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| Bangor University |
| The Effects of Management on Biodiversity and Biogeochemistry of the Cors Goch Site, Anglesey |
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| **1/29/2021** |

**Acknowledgements**

Foremost, I would like to express my special thanks of gratitude to my supervisor Prof. Christian Dunn for all of his help throughout the course of this project and for giving me the opportunity to do it. His patience and assistance has helped me immeasurably during the analysis and research sections of my thesis and I am eternally grateful to him. This project was also helped by me fellow researchers and university staff at Bangor University who aided me throughout the duration of my thesis in many different facets.

I would also like to give a special thanks to my family; my mam Patricia, dad Graham, Michelle, Ben, Robert, Kona and Mattie and my friends; Kevin and Sean who have supported me throughout this process. Without them none of this would have been possible.Finally, writing a thesis during a global pandemic has created new challenges and I would like to express my gratitude to front line workers, essential staff and scientists who are fighting so hard to keep us all safe.

**Declaration**

I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards. ------------------------------------------------------------------------------------------------------------------------------------- Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw’r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o’r blaen ar gyfer unrhyw radd, ac nid yw’n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.

**Abstract**

Management of peatlands is an important aspect of global conservation and carbon sequestration efforts. Analysis of enzyme activity, soil respiration and species data to determine overall health of Cors Goch fen, Anglesey. Here we give a detailed analysis of all current management techniques used on Cors Goch and analyse available species data and collected peat samples to see how management may need to be adapted in order to create a “perfect” site. Current techniques such as cutting, mowing and grazing are used on Cors Goch and sites around the world. After analysis of biogeochemistry data and species data we determined that there aren’t any significant changes that are required on the site. We have recommended that the addition of ancient species like Konik horses and Heck cattle, or native breed such as highland cattle and belted galloways, controlled burns and a more up to date species survey could be used to help protect the site and make sure it is optimal. Heck cattle and Konik horses have coarser diets, they require little active management and have been shown to improve vegetation structure and enhance biodiversity. They have varied diets which helps create a diverse plant population which helps aid biodiversity. Highland cattle also help increase plant species richness, reduce inflorescence of certain plants and establish others. Cattle breeds help trample bracken and low scrub and also create paths through vegetation. A noticeable trend in the biogeochemistry data is that the area of shrub consistently showed lower enzyme activity than the firebreak or sawgrass areas. This is likely linked to the woody litter from the shrub that helps lower decomposition rates. We also analysed the species data for wetland bird indicator species to see if the essential UK wetland birds had good populations. Some important birds such as the reed bunting (*Emberiza schoeniclus*), sedge warbler (*Acrocephalus schoenabaenus)* and snipe (*Gallinago gallinago)* have large numbers of records which indicates the site is healthy. However, some of the indicator species weren’t identified recently which may mean more regular surveys are needed to keep track of particular species. This is also relevant for many of the rare and/or important invertebrate species that exist on the site. The current management plan for Cors Goch gives a lot of weight to protecting the rare species that occupy the site. The current measures seem to benefit these species quite well due to our analysis of the species data. Many of the rare plants are found on specific areas of the site, and those areas need to be carefully managed. Overall the site is in good health and the current techniques are beneficial but the addition of alternate techniques could also benefit the biogeochemistry of the site and in turn aid in increasing the overall biodiversity. Further analysis may be required on certain management techniques to make sure they are going to benefit the site and other sites throughout the UK.

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**1. Introduction**

**1.1. Wetland Definitions**

A wetland is defined by USEPA (United States Environmental Protection Agency) is an area where water covers the soil for large periods throughout the year. The main way to identify a wetland is by the presence of aquatic plant species (hydrophytes) (Tiner, 1991). These plants are adapted to grow in hydric soils, which develop when soils are saturated for long periods of time; wetlands are also home to a variety of aquatic and terrestrial organisms (Tiner, 1991). Peatlands are defined by Frolking *et al* (2011), as a wetland with partially decomposed plant material (peat), a saturated environment and hydrophytic plant species. Fens themselves are defined as peat accumulating systems which are influenced by groundwater (Joosten and Clarke, 2002). One of the descriptions of lowland wetland habitats in the UK is that they grow and develop on peat, peaty or mineral soils which may be permanently, seasonally or periodically waterlogged. Lowland wetland habitats are made up of raised bogs and fens. Fens are fed by groundwater or run-off and therefore support a variety of vegetation. Raised bogs are made up of elevated deposits of raised peat. Raised bogs are usually acidic and nutrient poor as they are fed by rainwater instead of groundwater (Joint Nature Conservation Committee, 2012). Lowland wetland habitats are vital part of the conservation routine in the UK. This is because they support an extremely large variety of specialised plants and animals and because their area has dramatically declined in recent years. There is evidence to suggest that fewer than 20% of peatlands in the UK are undamaged (Bain *et al*, 2011). They are among the rarest and most endangered habitats in the entire UK. Lowland raised bogs and lowland fens are marked as a priority within the UK Biodiversity Action Plan (BRIG, 2011). Much of the world’s peatlands are spread across Europe in Ireland, United Kingdom, Scandinavia and Northern Russia. There is around 960,000 km² of peatland in Europe or what accounts for around 20% of Europe (Mitsch and Gosselink, 2015). Blanket and raised bogs cover around 23,000 km², which is 9.5% of UK land area which estimates place at around 3.2 billion tonnes of carbon stored in these areas. If even 5% of this carbon was released then it would equal the total amount of greenhouse gases released annually in the UK by human factors (Bain *et al*, 2011). Worrall *et al,* (2009a) worked out the average annual carbon budget of a UK blanket peatland over the course of 13 years and it worked out to be -59 tonnes C Km-2 yr-1. Nearly 60% of these peatlands have been changed to support agriculture, peat extraction and forestry development (Vasander *et al,* 2003). The Endla bog in Estonia and the Berezinski bog in Byelorussia are now protected reserves. The Berezinski reserve is just over half peatland and then forested peatland which is dominated by pine (*Pinus*), birch (*Betula*) and black alder (*Alnus*) (Mitsch and Gosselink, 2015). These sites are similar in many respects to the site that we will be studying and show the potential to create peatland reserves like these in the UK and Ireland. The three main factors that are responsible for maintaining a wetlands health. These are nutrient status, water level and natural disturbances. Any change to these things can cause wetland alteration to varying degrees.

**1.2.Wetland Ecosystem Services**

Before we continue to describe how to effectively manage and maintain wetland sites throughout the country, we would first like to point out why they are so important to us. One of the most important things that wetlands provide us with is they act as a huge carbon stores. Peatlands are net sinks of carbon, they store around 650 gigatonnes of carbon (gigatonne= 1 billion metric tonnes), (Yu *et al,* 2010), which is around 20-30% of the total soil organic carbon (Scharlemann *et al,* 2014). Slow organic matter decomposition rates as a result of water logged soils and accumulation of large amounts of organic matter due to high biomass productivity makes wetland soils significant sinks of carbon (McLeod *et al,* 2011). One third of all carbon is stored in earth’s soils (Gorham, 1991). Two thirds of the entire atmospheric carbon pool is stored in wetlands. This is twice the amount found in the world’s forests. Carbon accumulation in global wetlands is 10-30g C m-2 per year. Wetlands are extremely important for storing carbon, if we destroy wetlands then we risk releasing greenhouse gases and stored carbon which would significantly speed up the rate of climate change. Wetlands perform a number of other functions such as nutrient transportation, clean water supply, habitats for flora and fauna, sediment deposition and buffers to climate changes (Hsu *et al*, 2011) and (Mitsch *et al*, 2012). Wetlands can become sources, sinks or transformers of nutrients and chemicals but it depends on a number of factors including wetland type, hydrological conditions and length of chemical loading period. Peatlands are usually carbon sinks (Turunen *et al,* 2002). Wetland habitats are heavily protected by laws these days and this is due to the fact that they provide a number of key ecosystem services. These ecosystem services provide a vast array of services that are beneficial for human society. A number of supporting services that peatlands provide include peat accumulation (Waddington *et* al, 2009), nutrient cycling (Kieckbusch and Schrautzer, 2007) and increasing global biodiversity (Malson and Rydin, 2009). They have provisioning services such as food, fuel, wood, thatch and freshwater supply. These provisioning services include fish, waterfowl, collecting of shellfish, fur from animals, peat and timber. They also provide us with a number of cultural services like recreational usage, their natural aesthetic beauty and the ability to use them to educate a new generation to their importance. They also have heritage values which can demonstrate parts of ancient cultures that used wetlands for survival. Wetlands are extremely useful for being able to educate students of any level on natural history. Wetlands are very beautiful to look at and present a range ecological diversity that people can immerse themselves in. Wetlands are also popular sites for hunting and fishing. People who go hunting and fishing must buy the correct equipment and travel to and stay close to sites, which in turn helps the local economy. These types of activities must be carefully monitored but are just some examples of how useful wetlands are to human society. Wetlands give us a number of supporting services as well. They have high primary production of terrestrial and aquatic forms of life and have a relatively high form of nutrient accumulation. However, their most important service is how they regulate the environment. The regulating services that wetlands provide are flood mitigation, better water quality, aquifer recharge, prevent damage on coasts from hurricanes, storms and tsunamis and climate regulation. They also provide water regulating services (Banaszuk & Kamocki, 2008). There are many wetlands around the world that provide services to humanity that are not seen in UK wetlands. For example mangrove swamps found in Florida, Indo-Malaysia and Australia act as barriers for tsunamis and tropical storms which can prevent damage to human settlement and a loss of life. A number of studies support the idea that mangroves have mitigating capabilities for cyclone storm surges and small tsunamis (Marois and Mitsch, 2015). In fact it is even thought that the life cycle of mangroves in Florida (around 20 to 24 years) generally tend to correlate with the initiation of huge tropical hurricanes. This means that mangroves may have adapted in order for their mature stage to coincide with huge tropical storms that occur on a similar timeline.

**1.3.Wetland Development**

Probably the most important aspect in relation to the development and maintenance of a wetland site is the hydrology. The hydrological conditions of a wetland affect soil anaerobiosis and nutrient availability which in turn determines what plants and animals can develop in the wetland. The anaerobic conditions favour the rapid peat accumulation because decomposition rates and inorganic content is low in waterlogged soils. As a result of anaerobic soil conditions we see a slowing of the decomposition of organic matter and this results in the enrichment of wetland soils with organic matter (Craft, 2016). This creates a cycle were the flora and fauna are important for altering the wetland hydrology. The lack of oxygen in wetland soils affects the aerobic respiration of plant roots and changes the availability of nutrients for plants (Scholz, 2016), which in turn affects which plants can survive in these conditions. The hydroperiod which is the hydrological signature of a wetland is created by a mixture of the total water budget, subsurface conditions and the basin geomorphology. Nearly all of a wetlands water comes from surface inflows, groundwater and precipitation and is lost through surface outflows and evapotranspiration. Understanding the hydrology of a wetland is integral as the hydrology plays a role in organic accumulation, nutrient cycling, species richness and composition and primary productivity. Hydrology is the single largest determinant of the establishment of specific types of wetlands and wetland processes. Hydrogeomorphology is the make-up of climate, hydrology and basin geomorphology. Hydrology can change the physiochemical environment (chemical and physical properties) of a wetland including pH, nutrient availability, toxicity (e.g. hydrogen sulphide production) and oxygen availability. Hydrology is also known to transport sediments, dissolved organic carbon and toxins around a wetland system which can affect the physiochemical environment in a new area of the site. Changes in hydrology can create anoxic conditions which could be detrimental to some wetland life. A large variety of the plants that survive in wetlands can then in turn control the hydrology and its many effects in what resembles a biological feedback loop. Another important aspect of the hydrological conditions is the hydroperiod. The hydroperiod of a wetland is integral in determining the type of wetland and what biota exists there. The hydroperiod is the seasonal pattern of water level fluctuation of an area. The hydroperiod is created and changed due to natural features of the terrain and its proximity to other bodies of water. The main threats to wetlands are commercial development, drainage schemes, peat extraction, pesticide discharge from intensive agriculture, toxic pollutants from industrial waste and dam and dike construction. The draining or damming of a fen can have severe effects on the biogeochemistry of peatlands. When areas of peat are drained it allows the peat to waste away as a result of oxidation. Draining or damming a peatland can lower the water table and allow plants to grow that don’t easily create peat (Bain *et al*, 2011), and thus adjusts the biogeochemical properties of the site. Long-term drainage on a site in the Czech Republic led to an overall decline in the quality of the ecosystem indicated by a change in vegetation composition, reduced decomposability of peat, with high content of recalcitrant compounds and decreased pH and reduced soil microbial biomass and activity (Urbanova *et al,* 2018).

**1.4.Wetland Soils**

The soils of a wetland are very important for the makeup of each site. Wetland soils as defined by the U.S. Department of Agriculture’s Natural Resources Conservation Service (NRCS, 2010) are hydric soils and are created when soils are saturated or flooded for large parts of the growing season and then anaerobic conditions develop in the upper parts of the soil. Bogs and fens are organic soils and they are water logged for lengthy periods of time and have high organic carbon content. The general properties of organic soil are:

Table 1: Shows some common properties of organic soils

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| **Organic Soil** | **Properties** |
| Organic Content (percent) | Greater than 20 to 35% |
| Organic Carbon (percent) | Greater than 12 to 20% |
| pH | Acidic |
| Bulk Density | Low |
| Porosity | High (80%) |
| Hydraulic Conductivity | Low to High |
| Water Holding Capacity | High |
| Nutrient Availability | Often Low |
| Cation Exchange Capacity | High, dominated by hydrogen ion |
| Typical Wetland | Northern Peatland |

The main four physiochemical properties of organic soils are bulk density and porosity, hydraulic conductivity, nutrient availability and cation exchange capacity. Bulk density is the dry weight of soil material per unit volume. In this regard peatlands tend to be very light as they consist of sphagnum a lot of the time. Bulk density is low for organic soils as a result of high porosity which is the amount of space within the soil that water can occupy when saturated. As a result of all these factors organic soils can be up to 80% water. The hydraulic conductivity of organic soils is linked with the rate of decomposition. If decomposition increases then the hydraulic conductivity of a soil generally decreases. This means that the plants of a wetland have a significant amount of influence over the hydraulic conductivity with *Phragmites* and *Carex* species making soils more permeable than mosses. The amount of nutrients available in a wetland obviously has a massive influence on a wide range of factors including flora and fauna diversity and spread, decomposition rates and primary productivity. *Phragmites australis* for instance has huge potential for nutrient removal from sites (Hernandez-Crespo *et al,* 2016). Nutrient enrichment leads to changes in species composition, declines in overall plant diversity and a loss of rare and uncommon species (Bedford *et al,* 1999). Organic soils have a high amount of organic minerals that are not available for uptake by plants. There is a rather high possibility that organic soils could have very low iron and phosphorous availability and this can severely limit plant productivity. However iron rich fens are rich in phosphorus whereas iron poor fens are poor in phosphorus but iron rich fens are also limited by a number of other nutrients which also limits productivity (Kooijman *et al,* 2020). Organic soils also have a high cation exchange capacity which is the amount of cations (positive ions) that a soil can store. As organic content goes up then the amount and percentage of hydrogen ions also increases. Peat that has a lot of sphagnum growth also seems to have a high cation exchange capacity and this is thought to be a result of long-chain polymers from uronic acid (Clymo, 1983). Peat is also important for stabilising the flooding regime and changes the main source of nutrients to recycled material in a wetland. As a result of the decomposition being inhibited by low pH’s in peatlands, organic matter then has chance to accumulate.

One of the most interesting things about wetlands is how their natural state of being waterlogged is integral for preventing decomposition of the site. Waterlogging reduces O₂ abundance and a lack of O₂ restricts decomposition. Carbon accumulation in peatlands is made possible by the carbon fixation from primary production and cause of carbon loss from decomposition under a high water table (Ballantyne *et al,* 2014). This carbon sequestration is only possible if the enzymic latch remains intact. Peatlands are packed full of phenolics (polyphenols, tannins and humics), this gives peatlands their distinctive brown water characteristic. Phenol oxidase is one of the few enzymes that can degrade phenolics, so without them phenolics accumulate. When drought occurs, a peatland is dammed or drainage schemes are introduced, O₂ is added to the peat. Phenol oxidase needs oxygen for its activity so isn’t as active in the anaerobic conditions found in peatlands and its activity can increase seven fold with oxygen (Freeman *et al,* 2004). This results in a rise in phenol oxidases and thus a decline in phenolics. Phenolics are strong hydrolase enzyme inhibitors. Removing miniscule amounts of phenolics can drastically increase hydrolase enzyme activity. Phenolic materials are extremely inhibitory to enzymes and if their abundance is lower it results in higher hydrolase enzyme activity, so oxygen restrictions on phenol oxidase activity provides conditions that are inhibitory to decomposition (Freeman *et al,* 2004). Hydrolase enzymes are responsible for the majority of organic matter decomposition in soils. This means that they are exceptional at breaking down peat. Hydrolase enzymes are good at breaking down organic matter which is then used by microbes and respired as CO₂. Hydrolase enzyme activities are relatively low in general in peatlands which is unexpected as Lee *et al* (1999), showed that hydrolases can even remain active in anaerobic conditions like the rumen. The idea that phenol oxidase is critical in regulating the suite of hydrolase enzymes is known as the enzymic latch (Freeman *et al,* 2001). The breakdown of the enzymic latch could cause serious issues in relation to climate change, as it leads to the release of stored carbon and this could increase the rate of climate change. Flooding of soils slows decomposition because oxygen diffuses through water much slower (up to 10,000 times slower than normal) and this creates the anaerobic conditions that wetlands are well known for. The idea that peatlands are fragile systems is demonstrated by Kang *et al* (2018), who discusses the fact that an increase in pH can activate latent phenol oxidase therefore breaking the enzymic latch and causing decomposition. The extremely low concentrations of oxygen, changes the availability of nutrients and toxic materials. This leads to many plants having to develop site specific adaptions in order to survive. However a thin layer of oxidised soil forms at the top of the soil where it meets the water.

The gases that are measured for soil respiration, because they are the three main greenhouse gases, are carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Peat produces CO₂ in larger quantities compared to other gases, this is due to respiration of microorganisms in the oxic layer which are constantly breaking down organic matter (Vasander and Kettunen, 2006). In the anoxic area of the soil CH₄ is formed by archaea by using substrates such as hydrogen and acetate (Segers, 1998). Peatlands account for around 10% of global CH₄ emissions (Moomaw *et al,* 2018). The production of N₂O is linked with the processes of nitrification and denitrification (Freeman *et al,* 1997).

**1.5.Wetland Plants**

Plants that live in wetlands are specially adapted to survive in there and have a significant advantage over ordinary terrestrial plants when in inundated conditions. UK peatlands contain both nationally and internationally significant biodiversity. Many common species are showing declines. Macrophytes are generally regarded as the main biological components of wetlands. They’re main purpose is to assimilate pollutants, act as catalysts for water purification (Hadad *et al,* 2006) and effects biodiversity in created wetlands (Hsu *et al*, 2011). Plants in a wetland have a major effect on water chemistry because they influence nutrient availability. They act as sinks as they uptake nutrients and pumps by moving compounds from the sediment into the water column. They can help improve the quality of the water by acting as sinks for nutrients, metals and other contaminants (Cronk & Fennessy, 2009). Many different hydrophytes have developed pore spaces in their cortical tissues to allow oxygen to move from the aerial parts of the plants to the roots in order to negate the anaerobic conditions. Plant adaptions in wetlands include morphological, physiological and whole plant strategies. The main morphological adaptions are the development of aerenchyma (air pockets), which allows oxygen to diffuse from the aerial plant parts to the roots. Around 60% of root volume in wetland plants is pore space compared with around 2 to 7% in terrestrial plants. Marsh ragwort (*Senecio aquaticus*) was only 50% inhibited by root anoxia while common ragwort (*Senecio jacobaea*) was fully inhibited. Another adaption is the growth of adventitious roots through an increased concentration of ethylene. Tree species like *Salix* and *Alnus* and herbaceous plants such as *Phragmites, Ludwigia* and *Lythrum salicaria* are known to produce adventitious roots. The roots grow on the stem above the anoxic zone so they can function normally in aerobic conditions. If the roots of a plant aren’t adapted to gather oxygen in efficient ways then this can have severe consequences for the plant. Common terrestrial plants gather oxygen from the surrounding soil through diffusion but this is obviously not possible for wetland species. If oxygen is not present then root metabolism and therefore cell division, cell extension and nutrient absorption grind to a halt. As a result of this, anaerobic glycolysis and ATP production decreases. Fermentation begins and its end products may cause cytoplasmic acidosis and the plant will eventually die. Wetland vegetation is important because it can also filter excess nutrients and remove contaminants from agricultural runoff before it flows into nearby watersheds (Farrell and Scheckenberger, 2003).

