, saline influence and other factors associated with management of Ballyvergan Marsh in Youghal, Co. Cork. The marsh examined in this study, has been proposed as a Natural Heritage Area (pNHA Site code: 0078). Ballyvergan marsh is of high ornithological importance. Common reed (*Phragmites austrailis*) dominates the marsh, which is also known to be used by reed warbler (*Acrocephalus scirpaceus)* and barn swallow (*Hirundo rustica)*. Ballyvergan is an important site for wading bird species, is home to a kingfisher (*Alcedo atthis*) population and is a known winter roosting site for hen harrier (*Circus cyaneus*). Wild clary (*Salvia verbenaca*) is also found within the pNHA, which signifies the importance of the habitat for this rare species. In order to design this this project, several indicators and baseline studies were examined. These included establishing the extent of saline intrusion into the marsh, the invertebrate communities, and the presence of the invasive Azolla fern (*Azolla filiculoides*) which was previously recorded in a 2017 Biodiversity Action Plan. Data collection for this project was completed by measuring conductivity between the different sites in relation to potential saline intrusion and through invertebrate sample collection, to analyse and to create an inventory of the species in the marsh. Invertebrate communities have not been previously studied in Ballyvergan. Fieldwork showed that the invertebrate richness and diversity was higher in the freshwater areas than in brackish and saline areas.

Introduction:

Ballyvergan Marsh is located just south of the N25 and lies 3km southwest of the town of Youghal, Co Cork. Ballyvergan (pNHA: site code 0078) is one of 630 proposed Natural Heritage Areas (pNHAs) which were published on a non-statutory basis by the NPWS in 1995 but have not since been statutorily proposed or designated (www.npws.ie). The National Parks and Wildlife Service site synopsis has been included as Appendix 1 at the end of this document.

This project follows on from the 2017 Biodiversity Action Plan for Ballyvergan Marsh which was created by SECAD (South and East Cork Area Development) and Wild Work, a SECAD initiative which helps promote biodiversity in businesses and local communities. In this action plan several recommendations were made. The most relevant recommendations of which and those examined in this report are: "Establish source and extent of saline water intrusion" and "Establish extent of Water fern (*Azolla filiculoides*) infestation". More recommendations from the 2017 report are touched on in this report. However, as most recommended to develop a survey and future monitoring programme for species such as American Mink (*Mustela vison*) and others, these fell outside the scope of this project, as these are not to be believed to be key influences or damaging to the current state of the marsh.

It was clear from the onset of this project that the marsh is a key ornithological habitat, with many sightings of species such as kingfisher (*Alcedo atthis*) and reed warbler (*Acrocephalus scirpaceus)* being observed during fieldwork. However, the main concern for this project was the saline intrusion into the marsh. The best way to test this theory was to examine aquatic invertebrates and how the communities change due to a change in conductivity, as this has been done in many studies previously (Waterkeyn *et at.,* 2008; Harrison *et at.,* 2019). It was hypothesised that aquatic invertebrates were likely to decrease in areas with increased salinity (Williams *et at.,* 1998). It was also deemed important to examine the effect of salinity changes on aquatic communities.

The need for a management plan for a habitat such as this is cruciat., Only two of Irelands six National Parks have a management plan in place (Killarney and Wicklow National Parks). Sadly, due to the lack of such management plans, habitats are often degraded over time and repurposed over the years by landowners. During the fieldwork for this report it became clear that much of the Ballyvergan landscape had been altered repeatedly in recent years. The most obvious alteration is the planting of trees or conversion into farmland of approximately 40% of the proposed Natural Heritage Area within the last twenty years. In 1996, Cork County Council listed Ballyvergan marsh as an area requiring ecological protection and further stated that the County Council "supports the proposal for an ecological park at Ballyvergan Marsh" (County Development Plan 1996: South Cork). However, nothing has ever come of this.

In relation to Ballyvergan marsh, some discussion has arisen over the years about the "natural state of the marsh". For instance, the building of the railway line in 1860, which completely bisected the marsh (Smiddy, 2001). It should also be noted that the drains running through most of the marsh are manmade and therefore not naturat., Around the end of the 19th century, beach erosion and flooding were recognised as a real threat to Youghal strand, with coastal protection works put in place as early as 1900 (Aallanson-Winn, 1903). This work consisted of the construction of 17 Case groynes to protect dunes, a sluice run, and a 500-foot embankment (Kandrot, 2012). The inputting of a sluice also made it more suitable for livestock grazing on the marsh as it allowed for the marsh to dry out more than it had naturally before. The stream running through the marsh has also been subjected to significant human alterations, with reports of widening and deepening of the stream in the past. An active rifle range was operated on the marsh for a period of time, originally built by the British and then eventually used by the Free State and Irish Armies (Smiddy, 2001). It is only in recent times, after the compromise of the sluice that saltwater has started to enter the marsh and to change the composition of vegetation and invertebrate communities.

Invertebrate studies and records are poor for Ballyvergan marsh. Odonata records have been published previously, these records however just indicate the presence of species such as Emperor (*Anax imperator*) and Lesser Emperor (*Anax parthenope*) dragonflies (Murphy and Rogan, 2004). Lepidoptera traps have previously been set up by Kenneth Bond along the railway line; this work was used in the 2002 Management Plan. These records along with the updated versions, have been included in the discussion section of this report.

Methods

Site Details

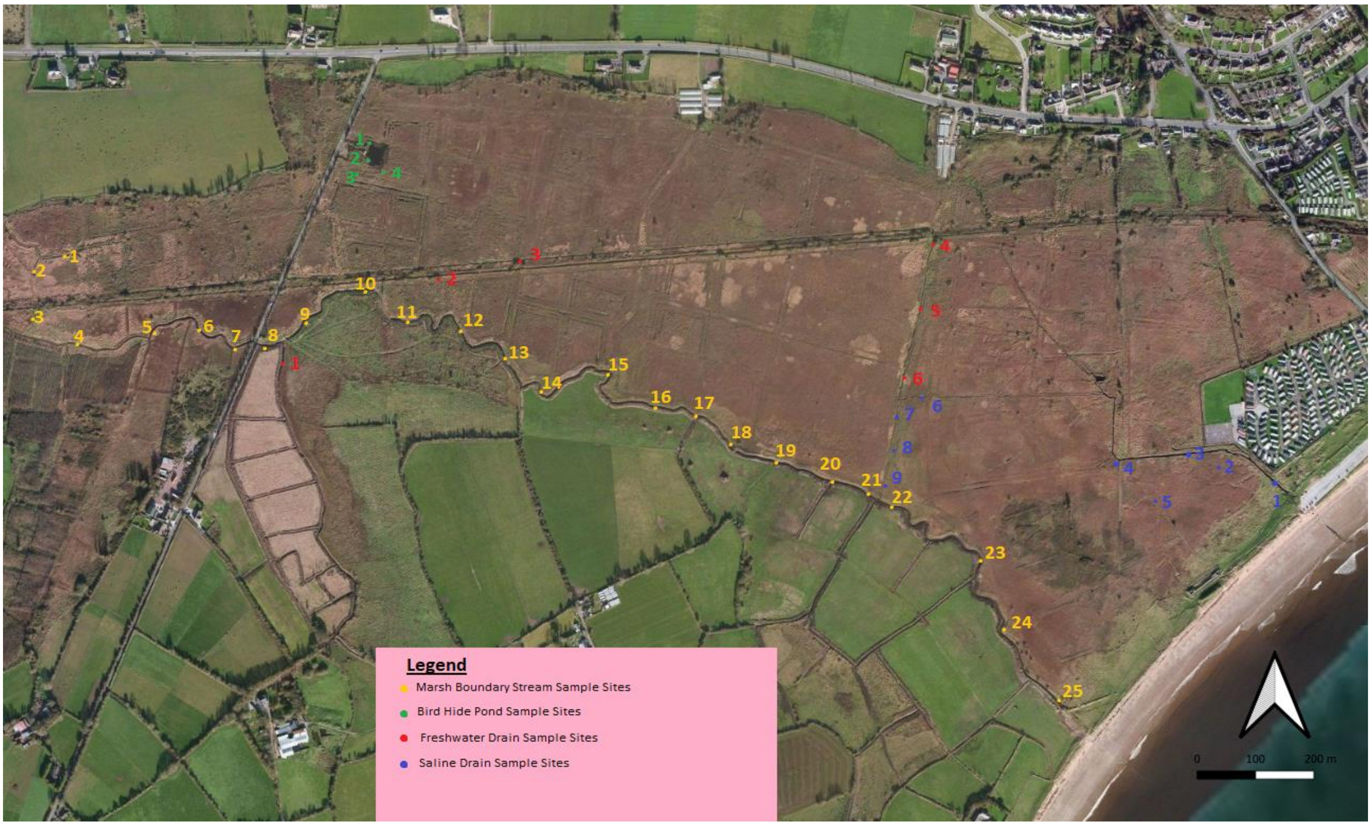

Figure 1. Map of Ballyvergan Marsh, Youghal Co. Cork with Sample Sites marked.

Ballyvergan Marsh is a pNHA, with a total area of 247.06 HA at the time of proposal., Since then approximately 42.15 HA has been planted with trees (18.17 HA of coniferous Sitka spruce (*Picea sithensis.*) on the western most part of the pNHA.). A further 40-50 HA of land has been reclaimed into pastural land by local landowners, depending on the maps used. Altogether, approximately 100 HA of the 247.06 HA (40.4%) has been repurposed since the mid-1990s.

The marsh lies on a Carboniferous limestone bed, with formations of Old Red Sandstone to the north and south. Most of Old Red Sandstone formations are dated from the Late Devonian (MacCarthy and Higgs, 2013). The marsh level with or just below water at high tide but is protected by a small formation of sand dunes (Smiddy, 2001). The dune formation provides protection to the marsh and prevents a large saline intrusion. Dune vegetation is largely marram grass (*Ammophila arenaria*), this helps to stabilises the sand dune, but these dunes are still heavily degraded due to erosion (Kandrot, 2012). Seawater enters the marsh from two locations via sluice gates. One, which adjacent to the carpark, is confirmed to be in a state of disrepair (2017 Biodiversity Action Report). The stream and second sluice used to run through the marsh, but land has been reclaimed to the south and now forms a boundary between the marsh and improved grassland (See Figure 1). Along the centre of the marsh runs the old Midleton to Youghal railway line which has been out of use since the 1980's. At the time of publication, this railway line is being converted to a new greenway (Midleton to Youghal Greenway Ecology Report). This greenway underwent an environmental impact assessment (EIA) and is not expected to cause any ecological damage to the marsh (Midleton to Youghal Greenway EIA Screening).

For the purpose of this project, four waterbody types were investigated: the marsh boundary stream, freshwater drains, saline drains and the bird hide pond. All waterbody types are interconnected with exception to the bird hide pond. The fieldwork involved in this project was entirely based on the waterbodies within Ballyvergan marsh. Large portions of the marsh were not surveyed, as the main aim was to determine the saline intrusion. This was done by examining the change in conductivity along the marsh boundary stream between low tide to high tide to establish the maximum extent and also by examination of the drains near the compromised sluice, bird hide pond, and freshwater drain. Some of the inner-most marsh in inaccessible by foot and would require either a makeshift bridge or a canoe to access, both of which were not practical to carry around through the marsh.

Figure 2&3. (Left) Bird hide pond site, displaying the encroachment of common reed (Phragimites austrailis) on the pond. (Right) Example marsh boundary stream sample sites in Ballyvergan Marsh.

Sampling

In order to establish the correct sampling method for the marsh, several walkovers of the habitat took place in August 2019. During these trips, plant species adjacent to the waterbodies were identified and recorded as well (included in the appendices).