A significant physiological adaption that aids in oxygen absorption is a pressurised gas flow. The common reed (*Phragmites australis*) has a pressurised gas flow (Brix *et al,* 1992). This high pressure may be a result of the fact that the common reed can grow in waters up to 2m deep. Oxygen is absorbed through aerial leaves and is forced down the stem to the roots due to the high pressure gradient. A similar process is seen in the common alder tree (*Alnus glutinosa*) which is found all over Europe (Grosse *et al,* 1992). Alder relies more on temperature to move the oxygen to the roots using a method called thermal pumping. The rate of gas movement seems to increase in the trees when the leaves are heated by the sun. This method is said to be more effective when the trees are trying to increase seedling establishment before aerenchyma have fully developed. When water levels are high for plants that aren’t adapted for anaerobic conditions they demonstrate the ability to lower their water uptake. This results in a number of changes to the plant including lower carbon dioxide uptake, wilting, decreased transpiration and the shutting of stomata. A large abundance of wetland plants have developed life history adaptions which allow them to survive. The most common strategies include buoyant seeds which float away to find an unflooded area in order to establish itself, a large seed bank and the growth of tubers, roots and seeds that can survive for long periods of time underwater.

Flora and fauna must have a number of adaptions in order to survive in the peatland environment. Plants in peatlands have aerenchyma, reduced oxygen consumption and oxygen leaked from roots which creates a local aerobic root environment. One of the most common plants that cover large quantities of peatlands is Sphagnum mosses. They also have the ability to change the conditions of a site. They have a couple of adaptions which allow them to maintain their waterlogged nature. They have overlapping leaves, compact growth and rolled leaves that draw up water and store it. This means that sphagnum species can hold between 15 to 23 times their own dry weight in water. Sphagnum can adjust the pH of its local environment usually towards acidic. The moss creates polygalacturonic acid in its cell wall which increases cation exchange capacity. Creating a lower pH slows decomposition and allows peat to accumulate. Sphagnum decomposition rates are highest near the surface and by 20cm depth the rate drops to around one/fifth of what it is at the surface due to anaerobic conditions. Plants in fens and bogs must adapt to the low nutrient conditions. They do this by uptake of amino acids, evergreenness, high root biomass and sclerophylly (reducing grazing by increasing epidermic thickness. The bog myrtle (*Myrica gale*) and alder plants have grown root nodules that help them fix atmospheric nitrogen. Many of the adaptions that plants have in turn have an effect on the rate of peat accumulation. The rate of peat gathering is also affected by chemical, hydrological and topographic factors. Peat stores a large amount of nutrients but they are usually very deep and therefore plants can’t use them. There are a number of predictions for the rate of peat accumulation in European bogs and fens. Moore and Bellamy, (1974) believed it to be between 20 and 80cm/1,000 years while Malmer (1975), described a vertical accumulation rate of 50 to 100cm/1,000 years in Western Europe.

**1.6.Wetland Biogeochemistry**

One thing that can cause chemical changes in a wetland is microbes. They have control over the amount of nutrients that plants have available to them and also play a role in controlling phytotoxin production. However plants also have a significant amount of control when it comes to causing physical changes in their local environment. They use a number of methods in wetlands to do this including nutrient retention, water shading, transpiration, sediment trapping and peat building. Plants can also alter hydrological conditions by building peat, trapping sediment, binding sediments together to reduce erosion and by interrupting water flows.

Climate change can have serious effects on wetlands. Elevated CO₂ levels leads to an increase in CH₄. This is because CO₂ stimulates photosynthesis which leads to a rise in biomass, as a result exudates leak and create more litter. This then creates more substrates and stimulates methanogenesis (Ziska *et al,* 1998). Soil respiration is the CO₂ produced by the biological activity of soil organisms, including plant roots, microbes and soil animals. Soil respiration which is generally measured as flux of CO₂ from the soil surface (e.g. µ mol CO₂ m-2 s-1), is a barometer of soil metabolic activity, representing an integrated response of diverse organisms occupying microhabitats throughout the soil profile (Phillips and Nickerson, 2015). Soil respiration is an integral part of the ecosystem carbon cycle. Soil respiration also associated with nutrient processes such as decomposition and mineralization, also part of regulating atmospheric CO₂ concentrations and climate dynamics (Luo and Zhou, 2006). As we know climate change can also increase temperatures due to the indirect effect of higher CO₂ levels. A possible increase of around 1.5-5.9°C is expected. Microbial activity rises exponentially with temperature (Biederbeck and Campbell, 1973). Changes to climate also results in an increase in the likelihood of extreme hydrological events such as drought. This is dangerous as wetlands rely heavily on water abundance and will increase the rate at which the enzymic latch is broken. There are a number of theories that suggest that anticyclone activities may increase and this could lead to a rise in drought frequency in Western Europe and North America. Lab and field experiments by Carter *et al,* (2011) showed rises in N₂O and CO₂ release and a decrease in CH₄ release as a result of increased rates of drought. Other consequences of droughts include increased inorganic nutrient release, impacts on water quality amelioration and impacts on life in streams which may feed into wetlands.

A key aspect of wetlands and peatlands in particular is there lack of nutrient availability for plants, which in turn lowers primary productivity. Nitrogen is considered to be the main limiting factor for nutrients in saturated soils. Due to the anaerobic conditions of wetland a large percentage of the loss of nitrogen is to the atmosphere. This means that microbial denitrification of nitrates to gaseous forms allows nitrogen to be released to the atmosphere. The ammonium ion (NH4+) is the most abundant type of mineralised nitrogen found in inundated wetland soils. The thin layer of oxidised soil present in wetlands allows for the initiation of several nitrogen pathways. Denitrification is relatively slow in peat so doesn’t cause a large loss of nitrogen in Northern peatlands. Sulphur is lost from wetlands when it’s hydrogen sulphide (H₂S). Phosphorus is another limiting nutrient in bogs and fens. Large amounts of phosphorus are stored in organic litter and peat. Phosphorus is available for uptake when the pH is slightly acidic or neutral (Reddy and DeLaune, 2008). Plants are able to change inorganic phosphorus to organic phosphorus which is then stored by peat and mineralised by microbial activity before being removed from the wetland. Anything that enters a wetland site usually enters by geological, biological or hydrological pathways. The main geological input is through weathering of rock. Transport of materials by animals (e.g. birds), nitrogen fixation and the photosynthetic uptake of carbon are considered to be the main biological inputs. The hydrological inputs are through precipitation and surface and groundwater inflows.

**1.7.Wetland Types**

Peatlands have a number of features that differentiate them from other wetland types. They are usually acidic due to cation exchange with mosses, have low nutrients and low primary productivity. They also must have peat accumulation, slow decomposition rates, oxidation of sulphur compounds and varying nutrient cycling pathways. In order for a peatland to survive and develop precipitation must be higher than evapotranspiration and peat accumulation has to be higher than peat decomposition. After a peatland has developed it is considered a fairly resistant habitat due to the water holding capacity of peat and its low pH. These factors make it stable under a wide variety of environmental changes. The pH of peatlands tends to go down as organic content increases during the development from a minerotrophic fen to an ombrotrophic bog (Gorham, 1967). Fens generally get their minerals from the surrounding soils. The pH of fens varies from slightly acidic (poor fens) to strongly alkaline (rich fens) but this depends on groundwater flow rate and chemistry (Bedford and Godwin, 2003). Conductivity and pH are both strong indicators of mineral groundwater entering a site. We know that as little as 10% of the water supply being from groundwater could alter the pH of a fen from 3.6 to 6.8, essentially turning it into a rich fen. Fens tend to have more nutrients than bogs due to groundwater and surface inflows. Nitrogen and phosphorus are the major limiting nutrients in fen productivity. Calcium and potassium are also known to be limiting nutrients. Carbon inflows come from precipitation, groundwater and net community productivity. Whereas the outflows come from groundwater and surface flow and outgassing of methane. The addition of large amounts of these nutrients to peatlands can cause substantial vegetation shifts. It is thought that if large amounts of mowing occurs then the limiting factor might shift from nitrogen to phosphorus.

The site that we will be studying is a lowland fen. Fens tend to be transitional sites, as in they are in between a freshwater marsh and a fully developed bog and therefore they tend to share attributes from both wetland types. Freshwater marshes are sometimes counted as fens due to their ability to convert to other wetland types over rather short periods of time. The organic substrate in freshwater marshes is not very deep especially when compared with fens and bogs. However they have higher productivity rates than bogs. Fens usually have some drainage from underlying mineral soils while bogs generally don’t. Fens usually support large amounts of sedges, reeds and grasses. Lowland fens are minerotrophic peatlands, as they get their nutrients from groundwater as well as rainwater. They are periodically waterlogged and decomposition is relatively high so peat depth is shallow. Fens are usually made up of a number of habitats including wet woodland, reedbed, lowland heathland and lowland meadow. There are two distinguished types of fens: topogenous fens where water movement is generally vertical (floodplain and basin fens) and soligenous fens where water movement is mostly lateral. Topogenous fens form in basins, where water from upwelling groundwater or surface runoff enters the fen. Water fluctuations tend to be vertical and water builds up due to topography. Soligenous fens however form on the floors of valleys with a dispersed flow of water throughout. Usually the slope of the terrain provides a nonstop flow of water and horizontal water movement is more important than a vertical one.

**1.8 Wetland Enzymes**

There are two main groups of enzymes in peatlands that we will be looking at, these are hydrolase and phenol oxidase. Hydrolase enzymes are a group of enzymes that are responsible for most of the organic matter decomposition in soils. Hydrolase enzymes operate by breaking organic matter into smaller parts which are then utilised by microbes and respires as CO₂. Hydrolase enzymes are also known to release nutrients that were attached to organic matter. Phenolic compounds inhibit hydrolase enzymes so the activity of phenol oxidase is important in regulating hydrolase enzyme activities. The main 5 hydrolase enzymes that we study are β-D-glucosidase, arylsulphatase, β-D-xylosidase, N-acetyl-β-D-glucosaminidase and phosphatase. The measurement of extracellular enzyme activity in wetland soils can tell us the biogeochemical processes, nutrient rates and carbon cycling of these areas (Dunn *et al,* 2013). A group of extracellular hydrolysing enzymes control the rate of substrate degradation and are then used for microbial or plant uptake. This means that these enzymes are key for organic matter decomposition, mineralisation and nutrient cycling (Marx *et al,* 2001). The five main hydrolase enzymes are produced by a number of bacteria, fungi, micro-organisms and plant cells. We have already acknowledged that phenol oxidases are essential for maintaining inhibitory phenolic compound levels which suppress the activities of hydrolase enzymes among others (Burns, 1982). A large number of environmental conditions can have huge effects on carbon and nutrient cycling which is maintained by enzymes. Some of these conditions include the lowering of water level by climate change or human interaction (Freeman *et al,* 1997), land use changes (Ye *et al,* 2009), temperature (Fenner *et al,* 2006), UV (Thomas *et al,* 2009), elevated O₂ (Kang *et al,* 2001), O₃ (Williamson *et al,* 2010) and metals (Siciliano and Lean, 2002). Each of the 5 key hydrolase enzymes has a different role to perform and each is as important as the others.

* β-D-glucosidase: Glucosidases break down glycosidic linkages between carbohydrate molecules and other groups which ends up releasing smaller sugars like glucose. They also degrade cellulose and provide labile carbon and energy sources for microbial organisms in soil. β-D-glucose is the most common stereoisomer of glucose that is known (Deng and Popova, 2011).
* Arylsulphatase: Arylsulphatase is the main enzyme that is a part of the soil sulphur cycle. It initiates the removal of the sulphate ion from arylsulphate esters (Press *et al,* 1985), in types like choline sulphate, phenolic sulphate and sulphated polysaccharides (Oshrain and Wiebe, 1979). Its main source in soils is believed to be micro-organisms (Klose *et al,* 1999).
* β-D-xylosidase: This enzyme allows the breakdown of hemicelluloses. Hemicellulose is a weaker structure and is made up of a variety of sugar monomers including xylon. β-D-xylosidases main role is in the last step of hemicellulose decomposition where xylobiase (C₁₀H₁₈O₉) is hydrolysed to xylose (C₅H₁₀O₅), (Wittmann *et al,* 2004).
* N-acetyl-β-D-glucosaminidase: This enzyme is necessary for the breakdown of chitin (C₈H₁₃O₅N)n. Chitin is the second most common polysaccharide after cellulose. Chitin is a high percentage of humus bound nitrogen and its decomposition in wetland soils. It is also heavily involved in nitrogen cycling (Kang *et al,* 2005).
* Phosphatase: Phosphatase is involved in taking phosphate groups from organic molecules by breaking down phosphoric acid monoesters into a phosphate ion and a free hydroxyl group attached to a molecule. The most common and highly dominant is phosphomonoesterase which acts on a number of low molecular weight phosphorus compounds that have a monoester attachment (Kang *et al,* 2005).

Phenol oxidases are also key to the biogeochemistry of wetlands. They are known for oxidising phenolic compounds from aromatics to sophisticated polyphenols which can lead to partial oxidation and oxidative intermediates release to even complete degradation and creation of non-phenolic end products like CO₂ (Duran *et al,* 2002).

**2.Cors Goch**

The site we will be studying throughout the year is Cors Goch, which is a fen in a shallow valley on the Eastern side of Anglesey located near the village of Llanbedrgoch. It is Anglesey’s most complete fen basin and is primarily a base rich fen sitting in a shallow valley fed with lime rich water. It has a number of different habitats associated with it including limestone grassland, acid grasslands, calcareous heath lands, woodlands and scrub. Cors Goch is 95 hectares in size. It tends to have a number of grazing animals including cattle, sheep and horses on the site at different points throughout the year. The site is a mosaic of different habitats not really laid out in any discernible pattern. From what we can tell Cors Goch is found where a number of former lake basins where and has been gradually filled in with clay, marl and peat sediments (North Wales Wildlife Trust n.d.). The botanical origin of the organic soils present on Cors Goch are most likely from *Sphagnum* mosses, reed grass (*Phragmites*), sedges like *Cladium* and *Carex* or possibly even from cattails (*Typha*).

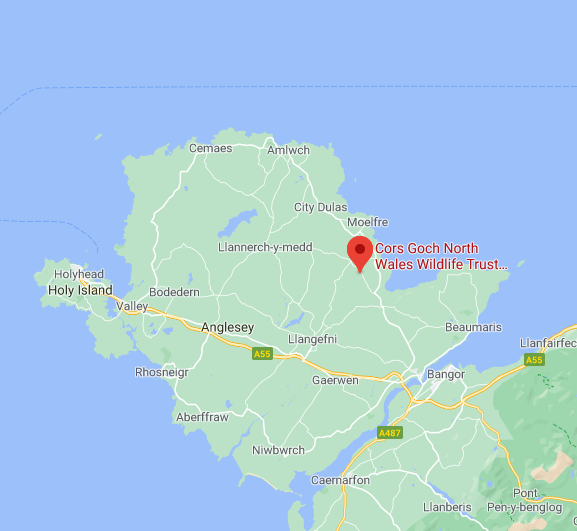


Figure 1: Shows the location of Cors Goch on the isle of Anglesey

There are many features of Cors Goch that make it a very interesting site, first of all it has been designated a Site of Special Scientific Interest. It has a lime-rich swamp which is full of great pond sedge (*Carex riparia*), bottle sedge (*Carex rostrata*) and common reed (*Phragmites australis*). An area of the fen is designated as lime-rich fen and is characterised by plants like black bog rush (*Schoenus nigricans*) and blunt flowered rush (*Juncus subnodulosus*). A number of vascular plants such as the marsh dandelion (*Taraxacum palustre*) and nationally rare species like the narrow leaved marsh orchid (*Dactylorhiza traunsteineri*), pale heath orchid (*Viola lactea*) and fen pondweed (*Potamogeton coloratus*) are found on the site as well. The site also includes a limestone grassland with green-winged orchids (*Anacamptis morio*) and a dry calcareous heath with western gorse (*Ulex gallii*) and heather. Various stoneworts, which are large aquatic algae, are found including the rare dwarf stonewort (*Nitella tenuissima*) alongside a collection of peatland invertebrates. Medicinal leeches are maintained on the site as part of the small open water community that is present. Cors Goch has a small but deep section of open water in Llyn Cadarn which is located on its western border (North Wales Wildlife Trust, n.d.). The hydroperiod of a site is difficult to know for certain without many years of tracking water levels, but at first glance the hydroperiod of Cors Goch appears to be saturated. Which means that the substrate is saturated for extended periods of time during the growing season but standing water is rarely present (Mitsch and Gosselink, 2015). However more accurate monitoring is required to determine this for sure. Peatlands in cooler climates usually have hydroperiods that have little seasonal fluctuation which seems to be the case in fens in North Wales. The hydroperiod of each wetland is created and maintained as a result of a number of factors including how balanced the inflows and outflows of water are, surface contours and geology, subsurface soil and groundwater conditions.

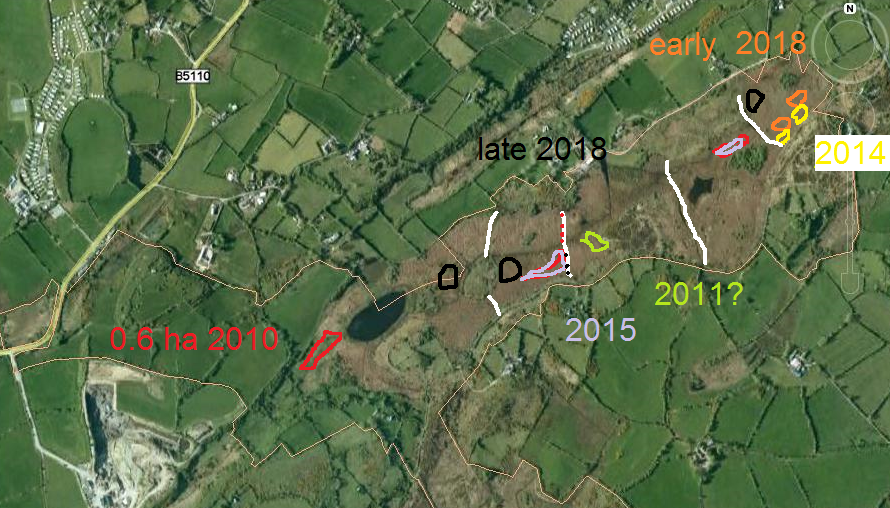


Figure 2: This is the map of Cors Goch with labels that show the areas that have been cut and in which years. The black areas were cut early 2020. Each of the white lines is a firebreak which has been cut annually since the early 90's, they have also been grazed

Above in Figure 1 is the site map of Cors Goch with annotations to show in which years different cuts of the site were undertaken. The black circles were cut in late 2019/early 2020. The white lines are firebreaks which have been cut annually since the early 90’s. The firebreaks have also been grazed throughout that period as well. The only exception to this is the central white line with the dotted black and red lines. The black dots were first cut in 2017 and the red line was originally cut in 2018. The red area was cut in 2010, the green area in 2011. The other major management schemes undertaken were the yellow section in 2014, the lilac area near the central firebreak was cut in 2015 and the orange section in the North East of the fen was cut in early 2018 (North Wales Wildlife Trust, n.d.).

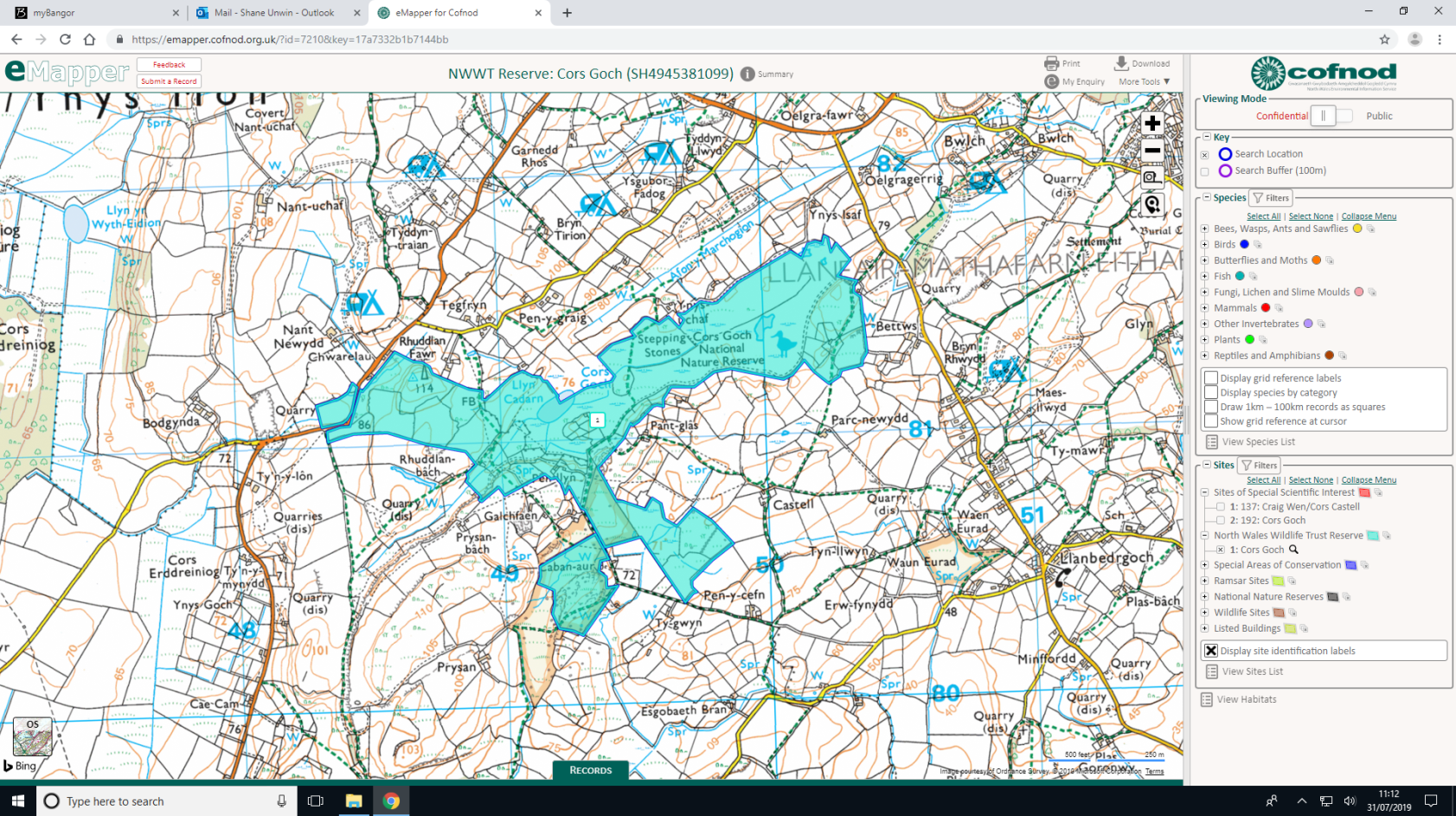


Figure 3: The highlighted blue area is what is designated by the North Wales Wildlife Trust as the Cors Goch Reserve

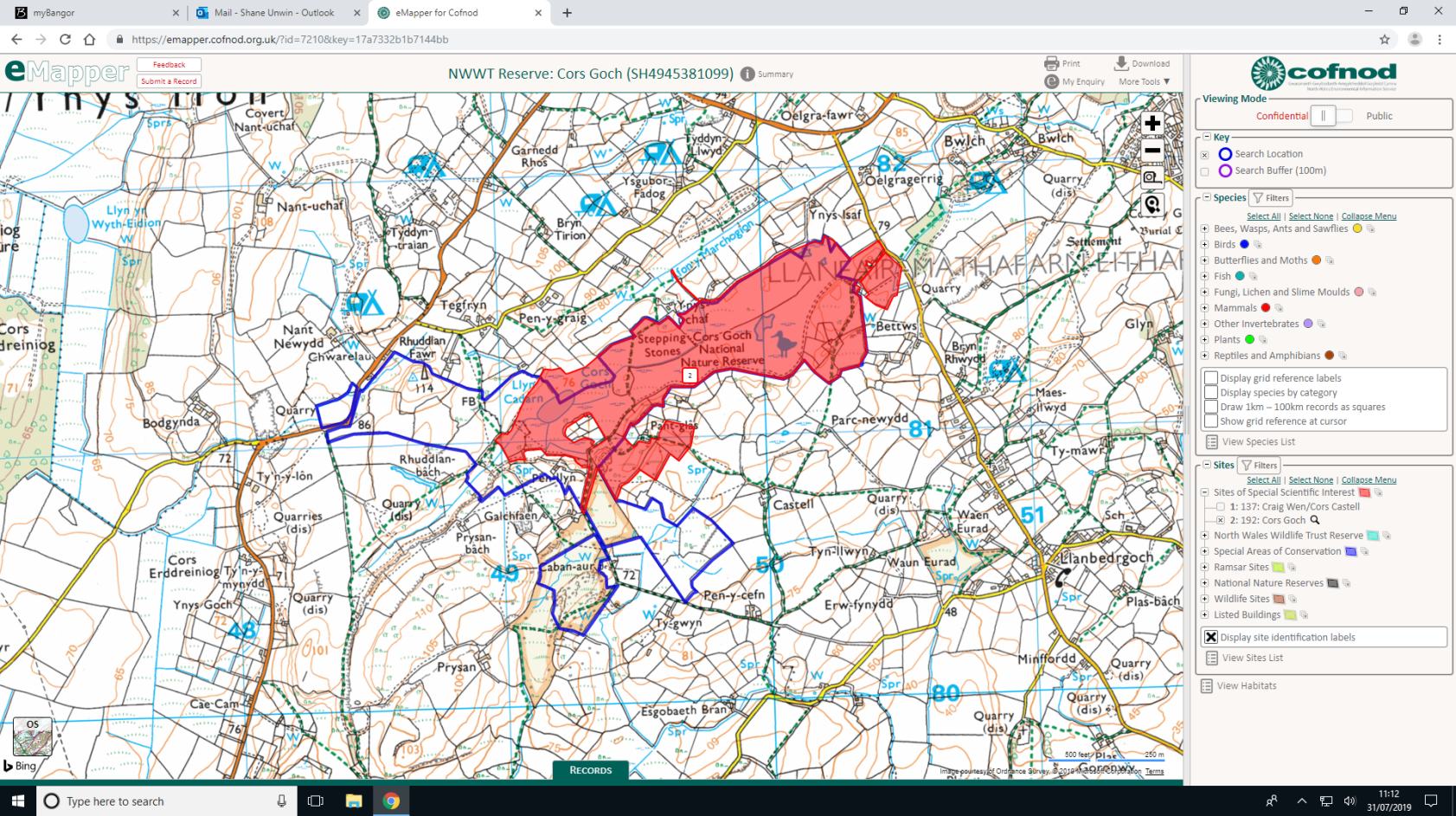


Figure 4: The highlighted red area is the main Cors Goch site itself

Figure 3 & 4 show maps of Cors Goch with different areas highlighted. The blue area in Figure 3 shows the full extent of the reserve as designated by the North Wales Wildlife Trust and the red rea in Figure 4 shows the amount of which is Cors Goch itself.

Another aspect of Cors Goch that would take a number of years to accurately measure is the water budget for the site. The annual water budget of a site is a way of accounting for the rates of change in stored water in an area. The amount of water in an area is changed and balanced by the rate in which water flows into and out of the area via a number of different methods (Mitsch and Gosselink, 2015). There are a number of factors that determine the water budgets of wetlands. These include precipitation, groundwater inflows and outflows, surface inflows and outflows and evapotranspiration. The expected factors that are important for Cors Goch are precipitation and groundwater. Water introduced from precipitation varies depending on climate and seasons while groundwater inflow is less seasonal than surface inflows as it relies on rainfall patterns. This means that groundwater may not always be present. Wetlands can lose water through evapotranspiration but this is extremely dependent on weather and the physical and biological conditions present on each individual wetland. Evapotranspiration is the way in which water is moved from the ground to the atmosphere via evaporation from the soil and through transpiration from plants. The figure below shows the annual water budget for a rich fen in North Wales, taken from Mitsch and Gosselink (2015).

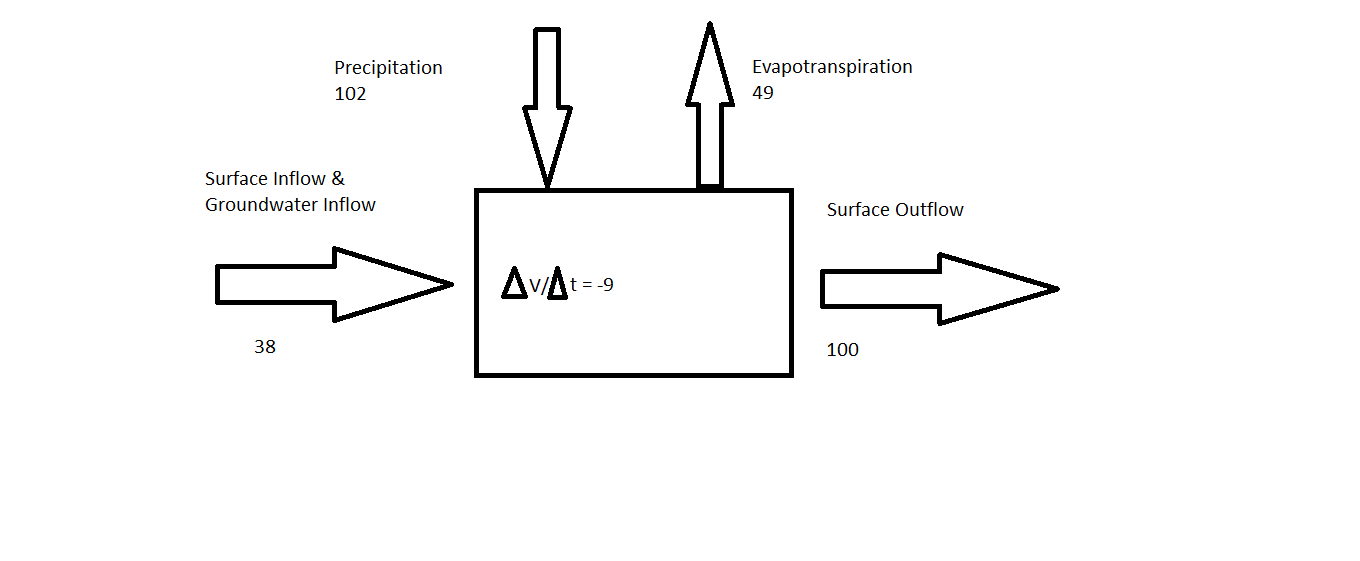
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Figure 5: Annual water budget for a rich fen in North Wales from Wetlands (Fifth Edition) by W.J. Mitsch and J.G. Gosselink

Not all of the precipitation that falls onto a site reaches the substrate. Some of the water is intercepted by canopy of plants (interception) and what actually reaches the substrate is known as throughfall. Interception can be altered by vegetation type, level and stage of development. A small percentage of the total water budget is moved through the stems of plants and is called stemflow (Mitsch and Gosselink, 2015). Determining water budget:

* Precipitation= Interception + Throughfall + Stemflow
* Net Precipitation= Precipitation – Interception

These factors also have to be taken into account when examining the water budgets of wetlands. Nutrient availability and cycling through a wetland system is integral for the development of a wetland. Nutrients enter into wetlands through precipitation and surface and groundwater inflows and exit through outflows. Nutrient cycling tends to be slow in areas that have low productivity and decomposition rates such as fens and bogs. The levels of potassium and magnesium ions and trace nutrients such as sulphur, iron and manganese are determined by the hydrological conditions of a wetland.

A plan has been developed for Cors Goch which states what the site should look like in order to encompass all of its special features and even regain areas that have been temporarily lost. This information is taken from the North Wales wildlife Trust and SAC management plan (Willis, 2008). The techniques used to establish this “perfect site” are still up for debate and are constantly been reconfigured and redesigned in order to determine the proper structure that should be applied to allow the site to flourish. Cors Goch should have at least 25 hectares of swamp and open fen and should be without scrub or tree cover. This area is characterised by great fen-sedge (*Cladium mariscus*) and elsewhere by the combination of black bog rush (*Schoenus nigricans*) and blunt-flowered rush (*Juncus subnodulosus*) or strands of bottle sedge (*Carex rostrata*) and slender sedge (*Carex lasiocarpa*). A number of brown mosses are also mixed in which should give the site a high species diversity which would signify that the appropriate amount of grazing is being used. Small areas of bare peat and open water should be allowed in the fen for the benefit of medicinal leeches and stoneworts. Less than 10% of the fen area should be designated for birch and willow scrub. Patches of heathland that have heather and western gorse (*Ulex gallii*) should be maintained with a varied structure, including around 10-20% of bare ground to permit pale heath violet (*Viola lacteal*) to flourish. The calcareous grassland, identified by the presence of the green-winged orchid (*Anacamptis morio*) should be kept at a minimum of 0.2ha. Llyn Cadarn which is a small kettle-hole lake that is surrounded by a floating fen and also a narrow strip of yellow and white water lilies. The water in the lake should be clear and the lake bed should be covered in thick patches of stoneworts and then covered with a light canopy of a variety of pondweeds. The site should provide a strong habitat for breeding great crested newts (*Triturus cristatus*) and a rich variety of other invertebrates including dragonflies, marsh fritillary butterfly (*Euphydryas aurinia*) and the medicinal leeches. Every hydrological system on the site should be intact and there shouldn’t be a single point source input of nutrients (North Wales Wildlife Trust n.d.). Agricultural run-off of nitrate and phosphate threatens the site with eutrophication, so any agricultural presence near the site needs to properly monitored and measured. The site has a number of boardwalks which are used for public access. This is obviously very important as it helps increase the publics understanding and appreciation for the beauty of the site. However, public access should be monitored so as not to damage the special features of the site.

Cors Goch is an extremely interesting site and this is in part due to the variety of flora and fauna that is present on the site. Along with an assemblage of common plants and animals the site also contains a number of rarer species. The site has 10 species of orchid, 15 species of dragonfly and over 19 species of butterfly. In general the presence of dragonflies on a site tends to indicate good water quality. Some of the species are nationally rare and are only found on a few select sites throughout the whole of the UK. Some of the rare dragonfly species include the common darter (*Sympetrum striolatum*) and the golden-ringed dragonfly (*Cordulegaster boltonii*). The common darter is a red, narrow-bodied dragonfly which is usually seen from July to October. They rely heavily on an appropriate water table as they breed in a number of water bodies including ponds, rivers, lakes and ditches. The golden-ringed dragonfly is the UK’s longest species and is seen usually from May to September. Usually found around acidic water bodies in heathland habitats. Females tend to be larger as they have a long ovipositor. However, both males and females are black with yellow bands and have green eyes. This species of dragonfly usually feeds on large insects including wasps, beetles, damselflies and it is even known to eat other dragonflies. Their larvae live at the bottom of streams and survive by attacking passing organisms. They can spend as many as five years in the water developing before turning into a dragonfly.

One of the rarest orchids in the UK is found on Cors Goch, the green-winged orchid (*Anacamptis morio*). It is named after the green veins in the hood of its flowers. The flowers appear from May to June. The orchid grows mainly on chalky soils, is pollinated by bumblebees and has a number of pinky-purple flowers. One of the main reasons that the green-winged orchid is so rare is that its seeds do not have enough energy to germinate on their own and rely on a symbiotic relationship with mycorrhizal fungus to grow. The orchid is usually only found on unaltered grasslands as a high percentage of the fungi are lost via cultivation or the application of fertilisers and herbicides. Another one of the rare plants found on Cors Goch is the marsh gentian (*Gentiana pneumonanthe*). It is bright blue and has trumpet-shaped flowers and flowers from July to October. It is a rare plant of acidic bogs and wet heathlands. It has branched stems which hold the flowers that are striped with green, narrow leaves and are carried up the stem in pairs. The plant roots were previously used to treat diseases as well as certain stings and bites.

The site also has a number of rare butterfly species which are found in only a few places. The small pearl-bordered fritillary (*Boloria selene*) can be seen from May to August. It is fairly widespread but has experienced drastic declines. It is found in damp grassland areas, woodland clearings and in moorlands. Adults use a flutter and glide technique to fly near to the ground in order to feed on nectar from bramble and thistle flowers. The caterpillar eats violet species such as the common dog-violet (*Viola riviniana*) and marsh violet (*Viola palustris*). The butterfly is orange with black marks on the upper parts of the wings. It also has black and silver lines on its underside as well as a row of white pearls on the outer rim of its wing, where it gets its name from. It tends to appear earlier in the South West of England and the timing of emergence eventually trends Northwards. A second batch of butterflies may develop if an early emergence occurred. Another species which is near-threatened but can be seen on Cors Goch is the small copper (*Lycaena phlaeas*). It is often seen from April to October. The males are very territorial and tend to chase away other insects while basking on rocks awaiting the arrival of females. The caterpillars feed on common sorrel (*Jacobaea vulgaris*) and thistles. Commonly found in dry, sunny habitats including heathlands, fringes of woodlands and downland. The small copper has bright orange forewings with dark brown spots and a thick brown margin. The dark brown back wings are banded with orange. The information about both of these species was drawn extensively from The Wildlife Trusts (n.d.) website. There were a few unsuccessful attempts to re-establish a larger UK population. Some other species that are found in Cors Goch include the barn owl (*Tyto alba*), sedge warbler (*Acrocephalus schoenobaenus*), common butterwort (*Pinguicala vulgaris*), yellowhammer (*Emberiza citrinella*), water vole (*Arvicola amphibus*), great crested newt (*Triturus cristatus*) and common stoneworts (*Chara vulgaris*).

**2.1 Site Management of Cors Goch**

There are a number of management techniques being employed on Cors Goch. They change depending on what part of the site is being managed. There is a possibility that other techniques could be used depending on the results of our research. The fen is currently grazed by cattle, horses and ponies usually in the spring and summertime but it does occur at various points throughout the year. The introduction of grazing animals helps to limit scrub growth and keep open areas in the fen and heathland which allows other species to prosper. There are some areas of scrub on Cors Goch. These areas are important as they provide shelter for invertebrates and are key as sites for bird nesting. However, too large an area of scrub can change the nature of the site. Grazing is usually enough to contain scrub growth but an active scrub control technique may be necessary. Cutting and mowing is the main management process that is used on Cors Goch. Cutting of Western gorse (*Ulex gallii*) is an approach often used to stop its rapid growth. Cutting and mowing is used on the site to create firebreaks between plant areas. The cuttings from this process should be removed from the site, however small mounds of cuttings could be left on the site in order to create microhabitats for invertebrates. Removal of dwarf-shrub vegetation on the heathland is also done by cutting. This opens up new areas of the site and helps diversify the flora. A strong cutting and mowing regime is currently being employed on the site. The firebreaks are cut every year and most of the cuttings are removed. Two more strips are cut parallel to both sides of the firebreak. The zone either side of the firebreak is cut every six years and the zone furthest away is planned to be cut every twenty five years. One method that is used around the world but not very often in the UK is fire. Fire is used heavily in North America as an effective and efficient control method. Fire can be used to remove old vegetation, but maintaining control of the fire is essential. An uncontrolled fire could ravish the invertebrate population and destroy any heathland present. Any destruction of a heathland could lead to the spread of Western gorse (*Ulex gallii*). A carefully planned number of winter burns could allow the rejuvenation of the fen. Firebreaks, which are already present on the site, are necessary to have controlled burns and prevent the spread of wildfires.

A large amount of the site management is invested in maintaining the water level, quality and movement. Water is essential on a wetland especially for fen plants and animals. A high water table should be maintained for a large portion of the year. Outfalls from the site should not be deepened or widened. A weir or sluice could prevent drastic changes to the flow of springs. No actions should be undertaken in the catchment area that affects the water table as this could have damaging effects. One of the most important factors that keep the fen so pristine is a high water quality. A good concentration of calcium and magnesium and low levels of nitrogen and phosphorus is essential for the perfect site. An increase in nutrient levels could allow the populations of tolerant plants to swell rapidly. This would also lead to a decline in rarer and possibly more desirable species. Any addition of toxins to the site could change the careful balance that has been developed there, specifically the microscopic flora and fauna in the lake. The toxins could also kill many of the fish species that live there. Management of the water supply and levels is essential for maintaining the distinctive features of the fen, so keeping a close eye on the movement of groundwater from springs throughout the site is a must.

**3. Aims/Hypotheses**

The aim of this research is to determine the best course of action in relation to management techniques on Cors Goch. We predict that we will see changes in the biodiversity of the site in relation to the addition of management techniques on the site over the course of a number of years.

**4. Methods**

**4.1 Biogeochemistry**

**4.1.1 Study Area**

The site we are examining is Cors Goch on Anglesey and it is a rare wetland fen fed by alkaline water that drains on to the site after flowing through porous limestone rocks that surround the area. There are a number of tests that we run on Cors Goch in order to determine the health of the site and to understand what current site management techniques are working appropriately and which ones need to be adjusted. When visiting the site we take a number of grab samples and a number of core samples using the Russian corer. The samples were extracted from the Cors Goch reserve which is a lowland fen. The main samples were taken at the end of October 2018, with a number of grab samples of peat being taken throughout 2019. The reason we took core samples was because peat samples between 50 and 100 mm deep show the highest levels of microbial activity (Freeman *et al,* 1995). The core samples were taken from the lowland fen that is Cors Goch, Anglesey which is located at 53° 18’ 29.88” N, -4° 15’ 10.08” W. The isle of Anglesey average annual temperature is 13°C and receives a mean annual rainfall of 153mm. Samples were taken at random from three different areas. The site is covered predominately in Great Pond Sedge (*Carex* riparia), Bottle Sedge (*Carex rostrata*) and Common Reed (*Phragmites australis*). There are also large areas of Black Bog Rush (*Schoenus nigricans)* and Blunt Flowered Rush (*Juncus subnodulosus)*.