The extent of saline water intrusion into the marsh was established by measuring the conductivity of the waterbodies in the pNHA. A hand-held WTW conductivity meter (Cond 330i; accuracy ± 0.5% of value) was used to measure water conductivity at spatial intervals of approximately 100m within the marsh where possible. These measurements were taken at both high and low tides, and as per recommendation of the 2017 Biodiversity Action Plan. Measurements were also taken during a Spring Tide to establish maximum extents of saline intrusion. Conductivity ratings were originally taken in mid-August and throughout the month of November, to account for both dry and wet periods of rainfall and respective different, water levels in the marsh. Conductivity was also measured again along the stream that forms the southern boundary to the marsh during high tide in February to give a clear extent of the saline intrusion.

Aquatic invertebrates were collected to account for the taxon richness and abundance of water invertebrates in the marsh. In either of the previous management plans for Ballyvergan marsh, or any other report in relation with the marsh, no aquatic invertebrates were recorded, this work the first of its kind in Ballyvergan marsh pNHA. Collection of invertebrates was done by completing dabbing along the edge of the waterbodies with a long-handled 500 µm mesh pond net for thirty seconds, while moving along the edge to achieve maximum area. Due to the nature of the environment, such as varying amounts of leaves and debris, some samples covered less area than others. In some sites, the thirty second timespan was divided into two fifteen second samplings to allow for removal of debris from pond net. The contents of the pond net were placed into a plastic bag, along with a sample location and number. The samples were preserved by addition of 70% ethanol into the sampling bags and taken back to UCC to be examined at a later stage.

At the identification step, each sample was looked at separately and with the aid of a microscope. All the invertebrates, and thereafter sticklebacks (*Gasterosteus*), were identified to at least family level.

Analysis of Samples

IBM's SPSS statistical software package and Microsoft Office Excel 2016 were used to analyse the invertebrate data collected from Ballyvergan Marsh. Invertebrate Taxon Richness per sample site was calculated. As invertebrate specimens were identified down to various taxonomic levels (e.g. species, genus, family), species richness alone was not possible to be calculated. Taxon richness for samples ranked each site from 0-9, depending on how many taxa were present. From this rank calculated the Shannon-Wiener Diversity Indexes (or also called Shannon Entropy) ($H = \sum ((p_i)\ (\ln p_i))$) were calculated for each site. The Shannon Entropy has the value of the natural logarithm of Richness $H = \ln(R)$, thus the more unequal the proportional abundances, the smaller the Shannon Entropy. Using IBM's SPSS statistical software, a Shapiro-Wilk test to test for normality was performed. Following this, Independent Samples T Test for any significance between the various sites (Outputs of this can be found in the appendices) was performed. Two One-Way ANOVAs were run to test the difference between the overall site types, one for invertebrate taxon richness and another for Shannon Wiener Diversity Index. Questions addressed in this analysis included: 1) Is there a significant difference between fresh stream and brackish stream invertebrate richness and diversity? 2) Is there was a difference between fresh and saline drains for invertebrate richness and diversity? 3) Is the freshwater part of the stream the same in invertebrate richness and diversity as the freshwater drains? 4) Is the brackish stream the same in invertebrate richness and diversity as the saline drains? 5) If the bird hide pond for invertebrate richness and diversity was comparable with the freshwater aspect of the stream. For all tests, significant differences are reported where $P - < 0.05$.

Results:

Extent of the Saline Intrusion

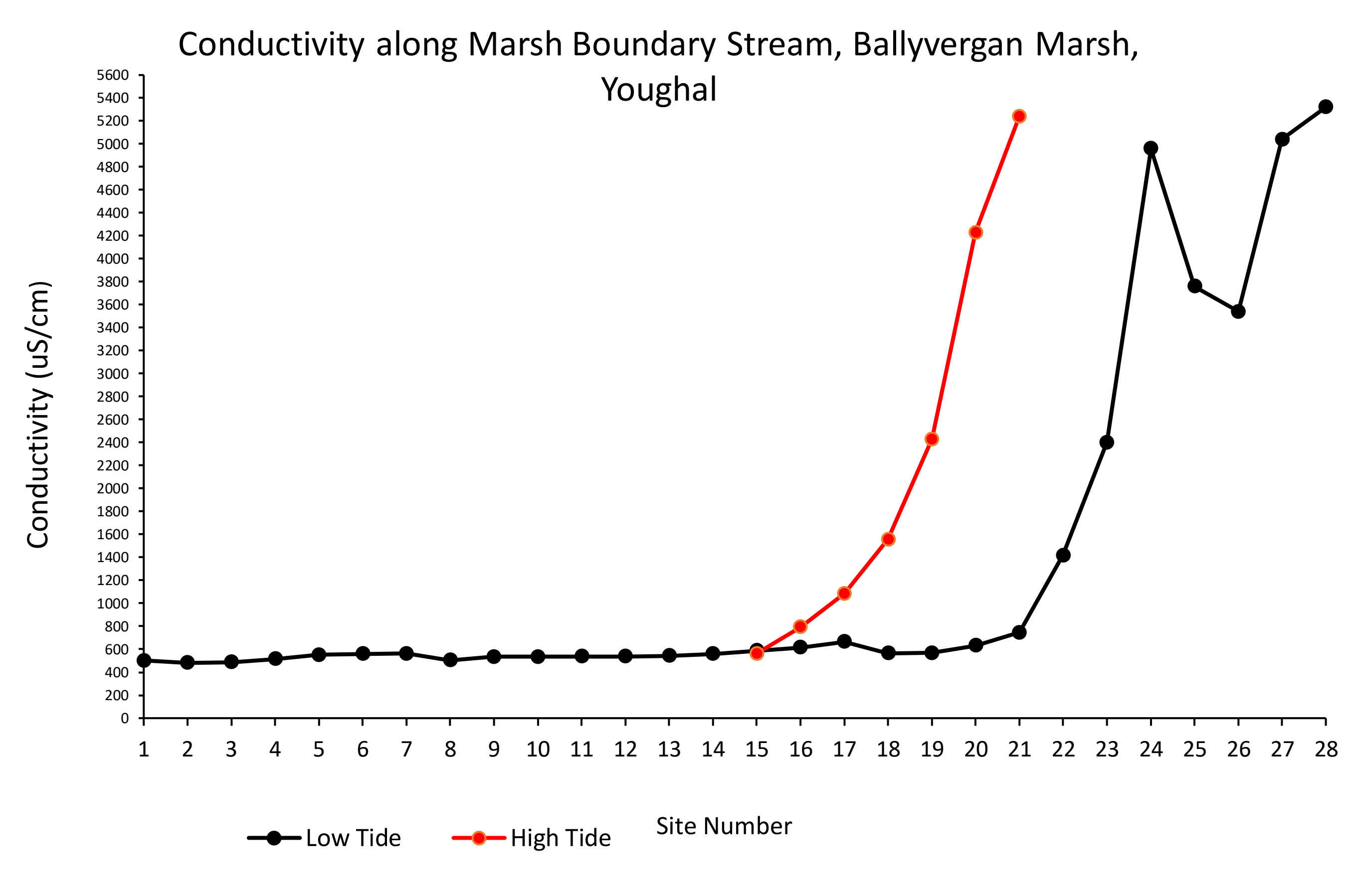

Figure 4. Conductivity variation along of the Marsh Boundary Stream displaying the difference between high and low tide, Ballyvergan Marsh, Youghal, Co. Cork. Three extra conductivity readings were taken from site 21 onwards compared to the sample map which only shows 25 sample sites.

Saline intrusion within the marsh appears to have increased, judging from the 2017 Biodiversity Action Plan (See Figure 13). The saline extent has been measured up to sample Site 16 during high tide (3.97m). However, this maximum extent is thought to only last for a short period of time, as once the tide begins to change the seawater drains out of the marsh. Site 21 and onwards have shown high salinity even during low tide. This is due to the input of saltwater into the marsh boundary stream at Site 21, This saline input changes the freshwater stream into a brackish stream from approximately Site 21 until it flows back out into the sea at the working sluice gate.

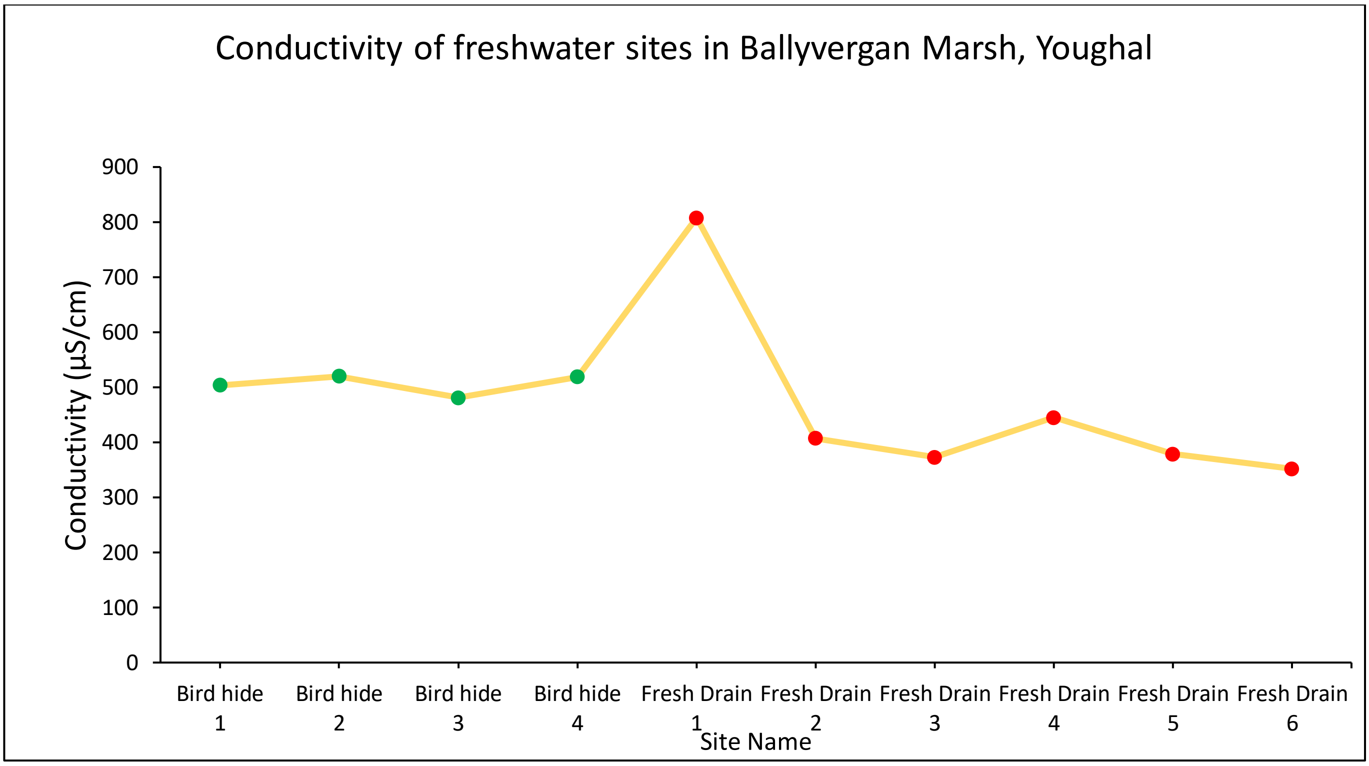

Figure 5. Conductivity of freshwater waterbodies in Ballyvergan marsh (excluding the marsh boundary stream). (Colour coded to match figure 1).