**4.1.2 Sampling Strategy**

The core samples were collected using a Russian corer and wrapped in plastic and foil and transported in cooled, insulated container. The cores were around 1 m in length and 5 cm in diameter. Our core samples were then measured and split into three equal sections. The laboratory work included removing large debris and macroinvertebrates from soil samples. The samples were then placed in air-tight dark areas which were set at 4°C and the samples are taken to field temperatures at least 12 hours before performing analysis.

**4.1.3 pH and Conductivity**

We then use the samples to test for pH and conductivity and measure soil dry, organic and ash weights. A test is also run to determine the soil respiration on the site. Each of the samples is then divided into three equal parts, which designate the top, middle and bottom of the sample. Each test is then run on each individual sample. The main aspects of the study are measuring the activities of the hydrolase and phenol oxidase enzymes. When measuring pH and conductivity the samples are placed on an orbital shaker overnight. Usually the samples are created using a 1:5 ratio, with 1 being the soil and 5 being the distilled water. Conductivity is usually measured first as the pH probe injects chemicals into the solution to help it get a measurement and this could affect conductivity slightly. The first step once you have your samples is to calibrate the conductivity meter. Then place the sensor into the sample and note the reading, repeat for each sample. For pH, you should clean electrode and calibrate pH meter. Calibration is usually done by placing the sensor in pH 4 and pH 7 buffer solution. Then place electrode in sample and note pH value. Take electrode out of samples, clean and dry it and then place it in the next sample. Repeat for all samples and put electrode back in storage solution when finished.

**4.1.4 Soil Organic and Dry Weights**

The methods for calculating dry and organic weights are taken from Frogbrook *et al* (2009). First you should clean the inside and outside of all the crucibles you are going to need. Every crucible should be labelled with a sample number in pencil. We weighed each crucible on the analytical balance and noted the answer to four decimal places. All of our samples were homogenized for a couple of minutes. Fill each crucible up till they are nearly full and weigh them again. We placed all of our samples in the drying oven at 105°C for 24 hours. After 24 hours has passed remove your samples and re-weigh them. The samples are then placed in the muffle furnace at 550°C for 200 minutes. When the time has elapsed leave the samples for an hour or two to allow them to cool and then weigh each crucible one last time.

**4.1.5 Enzyme Assays**

One of the most critical parts of our study is the testing of the phenol oxidase and hydrolase enzyme activity. The methods for both of these were taken from Dunn *et al* (2014). All of our soil samples were kept in the incubator at field temperature for a full day before we ran the phenol oxidase assay. We used a 10mM solution of phenolic amino acid L-3,4-dihydroxy phenylalanine (L-DOPA) as the substrate. The L-DOPA is made up using 500ml of ultrapure water and 0.986g of L-DOPA and then placed on a magnetic stirrer for a few hours. We stored the L-DOPA and a 500ml bottle of deionised water in the incubator. Each sample requires 2 stomacher bags and 6 1.5ml microcentrifuge tubes and label each of them with the appropriate codes. The samples should be homogenized in a tray by removing any roots or stones. For each sample we weighed 1 gram into each stomacher bag and place bags in incubator. We usually run 3 samples at a time (i.e. 6 bags). We added ultrapure water to the stomacher bags which have been maintained at field temperature. We also added 9ml of ultrapure water using the pipette to each stomacher bag. We then placed the bags in pairs into the stomacher for 30 seconds. Then added 10ml of ultrapure water to one bag and 10ml of L-DOPA to the other and mix them for another 30 seconds. The bags with just the ultrapure water contained no substrate and acted as the blanks. Blanks are used to measure the background absorbance. We stored all bags in the incubator once again, usually 10 minutes is adequate for organic soils. After time has elapsed, take samples out and fill 3 microcentrifuge tubes with the blank samples and 3 with the substrate samples. The samples are then centrifuged at 10,000rpm for 5 minutes and are then transferred to a clear well microplate using a P1000 pipette. The amount in each well is 300µL of supernatant. The microplate is then placed on a spectramax to be analysed.

Another important test that we run is to determine the activity of hydrolase enzymes. For hydrolase enzymes the incubator was once again be set at field temperature and all samples should be left overnight. The MUF solutions are best made on the day the assay is to be carried out, however they can be kept for days if they are stored adequately in the dark at 4°C. They must be brought up to field temperatures before being used. The MUF substrate for the hydrolase enzyme assay was prepared in advance by dissolving the accurate amount of substrate in 20ml of cellosolve (ethylene glycol monomethyl ether) and around 700ml of deionised water. Volumes were made up to 1000ml in a volumetric flask. Each sample was left to dissolve for 2 hours in a dark cupboard. The flasks were then made up with ultrapure water. We then labeled all flasks correctly and placed them along with a 1L bottle of ultrapure water into an incubator. However you must make the MUF-free standard solution on the same day as you do the assays as the solution is unstable. We weighed 0.0881g MUF-free acid and add 10ml cellosolve to it and let it dissolve for 10 minutes in the dark at room temperature. Then we added 500ml of ultrapure water to the solution and shook it. The solution should always be stored in a dark place. Each sample requires 6 stomacher bags and should be labelled with the correct code. We required 1 x 1.5ml microcentrifuge tubes per sample per enzyme, 2x 2ml microcentrifuge tubes for each sample of the standard and 8 x 2ml microcentrifuge tubes for each concentration of MUF. Also for this experiment we needed to make a dilution series from the stock solution using the P1000 pipette and 2ml centrifuge tubes. The 1000µM MUF stock solution for the calibration curve is created by dissolving 0.1762g of 4-methylumbelliferone sodium salt in around 20ml of cellosolve and then in 700ml of deionised water to reach the desired concentration. Similar to the phenol oxidase method the samples should be mixed by hand. Then we weighed 1gram of the sample into 6 pre-labelled stomacher bags and place them in the incubator. After this we used the 10ml pipette with different tips to add 7ml of substrate solution to the stomacher bags and placed the bags in the stomacher for 30 seconds. Incubate all bags for 60 minutes except for the phosphatase solution which only stays in for 45 minutes. A couple of minutes before the end of the incubation period we started taking 1.5 ml of solution from the bags and put them in labelled 1.5 ml centrifuge tubes. We centrifuged all tubes at 10,000 rpm for 5 minutes. At the same time we added 50 µl of ultrapure water to the same amount of microplate wells as you have samples, using a P200 pipette. After the centrifuge had finished we extracted 250 µl of each enzyme sample and added it to the correct wells on the microplate. The microplate is then analysed on the spectramax. We also ran the same procedure on the standard solution. However this time we added 50 µl of each of the standard solutions to a black microplate and added 250 µl of centrifuged supernatant from the 2 centrifuge vials per soil sample to corresponding wells. While testing the enzyme activities it’s important to not alter the pH and by incubating the samples at field temperature the field conditions are mimicked as near as possible (Dunn *et al,* 2013). Samples must be centrifuged at at least 10,000 rpm to make sure of adequate separation of particulate organic matter (POM) and supernatant.

**4.1.6 Soil Respiration**

The method for our soil respiration analysis is taken from (Dunn *et al*, unpublished). The soil respiration analysis is done using 50 ml adapted centrifuge tubes. We weighed out 10 grams of peat from each sample and add them to centrifuge tubes. Using a 10 cm³ gas syringe with a two-way valve and a hypodermic needle we extracted 10 ml of gas by putting needle through rubber septa in the lid of the tubes. The collected sample is then transferred to a labelled pre-evacuated 5.9 ml exetainer. Evacuation is done by removing three 20 ml gas syringes of air from the exetainers. Samples are taken from a couple of the tubes at the start of the experiment and this is known as time 1 (T-1). The samples are left for a set amount of time to allow gas to accumulate and is then gathered and placed in exetainers. The samples are then analysed by gas chromatograph. The exetainers are placed on a tray that can hold 50 5.9 ml exetainers. Three blank samples and then three standard gases are placed at the beginning of an analysis run. After every 10 samples a quality control standard is inserted. A set of standard gases are placed at the end of every set of samples.

**4.1.7 Statistical Analysis**

The analysis we performed on the soil organic and dry weights was done using the data compiled from running the experiment. The data that was gathered from that included the crucible weight, crucible & wet soil weight, wet soil weight, crucible & soil weight after 105°C and crucible & soil weight after 505°C. We then calculated the dry soil weight, %water, inorganic weight, organic weight and %SOM.

Above we discussed the methods that were used for gathering the absorbance values for the phenol oxidase enzyme activity test. The absorbance values are converted into activity values which are displayed in the units’ nmol diqc g-1 m-1 which has been corrected for both % water and %SOM. The equation used to calculate phenol oxidase activity helps convert the concentration of dicq, which is the product formed during the breakdown of L-DOPA, to an activity value. The first section of the equation is Cdicq= A/εl where: Cdicq= concentration of dicq(M), A= absorbance of substrate – absorbance of blank, ε= molar extinction coefficient of dicq (3700) and l= pathlength (cm) – 0.865 for a 300µL microplate well. The second part uses the formula: Activity (nmol dicq g-1 min-1)= ((Cdicq x 0.020 x 1000 x 1000)/Mdry)/tassay where: Cdicq= concentration of dicq (M), 0.020= convert from M to mol. M is mol per L, 1000= convert from mol to mmol, 1000= convert from mmol to µmol, 1000= convert µmol to nmol, Mdry= dry weight of 1 gram of wet soil and tassay= time of assay i.e. 10 mins. The phenol oxidase activity data is analysed using a one-way anova. The phenol oxidase enzyme activity results are displayed in figure 7 and tables 3 & 4.

By using the methods outlined above we gathered raw florescence data which is then used to calculate hydrolase enzyme activity. The equation that is used converts the concentration of each enzyme to an activity per unit weight of dry soil. The equation for this is Activity (nmol g-1 min-1) = ((Cenzyme\*0.008)\*1000)/Mdry/tassay where: Cenzyme= enzyme concentration (µM), 0.008= convert from M to mol. µM is µmol per L, 1000= to convert from µmol to nmol, Mdry= dry weight of 1 gram of wet soil and tassay= time of assay i.e. 60 mins or 45 mins for phosphatase. The hydrolase enzyme data is analysed using a one-way anova. The hydrolase enzyme activity results are displayed in figure 6 and table 2.

After carrying out the experiment to measure soil respiration, the data was analysed in order to calculate the flux of CO₂, CH₄ and N₂O from soil samples. The flux of these gases is expressed as an amount of gas (in mg) produced per unit time (1 hour) and space (in m²). The flux is measured by calculating the change in concentration of gas between two sampling time periods and then correcting for different constants and methodological parameters. We then use the flux equation to calculate the results. The flux equation is F=dC/dt x rho x V/A, which is calculated by: F= flux (µmol m-2 s-1), dC= change in mixing ratio (µmol/mol), dt= change in time (s), rho= density of air (mol m-3)= pressure Mb\*100/(8.314\*(T+273.15), V= volume (m³) and A= area (m²). The calculation for gas flux from initial background concentrations is flux (µg g-1 s-1)= δC/δt X (V X M/ m X Vmol) from Levy *et al,* (2011). Where: δC = rate of change in the gas concentration T-1 Minus T-2, δt= change in time from the background reading to the final measurement (in seconds), V= is volume of headspace of chamber (m³) with centrifuge tubes this is generally 0.00004926 m³, M= is the molecular weight of gas (16.04 CH₄, 44.01 CO₂ & N₂O) in g mol-1, m= mass of peat sample used in grams, Vmol= volume of a mole of gas (air) at a given temperature (m³ mo-1) calculated by: p X (R X K) where: p is pressure (kPA), R is equal to 8.314 (ideal gas constant) and K is temperature (Kelvin). The soil respiration data was analysed using a one-way anova. The soil respiration results are displayed in table 6.

**4.2 Biodiversity**

However another key aspect to this research project is the acknowledgement and study of the changes in biodiversity and plant and animal locations on the site throughout the years. Obviously it takes considerable resources to be able to carry out a full study of a site and determine its exact species population and distribution. To get an idea of how the populations and distributions of the flora and fauna has changed throughout the years we used data and information collected by the North Wales Wildlife Trust who manage the site. Also we were given access to a considerable amount of data through COFNOD which is the North Wales Environmental Information Service were data has been archived for decades. The COFNOD service allowed us to examine site specific data which was logged and recorded by a number of individuals over many years and is rated for its accurateness. COFNOD uses a system to rate the data it receives to make sure it is of good quality so as it can be added to its library. I will only be using data from categories from 1 to 4 as they are rated the most accurate by COFNOD. Category 1 means a dataset that originates from a Biological Records Centre or a National Scheme. Category 2 is a dataset that comes from a County Recorder, while category 3 is data that has come from other trusted sources. Category 4 is undergoing assessment through the COFNOD data verification process, but is believed to be valid. If any changes or problems are found with the data it will be removed from the database and inserted into one of the categories that say it is irrelevant or of poor quality. The main aspect of looking at the species data that COFNOD have collated over the years on Cors Goch is examining the differences or relationships in the data. Seeing how the biodiversity over the whole site has increased or decreased over time, specifically when new cuts were undertaken is important as it allows us to gain an insight into whether the mosaic system of cuts is benefitting diversity on the site. We should also be able to compare biodiversity data across the sites from which we took our core samples to see if there are any significant differences between the sites.

For an estimate of the diversity and evenness of the spread of species we used the Shannon diversity index. The formula we use for the Shannon index is H=∑[(pi)×ln(pi)] where pi is the proportion of individuals that belong to species i.

**5. Results**

**5.1 Biogeochemistry**

The methods described above gave us results for the pH and conductivity, the dry weight and organic percentage of the soil and the activity of hydrolase and phenol oxidase enzymes. The main things we are looking for when examining the biogeochemistry data is are there any differences between sites at different depths. As mentioned previously when our cores were taken from the site they were split into three even sections. Looking at differences in the analyses from each section is an important part of the study. As a result we then examine the differences between various sites at different depths. We want to examine the carbon sequestration abilities of the site and specifically what the differences in the carbon sequestration are in the different habitats/sites on Cors Goch. This is why we have carried out the specific tests that we have. Knowing the organic matter content, hydrolase enzyme activity and phenol oxidase enzyme activity allows us to gain an overall picture of the sites carbon sequestration and thus an idea of the general health of the site. There were three areas sampled for our tests and four cores were taken from each area. Then each core was split into three equal sections, simply designated as the top (T), middle (M) and bottom (B).

A large percentage of our samples were taken from a small area of Cors Goch. The reason for this is there are a number of different cuts in the North East section of the site which help with distinguishing variation over small areas. Some of my samples were taken from the firebreak (the North Eastern most white line in Figure 2) and some were taken from the surrounding areas which contains areas that haven’t been managed along with areas where cuts took place in 2014 (the yellow areas in Figure 2) and early 2018 (the orange areas in Figure 2). We then took special care to examine records for flora and fauna in this particular part of the fen to see if the management techniques had any significant effects on the biogeochemistry, animal populations or plant densities in the fen.

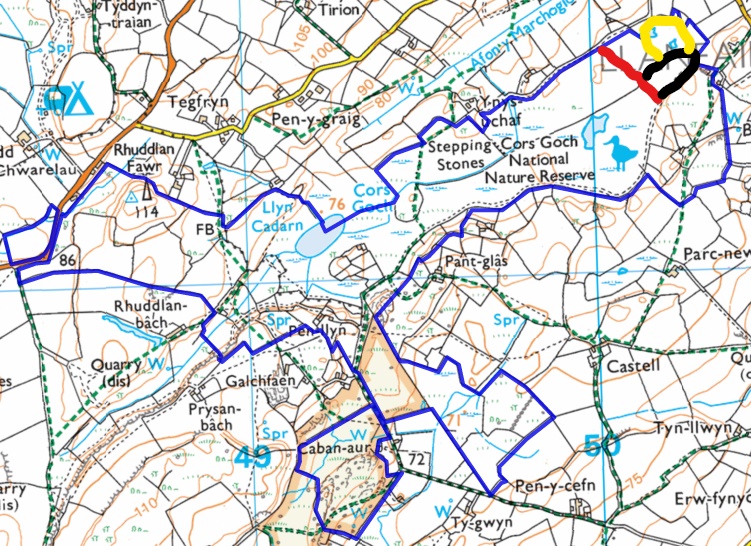


Figure 6: This figure shows the area of the site in which most of our samples were taken from. The red line indicates the firebreak seen in in Fig 2. The black area is a predominately sawgrass area and the ajoined yellow area is an area of mixed shrub.

The black area in Fig 5 is an area that is mostly made up of sawgrass but with other common species mixed in. The yellow shrub area has a large variation in plant species with a number of small tree species found in this area. One of the main reasons we used this area of the site is that we noticed trends in the amount of species that were located in this part of the site and believed that taking samples from this area of the site might indicate any changes in the biogeochemistry over the various landscapes. This particular area allows us to see three extremely different sites which vary in how they are managed (i.e. what techniques are used) and also what varying plant species occupy each site which could have effects on the biogeochemistry of each. Also as can be seen in Fig 2 the area where we took our samples from has had a number of cuts over the years. The firebreak from Fig 2 (white line) and Fig 5 (red line), has been cut annually since the early 90’s by the North Wales Wildlife Trust. The cuts from early 2018 (orange on Fig 2) and 2014 (yellow on Fig 2) also overlap with the areas were the samples were taken, which are marked on Fig 5. The sawgrass area (black area on Fig 5) and mixed shrub (yellow area on Fig 5) both have parts of them where management techniques have been employed before. The overlapping nature of this area creates an irregular mosaic pattern that is hard to correctly sub-divide into identifiable areas, specifically on the borders of these areas. Without identifying the different plant species that occupy each site and seeing the differences in biogeochemistry that is created by them we won’t be able to correctly acknowledge the individuality of the sites diversity.

The activity of the hydrolase enzymes varies from enzyme to enzyme and from site to site. For enzyme B (β-D-glucosidase) the activity was significantly higher in the firebreak at 10.3 (standard error, SE, 3.14) nmol g-1 min-1 than in the saw, 7.01 (SE, 1.19) or the shrub, 6.51 (SE, 1.12). A similar trend is seen in enzyme S (Arylsulphatase) activity as it is highest in the firebreak at 0.95 (SE, 0.41) and lower in the saw, 0.67 (SE, 0.15) and the shrub, 0.72 (SE, 0.19) nmol g-1 min-1. For enzyme X (β-D-xylosidase) the activity in the firebreak is once again higher than in the other two sites. In the firebreak it is 6.93 (SE, 0.90), while in the saw it is 5.99 (SE, 0.57) and in the shrub it is 3.06 (SE, 0.45) nmol g-1 min-1. The main differences are seen in the activities of enzyme N (N-acetyl-β-D-glucosaminidase) and enzyme P (Phosphatase). For enzyme N the activity is highest in the saw at 5.05 (SE, 1.19), followed closely by the firebreak at 4.99 (SE, 1.08) nmol g-1 min-1. The activity in the shrub is 2.75 (SE, 0.33) nmol g-1 min-1. There is evidence of a similar trend in enzyme P, the activity in the saw is 61.17 (SE, 5.85) which is slightly higher than in the firebreak at 59.73 (SE, 5.68) nmol g-1 min-1. Meanwhile just like in enzyme N the activity of enzyme P in the shrub area is significantly lower than the other areas coming in at 30.05 (SE, 4.87) nmol g-1 min-1.

Figure 7: Shows the activity of hydrolase enzymes in soil samples from three different areas on Cors Goch, Anglesey. B=β-D-glucosidase, S= Arylsulphatase, X= β-D-xylosidase, N= N-acetyl-β-D-glucosaminidase, P= Phosphatase. Enzyme activities shown as mean

Table 2: These tables show the mean, standard deviation and standard error of the five hydrolase enzymes in the three different areas on Cors Goch. One-Way Anova results.

|  |  |  |  |
| --- | --- | --- | --- |
| Enzyme **B** | **Firebreak** | **Saw** | **Shrub** |
| **Mean** | 10.2988 | 7.0113 | 6.5085 |
| **Standard Deviation** | 10.8807 | 4.1074 | 3.887 |
| **∑X** | 123.586 | 84.136 | 78.102 |
| **Standard Error** | 3.141 | 1.1857 | 1.1221 |

The *f*-ratio value is 1.01459. The *p*-value is .37358. The result is *not* significant at *p* < .05.

**Enzyme S**

|  |  |  |  |
| --- | --- | --- | --- |
| **Enzyme S** | **Firebreak** | **Saw** | **Shrub** |
| **Mean** | 0.9548 | 0.6654 | 0.7192 |
| **Standard Deviation** | 1.4314 | 0.5097 | 0.6605 |
| **∑X** | 11.458 | 7.985 | 8.63 |
| **Standard Error** | 0.4132 | 0.1471 | 0.1907 |

The *f*-ratio value is 0.31078. The *p*-value is .734995. The result is *not* significant at *p* < .05.

**Enzyme X**

|  |  |  |  |
| --- | --- | --- | --- |
| **Enzyme S** | **Firebreak** | **Saw** | **Shrub** |
| **Mean** | 6.9341 | 5.9962 | 3.0553 |
| **Standard Deviation** | 3.1143 | 1.9665 | 1.558 |
| **∑X** | 83.209 | 71.954 | 36.663 |
| **Standard Error** | 0.899 | 0.5676 | 0.4498 |

The *f*-ratio value is 9.21925. The *p*-value is .00066. The result is significant at *p* < .05.

**Enzyme N**

|  |  |  |  |
| --- | --- | --- | --- |
| **Enzyme S** | **Firebreak** | **Saw** | **Shrub** |
| **Mean** | 4.9939 | 5.0496 | 2.7548 |
| **Standard Deviation** | 3.7336 | 4.1082 | 1.1415 |
| **∑X** | 59.927 | 60.595 | 33.057 |
| **Standard Error** | 1.0778 | 1.1859 | 0.3295 |

The *f*-ratio value is 1.92094. The *p*-value is .162495. The result is *not* significant at *p* < .05.

**Enzyme P**

|  |  |  |  |
| --- | --- | --- | --- |
| **Enzyme S** | **Firebreak** | **Saw** | **Shrub** |
| **Mean** | 59.727 | 61.1695 | 30.0499 |
| **Standard Deviation** | 19.6677 | 20.2727 | 16.8618 |
| **∑X** | 716.724 | 734.034 | 360.599 |
| **Standard Error** | 5.6776 | 5.8522 | 4.8676 |

The *f*-ratio value is 10.26453. The *p*-value is .000342. The result is significant at *p* < .05.

The phenol oxidase activity tended to be higher in the firebreak in both the dry soil and organic soil. In the dry soil the activity in the firebreak was 724.09 (standard error, SE, 90.21) nmol dicq g-1 min-1, the saw activity was 645.85 (SE, 96.21) nmol dicq g-1 min-1 and in the shrub it was 607.16 (SE, 171.21) nmol dicq g-1 min-1. Meanwhile a similar trend is seen in the organic soil where the highest activity is found in the firebreak at 1544.87 (SE, 299.99) nmol dicq g-1 min-1 and the second highest in the saw at 1067.54 (SE, 149.20) nmol dicq g-1 min-1 and the lowest activity was seen in the shrub at 909.52 (SE, 194.72) nmol dicq g-1 min-1.

Figure 8: Shows activity of the phenol oxidase enzyme in dry soil and organic soil matrixes from three sites on Cors Goch. Activity in nmol dicq g-1 min-1.

Table 3: Shows the results of a one way anova per gram dry soil phenol oxidase activity

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Summary of Data** | | | | | | | | |
|  | ***Treatments*** | | | | | | | |
| 1 | | 2 | 3 | 4 | 5 | | Total |
| N | 12 | | 12 | 12 |  |  | | 36 |
| ∑X | 8689.07 | | 7750.25 | 7285.93 |  |  | | 23725.25 |
| Mean | 724.0892 | | 645.8542 | 607.1608 |  |  | | 659.035 |
| ∑X2 | 7365817.4573 | | 6227391.7695 | 8293026.4847 |  |  | | 21886235.7115 |
| Std.Dev. | 312.4909 | | 333.284 | 593.0886 |  |  | | 422.5931 |
| **Result Details** | | | | | | | | |
| ***Source*** | | ***SS*** | | ***df*** | ***MS*** | |  | |
| Between-treatments | | 85160.4976 | | 2 | 42580.2488 | | *F* = 0.22791 | |
| Within-treatments | | 6165311.6705 | | 33 | 186827.6264 | |  | |
| Total | | 6250472.1681 | | 35 |  | |  | |

The *f*-ratio value is 0.22791. The *p*-value is .797437. The result is *not* significant at *p* < .05

Table 4: Shows results of one way anova per gram organic soil for phenol oxidase activity

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Summary of Data** | | | | | | | |
|  | ***Treatments*** | | | | | | |
| 1 | | 2 | 3 | 4 | 5 | Total |
| N | 12 | | 12 | 12 |  |  | 36 |
| ∑X | 18538.47 | | 12810.46 | 10914.2 |  |  | 42263.13 |
| Mean | 1544.8725 | | 1067.5383 | 909.5167 |  |  | 1173.976 |
| ∑X2 | 40519031.9509 | | 16614038.7472 | 14931661.6286 |  |  | 72064732.3267 |
| Std.Dev. | 1039.2068 | | 516.842 | 674.5379 |  |  | 800.8717 |
| **Result Details** | | | | | | | |
| ***Source*** | | ***SS*** | | ***df*** | ***MS*** | |  |
| Between-treatments | | 2625983.155 | | 2 | 1312991.5775 | | *F* = 2.1858 |
| Within-treatments | | 19822855.9107 | | 33 | 600692.6034 | |  |
| Total | | 22448839.0657 | | 35 |  | |  |

The *f*-ratio value is 2.1858. The *p*-value is .128394. The result is *not* significant at *p* < .05.

Figure 9, 10 and 11 show the changes in inorganic and organic weight from the top, middle and bottom of each of the samples from the firebreak in figure 9, saw in figure 10 and shrub in figure 11. Figures 9, 10 and 11 are line graphs because I believe that in this format you get a good idea of the trends involved in the differences between each analysed section. I think it adequately displays the information we are trying to emphasise. The group of tables in Table 5 shows the mean weight and range of weights for inorganic and organic content in the firebreak, saw and shrub sites. They also show the average water % and average SOM % in each site. As expected in each site the samples had a higher organic weight than inorganic. The average water % was highest in the saw samples but the average SOM % was highest in the shrub area.

Figure 9: Shows the weight in grams of inorganic and organic content from the FB samples

Figure 10: Shows the weight in grams of inorganic and organic content from the Saw samples

Figure11: Shows the weight in grams of inorganic and organic content from the SH samples

Table 5: These tables show the average weight of inorganic and organic matter in the three different areas along with the average water % in each area and the average SOM %

|  |  |  |
| --- | --- | --- |
| **Firebreak** | Inorganic | Organic |
| Mean | 0.6117 | 0.6497 |
| Range | 0.0381-1.5283 | 0.3121-1.0476 |

|  |  |  |
| --- | --- | --- |
| **Saw** | Inorganic | Organic |
| Mean | 0.4728 | 0.6114 |
| Range | 0.0737-1.1705 | 0.4204-0.8094 |

|  |  |  |
| --- | --- | --- |
| **SH** | Inorganic | Organic |
| Mean | 0.6512 | 0.8241 |
| Range | 0.0269-4.1144 | 0.4554-1.107 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Average Water %** | FB | Saw | SH |
|  | 86.5% | 88.4% | 83.9% |

|  |  |  |  |
| --- | --- | --- | --- |
| **Average SOM %** | FB | Saw | SH |
|  | 58.1% | 62.1% | 67.5% |

The CO₂ fluxes of the Cors Goch samples showed that it was significantly higher in the firebreak samples. The mean average flux of the firebreak samples was 6.84 (standard error, SE, 2.43) µg CO₂ g-1 h-1, whereas the mean flux for the saw area was -1.49 (SE, 0.20) µg CO₂ g-1 h-1. The second highest CO₂ flux was in the mixed shrub area with a flux of 2.25 (SE, 1.64) µg CO₂ g+ h-1. A similar trend is seen in the CH₄ fluxes where the mean average for the firebreak was 6.04 (SE, 5.11) ng CH₄ g-1 h-1 and the second highest flux was in the shrub which had a flux of 5.04 (SE, 4.79) ng CH₄ g-1 h-1. Once again the lowest flux was found in the saw samples with a mean of 0.04 (SE, 0.03) ng CH₄ g-1 h-1. The statistical trend continues in the N₂O fluxes where the flux from the firebreak samples was 1.63 (SE, 1.12) ng N₂O g-1 h-1 and the second highest flux was in the shrub area which was 0.78 (SE, 0.99) ng N₂O g-1 h-1. The lowest flux again was seen in the saw area with an average flux of -0.25 (SE, 0.073) ng N₂O g-1 h-1.

Table 6: Shows results of one-way anova on soil respiration data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Summary of Data** | | | | | | |
|  | ***Treatments*** | | | | | |
| ug CO2 | ng CH4 | ng N2O |  |  | Total |
| N | 36 | 36 | 35 |  |  | 107 |
| ∑X | 91.2407 | 133.4267 | 25.912 |  |  | 250.5794 |
| Mean | 2.5345 | 3.7063 | 0.7403 |  |  | 2.342 |
| ∑X2 | 1789.186 | 7213.036 | 336.3971 |  |  | 9338.6191 |
| Std.Dev. | 6.6718 | 13.8549 | 3.0545 |  |  | 9.0865 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Result Details** | | | | |
| ***Source*** | ***SS*** | ***df*** | ***MS*** |  |
| Between-treatments | 158.1261 | 2 | 79.0631 | *F* = 0.95682 |
| Within-treatments | 8593.6704 | 104 | 82.6314 |  |
| Total | 8751.7965 | 106 |  |  |

The *f*-ratio value is 0.95682. The *p*-value is .387469. The result is *not* significant at *p* < .05.

**5.2 Biodiversity**

Using the COFNOD data the plants and animals are separated into a number of different groups. The various groups include Bees, Wasps, Ants and Sawflies, Reptiles and Amphibians, Mammals, Fungi, Lichen and Slime Moulds, Birds, Butterflies and Moths, Other Invertebrates and Plants. There a thousands of records for the Cors Goch site, however we will be using examples of species that have multiple records instead of ones that have only singular records. The reason for this is that species with multiple records are more likely to live in Cors Goch and we will be able to see changes in their populations and location throughout the site. Although mammals are not in the highest densities as the site supports a large variety of bird and invertebrate life. Also it is more difficult to consistently measure mammal populations on sites like this. However there is a number of mammal species that have been recorded on the site. The predominant mammal species that have been recorded on the site are Fox (*Vulpes vulpes*), Hare (*Lepus europaeus*), Hedgehog (*Erinaceus europaeus*), Mole (*Talpa europaea*), Rabbit (*Oryctolagus cuniculus*), Stoat (*Mustela erminea*) and Water Vole (*Arvicola amphibius*). Many of these species are common throughout the UK, however the Water Vole (*Arvicola amphibius*) is a threatened species and its population has been on the decline. It survives it very specific sites that can supports its semi-aquatic lifestyle and sites that are mainly free from large predators which have been one of the main causes of its decline. Water Vole populations in the UK have been in sharp decline due to two main factors, the predation from the invasive American Mink (*Mustela vison*) and habitat changes. The Water Vole prefers rivers or wet areas that have vegetated banks (Lawton and Woodroffe, 1991). The fragmentation of their habitat due to changes from human influence has had a severe effect on their population. Many reintroduction schemes and population management plans are run throughout the UK to make sure that their populations can increase. Showing that they are found on Cors Goch is another important aspect of the site ecology and another reason why we should be practising the most effective management techniques for the site so that all the rare species are protected.

Through looking at the data from COFNOD we selected a number of species that had been recorded a large number of times on Cors Goch throughout the years. This allowed us to see any changes in the amount of different species on the site. It is obviously impossible to have a total species count for every species on the site every year. However we are able to see if species are recorded year to year on the site. The problem with this is that not every species is recorded every year and could still be heavily present on the site even though they haven’t been recorded in a number of years. Through looking at the data we began to select species that hadn't been recorded on the site in at least a decade as we believed this might give us the best chance at seeing species which are no longer present on the site. Some species haven’t been seen on the site in a significantly longer period of time than the one suggested. A number of bird species including the Curlew (*Numenius arquata*), Great Crested Grebe (*Podiceps cristatus*), Hen Harrier (*Circus cyaneus*) and the Lapwing (*Vanellus vanellus*) haven’t been recorded since 2007 and 2008 respectively. We paid special attention to these species as we wanted to understand what may have caused their transition away from the site. Was it related to specific biogeochemistry changes, addition of certain management techniques, a natural change or some other human influence that was active on or near the site? Some species specifically plant species haven’t been recorded on the site in a number of years, but are likely still found on the site. The likely scenario being that the recording of extremely common species was of no inherent value. A significant amount of plants species last record was in 2008 and before, this is likely because they are extremely common species and the amount of effort and time it would take to keep up to date on their population could be spent more efficiently on adjusting site management techniques and analysing animal population numbers to see how they are changing. We will take this into account when looking at these species and only select ones that would be considered less common. Some species such as the Daisy (*Bellis perennis*), Soft Rush (*Juncus effusus*), White Clover (*Trifolium repens*) and Common Bent (*Agrostis capillaris*) are examples of common species that haven’t been recorded on the site since 2008. The likelihood of species like this completely disappearing from the sight I would say is extremely unlikely. We won’t discuss in too much detail the distribution or individual records of plants on Cors Goch. This is because many of the plants that are frequently recorded on Cors Goch are common and widespread across the site and throughout the UK. However some plants such as the Delicate Stonewort (*Chara virgate*) and Green-Winged Orchid (*Anacamptis morio*) are rarer species that only grow in very particular areas and aren’t found frequently throughout the UK. We will however examine species in which many animal species are regularly found and are important for their life histories. Many species on Cors Goch live on black bog rush, in cladium areas and on gorse, hawthorn and hazel which we will mention as they are important because a wide variety of species rely on these species for a number of different reasons including as food sources and as habitats.

It is also important to have an understanding of how a number of species on Cors Goch survive on the site. This means knowing the life histories of species especially things like what do they eat, what is their life cycle and in what conditions do they grow the best. Having this information about the rarer species on Cors Goch could allow us to know what techniques are helping certain species flourish and increase the overall diversity of the site. Also knowing what species survive on certain areas of the site is important for taking care of that site in a special way to maintain these rare species. The specific life histories of some species means they might only grow in special areas. For instance some species might require certain pH’s while others might grow in varying levels of water. Species like this must be carefully monitored as we could unintentionally eradicate these species from the site by making extremely small changes to the biogeochemistry or altering the inflows and outflows of water on the site. For example there are a number of species found on Cors Goch that survive on particular plant species or other organic substances. For instance a number of species such as those found on Table 7 have been found in horse and donkey dung from animals that have been grazing on the site. There is the possibility to increase biodiversity by maybe increasing the amount of grazing animals on the site. Also as can be seen in Table 7 four out of the five species were last recorded in 1998. This may indicate that there hasn’t been a sufficient count of these species since 1998 or there has been a reduction in the number of these species on the site due to changes in grazing patterns or grazing species.

Table 7: Shows species found on Horse and Donkey dung on Cors Goch

|  |  |  |  |
| --- | --- | --- | --- |
| **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** |
|  |  |  |  |
| *Aphodius contaminates* | 2 | 1998 | 1998 |
| *Aphodius prodromus* | 2 | 1998 | 1998 |
| *Aphodius rufipes* | 3 | 1998 | 2006 |
| *Cercyon pygmaeus* | 2 | 1998 | 1998 |
| *Cercyon melanocephalus* | 4 | 1997 | 1998 |

A number of butterfly and moth species have been found on Cors Goch feeding on *Myrica* species. This includes the Alder Bent-Wing (*Bucculatrix cidarella*) and the Broom Moth (*Ceramica pisi*). There are 22 records from 1998 to 2016 of the Broom Moth (*Ceramica pisi*) on Cors Goch but only 2 records from 2003 to 2014 of the Alder Bent-Wing (*Bucculatrix cidarella*) on Cors Goch. This may mean that cause these species are known to feed on the same species the Broom Moth may out compete the Alder Bent-Wing. There is also the Dark-Barred Twist (*Syndemis musculama*) which has been recorded spinning on *Myrica* species. The fact that *Myrica* species are used by a number of different butterfly and moth species for some different reasons means that keeping an established *Myrica* population on the site may benefit the existing species and possibly allow other species to flourish.

A number of invertebrate species have been seen and recorded on gorse, hawthorn and hazel. These woody plants and shrubs are dotted around Cors Goch. They are usually seen on the outskirts of the main basin in the slightly drier parts of the site. Some of them are seen mixed in with large groups of herbaceous plants in the grassland. They appear as woody outcrops in the mosaic of plants. Some of the species that have been recorded on gorse, hawthorn and hazel appear in Table 8.

Table 8: Shows a list of species that have been recorded on Gorse, Hawthorn and Hazel on Cors Goch

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Name** | **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** | **Notes** |
|  |  |  |  |  |  |
|  | *Clubiona comta* | 2 | 2008 | 2008 | 2 Males |
|  | *Erigone atra* | 14 | 1973 | 2013 | 6 Females & 67 Individuals |
| Gorse Weevil | *Exapion ulicis* | 1 | 2007 | 2007 | 1 Adult found on *Ulex europaeus* (Gorse) |
|  | *Metellina mengei* | 5 | 1973 | 2008 | 2 Males, 2 Females & 1 Individual |
|  | *Philodromus cespitum* | 2 | 2008 | 2008 | 2 Males & 2 Females |
|  | *Phylloneta impressa* | 4 | 1998 | 2011 | 2 Males & 3 Females |
|  | *Poeciloneta variegata* | 3 | 1973 | 2008 | 6 Males & 2 Females |
|  | *Protopirapion atratulum* | 1 | 2007 | 2007 | 1 Adult found on *Ulex europaeus* (Gorse) |
|  | *Savignia frontata* | 4 | 1973 | 2008 | 2 Males & 2 Individuals |
|  | *Stenopterapion scutellare* | 2 | 2007 | 2008 | 1 Adult & 1 Gall on *Ulex europaeus* (Gorse) |
|  | *Tenuiphantes tenuis* | 17 | 1973 | 2011 | 5 Males, 10 Females & 6 Individuals |
| Speckled Wood | *Pararge aegeria* | 32 | 1995 | 2019 | Found on Hazel wood |

A significant number of invertebrate species found on Cors Goch reside in *Carex* beds, Black Bog Rush and *Juncus* tussocks and in *Juncus/Phragmites* swamps. These areas do make up a large part of Cors Goch. However when you look at Table 9 and see the amount of species that seem to rely on this area to survive, the value of these areas increases dramatically. Any changes to the biogeochemistry or water levels in these areas could have serious knock on effects for species that live and feed in these areas and could be extremely detrimental to the overall health and diversity of Cors Goch. Water level is a predominant driver of peatland vegetation succession (Malhotra *et al,* 2016), so even a short-term lowering of the water level can drive species shifts (Garssen *et al,* 2014). Duval and Radu (2018), also reported that the lowering of the water table has decreased sedge cover in bogs and fens. If water levels change in a site then decreased plant productivity has followed (Olefeldt *et al,* 2017). The anaerobic conditions in peatlands which are caused by the high water table determine vegetation composition and decomposition therefore deciding ecosystem function (Strakova *et al,* 2012). Changes to water levels can result in biogeochemistry changes and therefore potentially negatively affect the overall health of the site.