Figure 5, illustrates that freshwater sites around Ballyvergan marsh are of a consistent conductivity, with the exception of Fresh Drain 1, which had a conductivity of 808 µS/cm. This is likely due to nutrients stored within the drain and not an indication of saline intrusion, as suggests to its location within the marsh (Figure 1 for reference).

Invertebrate Communities

To compare invertebrates within the various sites in the marsh, Firstly One-way ANOVAs were conducted to account for any significance between waterbody types. Subsequently, independent t-tests were carried out to compare different site types, for example pond compared to freshwater stream. Using a 95% confidence interval, the p values for invertebrate richness and Shannon-Wiener Diversity Index were calculated.

Table 1. Output of One-way ANOVA analysis (with standard error also included), comparing the invertebrate taxon richness across the different sample site types in Ballyvergan Marsh.

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Standard Error*
Fresh Stream	15	89	5.933333	2.209524	0.383799
Brackish Stream	10	35	3.5	8.277778	0.909823
Saline Drains	9	14	1.555556	1.277778	0.376796
Fresh Drains	6	27	4.5	3.5	0.763763
Bird hide Pond	4	31	7.75	1.583333	0.629153

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	161.0035	4	40.25088	11.38304	3.23E-06	2.612306
Within Groups	137.9056	39	3.53604			
Total	298.9091	43				

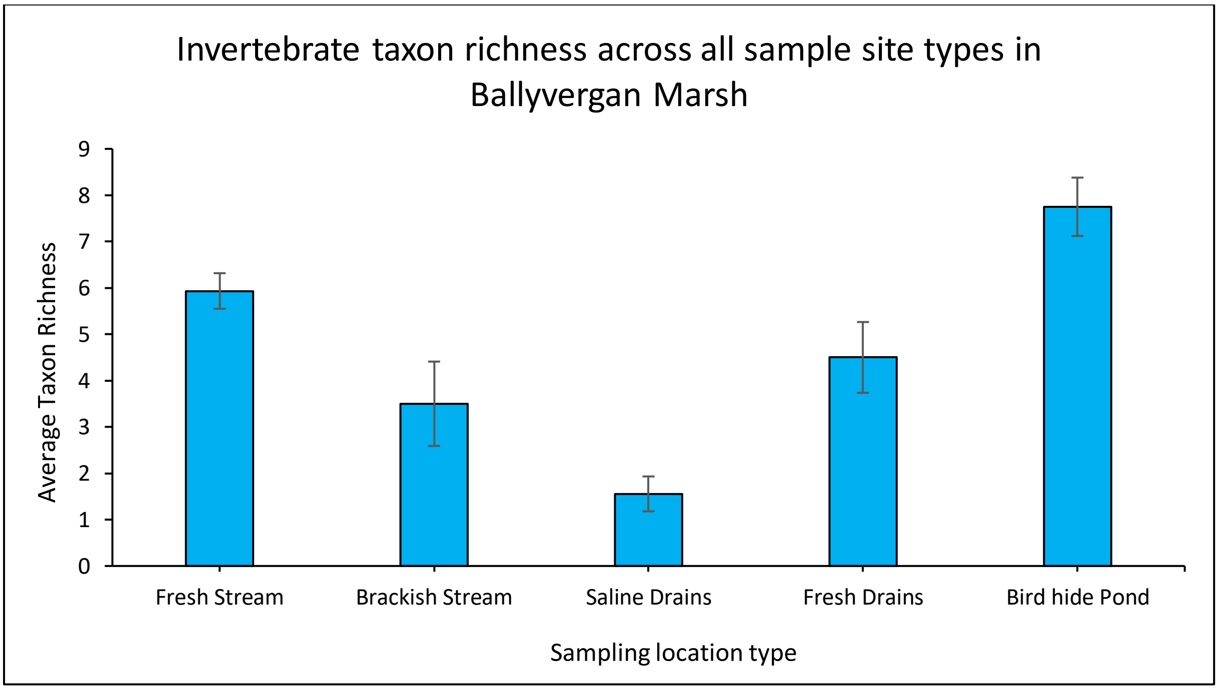

Figure 6. Bar chart comparing the average invertebrate taxon richness found across all site in Ballyvergan Marsh, broken down by site type.

Table 2. One-way ANOVA output for Shannon Wiener Diversity Index (with Standard Error included) for invertebrates collected during fieldwork in Ballyvergan Marsh, comparing the different sampling site types.

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Standard Error*
Fresh Stream	15	19.7332	1.315547	0.115892	0.087898547
Brackish Stream	10	4.81514	0.481514	0.209299	0.144671584
Saline Drains	9	3.282615	0.364735	0.159059	0.132940544
Fresh Drains	6	5.257466	0.876244	0.042285	0.083949132
Bird hide Pond	4	5.795804	1.448951	0.165874	0.203638183

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.117198	4	2.029299	14.42184	2.58587E-07	2.612306
Within Groups	5.487696	39	0.14071			
Total	13.60489	43				

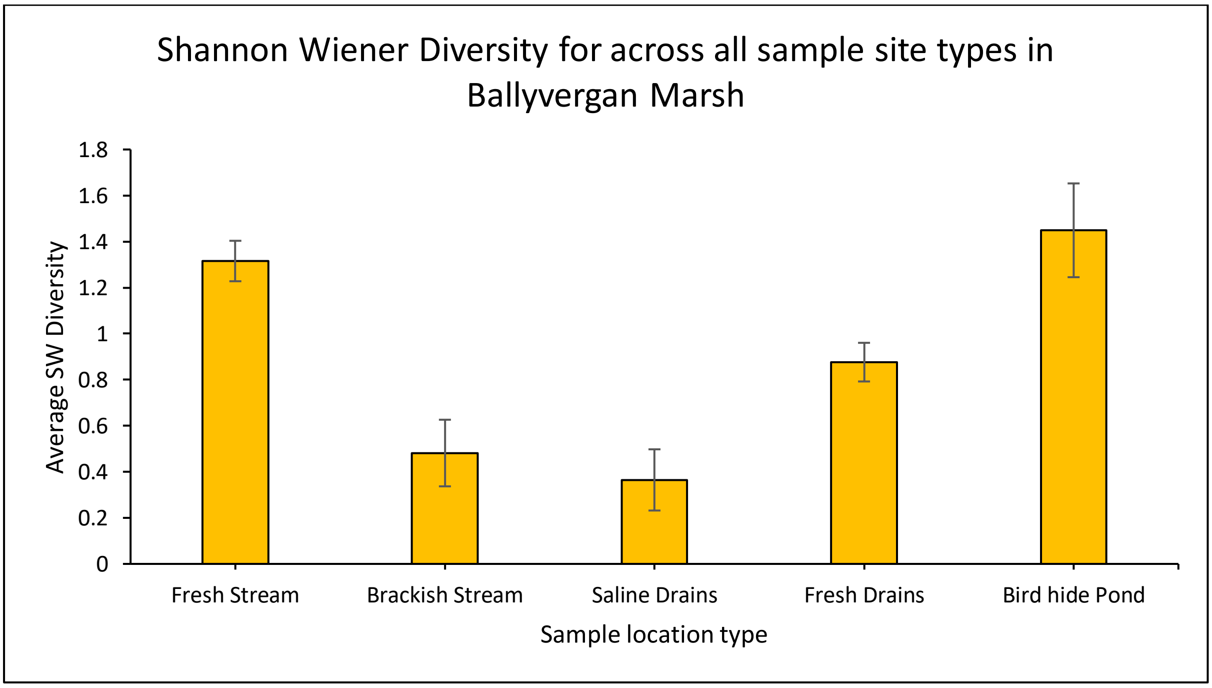

Figure 7. Bar chart comparing the average invertebrate Shannon Wiener Diversity across all site in Ballyvergan Marsh, broken down by site type.

Using One-way ANOVA tests, it can be concluded that there is a significant difference between the sample location type, invertebrate taxon richness, as well as Shannon Wiener Diversity. To break results down further, Independent T-tests were run on the different types of sites and different conductivity and their impacts on the aquatic invertebrates.

Freshwater Stream Compared to Brackish Stream

Invertebrate Richness was found to be significantly different (p-value = 0.024) when comparing the freshwater stream invertebrates to the brackish stream. Similarly, the Shannon Wiener Diversity Index was shown to be significantly different (p-value = 0.000 ($P < 0.05$)). This proves that invertebrate richness and diversity is significantly higher in the freshwater part of the stream compared to the brackish part.

Freshwater Drain Compared to Saline Drain

Invertebrate Richness was found to be significantly different (p-value = 0.006) when comparing invertebrate richness between freshwater drains in Ballyvergan and saline drains. Invertebrate Shannon Wiener Diversity Index was also significant (p-value = 0.022). Once again showing that freshwater drains have a higher richness and diversity compared to identical saline drains.

Freshwater Stream Compared to Freshwater Drain

Invertebrate Richness when comparing freshwater stream samples to freshwater drain samples were found not to be significantly different in richness (p-value = 0.79) but were significantly different for diversity (p-value = 0.009). This is due to one family, in this case Lymnaeidae dominating the samples.

Brackish Stream Compared to Saline Drain

When comparing the brackish stream to the saline drains, Invertebrate Richness was found not to be significant (p-value = 0.75). Similarly, the invertebrate Shannon Wiener Diversity Index was not significant either (p-value = 0.563). This, it can be concluded that invertebrate richness and diversity are similar in both the brackish stream and saline drain.

Freshwater Stream Compared to the Bird hide Pond

Ponds and streams are profoundly different types of habitat and invertebrate species can vary between those habitats due to species preference for flowing water or pools. For data in Ballyvergan invertebrate richness was found to be significantly different (p-value = 0.04) from freshwater stream sites and the bird hide pond. However, the Shannon Wiener Diversity Index was not found to be significantly different (p-value = 0.511). The presence of Odonata nymphs in the bird hide pond is likely to be major driving factor behind the richness difference.

Table 3. Breakdown of total invertebrate taxa collected from samples in Ballyvergan Marsh.

Group	Family	Abundance
Mollusca	Lymnaeidae	335
	Planorbidae	248
	Sphaeridae	29
	Hydrobiidae	166
Hemiptera	Notonectidae	45
	Gerridae	1
	Corixidae	2
Crustaecea	Asellidae	490
	Gammaidae	339
	Hydracarina	97
Coleoptera	Dytiscidae	58
	Haliplidae	7
	Elmidae	8
	Hydrophilidae	3
Diptera	Limoniidae	3
	Empididae	1
	Unidentified	11
Odonata	Coenagrionidae	15
	Aeshnidae	4
Annelida	Lumbricidae	3

Comparing the aquatic communities (both invertebrates and sticklebacks) between the stream (Figure 6) and the bird hide pond (Figure 7), it is clear that while there are many taxa that occur in both habitats, there are also some which only occur in one type. Aeshnidae (Dragonfly nymphs) for example were only found in the bird hide pond. Hydracarina likewise were only found in the stream. Although, *Gasterosteus* and *G. duebeni* did occur in the pond as well, their numbers are clearly much lower than along the stream.