Table 9: Shows a list of species found on *Carex* beds, on Black Bog Rush and *Juncus* tussocks and in *Juncus/Phragmites* swamps on Cors Goch

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Name** | **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** | **Notes** |
|  |  |  |  |  |  |
|  | *Cnephalocotes obscurus* | 3 | 1973 | 2011 | 1 Male on Black Bog Rush tussocks |
| Common Ground-Hopper | *Tetrix undulata* | 9 | 1997 | 2016 | 1 Female & 1 Individual on Black Bog Rush & *Juncus* tussocks |
|  | *Drepanotylus uncatus* | 5 | 1988 | 2011 | 2 Males, 6 Females & 2 Individuals on *Juncus/Phragmites* swamp, in *Carex* bed & on Black Bog Rush & *Juncus* tussocks |
|  | *Ero cambridgei* | 2 | 1995 | 2011 | 1 Female & 1 Individual on Black Bog Rush tussocks |
|  | *Euophrys frontalis* | 5 | 1973 | 2011 | 1 Male, 1 Female & 1 Individual on Black Bog Rush tussocks |
| Garden Orb-Web Spider | *Araneus diadematus* | 7 | 1973 | 2016 | 2 Females on Black Bog Rush tussocks |
|  | *Gnathonarium dentatum* | 16 | 1988 | 2011 | 15 Males, 30 Females & 10 Individuals on Black Bog Rush tussocks & *Juncus/Phragmites* swamp |
|  | *Gonatium rubens* | 8 | 1973 | 2011 | 1 Male, 6 Females & 26 Individuals on Black Bog Rush & *Juncus* tussocks |
|  | *Hypomma bituberaulatum* | 6 | 1988 | 2011 | 2 Males, 1 Female & 3 Individuals on *Juncus/Phragmites* swamp |
|  | *Kastneria pullata* | 6 | 1973 | 2011 | 2 Males, 1 Female & 1 Individual on Black Bog Rush & *Juncus* tussocks |
|  | *Lamyctes emarginatus* | 3 | 1988 | 2011 | 1 Female & 1 Individual on Black Bog Rush tussocks |
|  | *Leiobunum blackwalli* | 1 | 2011 | 2011 | 1 Male & 1 Female on Black Bog Rush tussocks |
|  | *Laphomma punctatum* | 5 | 1973 | 2011 | 1 male & 5 Females on Black Bog Rush tussocks |
| Marsh Whorl Snail | *Vertigo antivertigo* | 9 | 1985 | 2011 | 6 Adults & 8 Individuals on Black Bog Rush tussocks |
|  | *Maso sundevalli* | 8 | 1973 | 2011 | 9 Females on Black Bog Rush tussocks |
|  | *Metellina segmentata* | 4 | 1973 | 2011 | 2 Males & 1 Female on Black Bog Rush & *Juncus* tussocks |
|  | *Micrargus herbigradus* | 3 | 1973 | 2011 | 1 Female on Black Bog Rush tussocks |
|  | *Nemastoma bimaculatum* | 3 | 1988 | 2011 | 9 Individuals on *Carex* bed & Black Bog Rush & *Juncus* tussocks |
| Nursery-Web Spider | *Pisaura mirabilis* | 7 | 1973 | 2011 | On Black Bog Rush & *Juncus* tussocks |
|  | *Oedothorax fuscus* | 5 | 1973 | 2011 | 2 Males, 4 Females & 1 Individual on Black Bog Rush tussocks |
|  | *Oedothorax gibbasus* | 3 | 1973 | 2013 | 2 Female & 17 Individuals on Black Bog Rush & *Juncus* tussocks |
|  | *Oligolophus tridens* | 1 | 2011 | 2011 | 1 Individual on *Carex* bed |
|  | *Ozyptila atomaria* | 4 | 1973 | 2011 | 1 Male & 14 Individuals on Black Bog Rush tussocks |
|  | *Ozyptila trux* | 3 | 2011 | 2011 | 3 Females on Black Bog Rush & *Juncus* tussocks |
|  | *Pachygnatha clercki* | 14 | 1973 | 2011 | 3 Males, 7 Females & 3 Individuals on *Carex* bed & Black Bog Rush & *Juncus* tussocks |
|  | *Pachygnatha degeeri* | 10 | 1973 | 2011 | 3 Males, 3 Females & 12 Individuals on *Carex* bed |
|  | *Palliduphantes ericaeus* | 7 | 1995 | 2011 | 5 Females & 8 Individuals on Black Bog Rush tussocks |
|  | *Pardosa pullata* | 13 | 1973 | 2011 | 5 Females, 18 Individuals & 1 Egg on Black Bog Rush tussocks |
|  | *Paroligolophus agrestis* | 4 | 1988 | 2011 | 2 Males, 2 Females & 1 Individual on *Carex* bed & on Black Bog Rush & *Juncus* tussocks |
|  | *Pirata latitans* | 4 | 1973 | 2011 | 6 Males, 1 Female & 1 Individual on Black Bog Rush tussocks |
|  | *Pirata piraticus* | 15 | 1973 | 2011 | 2 Males, 7 Females & 34 Individuals on Black Bog Rush & *Juncus* tussocks |
|  | *Pirata tenuitarsis* | 8 | 1988 | 2011 | 11 Females & 9 Individuals on Black Bog Rush & *Juncus* tussocks |
| Sedge Jumper | *Sitticus caricis* | 5 | 1973 | 2011 | 2 Males & 7 Infants on Black Bog Rush tussocks |
|  | *Tallusia experta* | 5 | 1988 | 2011 | 2 Males, 4 Females & 2 Individuals on *Carex* bed & Black Bog Rush & *Juncus* tussocks |
|  | *Tenuiphantes tenuis* | 17 | 1973 | 2011 | 5 Males, 10 Females & 6 Individuals on Black Bog Rush tussocks |
|  | *Tenuiphantes zimmermanni* | 7 | 1973 | 2011 | 2 Males, 1 Female & 4 Individuals on Black Bog Rush & *Juncus* tussocks |
|  | *Tetragnatha extensa* | 15 | 1973 | 2016 | 6 Adults, 1 Juvenile & 8 Infants on Black Bog Rush & *Juncus* tussocks & on *Juncus/Phragmites* swamp |
|  | *Tetragnatha striata* | 1 | 2011 | 2011 | 1 Infant Male on *Juncus/Phragmites* swamp |
|  | *Walckenaeria kochi* | 4 | 1988 | 2011 | 1 Male, 1 Female & 1 Individual on *Carex* bed & Black Bog Rush tussocks |
|  | *Zora spinimana* | 7 | 1973 | 2011 | 4 Females & 1 Individual on Black Bog Rush & *Juncus* tussocks |

Also there is a large number of species found on Cors Goch that exist in *Cladium* fen pools. These pools are usually formed of *Cladium mariscus* which is found in many areas of Cors Goch. *Cladium mariscus* is usually accompanied in the fen pools by a number of species. Some of the most common ones include Purple Moor-Grass (*Molinia caerulea*) and Black Bog-Rush (*Schoenus nigricans*). The *Cladium* fen pools are an important microhabitat on the site. Numerous species rely on these particular pools as can be seen in Table 10. As mentioned before even miniscule changes to the biogeochemistry or water levels in these areas could cause serious damage to a wide variety of plants and interfere with the life cycles of many animals. Thus decreasing the diversity and reducing the overall health of the site.

Table 10: Shows species found in *Cladium* fen pools on Cors Goch

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Name** | **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** | **Notes** |
|  |  |  |  |  |  |
|  | *Agonum fuliginosum* | 6 | 1988 | 2000 | 1 Adult & 3 Individuals |
|  | *Agonum thoreyi* | 7 | 1988 | 2000 | 14 Adults & 6 Individuals |
|  | *Anacaena globulus* | 8 | 1988 | 2000 | 21 Individuals |
|  | *Anotylus rugasus* | 3 | 2000 | 2000 | 2 Adults |
|  | *Bryaxis puncticollis* | 3 | 2000 | 2000 | 2 Adults |
|  | *Cyphon hilaris* | 3 | 1988 | 2000 |  |
|  | *Enochrus coarctatus* | 22 | 1997 | 2004 | 12 Males, 5 Females & 10 Individuals |
|  | *Enochrus ochropterus* | 4 | 1997 | 2000 | 2 Females |
|  | *Enochrus testaceus* | 12 | 1997 | 2004 | 3 Adults & 5 Individuals |
|  | *Erichsonius cinerascens* | 3 | 2000 | 2000 | 3 Adults & 3 Individuals |
|  | *Graptodytes granularis* | 9 | 1997 | 2006 | 3 Males & 4 Adults |
|  | *Gymnusa brevicollis* | 2 | 2000 | 2000 | 4 Adults |
|  | *Gyrinus suffriani* | 5 | 2000 | 2003 | 3 Males & 1 Female |
|  | *Helophorus brevipalpis* | 18 | 1997 | 2004 | 12 Adults & 17 Individuals |
|  | *Hydroporus angustatus* | 13 | 1997 | 2004 | 1 Female, 25 Adults & 7 Individuals |
|  | *Hydroporus erythrocephalus* | 12 | 1997 | 2003 | 4 Females & 3 Individuals |
|  | *Hydroporus gyllenhalii* | 4 | 1998 | 2006 | 1 Male |
|  | *Hydroporus tristis* | 2 | 2000 | 2000 |  |
|  | *Ilybius guttiger* | 7 | 1998 | 2004 | 2 Males & 4 Females |
| Larger Noterus | *Noterus clavicornis* | 20 | 1997 | 2004 | 8 Adults & 13 Individuals |
|  | *Lathrobium brunnipes* | 3 | 2000 | 2000 | 2 Adults |
|  | *Lathrobium terminatum* | 3 | 2000 | 2000 | 4 Adults |
|  | *Myllaena intermedia* | 3 | 2000 | 2000 | 4 Adults |
|  | *Paederus riparius* | 14 | 1985 | 2012 | 11 Adults & 6 Individuals |
|  | *Philanthus corvinus* | 3 | 2000 | 2000 | 2 Adults |
|  | *Quedius fuliginosus* | 6 | 1988 | 2000 | 2 Adults & 3 Individuals |
|  | *Quedius maurorufus* | 4 | 1988 | 2000 | 4 Adults & 1 Individual |
|  | *Stenus juno* | 9 | 1988 | 2004 | 3 Males, 2 Females, 4 Adults & 1 Individual |
|  | *Stenus latifrons* | 10 | 1988 | 2004 | 4 Males, 1 Female, 4 Individuals & 60 Adults |
|  | *Stenus nitidiusculus* | 3 | 2000 | 2000 | 22 Adults |
|  | *Stenus pallitarsis* | 9 | 2000 | 2004 | 2 Males, 4 Females & 2 Adults |
|  | *Stenus umbratilis* | 4 | 1997 | 2000 | 2 Adults |

One of the main aspects of evaluating the health of a site and therefore the effects of current management techniques is by getting details on which species are successfully breeding on the site. On Cors Goch there are a number of invertebrate and bird species that we know or suspect are breeding on the site. Regarding the invertebrates the ways in which we know they are breeding is if eggs, pupa or larva are found. Some species have also been spotted either copulating or ovipositing. The ways in which birds are known to be breeding is we see juveniles on the site, discovery of nests, courtship displays and breeding pairs. Some species have left evidence of breeding on the site. The number of species that seem to be breeding on Cors Goch indicates that the site is in a healthy situation.

This is an important aspect of invertebrate life on Cors Goch is how well they are breeding. A number of species throughout the years have been recorded as eggs, larvae or pupae and some have even been spotted copulating and ovipositing. A list of these species can be seen in Table 11. The importance of these species breeding on the site cannot be understated. Maintaining the continuation of species breeding on the site is essential for the success of the site. We would suggest as well that there are a few more invertebrate species which aren’t seen in Table 11 that haven’t been recorded breeding on the site but likely do.

Table 11: Shows species that have been recorded breeding on Cors Goch

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Name** | **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** | **Notes** |
|  |  |  |  |  |  |
|  | *Athripsodes aterrimus* | 12 | 2005 | 2018 | 1 Adult, Pupa & Many Larvae |
| Common Hawker | *Aeshna juncea* | 8 | 2003 | 2016 | 9 Adults & Ovipositing Female |
|  | *Erotesis baltica* | 20 | 2005 | 2018 | 9 Males & 4 Adults, Larvae/Pupal cases found |
|  | *Glyphotaelius pellucidus* | 6 | 1979 | 2006 | 1 Individual & Larvae/Pupal cases found |
|  | *Limnephilus sparsus* | 4 | 2006 | 2017 | 1 Adult & Larvae/Pupal cases found |
|  | *Lype phaeopa* | 8 | 2006 | 2009 | Larvae present |
| Moss Bladder Snail | *Aplexa hypnorum* | 8 | 1985 | 2004 | Many Juveniles present |
|  | *Mystacides longicornis* | 5 | 2006 | 2018 | 1 Male & Pupal case |
|  | *Phalacrocera replicate* | 3 | 2003 | 2004 | 4 Larva & 1 Larva in moss |
|  | *Plectrocnemia conspersa* | 6 | 1985 | 2007 | 5 Males, 1 Individual & Larvae found |
|  | *Triaenodes bicolor* | 10 | 2004 | 2018 | 4 Larvae, Larvae & Pupal case |
|  | *Tricholeiochiton fagesii* | 3 | 2007 | 2009 | Several Larvae |
|  | *Triogma trisuleata* | 2 | 1998 | 2014 | 1 Male & 1 Larvae |

Another aspect of breeding species on Cors Goch that must be taken into account is the amount of breeding birds on the site. The main difference between birds and invertebrates breeding is that invertebrates remain on the site year round whereas many bird species migrate to and from the Cors Goch depending on the season. This instantly reduces the amount of time that they are available to breed on the site. Table 12 shows bird species with significant numbers of records including important indicator species. Showing the amount of birds that seem to be breeding on the site is important as it clearly indicates how essential the site is for birds in North Wales.

Table 12: Shows bird species on Cors Goch

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Name** | **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** | **Notes** |
|  |  |  |  |  |  |
| Barn Owl | *Tyto alba* | 17 | 1975 | 2018 | Hunting on heath & Believed to be breeding |
| Blackbird | *Turdus merula* | 26 | 1972 | 2018 | Probably breeding |
| Chiffchaff | *Phylloscopus collybita* | 22 | 1986 | 2018 | Auditory record on site & Probably breeding in 1996 & 1997 |
| Coot | *Fulica atra* | 70 | 1972 | 2018 | 16 Individuals, 112 Juveniles, 44 Broods, 105 Adults & Probably breeding |
| Cuckoo | *Cuculus canorus* | 13 | 1972 | 2007 | Auditory record on site & Evidence of breeding on site |
| Curlew | *Numenius arquata* | 25 | 1972 | 2008 | 16 Individuals, 2 Pair, Breeding, Defending territory & With young |
| Dunnock | *Prunella modularis* | 24 | 1972 | 2018 | 4 Individuals & Evidence of breeding |
| Goldcrest | *Regulus regulus* | 16 | 1972 | 2018 | Evidence of breeding |
| Grasshopper Warbler | *Locustella naevia* | 27 | 1976 | 2018 | Auditory record on site & Breeding on reserve |
| Great Crested Grebe | *Podiceps cristatus* | 39 | 1985 | 2007 | 5 Individuals, 10 Adults, 5 Juveniles, 4 Chicks, Courtship display & Breeding |
| Greylag Geese | *Anser anser* | 38 | 1985 | 2018 | 41 Individuals, 16 Adults, 20 Juveniles, 4 Broods & Probably breeding |
| Jackdaw | *Corvus monedula* | 18 | 1976 | 2018 | Auditory record on site & Probably breeding |
| Lapwing | *Vanellus vanellus* | 12 | 1972 | 2007 | 36 Individuals |
| Linnet | *Linaria cannabina* | 19 | 1976 | 2018 | Evidence of breeding on reserve |
| Little Grebe | *Tachybaptus ruficollis* | 62 | 1972 | 2018 | 89 Adults, 54 Juveniles, 25 Broods & Breeding |
| Long-Tailed Tit | *Aegithalos caudatus* | 11 | 1975 | 2018 | Evidence of breeding |
| Magpie | *Pica pica* | 22 | 1972 | 2018 | 26 Individuals & Probably breeding |
| Mallard | *Anas platyrhynchos* | 75 |  |  | 192 Individuals, 7 Male, 2 Female, 30 Juveniles, 105 Adults, 4 Broods & Breeding |
| Moorhen | *Gallinula chloropus* | 36 | 1975 | 2018 | 16 Adults & Evidence of breeding |
| Reed Bunting | *Emberiza schoeniclus* | 29 | 1964 | 2018 | 8 Individuals, 1 Male, 1 Female & Evidence of breeding |
| Ruddy Duck | *Oxyura jamaicensis* | 33 | 1985 | 2003 | 20 Individuals, 8 Male, 3 Female & Probably breeding |
| Sand Martin | *Riparia riparia* | 4 | 1976 | 2018 | Evidence of breeding |
| Sedge Warbler | *Acrocephalus schoenobaenus* | 26 | 1964 | 2018 | Heard on reserve & Probably breeding |
| Song Thrush | *Turdus philomelos* | 21 | 1972 | 2018 | 4 Individuals & Evidence of breeding |
| Snipe | *Gallinago gallinago* | 27 | 1964 | 2018 | 110 Individuals, heard chirping & usually in areas burnt or cut |
| Stonechat | *Saxicola rubicola* | 20 | 1964 | 2018 | 3 Individuals, 1 Juvenile & 1 Breeding pair |
| Swallow | *Hirundo rustica* | 26 | 1976 | 2018 | 5 Individuals, Nests & Probably breeding |
| Water Rail | *Rallus aquaticus* | 17 | 1975 | 2013 | 11 Individuals, Nests, 1 Adult & Probably breeding |
| Willow Warbler | *Phylloscopus trochilus* | 29 | 1972 | 2018 | 5 Individuals, Auditory record on site & Probably breeding |
| Wren | *Troglodytes troglodytes* | 28 | 1972 | 2019 | 6 Individuals, Auditory record on site, Breeding pair & Probably breeding |

There are a number of birds of prey that are found on Cors Goch. These include Barn Owls (*Tyto alba*), Hen Harriers (*Circus cyaneus*), Kestrel (*Falco tinnunculus*), Buzzards (*Buteo buteo*) and Tawny Owls (*Strix aluco*). Birds of prey have an important ecological niche in a habitat as they are generally the top predators on a site and fill the role of scavengers also. These roles are an integral part of the ecological process. The reason that we are mentioning the populations of birds of prey on Cors Goch is because they are generally are good indicator of the overall health of a habitat. The general consensus is that if there are strong populations of these animals then there is plenty of food available and the rest of the food web would seem to be in good health. There are a number of records of birds of prey on Cors Goch which can be seen in Table 13.

Table 13: Shows bird of prey species on Cors Goch

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Name** | **Latin Name** | **No. of Records** | **First Year Recorded** | **Last Year Recorded** | **Notes** |
|  |  |  |  |  |  |
| Barn Owl | *Tyto alba* | 17 | 1975 | 2018 | Hunting on heath & Believed to be breeding |
| Buzzard | *Buteo buteo* | 26 | 1989 | 2018 | 9 Individuals recorded, Not all recorded |
| Hen Harrier | *Circus cyaneus* | 11 | 1989 | 2007 | 2 Males, 1 Female & 1 Individual |
| Kestrel | *Falco tinnunculus* | 20 | 1972 | 2018 | 4 Individuals |
| Marsh Harrier | *Circus aeruginosus* | 6 | 1996 | Before 2007 |  |
| Peregrine Falcon | *Falco peregrinus* | 4 | 1986 | 2017 |  |
| Tawny Owl | *Strix aluco* | 8 | 1989 | 2018 | 1 Individual |

Through examining the COFNOD data we selected a number of animal species that had at least 25+ records. We then examined individual records of each of these species to see the exact years the records were taken and to study the individual notes on each of them. Some of the records were compiled into groups with dates spanning huge numbers of years, this made it impossible to determine in which year each individual record was taken. This was likely caused by large groups of records being submitted without dates of origin only having a first year and a last year recorded. However there are a number of records that have exact dates in which they are recorded and these will be shown below. Looking at these records gave me a better insight into the trends of each population and allowed us to see any changes in relation to the management techniques being employed over the years. Analysis of this data allows us to see how changes or additions to management schemes over the years affect the diversity of the site. Data for individual records for birds, butterflies & moths and invertebrates are found in table 14, 15 and 16 respectively.