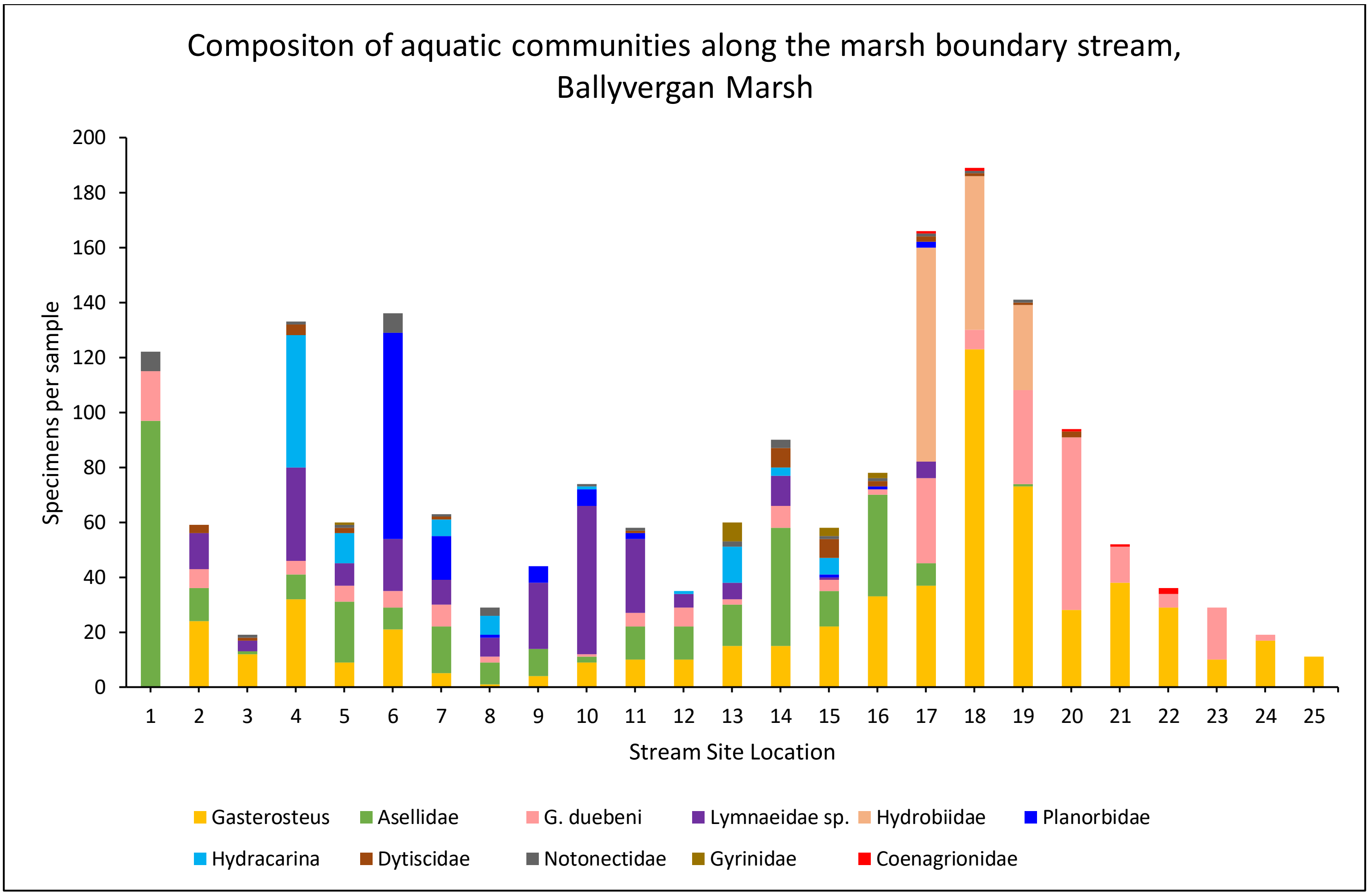

Figure 8. Stacked bar chart showing the aquatic community composition along the marsh boundary stream, Ballyvergan marsh, Youghal, Cork.

Only the most abundant 11 taxa are displayed in Figure 8, as some taxa were excluded due to their low occurrence to make the graph more interpretable. Figure 9 shows the entire composition of taxa that were found to occur in the bird hide pond. Hydrobiidae were only found in sites 17,18,19 along the stream and were not present in any of the other sample from the marsh (N=44).

Three groups of interest emerged during the project due to their apparent relationship with salinity, *Gasterosteus* (sticklebacks), Coenagrionidae (Damselfly nymphs) and *G. duebeni* (Freshwater shrimp). While present in most sites along the stream, these three families surged in numbers along the marsh boundary stream at the uppermost point of saline intrusion, until it became brackish at Site 21 (see Figure 1 for map). Coenagrionidae were only found in Sites 16, 17, 18, 20, 21 and 22 along the stream, in the bird hide pond and at Saline Drains 2 and 4. The Odonata specimens are widely distributed, with Anisoptera (Dragonfly nymphs) confined to the pond by the bird hide and Coenagrionidae found along the marsh boundary stream and also in the bird hide pond. Anisoptera were identified as Aeshnidae or commonly known as

Darner Dragonflies, which is consistent with previous dragonfly observations in the marsh. Coenagrionidae are known as the Narrow-winged Damselflies.

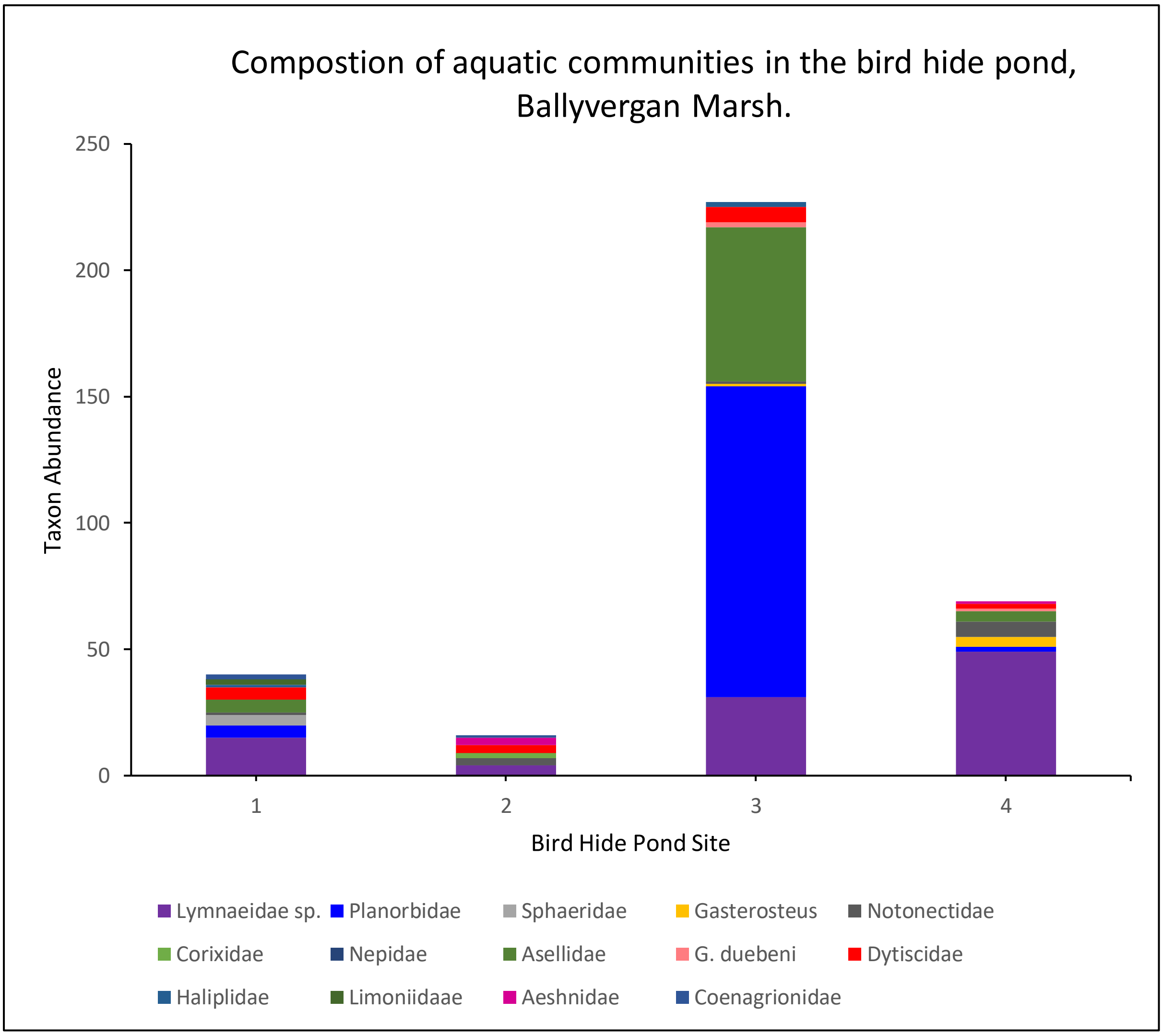

Figure 9. Stacked bar chart showing the aquatic community composition in the Bird hide pond, Ballyvergan marsh, Youghal, Co. Cork

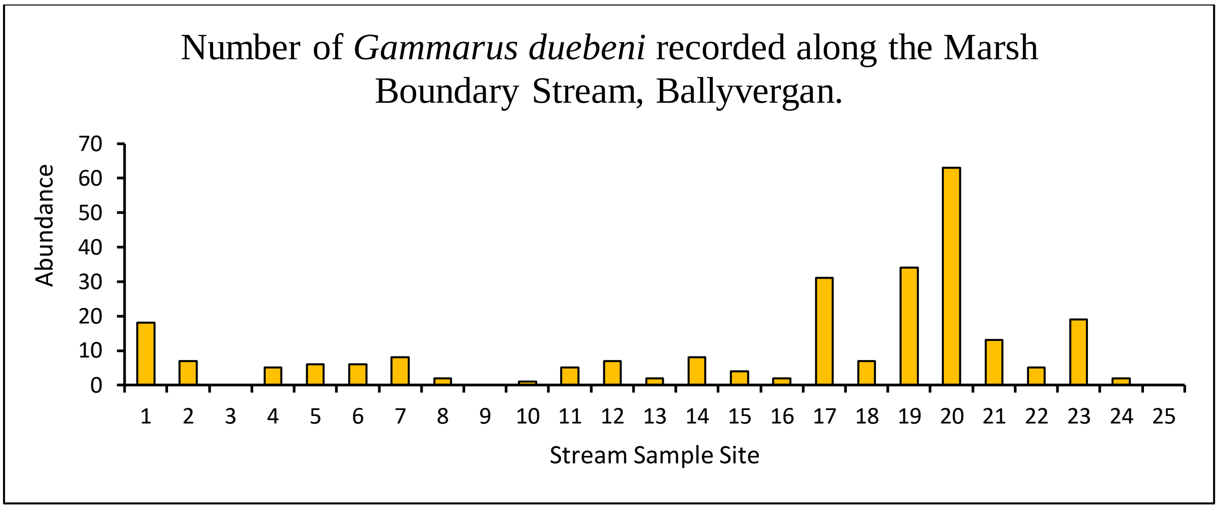

Figure 10 Number of Gammarus duebeni collected in each sample along the Marsh Boundary Stream, Ballyvergan marsh, Youghal, Co. Cork.

Gammarus duebeni was the species identified in all samples found in Ballyvergan marsh. Originally just identified to family level, this group was re-examined and identified to species level in order to better understand the distribution of the species.

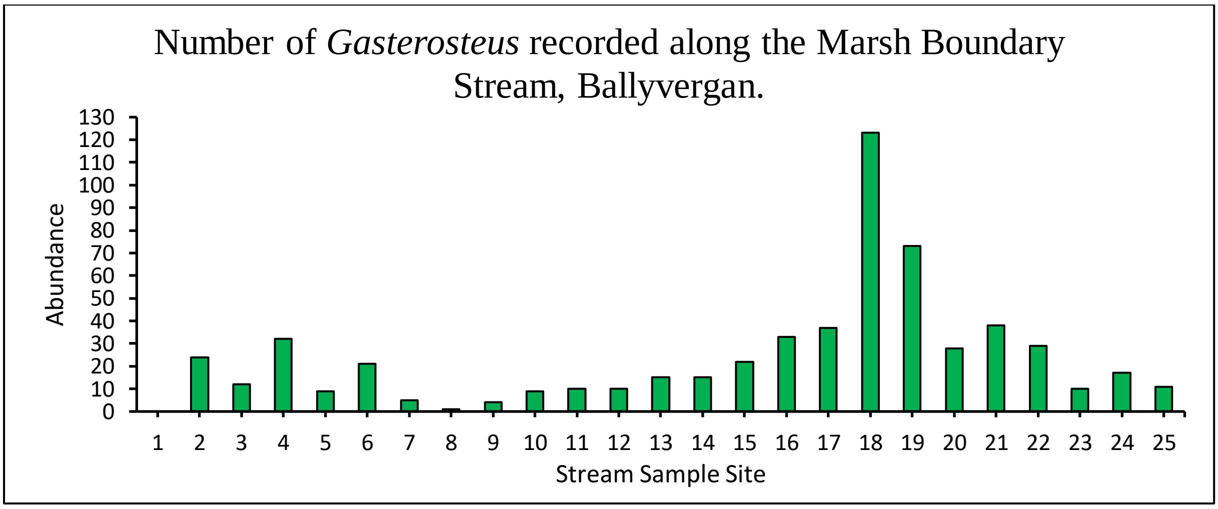

Figure 11. Number of Gasterosteus individuals collected in each sample along the Marsh Boundary Stream, Ballyvergan marsh, Youghal, Co. Cork.

While not being invertebrates, *Gasterosteus* or more commonly known as sticklebacks were collected during the invertebrate collection. *Gasterosteus* were the most numerous specimens in most samples collected, and as they followed an interesting distribution alongside the likes of *G. duebeni*, they were recorded and included in the analysis.

Azolla Fern Extent

From the fieldwork carried out during the course of this project, it was found that Azolla Fern (*Azolla filiculoides*) distribution extends for approximately 1.05km straight along the marsh boundary stream. This stream divides the marsh from the now reclaimed improved grassland. *A. filiculoides* was recorded along the stream as far as Site number 17 (Figure 1). This indicates that *A. filiculoides* has an intolerance to saltwater. From Figure 13 below, it was shown that Azolla was present in the east marsh along the drains which according to data collected in this project, consist mainly of saltwater (see conductivity map in 3.1). Considering the estimated salt intrusion from the 2017 report compared to the data in the report, if *A. filiculoides* was indeed present in those locations, an increase in saltwater may have removed the local *A. filiculoides* specimens from that part of the marsh.

Figure 12. Example of Azolla filiculoides found in Ballyvergan, during fieldwork for the project.

Discussion

Extent of the saline intrusion in Ballyvergan and future management

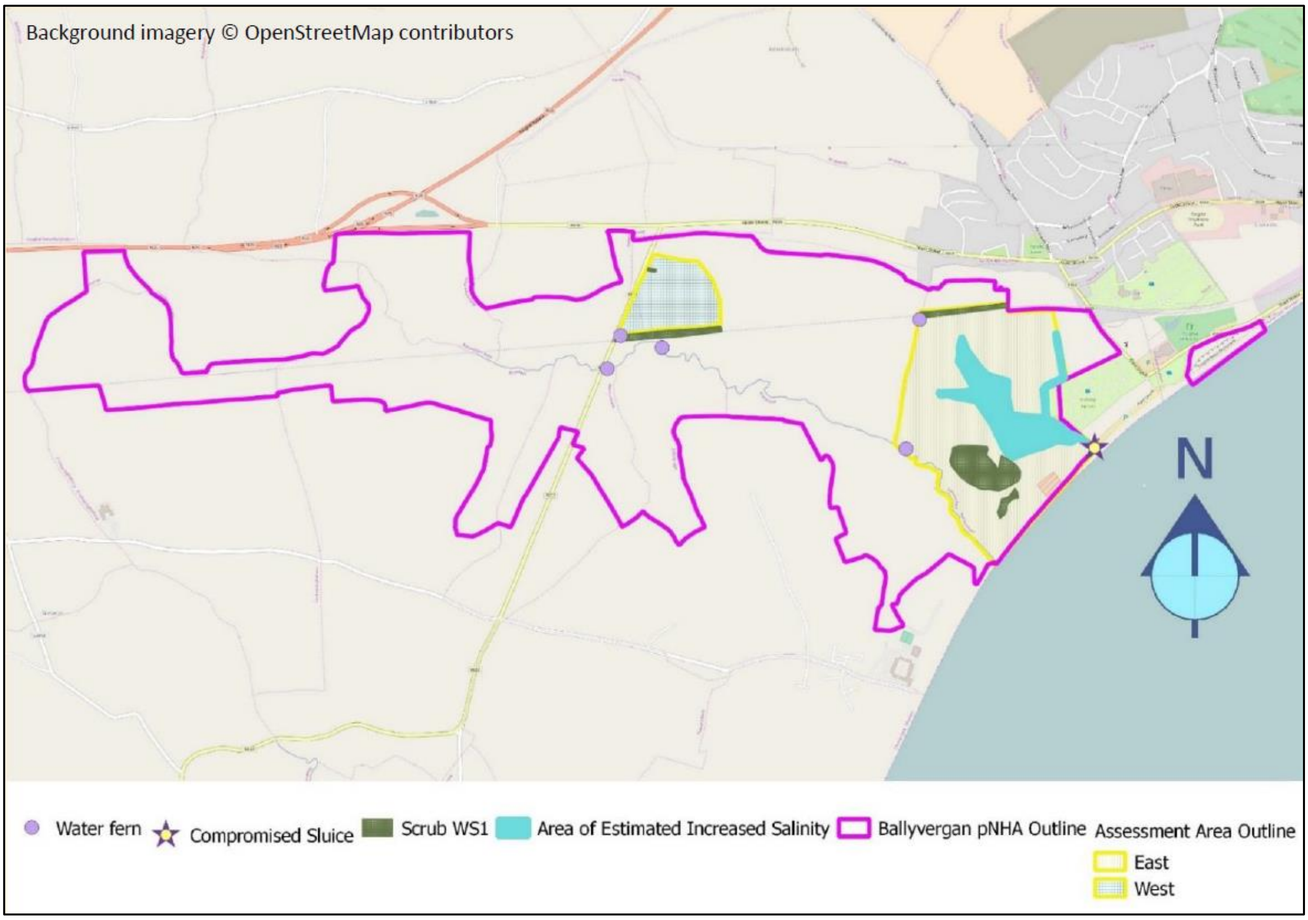

Figure 13. Base map of Ballyvergan pNHA with estimated saline intrusion and Azolla fern extent. (Taken from the 2017 Biodiversity Action Plan)

The extent of the saline intrusion is much greater than originally estimated in the 2017 Biodiversity Action Plan (Figure 13). Using Figure 13 as a baseline, the fieldwork from this project leads to the conclusion that the saline intrusion is consistent with the estimated map. With exception to the northeast most part of the defined “east” marsh in Figure 13. The marsh boundary stream, which is naturally freshwater, turns to a brackish state during hightide. In contrast with this variability, the southernmost part of the marsh boundary stream has been found to be in a constant brackish state, mainly due to the saline water which enters via the broken sluice mixing with the freshwater from the stream at Site 21 (Figure 1). This saline intrusion has caused a significant decline in the invertebrate richness and invertebrate diversity in Ballyvergan marsh. With saline and brackish drains being significantly lower for both richness and diversity, as shown in the results, it is therefore clear that freshwater streams and drains would provide a more invertebrate rich and diverse habitat in Ballyvergan. It can be therefore argued, that by repairing the compromised sluice and thus stopping the intrusion of saline water into the marsh should increase the biodiversity of the aquatic communities.

This study concludes that the repair of the sluice should be the upmost concern in regard to managing Ballyvergan Marsh going into the future. Once this sluice is repaired, it could be investigated to see if removal of the sluice entirely would be of benefit to the habitat. It can be assumed that with the sluice being repaired, the habitat would return to an all freshwater environment, with probable rare saline intrusions in extreme high tides if the limited sand dune formation is breached.

Aquatic Communities in Ballyvergan

As highlighted in the Results section, four taxa were identified during our sampling which proved to be an indicator of salinity change along the marsh boundary stream, *Gasterosteus*, Coenagrionidae, Hydrobiidae and *Gammarus duebeni*. As more than one species of Gammaridae could have been present, it was important to understand which species was in Ballyvergan marsh as certain species like *Gammarus pulex* are more competitive than *G. duebeni*. There are of course other invertebrates identified in Ballyvergan which may be of importance, but Coenagrionidae, Hydrobiidae and *G. duebeni* have a clear relationship with salinity change, as did *Gasterosteus*.

Gammarus duebeni is a species with interesting distribution: with few exceptions, the species worldwide is largely confined to habitats with high salt concentration. However, in Ireland and Britany, France, it can also occupy freshwater systems where *Gammarus pulex* is absent (Pinkster *et at.,* 1970). *G. pulex* invades the habitats with *G. duebeni* is present and subsequently out competes them, as they are more adapted to freshwater systems. Of the two species, *G. duebeni* was identified as the species present in Ballyvergan, which is to be expected as *G. duebeni* is the most common freshwater shrimp in Ireland (Sutcliffe, 1991). A spike in abundance of *G. duebeni* is observed once the freshwater and saline water meet on the marsh boundary stream. Physiologically, this saline increase would make osmoregulation easier for *G. duebeni* in this location. It is possible that the presence of both fresh and saline provides an optimum habitat and accounts for this increase in abundance. Several scientific papers on Gammarus have found that individuals that have been infected by parasites are shown to have an improved tolerance of to increased salinity (Cézilly *et at.,* 2000; Piscart *et at.,* 2007). The presence of such parasites increases levels hemocyanin from 30% to 45%, which improves respiration in most Gammarus species (Bentley and Hurd, 1993). These parasites are also known to make infected Gammaridae more active and swim closer to the surface (MacNeil *et* *at.*, 2003). Parasitism was not looked at in the specimens of *G. duebeni* from Ballyvergan, but this is one possible explanation for the spike in numbers. Studies have shown that *G. duebeni* have the highest survival rate in conditions of 1-10% seawater at 5℃ (Dennert, 1974). Suggesting that the conditions just prior to the transition zone fulfil these requirements. A future study could be conducted on *G. duebeni* individuals in Ballyvergan marsh to identify if parasite level variation along the stream and if these correlate with the specimens collected in this study.

Ballyvergan has had various Odonata sightings over the years, with the bird hide pond providing an ideal breeding ground and the many drains within the marsh providing a hunting ground for adults. Sightings of species such as Emperor (*Anax imperator*) and Lesser Emperor (*Anax parthenope*) dragonflies have been recorded along with migrant hawker (*Aeshna mixta*) (Murphy and Rogan, 2004). Data for Odonata records in Ballyvergan is rare due to the lack of reports published on the topic in the area. Due to this lack of information, identifying the nymphs that were found in our samples provided important insight into the other types of Odonata that are present in Ballyvergan marsh. The dragonfly nymphs were identified from the Darner dragonfly family (Aeshnidae), which is consistent with adult sightings (Murphy and Rogan, 2004). The Zygoptera nymphs belonged to the Coenagrionidae family, commonly known as Narrow-winged damselflies. These use the vegetation to hunt for their prey and spend considerable amount of time out of the water on the vegetation. No clear indication as to why their abundance peaked around the saline transition was found. It is possible they are present across the entire stream but due to their preference for living on the vegetation. Briers and Biggs (2003) showed that Odonata, specifically Coenagrionidae are good indicator species for species richness for ponds in Oxfordshire, UK. They investigated several species which occurred across a range of ponds in Oxforshire and concluded that Coenagrionidae appear to be the best suited to an indicator group as they are predators depending on the presence of other taxa for food. A similar study in Sweden also concluded that Odonata as a group are a good indicator for water quality and plant diversity (Sahlén and Ekestubbe, 2001). On further examination the Conenagrionidae specimens were identified as being one of the following species: *Coenagrion lunulatum, Coenagrion puella, Coenagrion pulchellum* or *Enallagma cyathigerum*. These species are commonly known as: Crescent Bluet, Azure Bluet, Variable Bluet and Common Bluet respectively (Nelson *et at.*, 2011).