Table 14: Shows individual records over the years for select bird species on Cors Goch

|  |  |  |
| --- | --- | --- |
| **Species Name** | **Latin Name** | **Individual Records** |
|  |  |  |
| Great Crested Grebe | *Podiceps cristatus* | * 1 Rec- Before 2007 * 2 Recs- 1996 to 1997- Probably Breeding * 4 Recs- 1985 to 1989- 2 Chick & 3 Full Grown * 2 Recs- 1995 to 1996- 1 Individual * 23 Recs- 1989 to 1994- 10 Adults, 5 Juveniles & 5 Brood * 3 Recs- 1988 to 1997- 2 Chick & 4 Full Grown * 3 Recs- 1988- 2 Individuals & Courtship Display * 1 Rec- 1998 |
| Greylag Goose | *Anser anser* | * 3 Recs- 1986 to 2007 * 2 Recs- 1996 to 1997- Probably Breeding * 1 Rec- 2008- 2 Individuals * 2 Recs- 1989- 4 Individuals * 4 Recs- 1985 to 1989- 10 Individuals * 1 Rec- 1995 * 6 Recs- 1994- 16 Adults, 20 Juveniles & 4 Brood * 1 Rec- 1997- 4 Individuals * 2 Recs- 1988- 8 Individuals * 16 Recs- 2013 to 2019 * 2 Recs- 1989- 13 Individuals |
| Herring Gull | *Larus argentatus* | * 4 Recs- 1975 to 2007 * 2 Recs- 1996 to 1997 * 1 Rec- 1959 * 2 Recs- 1972- 45 Individuals * 1 Rec- 1976 * 4 Recs- 1988 to 1997- 2 Individuals * 1 Rec- 1994 * 15 Recs- 2013 to 2019 |
| Little Grebe | *Tachybaptus ruficollis* | * 4 Recs- 1975 to 2007 * 5 Recs- 1972 to 2002- 1 Chick, 1 Pair, 2 Adults & 2 Individuals * 3 Recs- 1978 to 1997- 1 Individual & Probably Breeding * 1 Rec- 1972- 2 Individuals * 3 Recs- 1994 to 2003 * 6 Recs- 1985 to 1989- 7 Individuals * 31 Recs- 1994- 72 Adults, 46 Juveniles & 20 Broods * 9 Recs- 1994- 6 Adults, 12 Juveniles & 5 Broods * 2 Recs- 1994 to 1997 * 2 Recs- 1988- 1 Individual * 6 Recs- 2013 to 2018 |
| Mallard | *Anas platyrhynchos* | * 4 Recs- 1975 to 2007 * 4 Recs- 1964 to 2002- 77 Individuals & 1 Adult Male * 2 Recs- 1964 to 1972- 5 Individuals & 1 Adult Female * 1 Rec- 1964- 6 Males * 2 Recs- 1996 to 1997 * 7 Recs- 1994- 37 Adults * 2 Recs- 1989 to 1997- 1 Adult Female & 10 Chicks * 1 Rec- 1988 * 6 Recs- 1985 to 1990- 14 Individuals * 2 Recs- 1989- 93 Individuals * 11 Recs- 2013 to 2019 * 2 Recs- 1996 to 2003 * 2 Recs- 1976 to 1994 * 29 Recs- 1994- 63 Adults, 20 Juveniles & 4 Broods * 2 Recs- 1972- 8 Individuals |
| Moorhen | *Gallinula chloropus* | * 3 Recs- 1975 to 2007 * 4 Recs- 1978 to 1997- Probably Breeding * 1 Rec- 1976 * 2 Recs- 1985 to 1988 * 21 Recs- 1994- 15 Adults & 1 Juvenile * 1 Rec- 1994- 1 Adult * 2 Recs- 1994 to 1997 * 3 Recs- 2013 to 2019 |
| Pheasant | *Phasianus colchicus* | * 5 Recs- 1975 to 2007 * 2 Recs- 1996 to 1997 * 1 Rec- 1972- 1 Individual * 1 Rec- 1989- 1 Individual * 5 Recs- 1988 to 1997- 1 Individual * 17 Recs- 2013 to 2019 * 1 Rec- 1972- 1 Individual * 1 Rec- 1994- 1 Egg |
| Ruddy Duck | *Oxyura jamaicensis* | * 2 Recs- 1996 to 1997 * 4 Recs- 1985 to 1989- 2 Adult Males & 1 Adult Female * 2 Recs- 1995 to 2003- 2 Males * 1 Rec- 1994- 1 Female * 18 Recs- 1994- 16 Individuals * 2 Recs- 1990 to 1997- 1 Male & 1 Female * 2 Recs- 1988- 3 Males * 1 Rec- 1998 * 1 Rec- 1989- 4 Individuals |
| Tufted Duck | *Aythya fuligula* | * 4 Recs- 1975 to 2017 * 3 Recs- 1972 to 2002- 38 Individuals * 1 Rec- 1972- 2 Individuals * 21 Recs- 1989 to 1994- 6 Adults * 3 Recs- 1988- 8 Individuals * 6 Recs- 1985 to 1990- 2 Individuals * 1 Rec- 1989- 8 Individuals * 3 Recs- 2013 to 2018- 1 Pair * 3 Recs- 1994 to 1996 * 2 Recs- 1972- 30 Individuals |

Table 14 shows individual records for a number of select bird species from Cors Goch. Seeing the records demonstrated like this allows us to examine the records from year to year and see any changes in species records due to management techniques being introduced through the years. Similarly Table 15 and Table 16 show the individual records for selected species of butterflies and moths and invertebrates respectively on Cors Goch.

Table 15: Shows individual records for select Butterflies and Moths on Cors Goch

|  |  |  |
| --- | --- | --- |
| **Species Name** | **Latin Name** | **Individual Records** |
|  |  |  |
| Brimstone Moth | *Opisthograptis luteolala* | * 11 Recs- 1988 to 2008- 4 Adults * 1 Rec- Before 1975 * 3 Recs- 2006- 2 Adults * 1 Rec- 2008- 1 Adult * 2 Recs- 2009- 2 Adults * 1 Rec- 2010- 1 Adult * 2 Recs- 2012- 1 Adult * 2 Recs- 2013- 2 Adults * 2 Recs- 2016- 1 Adult * 1 Rec- 1961 to 1981 * 1 Rec- 2017- 2 Adults |
| Bog-Rush Fanner | *Glyphipterix schoenicolella* | * 1 Rec- 2013 * 5 Recs- 2012 to 2016- 55+ Adults * 4 Recs- 2012 to 2015- 26 Adults * 2 Recs- 2012 to 2016- 6 Adults * 1 Rec- 2012- 5 Adults * 11 Recs- 2014- 100+ Adults * 1 Rec- 2015- 2+ Adults * 2 Recs- 2016- 1 Adult * 1 Rec- 2017- 2 Adults |
| Buff Ermine | *Spilosoma lutea* | * 5 Recs- 1988 * 1 Rec- Before 1975 * 5 Recs- 1961 to 1996- 2 Adults * 2 Recs- 2008- 12 Adults * 2 Recs- 2008- 2 Adults * 4 Recs- 2009- 28 Adults * 2 Recs- 2010- 5 Adults * 2 Recs- 2013 to 2014- 1 Adults * 3 Recs- 2013- 8 Adults * 1 Rec- 2016- 5 Adults |
| Common Heath | *Ematurga atomaria* | * 1 Rec- 2013 * 1 Rec- 2006 * 1 Rec- 2002 * 1 Rec- 2004 * 1 Rec- 2007- 1 Adult * 1 Rec- 2009- 1 Adult * 2 Recs- 2010 to 2011 * 1 Rec- 2010- 3 Adults * 1 Rec- 2012- 1 Adult * 4 Recs- 2013 to 2015- 6 Adults * 1 Rec- 2013- 5 Adults * 2 Recs- 2016- 10 Adults * 1 Rec- 1988 * 1 Rec- 1961 to 1981 * 1 Rec- Before 1975 |
| Drinker | *Euthrix potatoria* | * 7 Recs- 1988 to 1990 * 1 Rec- Before 1975 * 1 Rec- 2008- Larvae * 2 Recs- 2007 * 3 Recs- 1961 to 1996- 2 Adults * 3 Recs- 2014 to 2018- 5 Adults & 1 Larvae * 1 Rec- 2003- Larvae * 2 Recs- 2006 to 2012- 2 Adults * 1 Rec- 2007 * 2 Recs- 2008- 6 Adults * 3 Recs- 2009- 18 Adults * 3 Recs- 2010- 6 Adults * 1 Rec- 2011- 1 Adult * 1 Rec- 2013- 1 Adult * 2 Recs- 2014- 2 Adults & 1 Larva * 2 Recs- 2016- 2 Adults |
| Flame Shoulder | *Ochropleura pleta* | * 11 Recs- 1988 to 2008- 4 Adults * 1 Rec- 2006 * 2 Recs- 2007 * 2 Recs- 1996- 3 Adults * 1 Rec- 2006 * 1 Rec- 2007 * 3 Recs- 2008- 4 Adults * 1 Rec- 2009- 1 Adult * 2 Recs- 2010- 4 Adults * 2 Recs- 2012- 5 Adults * 2 Recs- 2013- 3 Adults * 2 Recs- 2014- 7 Adults * 3 Recs- 2016- 1 Adult |
| Gatekeeper | *Pyronia tithonus* | * 5 Recs- 1975 to 2004- 2 to 9 & 30 to 99 Individuals * 1 Rec- 1982 * 4 Recs- 1979 to 1997- 197 Maximum Count * 3 Recs- 2013 to 2017 * 4 Recs- 2012 to 2015 * 3 Recs- 2016 to 2017 * 1 Rec- 1998- 10 to 29 Individuals * 2 Recs- 2012 to 2013 * 2 Recs- 2012 to 2017 * 1 Rec- 2013 * 1 Rec- 2017 |
| Ingrailed Clay | *Diarsia mendica* | * 9 Recs- 1988 to 1990 * 3 Recs- 2007 * 2 Recs- 1996- 12 Adults * 1 Rec- 2008- 1 Adult * 3 Recs- 2009- 13 Adults * 2 Recs- 2010- 40 Adults * 3 Recs- 2011- 11 Adults * 1 Rec- 2012- 7 Adults * 2 Recs- 2013- 9 Adults * 2 Recs- 2014- 27 Adults * 1 Rec- 1996- 12 Individuals * 1 Rec- 2008- 1 Individual * 3 Recs- 2009- 13 Adults |
| Large Skipper | *Ochlodes Sylvanus* | * 3 Recs- 1979 to 1997- 3 Max Count * 1 Rec- 1982 * 4 Recs- 2007 to 2011- 1 Adult * 3 Recs- 1975 to 1983 * 4 Recs- 2014 to 2015- 1 Individual * 1 Rec- 2016- 1 Individual * 2 Recs- 2016 to 2017- 1 Individual * 2 Recs- 1972- 1 Individual * 2 Recs- 2012 * 1 Rec- 2013 * 2 Recs- 2013 to 2017 * 1 Rec- 2002 * 2 Recs- 2005 * 1 Rec- 1999 |
| Large Yellow Underwing | *Noctua pronuba* | * 9 Recs- 1988 to 2008- 2 Adults * 1 Rec- Before 1975 * 1 Rec- 2006 * 3 Recs- 1961 to 1996- 4 Adults * 1 Rec- 2006 * 1 Rec- 2007 * 3 Recs- 2008- 9 Adults * 2 Recs- 2009- 13 Adults * 3 Recs- 2010- 13 Adults * 2 Recs- 2011- 58 Adults * 1 Rec- 2012- 2 Adults * 2 Recs- 2013- 8 Adults * 2 Recs- 2014 to 2017- 6 Adults * 2 Recs- 2014- 59 Adults * 2 Recs- 2016- 7 Adults |
| Meadow Brown | *Maniola jurtina* | * 5 Recs- 1975 to 2004- 10 to 29 Individuals * 4 Recs- 1979 to 1997- 184 Max Count * 1 Rec- 1982 * 4 Recs- 2013 to 2017 * 6 Recs- 2012 to 2015 * 4 Recs- 2016 to 2017 * 1 Rec- 1998- 10 to 29 Individuals * 3 Recs- 2012 to 2015 * 2 Recs- 2013 to 2017 * 1 Rec- 2002 * 2 Recs- 1999 to 2001 * 2 Recs- 2005 to 2006 * 2 Recs- 2007 to 2019- 1 Individual * 2 Recs- 1997 * 1 Rec- 2013 * 2 Recs- 2000 * 1 Rec- 2001 * 1 Rec- 2019- 3 Adults |
| Peacock | *Aglais io* | * 4 Recs- 1975 to 2004- 1 Individual * 6 Recs- 1982 to 2011 * 5 Recs- 1979 to 1997- 10 Max Count * 1 Rec- 1982 * 2 Recs- 1998 to 2007 * 1 Rec- 2003 * 3 Recs- 2014 to 2015- 3 Adults * 2 Recs- 2017- 1 Adult * 1 Rec- 1997 * 1 Rec- 2004 * 2 Recs- 2012 * 7 Recs- 2003 to 2017- 4 Adults * 1 Rec- 2018 * 3 Recs- 1998- 2 to 9, 2 to 9 & 1 Individual * 1 Rec- 1997- 2 to 9 Individuals * 1 Rec- 2018- 1 Adult |
| Small Heath | *Coenonympha pamphilus* | * 4 Recs- 1979 to 1997- 63 Max Count * 1 Rec- 2008 * 1 Rec- 1982 * 2 Recs- 1983 to 2004- 10 to 29 Individuals * 2 Recs- 1998- 2 to 9 & 10 to 29 Individuals * 6 Recs- 2003 to 2019- 1 Individual * 5 Recs- 2012 to 2015 * 1 Rec- 2002 * 2 Recs- 2005 * 1 Rec- 1991 * 2 Recs- 2013 * 1 Rec- 2002 * 6 Recs- 2016- 6 Individuals * 1 Rec- 2018- 1 Adult |
| Small Pearl-Bordered Fritillary | *Boloria selene* | * 1 Rec- 1982 * 3 Recs- 1979 to 1997- 1 Max Count * 1 Rec- 1983 * 1 Rec- 2013- 1 Adult * 1 Rec- 1998- 2 to 9 Individuals * 1 Rec- 2005- 1 Individual * 1 Rec- 2012- 1 Individual * 1 Rec- 2013- 12 Individuals * 3 Recs- 2013 to 2015- 7 Individuals * 3 Recs- 2014- 6 Individuals * 2 Recs- 2009- 6 Adults * 2 Recs- 2013- 5 Adults * 1 Rec- 2005- 4 Adults * 1 Rec- 1987 * 1 Rec- 1983 * 1 Rec- 2016- 1 Individual * 1 Rec- 2017- 1 Individual * 3 Recs- 1975 to 1989 |
| Small Tortoiseshell | *Aglais urticae* | * 2 Recs- 1982 to 2006 * 4 Recs- 1979 to 1997- 23 Max Count * 1 Rec- 1979- 3 Individuals * 4 Recs- 1975 to 2004- 2 to 9 Individuals * 4 Recs- 2013 to 2015 * 1 Rec- 2015- 2+ Individuals * 1 Rec- 2013 * 1 Rec- 1995 * 2 Recs- 2003 to 2007 * 1 Rec- 2001 * 3 Recs- 1997- 1 Individual * 1 Rec- 2000 * 2 Recs- 2012 |
| Smoky Wainscot | *Mythimna impure* | * 2 Recs- 2007 * 5 Recs- 1961 to 1996- 6 Adults * 8 Recs- 2008- 26 Adults * 2 Recs- 2009- 16 Adults * 1 Rec- 2007 * 2 Recs- 2010- 2 Adults * 2 Recs- 2012- 4 Adults * 1 Rec- 2013- 16 Adults * 3 Recs- 2014- 14 Adults * 2 Recs- 1989 * 1 Rec- Before 1975 |
| Speckled Wood | *Pararge aegeria* | * 1 Rec- 2008 * 4 Recs- 1995 to 1997- 11 Max Count * 5 Recs- 2013 to 2015 * 2 Recs- 2001 to 2007 * 1 Rec- 1997- 1 Individual * 1 Rec- 2005 * 1 Rec- 2008- 1 Individual * 4 Recs- 2009 to 2019- 1 Individual * 1 Rec- 2012- 1 Individual * 3 Recs- 2003 to 2013 * 2 Recs- 2013 * 4 Recs- 2004 to 2006 * 1 Rec- 2000 * 2 Recs- 2017 |
| True Lover’s Knot | *Lycophotia porphyrea* | * 7 Recs- 1988 to 1990 * 2 Recs- 2007 * 3 Recs- 1996- 16 Adults * 2 Recs- 2009- 16 Adults * 2 Recs- 2008- 10 Adults * 1 Rec- 2007 * 3 Recs- 2010- 16 Adults * 3 Recs- 2011- 24 Adults * 2 Recs- 2013- 3 Adults * 2 Recs- 2014- 26 Adults * 2 Recs- 2016- 6 Adults |
| Wall | *Lasiommata megera* | * 3 Recs- 1975 to 1983 * 5 Recs- 1979 to 1997- 19 Max Count * 2 Recs- 1982 to 2006 * 2 Recs- 1998- 2 to 9 & 2 to 9 Individuals * 1 Rec- 2015- 1 Individual * 3 Recs- 2003 to 2019- 2 Adults * 1 Rec- 1991 * 1 Rec- 1997 * 1 Rec- 2017 * 2 Recs- 2015 to 2016- 3 Individuals * 1 Rec- 2016- 3 Individuals * 7 Recs- 2016 to 2017- 6 Individuals * 1 Rec- 2002 * 1 Rec- 2017- 1 Individual |