On closer inspection the Hydrobiidae specimens from sample sites 17, 18 and 19 were identified to be *Potamopyrgus antipodarum*. *P. antipodarum* are a species of mudsnail and are known to occur in low and high salinity, but being predominately a freshwater species (Healy, 1997). *P. antipodarum* can tolerate high salinity levels but reproduction is severely reduced (Siegismund and Hylleberg, 1987). The only apparent reason as to why this species was present in just these three sites is that these sampling sites were more shallow than other sites and sediment was collected during sampling.

Salinity tolerance in sticklebacks, *Gasterosteus* has been shown to be based on genetic variation. *Gasterosteus* can live in both freshwater and seawater, however, freshwater ecotypes cannot survive in 100% seawater (Kusakabe *et at.,* 2016). This alone however does not explain the spike in abundance near the brackish zone compared to the rest of the samples. *Gasterosteus* has a diet of mainly crustaceans and insects, which Asellus dominates (Hynes, 1950). From our records Asellus disappears from our samples completely when *Gasterosteus* spike in numbers around site 18 (Figure 8). Absence of Asellus is likely due to one of three factors, 1) the abundance of sticklebacks has wiped Asellus populations out completely in these sites. 2) due to high number of sticklebacks Asellus have chosen to move further upstream away from this area (Orrock *et at.,* 2010). Or, 3) the increased salinity in the area is too much for Asellus to live there, although studies have shown that freshwater Asellus do not display any difficulty living in brackish environments (Lagerspetz and Mattila, 1961). In a later study, copepods were again found to be the most abundant prey for sticklebacks in Autumn, but plant and debris becomes more important in Winter (Allen and Wootton, 1984).

Azolla filiculoides extent in Ballyvergan

Azolla species are nitrogen fixing, floating plants which reduce the light penetration in waterbodies. *Azolla* have a symbiotic relationship with cyanobacteria, which is the only known relationship of its type between a pteridophyte and a cyanobacterium (Stewart, 1978). Using the 2017 Biodiversity Plan report as a baseline for *A. filiculoides* extent in Ballyvergan, it appears in this case, it has decreased in abundance (Figure 13) within the larger marsh area and has ceased to exist by the bird hide. *A. filiculoides* presence or more accurately absence within the marsh could be indicative of the saline intrusion increase. However, *A. filiculoides* shows a boom-bust distribution naturally, dominating over native species in high summer temperatures, but dying off in large numbers. Its canopy can be broken up by winter floods, forces *A. filiculoides* to recolonise year after year. Biomass is also more abundant in summer months (Paolacci, 2016). As the fieldwork for this project was predominantly done during November 2019 and February 2020, it is difficult to say with certainty that *A. filiculoides* would not be present in the inner marsh during the summer. Evidence suggests that species of *Azolla* used to be present in both freshwater and marine ecosystems during the Eocene (Brinkhuis *et at.,* 2006). However, modern *Azolla* is only found in freshwater environments (Van Kempen *et at.,* 2013). Therefore, it is unlikely to be present within the marsh where there is a saline influence. Therefore, the increase in salinity in the marsh may be a possible reason for *A. filiculoides* absence in areas where it was previously recorded.

Figure 14. Example of Azolla filiculoides mat present in Ballyvergan Marsh.

A. filiculoides has a renowned biological control species of weevil (*Stenopelmus rufinasus*). This species has been widely used in South African to control *A. filiculoides* and is considered to be one of the move successful biological controls worldwide. With a local extinction rate of *A. filiculoides* at 81%, not a single site was failed to be controlled (McConnachie *et at.,* 2004). Weevil populations are reportedly widespread in Ireland, which control large mats of *A. filiculoides* (Baars, 2011). However, during the fieldwork for this project, no weevils were collected or observed from the *A. filiculoides* mats, that is not to say they are not present in Ballyvergan. If *Azolla* becomes an increased threat in coming years, then an introduction of *S. rufinasus* will control and likely cause a local extinction of *Azolla* in Ballyvergan.

Ornithological Interest in Ballyvergan

Ballyvergan is as described in the NPWS Site Synopsis as "the largest freshwater coastal marsh in Co. Cork." The main marsh remains to be of ornithological interest, with a wide range of breeding bird species having been found here through the years (See Table 2). The large area of common reed (*Phragmites australis*) provides a key habitat for reed warblers (*Acrocephalus scirpaceus),* whose numbers have been increasing since the species became a recognised breeding species in Ireland in the early 1980s. Ballyvergan is thought to be one of the most important sites for *A. spirpaceus* in Ireland (Smiddy and O'Mahony, 1997). More than 200 individuals of reed warblers were being trapped annually for ringing (placing identification tags on the birds) in the 1990s with populations increasing up until the latest survey in the mid-2000s. However, there is evidence that there is a recent decline in reed warbler numbers in places such as Ballyvergan (Bracken and Smiddy, 2012). Reedbeds have also been identified as roosting habitats for barn swallows (*Hirundo rustica*) and sand martins (*Riparia riparia*) during spring and summer roosting periods (Cullen and Smiddy, 2008).

Table 4. Status of breeding birds at Ballyvergan Marsh pNHA. (Taken from Ballyvergan 2002 Management plan and updated by Pat Smiddy Jan 2020.)

Species	Status	Details
Bittern	Possible breeding	Probably bred in the 19th century
Mute Swan	Scarce	One breeding pair, including in 2019
Mallard	Very Common	Estimated up to 50 pairs; perhaps fewer now
Marsh Harrier	Previously bred	Bred in 19th Century
Pheasant	Frequent	Several pairs
Water Rail	Very Common	Estimated up to 100 pairs; perhaps fewer now
Corncrake	Previously bred	Bred up to 1960s
Moorhen	Very Common	Estimated up to 100 pairs; perhaps fewer now
Snipe	Scarce	One or two pairs have bred in the past, but breeding may now have ceased
Woodpigeon	Common	Several pairs
Cuckoo	Scarce	A few have bred in the past, but breeding may now have ceased
Skylark	Frequent	Several pairs have bred in the past, but breeding has ceased in recent years
Swallow	Frequent	Several pairs have bred in the past, but with demolition of sheds none now do so
Meadow Pipit	Frequent	Several pairs breed in dunes near beach
Pied Wagtail	Scarce	A few pairs have bred in the past, but with demolition of sheds none now do so
Wren	Very common	Drier areas
Dunnock	Common	Drier areas
Robin	Common	Drier areas
Stonechat	Scarce	A few pairs breed, usually in dunes near beach
Blackbird	Common	Drier areas

Song Thrush	Scarce	Drier areas
Grasshopper Warbler	Scarce	One to three pairs
Sedge Warbler	Very common	Several hundred pairs
Reed Warbler	Common	Estimated up to 50 pairs; breeding continues, but has not been censused in recent years
Whitethroat	Possible Breeder	Drier areas
Willow Warbler	Frequent	A few pairs breed
Blue Tit	Frequent	Several pairs
Great Tit	Scarce	One or two pairs
Hooded Crow	Frequent	Several pairs
Redpoll	Scarce	One or two pairs
Bullfinch	Scarce	One or two pairs
Reed Bunting	Common	Estimated up to 50 pairs; perhaps fewer in recent years

The following species have bred in the periphery of the study area but are not known to be regular breeders within the of the marsh: Little Grebe; Ringed Plover; Sand Martin; Goldcrest; Magpie; Starling; Chaffinch; Goldfinch. Ballyvergan marsh is a known Hen Harrier (*Circus cyaneus*) wintering roost with up to five individual harriers being observed. Ringtails (female and juvenile hen harriers) are much more commonly observed than males in the marsh, as males tend to stay closer to their breeding habitats in winter. Hen harriers can often be seen hunting over the marsh prior to roosting at night and have been occasionally sighted hunting alongside short-eared owls during winter (Bracken and Smiddy, 2012). In Table 3 below, is a list of other non-breeding bird species that have been known to occur within or close to the marsh itself.

Table 5. Other species that occur in or around Ballyvergan marsh. (Thanks to Pat Smiddy for the information)

Teal: Small numbers (less than 20) regularly occur in drains during the winter months. Cormorant: One or two occur occasionally at the Bird Hide Pond.
Little Egret: One to five are regularly present in the drainage ditches, where they feed.
Grey Heron: One to five are regularly present in the drainage ditches, where they feed.
Glossy Ibis: Has occurred as a rare vagrant.
Marsh Harrier: Few spring seasons go by without at least one record of this species.
Hen Harrier: This site is a feeding and roosting site for this species in the non-breeding season; currently, one to three birds may occur.
Pallid Harrier: Has occurred as a rare vagrant.
Sparrowhawk: Single birds regularly occur, but it does not breed.
Buzzard: Has become a regular visitor in recent years; usually just one or two birds.
Spotted Eagle: Has occurred as a rare vagrant.
Kestrel: Single birds regularly occur, but it does not breed.
Merlin: Single birds regularly occur in winter.
Peregrine: Single birds regularly occur, but it does not breed.
Spotted Crake: Has occurred as a rare vagrant.
Baillon's Crake: Has occurred as a rare vagrant.
Coot: Has occurred only very occasionally.
Oystercatcher: Small numbers; usually fewer than ten occur in the pastures at the south side of bog.
Lapwing: Up to 50 occur in the pastures at the south side of bog.
Snipe: Occurs as a winter visitor; perhaps up to 50 birds in the surrounding pastures.
Black-tailed Godwit: Small numbers (fewer than 20) have occurred in the pastures at the south side of the bog.
Curlew: Occurs in the pastures regularly; sometimes in excess of 100 birds.
Green Sandpiper: One or two have occasionally occurred in the drainage ditches.
Barn Owl: Rare visitor, usually in winter.
Short-eared Owl: Scarce but regular winter visitor.
Swift: Feeding flocks of up to 20 occur over the bog.
Kingfisher: One or two birds occur are regular in the non-breeding season.
Wryneck: Has occurred as a rare vagrant.
Raven: Regularly passes over the bog, but rarely occurs at ground level.
Swallow: Very large numbers roost in the reeds throughout the autumn period.
Sand Martin: This species roosts in the reeds during the autumn, but rarely is as plentiful as the Swallow.
House Martin: Up to 50 birds have been seen in feeding flights over the reeds.
Chiffchaff: Occurs as a passage migrant, and as a scarce winter visitor.
Blackcap: Has occurred as a passage migrant in autumn.
Savi's Warbler: Has occurred as a rare vagrant.
Marsh Warbler: Has occurred as a rare vagrant.
Starling: Formerly (the 1980s) there was an enormous winter roost flock, but only small numbers roost in the reeds at present.
Fieldfare: Occurs as a winter visitor.
Redwing: Occurs as a winter visitor.
Spotted Flycatcher: A scarce to rare passage migrant.
Grey Wagtail: Passage migrant in autumn, usually in numbers of fewer than five.
Pied Wagtail: In autumn up to 50 have been recorded to roost in the reed bed.
Greenfinch: Small numbers occur regularly but it has not been recorded as a breeding species.

Only species which occur within the marsh area have been included in this list. Many species such as gulls, terns and some wading birds have been excluded as these, at best, are only seen flying over rather than occurring within the area. However, since the mid-2000s no detailed surveying of the bird populations has been undertaken. Although some of the data may be outdated, it is the most up recent and accurate dataset available. As stated earlier, approximately 17% (42.15 HA) of the total pNHA has been planted with woodland. This new habitat may in turn have brought new species of birds to the area, such as finches and warblers. At the time of the study, no ornithological inventory of the area has been taken since this woodland has matured, therefore this cannot be confirmed. In spite of this, Ballyvergan pNHA is clearly a valuable ornithological habitat and a key birdwatching spot. However, due to the continued growth of common reed around the bird hide pond, it has become increasingly overgrown. Therefore, one of the recommendations of this project is to put in place a management scheme for the reeds around the pond, not only to attract more bird species to the area again, but also to increase the viewing opportunities from the bird hide.

To complete this project for Ballyvergan marsh using only invertebrate data would have been nonsensical, due to the overall ornithological importance of the area. However, with the invertebrate data, inferences, and recommendations as to secure and maintain the ornithological diversity that exists in Ballyvergan can be made. Bird species, particularly wading birds are known to eat aquatic invertebrates, for example short-eared owls have been found with Dytiscidae beetles in their pellets when over-wintering in Cork (Cullen and Smiddy, 2012). This likely occurs when the beetles are dispersing by flight from one waterbody to another (Davy-Bowker, 2002). From this study it was shown that diversity and richness of invertebrates in the freshwater areas of the marsh is greater areas than in areas with a saline influence. It is therefore hypothesised that reducing the saline intrusion, will have a positive impact on the bird species, by increasing the invertebrates available for wading bird species and thereafter the birds which prey on waders.

Lepidoptera

Table 6. Rare species of Lepidoptera that have been recorded in Ballyvergan Marsh since 1989 by Ken Bond.

Species Name	Common Name	Associated Plants	Associated Plant Present in Ballyvergan?	Other Info
Pseudopostega crepusculella	none	Believed to be associated with Mint (*Mentha*)	Not recorded	Fens; Only seen as adult
Agonopterix yeatiana	none	wild carrot (*Daucus*) and hemlock water-dropwort (*Oenanthe crocata*)	Not recorded	Coastal
Bryotropha senectella	none	Mosses	No records available	Occurs where foodplants are present
Limnaecia phragmitella	none	Bulrush (*Typha* sp.)	Yes according to 2002 report	Fens and marshes
Phtheochroa inopiana	none	common fleabane (*Pulicaria dysenterica*)	Present	Damp places and woodland edges
Phalonidia manniana	none	water mint (*Mentha aquatica*) and gipsywort (*Lycopus*)	Water mint present according to 2002 report	Riverbanks and margins of streams
Celypha striana	none	dandelion (*Taraxacum officinale*)	Present	Open Grassy area
Celypha aurofasciana	none	Mosses and Liverworts on trees	Unknown	Unknown
Chilo phragmitella	none	Common Reed (*Phragmites australis*), Reed sweetgrass (*Glyceria maxima*)	Common Reed in high abundance	Fens and other wet habitats
Donacaula mucronellus	none	Common Reed (*Phragmites australis*), Reed sweetgrass (*Glyceria maxima*)	Common Reed in high abundance	Fens. Costal fens, river valleys
Anania crocealis	none	common fleabane (*Pulicaria dysenterica*), ploughman's spikenard (*Inula conyza*).	Common Fleabane present	Marshes, water-meadows and damp habitats
Leptidea juvernica	Cryptic Wood White	Vetches and Trefoil	Present	Open Habitats
Malacosoma neustria	Lackey	hawthorn (*Crataegus*), blackthorn (*Prunus spinosa*)	Along railway and roadway	Wide range of habitats
Chiasmia clathrata	Latticed Heath	lucerne (*Medicago sativa*) and clover (*Trifolium*)	Clover present in adjacent improved grassland	Moorland, Grassland and waste ground
Furcula furcula	Sallow Kitten	Willow (*Salix*) Aspen (*Populus tremula*) other *Populus* sp.	Willow Present in dry areas	Wide range of habitats
Thumatha senex	Round-winged Muslin	Lichens	No records available	Marshes and Fens
Hecatera bicolorata	Broad-barred White	hawkweed (*Hieracium*) and hawk's-beard (*Crepis* spp.)	Present	Wasteland and suburban
Apamea unanimis	Small Clouded Brindle	Grasses including Reed canary-grass (*Phalaris arundinacea*)	Yes according to 2002 report	Inhabiting marshes, fens and similar damp habitats
Lateroligia ophiogramma	Double Lobed	reed canary-grass (*Phalaris arundinacea*), reed sweet-grass (*Glycera maxima*).	Yes according to 2002 report	Inhabiting fens, damp woodland and other marshy places
Globia sparganii	Webb's Wainscot	yellow iris (*Iris pseudacorus*), reed-mace (*Typha* spp.)	Yes - Abundance unknown	Fens, marshes and brackish ditches
Chilodes maritimus	Silky Wainscot	Common Reed (*Phragmites australis*)	Yes - high abundance	Larvae carnivorous - feeds on insects

Lepidoptera species were analysed using records for Ballyvergan marsh provided by Ken Bond. There have been 147 different Lepidoptera species observed by Ken Bond since 1989, of which 21 species were found to be “rare” (see Table 4 above). Many of these species have been published to the Irish list of Lepidoptera previously (Bond, 1996). Further information on species preferred habitats and food plants was obtained from - ukmoths.org.uk. Almost all of the food plants of lepidoptera species identified were also found to be present in Ballyvergan.

The 2002 Management Plan for Ballyvergan Marsh also included Ken Bond's data and noted 129 species of Lepidoptera. There has been an increase of 18 species of Lepidoptera in 12 years (2002 report and latest records from 2014). Approximately 14% of the species found in Ballyvergan are considered noteworthy. With most of these species relying on food plants such as common Fleabane (*Pulicaria dysenterica*) and common reed (*Phragmites australis*). Both plant species, especially common reed is found in high abundance in Ballyvergan marsh and management of such plant species will need to be considered as a result. With such a large number of rare species of Lepidoptera in Ballyvergan, a future study on these populations is recommended.

Future recommendations for Ballyvergan Marsh:

Due to the overall nature of the marsh (key ornithological traditionally freshwater marsh with a recent saline intrusion) and the fieldwork undertaken in this project, it is suggested that Ballyvergan marsh should be managed overall as a freshwater marsh in the future. From a conservation and biodiversity point of view, the freshwater stream and drains are more valuable than the saline equivalent. As mentioned earlier, we believe the repair of the compromised sluice gate to be of the upmost importance to the future of the marsh.

It is recommended that a control method for Common Reed (*Phragmites austrailis*) is established and put in place, particularly around the bird hide pond area. These areas have become increasingly overgrown in recent years, which is likely to have an impact on the bird species utilising the pond. Due to health and safety regulations and concerns, the current TÚS participant, Tommy O'Connell, cannot carry out the maintaining of the reeds due to the deep nature of the pond. Meta-analysis studies on controlling of common reed (*Phragimites austrailis*) in Europe, suggest that cutting or mowing of reed on a rotational basis provides the best results. However, cutting the same area of reed for more than two years in a row has been shown to have significantly negative impacts on a wide range of groups including bird species, invertebrates and lepidoptera (Valkama *et at.*, 2008). Controlling the reed cover on a rotation basis is likely to improve the plant species richness by 90% in the freshwater marsh but not in the saline side of the marsh (Valkama *et at.*, 2008).

Riparian trees such as those around the bird hide pond should be managed in such a way to reduce the amount of shade that is put onto the pond, as the amount of shade is directly related with the number of Odonata species present within ponds (Gee *et at.*, 1997). If in future it is decided that further ponds should be created, native trees should be planted around the pond, but at such a distance not to shade the pond too much. It should be stated that this report does not recommend the trees adjacent to the bird hide pond be cut down or removed, or in fact anywhere else within the marsh. These trees enhance biodiversity within the marsh.

Regarding the construction of the Greenway, it is hard to quantify the changes it will bring to the marsh. It should enable the public to become more engaged and invested in the wildlife in Ballyvergan marsh, particularly the bird species. The opening of the greenway could see more interested people wanting to avail of the excellent bird hide that is already available, if so, more funding and personal should be made available for the maintenance of the hide and the surrounding pond.

Conclusion:

Data analysis showed that freshwater habitats in Ballyvergan Marsh pNHA, are more diverse and richer in invertebrate communities than aspects of the marsh with a saline influence. The bird hide pond was found to have the highest richness and diversity of invertebrates while the saline drains were of the lowest richness and diversity.

Following the completion of this report, the following actions are recommended to be carried out in Ballyvergan Marsh:

It is recommended that the boundaries of the pNHA are revised to represent the habitat as it is today, as the current outline is severely out of date and does not truly show the modern version of Ballyvergan Marsh. This new pNHA should include the Wild Clary (*Salvia verbenaca*) population that now exists behind the carpark, which could link the marsh to the sand dune as they are both within the same pNHA. Ballyvergan marsh should be managed as a freshwater marsh as this provides the most biodiversity value to the area. This can be done by repairing the sluice gate to prevent seawater entering the marsh. However, this will need to be monitored as the drains could potentially cause the marsh to significantly dry out and change the habitat, which is undesirable

Future Projects that could be undertaken in Ballyvergan:

- Re-establish a bird monitoring programme for the marsh, to examine if the greenway is having any direct effect on populations.

- Investigate area of the marsh that was inaccessible to establish saline intrusion here. (Although if the recommended action of repairing the sluice gate is completed, this action will not be necessary as the saline intrusion will eventually be replaced by natural freshwater systems again.)
- Investigate parasitism levels in *Gammarus duebeni* along the stream and examine if parasite levels are consistent with spikes in abundances.
- Analyse the sediment along the Marsh Boundary stream to see if the benthic invertebrate communities also change as drastically as the invertebrates investigated in this project.
- Look at using sticklebacks to control mosquito larvae in Ballyvergan by connecting the pools to the streams to allow access for the sticklebacks.
- Complete botanical inventory of the marsh area. Much work has been done to establish the Wild Clary (*Salvia verbenca*) population in the past and no other rare species have been documented for the marsh, but records for plants are poor for Ballyvergan.

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Online Resources:

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Appendices

Appendix 1

SITE SYNOPSIS SITE NAME: BALLYVERGAN MARSH SITE CODE: 000078

This site is located about 3km south-west of Youghal adjacent to the Cork Road. The area includes an extensive reed bed with some marshy land around the edges. The marsh is separated from the area by a shingle bank and sand hills.

The following habitat description for the site is derived largely from the 1986 An Foras Forbartha County Report: Common Reed (Phragmites australis) covers the largest area, but a great variety of the larger Sedges also occur (Carex riparia, C. acuta, C. pseudo-cyperns and C. acutiformis). Water Dock (Rumex hydrolapathum), Purple-loosestrife (Lythurim salicaria) and Branched Bur-reed (Spargamium erectum) grow interspersed among the sedges, while on muddier ground, which is flooded only in winter, Celery-leaved Buttercup (Raminculus sceleratus) and nodding Bur-Marigold (Bidens cernua) occur.

A secondary habitat, described in the Rare Plant Survey of Co. Cork (1992-93), is a clay/sand cliff occurring on the coast adjacent to the marsh. This adds to the interest of the site since it supports a rare species (see below), along with abundant Kidney Vetch (Anthylliz vulneraria) and Red Fescue (Festuca rubra).

Growing abundantly on the cliff is Wild Clary (Salvia verbenaca), a species described as rare in the Irish Red Data Book.

The main interest of the marsh is ornithological, with the reed bed supporting a sizeable proportion of the Irish breeding population of Reed Warblers. This species has only recently become an established breeding bird in Ireland. Other breeding birds using the site include Reed Buntings, Moorhen, Coot, Water Rail and Mallard.

The recent NHA survey reports that grazing is the dominant land use, but that the greatest threats come from land reclamation (for agriculture and tourism developments) along with large-scale reed burning.

This site is of interest because it contains the largest freshwater coastal marsh in Co. Cork, exhibiting well developed plant communities and holding a sizeable breeding population of Reed Warblers. Adding to the importance of the site is Wild Clary (Salvia verbenaca), a Rare Red Data Book species.

Appendix 2:

Individual data analysis run to compare different sampling sites for richness and diversity

Freshwater Stream Compared to Brackish Stream

Invertebrate Richness was found to be significantly different (p-value = 0.024) when comparing the freshwater stream invertebrates to the brackish stream. Similarly, the Shannon Wiener Diversity Index was shown to be significantly different (p-value = 0.000 ($P < 0.05$)). This proves that invertebrate richness and diversity is significantly higher in the freshwater part of the stream compared to the brackish part.

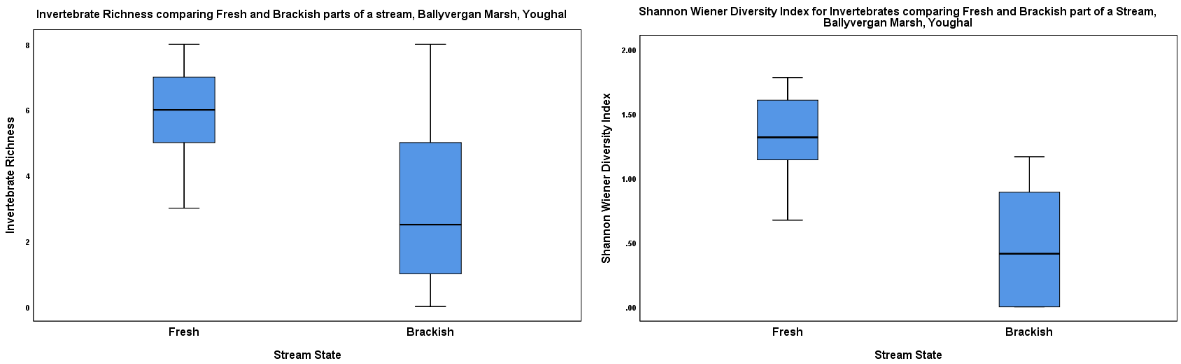


Figure 1 & 2. Boxplots displaying the invertebrate richness (left) and Shannon Wiener Diversity Index (Right) comparing fresh and brackish parts of the marsh boundary stream, Ballyvergan marsh, Youghal, Co. Cork.

Freshwater Drain Compared to Saline Drain

Invertebrate Richness was found to be significantly different (p-value = 0.006) when comparing invertebrate richness between freshwater drains in Ballyvergan and saline drains. Invertebrate Shannon Wiener Diversity Index was also significant (p-value = 0.022). Once again showing that freshwater drains have a higher richness and diversity compared to identical saline drains.

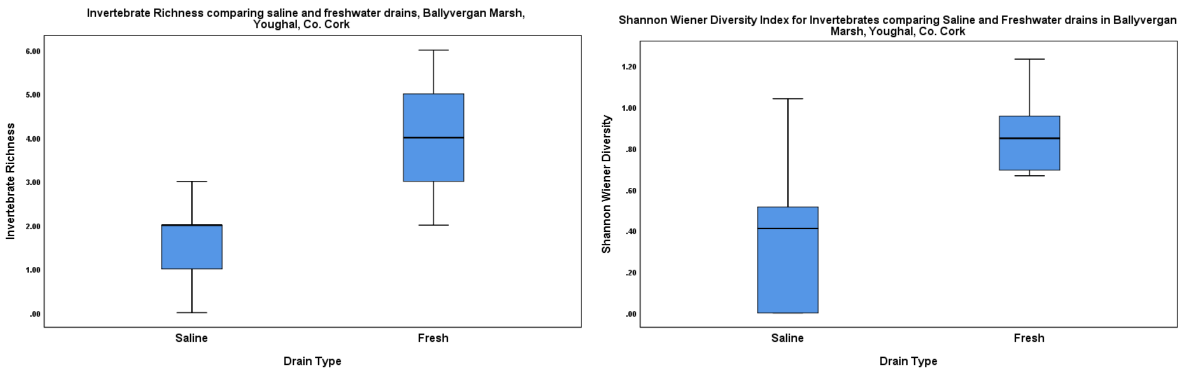


Figure 3 & 4. Boxplots displaying invertebrate richness (Left) and Shannon Winer Diversity Index (Right) comparing saline and freshwater drains, Ballyvergan marsh, Youghal, Co. Cork.

Freshwater Stream Compared to Freshwater Drain

Invertebrate Richness when comparing freshwater stream samples to freshwater drain samples were found not to be significantly different in richness (p-value = 0.79) but however, were significantly different for diversity (p-value = 0.009). This is due to one family, in this case Lymnaeidae dominating.

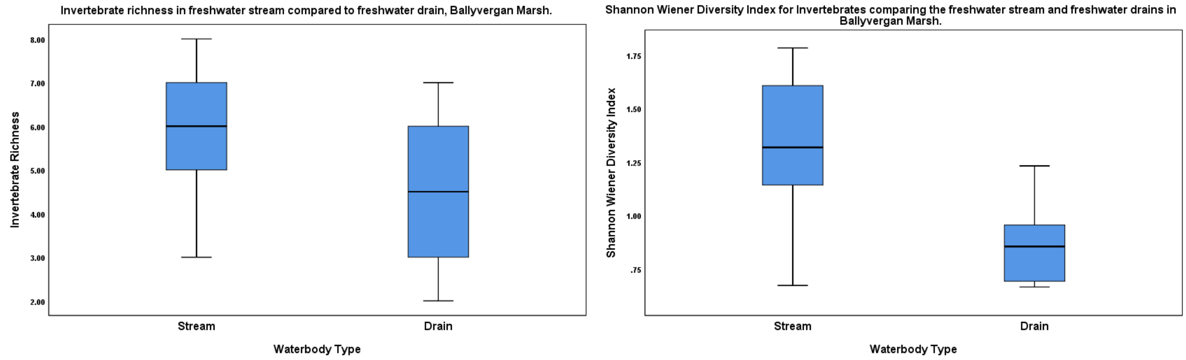


Figure 5 & 6. Boxplots displaying the invertebrate richness (Left) and Shannon Wiener Diversity Index (Right) comparing freshwater stream to freshwater drains in Ballyvergan Marsh, Youghal, Co. Cork.

Brackish Stream Compared to Saline Drain

When comparing the brackish stream to the saline drains the invertebrate Richness was found not to be significant (p-value = 0.75) and the invertebrate Shannon Wiener Diversity Index was not significant either (p-value = 0.563). This tells us that the invertebrate richness and diversity is similar in both the brackish stream and saline drain.

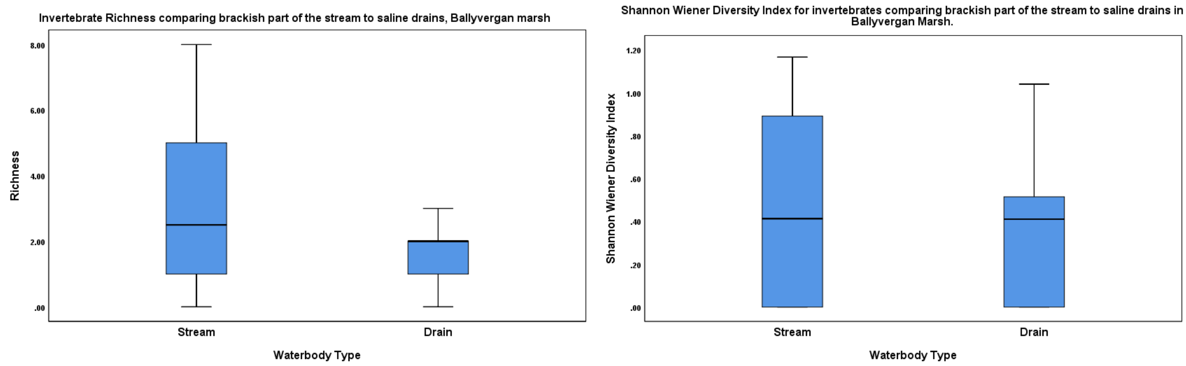
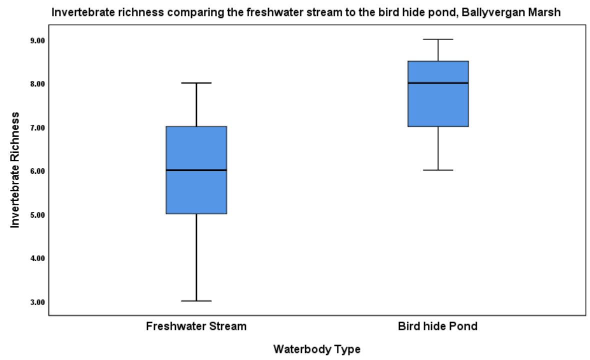


Figure 7 & 8. Boxplots displaying the invertebrate richness (Left) and Shannon Wiener Diversity Index (Right) comparing the brackish part of the marsh boundary stream and the saline drains within Ballyvergan marsh, Youghal, Co. Cork.

Freshwater Stream Compared to the Bird hide Pond

Ponds and streams are obviously very different types of habitat and invertebrate species can vary between those habitats due to species preference for flowing water or pools. For our data in Ballyvergan we found that invertebrate richness was significantly different (p-value = 0.04) from fresh stream and the bird hide pond. However, the Shannon Wiener Diversity Index was not found to be significantly different (p-value = 0.511). The presence of Odonata nymphs in the bird hide pond is likely to be major driving factor behind the richness difference.



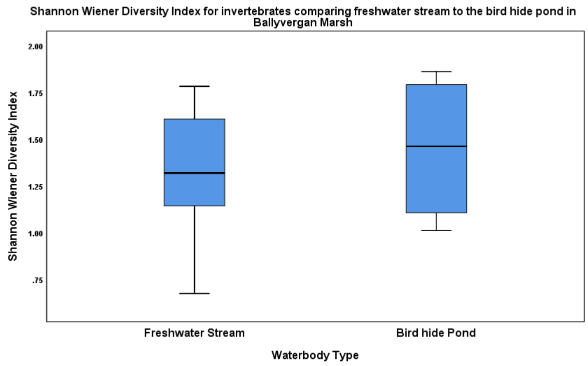


Figure 9 & 10. Boxplots displaying Invertebrate richness (Left) and Shannon Wiener Diversity Index (Right) comparing the freshwater stream and bird hide pond, Ballyvergan Marsh, Youghal, Co. Cork

Appendix 3.

Table of Plant species recorded during walk overs of Ballyvergan Marsh

Common Rest Harrow	Wild Clary	Common Cudweed
Smooth Hawk's Beard	Grasswort	Baddington's Orache
Common Fleabane	Tufted Vetch	Giant Willow herb
Common Reed	Bramble	Saw Sedge
Bindweed	Nettles	Giant Reed
Willow Tree	Greater Bladderwort	Purple Loosestrife
Meadow Sweet	Azolla fern	Duckweed