Table 16: Shows individual records of select invertebrate species on Cors Goch

|  |  |  |
| --- | --- | --- |
| **Species Name** | **Latin Name** | **Individual Records** |
|  |  |  |
|  | *Acrometopia wahlbergi* | * 1 Rec- Before 1991 * 3 Recs- 2001 * 3 Recs- 2014 to 2015- 22 Adults * 3 Recs- 2007 to 2009- 110 Adults * 4 Recs- 2003 to 2016- 8 Adults * 5 Recs- 2004 to 2012- 47 Adults * 2 Recs- 1999 to 2001- 29 Adults * 2 Recs- 2016- 3 Adults * 1 Rec- 2013- 6 Adults * 1 Rec- 2000- 10 Adults * 4 Recs- 1999 to 2002- 51 Adults * 1 Rec- 2002- 1 Adult * 1 Rec- 2000- 20 Adults |
| Black Snipefly | *Chrysopilus cristatus* | * 3 Recs- 2007 to 2009 * 4 Recs- 2003 to 2016 * 2 Recs- 2013 * 2 Recs- 2012 to 2015 * 1 Rec- 2013 * 1 Rec- 2016 * 3 Recs- 2004 to 2005 * 1 Rec- 1997 * 2 Recs- 1999 to 2002 * 2 Recs- 1999 to 2001 * 1 Rec- 2000 * 1 Rec- 2002 * 2 Recs- 2013 to 2014 * 1 Rec- 1974- 1 Individual * 2 Recs- 1988- 1 Individual |
| Blue-Tailed Damselfly | *Ischnura elegans* | * 1 Rec- 1983 * 1 Rec- 2008 * 2 Recs- 1979 to 2004 * 25 Recs- 1995- 75 Adult Males & 2 Females * 13 Recs- 1955 to 2015 * 2 Recs- 1997 * 7 Recs- 1997 to 2002 * 3 Recs- 2003 to 2009 * 5 Recs- 2003 to 2016 * 4 Recs- 2004 to 2006 * 6 Recs- 2003 to 2005- 2 to 5 Adults & 1 Adult * 12 Recs- 1983 to 2009- 2 to 5 Adults & 6 Adults * 1 Rec- 2012- 1 Adult * 4 Recs- 2003- 16 Adults & 4 Copulating Pairs * 3 Recs- 2000 to 2008 * 2 Recs- 2009 to 2016- 1 Adult * 3 Recs- 2003 to 2004- 1 Adult * 2 Recs- 2003- 3 Adults & 1 Copulating Pair * 3 Recs- 2003 to 2004- 2 Adults * 2 Recs- 1989 to 1999- 6 to 20 Adults & 21 to 100 Individuals * 1 Rec- 2009- 6 to 20 Adults * 9 Recs- 2005- 9 Males & 3 Females * 3 Recs- 1979 to 1985 * 1 Rec- 2013 * 2 Recs- 2016 |
| Clubbed General | *Stratiomys chamaeleon* | * 1 Rec- 2006- 1 Male * 1 Rec- 2001- 7 Males & 2 Females * 2 Recs- 2014 to 2015- 3 Males * 8 Recs- 2012 to 2016- 42 Adults & 19 Females * 1 Rec- 2014- 1 Male * 2 Recs- 2016- 1 Female * 2 Recs- 2013- 1 Male & 1 Female * 1 Rec- 1997- 2 Females * 1 Rec- 2003- 1 Male * 2 Recs- 2000 to 2001- 7 Males & 1 Female * 2 Recs- 2003 to 2006- 1 Male & 3 Females * 3 Recs- 1999- 1 Male & 5 Females * 2 Recs- 2014- 2 Adults & 4 Adults Male |
| Common Blue Damselfly | *Enallagma cyathigerum* | * 2 Recs- 1983 to 2017- 1 Adult * 1 Rec- 1979 * 11 Recs- 1987 to 2006- 9 Adults * 3 Recs- 1995- 3 Adult Males * 30 Recs- 1995- 165 Adult Males * 2 Recs- 1997 * 7 Recs- 1997 to 2002 * 6 Recs- 2003 to 2015 * 9 Recs- 1983 to 2010- 11 Adults * 4 Recs- 2003- 3 Adults * 3 Recs- 2000 to 2008 * 3 Recs- 2003- 3 Adults * 2 Recs- 2004- 2 Adults * 1 Rec- 1999- 6 Adults * 1 Rec- 2009- 6 Adults * 2 Recs- 2004 * 24 Recs- 2005- 14 Mature Males & 10 Mature Females * 3 Recs- 1979 to 1985 * 2 Recs- 2013 * 2 Recs- 2016 * 1 Rec- 2013 |
| Common Darter | *Sympetrum striolatum* | * 2 Recs- 1979 * 22 Recs- 1995- 164 Adults & 2 Females * 3 Recs- 1998 * 3 Recs- 1981 to 2005 * 9 Recs- 1955 to 2015 * 4 Recs- 2003 to 2012 * 5 Recs- 2012 to 2016 * 3 Recs- 1981 to 2003 * 3 Recs- 1983 to 2003 * 4 Recs- 2003- 14 Adults, 2 Exuviae & 2 Emergent * 1 Rec- 2008 * 1 Rec- 2012 * 3 Recs- 2003 to 2006- 7 Adults & 1 Copulating Pair * 6 Recs- 2003 to 2004- 9 Adults & Ovipositing Female * 1 Rec- 2004- 2 Adults * 1 Rec- 2003- 2 Adults & 1 Ovipositing Female * 2 Recs- 1997 * 1 Rec- 1999- 1 Adult * 10 Recs- 2005- 8 Mature Males, 1 Mature Female & Ovipositing Pair * 3 Recs- 1979 to 1985 * 2 Recs- 2016 |
| Common Red Soldier Beetle | *Rhagonycha fulva* | * 1 Rec- 1960 * 1 Rec- 1985 * 4 Recs- 1984 to 1987- 3 Individuals * 2 Recs- 1988- 1 Individual * 5 Recs- 2003 to 2015 * 2 Recs- 2016 * 1 Rec- 2001 * 2 Recs- 2003 to 2007 * 4 Recs- 2012 to 2015 * 1 Rec- 2012 * 4 Recs- 2012 to 2014 * 3 Recs- 2004 to 2006 * 1 Rec- 2013 * 1 Rec- 1997 * 2 Recs- 2000 * 1 Rec- 2002 |
| Four-Spotted Chaser | *Libellula quadrimaculata* | * 1 Rec- 1979 * 14 Recs- 1995- 32 Adults * 3 Recs- 2004 to 2016 * 2 Recs- 2005 to 2009- 3 Adults * 9 Recs- 1983 to 2009- 13 Adults, 3 Copulating Pairs & 1 Ovipositing Female * 2 Recs- 2012- 27 Adults * 9 Recs- 1955 to 2015- 1 Adult * 2 Recs- 2007 to 2009 * 4 Recs- 2003 to 2006- 10 Adults, 3 Copulating Pairs & 1 Ovipositing Female * 1 Rec- 2004- 2 Adults * 2 Recs- 1989 to 1999- 8 Adults * 1 Rec- 2017 * 3 Recs- 1979 to 1985 * 2 Recs- 2016 * 1 Rec- 2013 |
| Golden-Ringed Dragonfly | *Cordulegaster boltonii* | * 1 Rec- 1983 * 1 Rec- 1995- 1 Adult Female * 5 Recs- 1979 to 1995 * 1 Rec- 2012- 1 Adult * 2 Recs- 2004 * 2 Recs- 1983 to 2003- 1 Adult * 4 Recs- 2003- 4 Adults * 1 Rec- 1999- 2 Adults * 1 Rec- 2009- 1 Adult * 15 Recs- 2005- 15 Mature Males & 6 Mature Females * 2 Recs- 1982 to 1985 |
| Hairy Dragonfly | *Brachytron pratense* | * 2 Recs- 1983 to 2017- 4 Adults * 2 Recs- 1979- 6 Individuals * 4 Recs- 1979 to 1991 * 8 Recs- 1990 * 1 Rec- 2008 * 8 Recs- 1995- 10 Adult Males * 1 Rec- 2005- 1 Individual * 8 Recs- 1983 to 2009- 8 Adults * 1 Rec- 2012- 2 Adults * 6 Recs- 1979 to 2015- 1 Male * 2 Recs- 2008- 2 Adults * 1 Rec- 2009- 1 Adult * 3 Recs- 2003- 2 Adults * 1 Rec- 1989- 1 Adult * 3 Recs- 1988- 1 Adult * 2 Recs- 2004- 1 Teneral * 1 Rec- 2016- 1 Adult |
|  | *Helophilus pendulus* | * 1 Rec- 1995 * 3 Recs- 2003 to 2009 * 3 Recs- 2003 to 2015 * 4 Recs- 2012 to 2015 * 3 Recs- 2012 to 2016 * 2 Recs- 2012 to 2013 * 1 Rec- 2006 * 1 Rec- 2005 * 2 Recs- 1999 to 2001 * 2 Recs- 1997 * 2 Recs- 2013 * 2 Recs- 2016 * 3 Recs- 1988- 15 Individuals * 1 Rec- 1987 * 1 Rec- 2001 * 1 Rec- 2012 * 1 Rec- 2002 |
|  | *Herina frondescentiae* | * 3 Recs- 2007 to 2009 * 4 Recs- 2003 to 2016 * 3 Recs- 2013 * 2 Recs- 2016 * 5 Recs- 2012 to 2015 * 3 Recs- 2005 to 2006 * 2 Recs- 1999 to 2001 * 2 Recs- 2002 * 1 Rec- 1997 * 1 Rec- 2013 * 2 Recs- 2000 * 2 Recs- 1999 to 2001 * 1 Rec- 1987 |
| Large Red Damselfly | *Pyrrhosoma nymphula* | * 1 Rec- 1983 * 1 Rec- 1979 * 7 Recs- 1999 * 8 Recs- 2000 * 16 Recs- 1995- 21 Adult Males & 2 Females * 2 Recs- 2003 to 2009 * 9 Recs- 1979 to 2015 * 4 Recs- 2005- 1 Adult & 2 to 5 Copulating Pairs * 8 Recs- 2003 to 2006- 9 Adults * 13 Recs- 1983 to 2009- 15 Adults & 2 Ovipositing Females * 1 Rec- 2002 * 3 Recs- 1988 to 2003- 2 Adults & 1 Ovipositing Female * 2 Recs- 2002 * 4 Recs- 2003- 3 Adults * 1 Rec- 2012- 1 Adult * 2 Recs- 1989 to 1999- 27 to 120 Adults * 1 Rec- 2009- 2 Adults * 2 Recs- 2004 * 19 Recs- 2005- 15 Mature Males, 7 Females & 2 Ovipositing Females * 3 Recs- 1979 to 1985 * 2 Recs- 2013 |
| Medicinal Leech | *Hirudo medicinalis* | * 4 Recs- 1998- 7 Adults & 1 Juvenile * 4 Recs- 1998 to 2009- 1 Adult & 2 Juveniles * 1 Rec- 1997- 1 Adult * 1 Rec- 2001- 2 Adults * 2 Recs- 2000 * 1 Rec- 1997- 1 Adult * 5 Recs- 1997 to 1998- 10 Adults * 2 Recs- 1997- 2 Adults * 1 Rec- 1986- 1 Individual * 4 Recs- 1996 to 1998- 6 Adults & 20 Juveniles * 1 Rec- 1995- 5 Eggs/Ovum * 1 Rec- 2016- 16 Juveniles |
|  | *Neoascia tenur* | * 1 Rec- 2007 * 4 Recs- 2003 to 2009 * 9 Recs- 2012 to 2015- 23 Adults * 2 Recs- 2012 to 2013 * 3 Recs- 2016- 17 Adults * 4 Recs- 2003 to 2016- 14 Adults * 2 Recs- 2013- 31 Adults * 1 Rec- 2002 * 4 Recs- 2004 to 2006 * 2 Recs- 1999 to 2001 * 2 Recs- 1997 * 1 Rec- 2013- 12 Adults * 1 Rec- 1988- 1 Individual * 2 Recs- 2000 * 3 Recs- 1999 to 2002- 11 Adults * 1 Rec- 2002 |
|  | *Pherbina coryleti* | * 1 Rec- 2013 * 3 Recs- 2016- 4 Adults * 4 Recs- 2003 to 2015 * 5 Recs- 2012 to 2015- 3 Adults * 3 Recs- 2004 to 2006 * 2 Recs- 2003 to 2007 * 2 Recs- 1999 to 2001 * 1 Rec- 2013- 2 Adults * 1 Rec- 1988- 1 Individual * 2 Recs- 2000 * 1 Rec- 2002 * 3 Recs- 2001 to 2002 |
|  | *Tetanocera ferruginea* | * 2 Recs- 2005 to 2014- 1 Individual * 2 Recs- 2013- 2 Adults * 6 Recs- 2012 to 2015- 3 Adults * 1 Rec- 2013- 2 Adults * 3 Recs- 2003 to 2015- 2 Adults * 1 Rec- 2016 * 1 Rec- 2003 * 1 Rec- 2001 * 1 Rec- 2012- 2 Adults * 2 Recs- 1997 * 4 Recs- 1988- 6 Individuals * 2 Recs- 1999 to 2001 |

Table 17: Shows the individual records of a number of birds of prey species and Meadow Pipits on Cors Goch

|  |  |  |
| --- | --- | --- |
| **Species Name** | **Latin Name** | **Individual Records** |
|  |  |  |
| Meadow Pipit | *Anthus pratensis* | * 1 Rec- 1972- 1 Individual * 4 Recs- 1975 to 2007 * 2 Recs- 1988 to 1997 * 1 Rec- in 2013,2014,2015,2016,2017 & 2018 * 1 Rec- 1976 * 2 Rec- 1989- 4 Individuals * 1 Rec- 1972- 1 Individual |
| Hen Harrier | *Circus cyaneus* | * 1 Rec- Before 2007 * 1 Rec- 1997 to 1998 * 1 Rec- 2002- 1 Individual * 1 Rec- 1989- 1 Male * 6 Recs- 1989 to 1992- 1 Adult Female & 1 Adult Male * 1 Rec- 2003 |
| Barn Owl | *Tyto alba* | * 3 Recs- 1975 to 2007 * 6 Recs- 2010 to 2019- 4 Adults, 1 Chick, 1 Breeding Pair & 13 Eggs * 1 Rec- 1997 to 1998 * 1 Rec- 1985- 2 Individuals * 7 Recs- 1988 to 1990- 1 Individual * 1 Rec- 1989- 1 Individual * 3 Recs- 1 in 2015, 1 in 2016 & 1 in 2018- 1 Individual * 2 Recs- 2019- Adult on Nest, 3 Live Eggs, 2 Live Nestings |
| Buzzard | *Buteo buteo* | * 2 Recs- 2003 to 2007 * 4 Recs- 1995 to 1997 * 1 Rec- 2000- 5 Individuals * 3 Recs- 1989 to 1997- 1 Individual * 1 Rec- 1995 to 2003- 1 Individual * 1 Rec- 1998 * 1 Rec- 1994- 2 Individuals * 13 Recs- 2013 to 2019 |
| Kestrel | *Falco tinnunculus* | * 3 Recs- 1975 to 2007 * 1 Rec- 1995 * 2 Recs- 1972- 2 Individuals * 1 Rec- 1976 * 3 Recs- 1988 to 1989- 1 Individual * 1 Rec- 1972- 1 Individual * 9 Recs- 2013 to 2019 * 1 Rec- 2003 |
| Tawny Owl | *Strix aluco* | * 1 Rec- Before 2007 * 1 Rec- 1996 * 2 Recs- 1989 to 1997- 1 Individual * 4 Recs- 2013 to 2018 |

We then decided to create trend graphs of some of the species that had large number of records. The main issue encountered when doing this was that many of the individual records had a range of years in which they were taken and not just a single year. As a result of this we used only records that were taken in individual years. We used either the number of records in each year if the number of individuals seen wasn’t recorded or the number of records itself because it gives the minimum number of species seen. Figure 12 shows a prey predator graph between meadow pipits (*Anthus pratensis*) and hen harriers (*Circus cyaneus*). Figure 13 shows the changes in recorded numbers of other birds of prey species including barn owls (*Tyto alba*), buzzards (*Buteo buteo*) and kestrels (*Falco tinnunculus*). Figure 14 shows the trends for a number of water birds that call Cors Goch home during some parts of the year. Also Figure 15 shows trends in butterfly and moth populations throughout the years.

Figure 12: Shows a trend graph of Meadow Pipits and Hen Harrier records on Cors Goch

Figure 13: Shows the trends of changes in recorded numbers of birds of prey species including Barn Owls, Buzzards and Kestrels on Cors Goch

Figure 14: Shows trends in water bird recorded numbers on Cors Goch

Figure 15: Shows the trends in Butterflies and Moth records over the years on Cors Goch

Using the COFNOD data we wanted to examine how diverse the site is and decided to use the Shannon index to achieve this. Biodiversity measurement typically focuses on the species level and species diversity and is one of the most important indices which are used for the evaluation of ecosystems at different scales (Ardakani, 2004). The Shannon index is generally used to characterize species diversity in a community. It helps provide information on the complexity of communities on a site and allows us to see how the area adapts in relation to changes in the environment either man-made or natural (Rad *et al,* 2009). The Shannon index which takes into account is sensitive to changes in the importance of the rarest classes (Heuserr, 1998). Assessing the diversity of a site is important because it can be related to stability, maturity, productivity, evolutionary time, predation pressure and heterogeneity (Hill, 1973). Mayr (1992) mentions the Shannon-Wiener Index expresses the uniformity of values of importance across all species in the sample. The index requires that all species are represented in the sample and is very susceptible to abundance, normally it takes values between 1 and 4.5 and values above 3 are typically interpreted as diverse (Barajas-Gea, 2005). If the Shannon index figure is over 3 we can say that there is a high degree of species heterogeneity in certain communities (Chaname-Zapata *et al,* 2019). The data we received from COFNOD was analysed in two main data sets which were data for species that were recorded pre 2009 and from 2009 on. This was due to the fact that the main management techniques began from 2009 onwards. The Shannon index provides data on how diverse an area is and by providing results on their total species number and their relative abundances (known as evenness). Figure 16 shows the Shannon diversity and evenness for Butterfly and moth species from 2009 to 2018.

Figure 16: Shows the shannon diversity and evenness for Butterfly and Moth species between 2009-2018

Table 18 shows the Shannon diversity and evenness figures for bird species pre and post 2009, butterflies and moths from 2009 to 2018 and also pre and post 2009 and invertebrates’ pre and post 2009.

Table 18: Shows shannon diversity and evenness for some groups of species

|  |  |  |
| --- | --- | --- |
| **Shannon Index** |  |  |
| **Years/Species** | **Shannon Diversity** | **Evenness** |
|  |  |  |
| **Birds** |  |  |
| Post 2009 | 2.55 | 0.88 |
| Pre 2009 | 2.75 | 0.66 |
|  |  |  |
| **Butterflies & Moths** |  |  |
| 2009 | 2.09 | 0.87 |
| 2010 | 2.07 | 0.73 |
| 2011 | 1.38 | 0.63 |
| 2012 | 2.54 | 0.92 |
| 2013 | 1.87 | 0.61 |
| 2014 | 2.29 | 0.69 |
| 2015 | 1.47 | 0.91 |
| 2016 | 3.01 | 0.92 |
| 2017 | 1.74 | 0.97 |
| 2018 | 0.67 | 0.97 |
| Post 2009 | 3.21 | 0.7 |
| Pre 2009 | 2.82 | 0.63 |
|  |  |  |
| **Other Invertebrates** |  |  |
| Post 2009 | 3.79 | 0.75 |
| Pre 2009 | 4.87 | 0.79 |

**6. Discussion**

**6.1 Biogeochemistry**

The tests that we run are used to give us a clearer understanding of the overall characteristics of a site as well as showing subtle differences between the varying areas. Conductivity and pH are necessary for determining the health of a wetland. Measurement of the hydrogen ion (H+) concentration in a solution is what pH is. Most aquatic organisms prefer a pH range between 6.5-9.0. pH can also affect the solubility and toxicity of chemicals and heavy metals in water. Most freshwater wetlands range from slightly alkaline (>7) to moderately acidic (pH 4). Conductivity is a measure of waters capability to pass an electrical flow through it. It is related to the concentration of ions in the water. These ions originate from dissolved salts or inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds. Conductivity is measured in microsiemens or millisiemens per centimetre (µS/cm or mS/cm). A relatively constant conductivity is found in most water bodies. It is usually changed during events such as flooding, evaporation or influx of man-made pollutants and can severely damage water quality. Wetland conductivities range from 30µS/cm to over 30mS/cm. The soil dry and organic weight is used to find out the % moisture and organic content of soil samples. These characteristics influence the physio-chemical and biological properties of soil. Dry weight is the removal of the water component of soil and what remains is known as the bulk density which is comprised of organic and inorganic material. Peatland soils are usually 90% water and then 90% of whatever remains is organic material. Phenol oxidase is an enzyme that breaks down recalcitrant phenolic-based compounds like lignin. It works by breaking down polyphenolic compounds into smaller compounds. This is because phenolic compounds inhibit hydrolytic enzymes and phenol oxidase is critical for regulating organic matter decomposition in soils and acts like an enzymic latch for stored carbon (Pind *et al,* 1994).

There are a number of reasons that are usually used to explain the acidity of peatlands. Peatlands are not always acidic but a large percentage of them are especially bogs. Fens are more varied and can be acidic, neutral or alkaline. This is usually affected by the chemistry of the water which is input through groundwater and surface inflows. The possible explanations for peatland acidity are:

* What is believed to be the most important factor in creating bog acidity is the cation exchange by sphagnum. There is a relationship between peat pH and the amount of exchangeable hydrogen in it which may be a result of plant metabolic activity. Usually peats that are dominated by sphagnum have lots of exchangeable hydrogen and in turn a low pH when compared with peats that are covered in sedges which may be more alkaline in nature.
* The organic sulphur in peat could be oxidised to acidic compounds thus lowering pH.
* Sulphur deposition can cause acidity.
* Plants can take up cations and exchange them with hydrogen which in turn alters acidity.
* Due to the low decomposition rates in peatlands, organic acids can build up and act as a buffer for alkaline metallic cations which are introduced via rainfall and runoff from neighbouring areas, this theory was suggested by Gorham *et al,* (1984).

Studying the activities of enzymes allows us to gain a better knowledge of the decomposition processes in wetland soils and in what way they are affected by varying environmental factors and human interaction including management strategies. Developing a greater understanding of these environmental changes could allow us to better protect these areas. The enzyme activity data that we collected showed that the enzyme activity was consistently lowest in the shrub site compared to the others. Northern peatlands are vulnerable to decomposition during drought and low water tables. Woody litter added to these ecosystems during high water table conditions leaches polyphenolics that protect carbon stores against decomposition, even during subsequent drought (Fenner and Freeman, 2020). The polyphenolic compounds inhibit microbial extracellular and intracellular metabolism and they also deprive microbial growth of iron and substrates such as carbon and nitrogen. The lower phenol oxidase activity is the lower decomposition rates are in peatlands. Severe drought could disrupt the enzymic latch by speeding up nutrient cycling and raising pH (Fenner and Freeman, 2011). The woody litter which is the main difference between the shrub site and alternate sites, helps prevent decomposition by protecting the carbon stock of the site even if there is drought (Fenner and Freeman, 2020). This information possibly helps us understand how peatlands that contain wooded areas survive in intermittently dry conditions. This knowledge could be used in order to aid peatland areas that are susceptible to droughts by protecting carbon stocks and elevating carbon sequestration. More durable woods such as oak seem to help reduce decomposition and also makes the system more prepared for drought induced changes and effects such as carbon loss. As a result of this information we now have in relation to woody litter, it leads us to believe that areas of shrub in peatlands such as the area found in Cors Goch may be more naturally resistant to drought. This means that the use of small woody shrubs in other areas of the site could protect them in case of increased decomposition due to drought. As mentioned in the introduction the most important aspect of a wetland is the water. Water can introduce or remove sediment, nutrients and other materials which influence the soil and water chemistry of a site. Hydrology also has an effect on the structure and function of wetlands as it influences species richness, productivity, rates of organic matter accumulation and nutrient cycling (Cherry, 2011). This shows how important even slight changes to the biogeochemistry could be and how any changes to the water level could affect many aspects of the site and severely hamper the overall health. We could potentially slow down the rate of organic matter breakdown and therefore reduce the amount of biogenic greenhouse gases being releases into the atmosphere (Dunn *et al,* 2013). There are also a number of modern techniques being employed such as metagenomic sequencing which can determine microbial phylogenetics and functional genes associated with enzymic activity (Mackelprang *et al,* 2011). These techniques could be used to understand full biochemical pathways and connected processes. The long term hope is to be able to combine techniques and create a viable strategy which could be used to sequester carbon from the atmosphere using bio-geoengineering (Freeman *et al,* 2012). But in the short term we must carefully manage and maintain our wetlands so that the situation does not deteriorate and that when a viable solution is devised it could possibly be employed at a large quantity of sites instead of a few remaining ones. For this to work we must know the inner processes of each site and be able to apply a variety of management techniques to them in order to discover appropriate tactics for individual sites. There are a number of techniques being executed on Cors Goch and a couple of others that could be explored as avenues of development for the site.

**6.2 Biodiversity**

Throughout this report we use data collected by COFNOD over many years to assess changes to diversity. The data was collected by many different people who would have each had knowledge of varying species. The amount of data available is substantial, however the records themselves are uneven. This is due to the fact that some records are concentrated around a particular time period. There are a number of possible explanations for this, the most likely ones being availability of adequate recorders for specific species groups and also from time to time the North Wales Wildlife Trust gets funding which may be put towards a site survey for a specific animal group. So when we see high numbers of records for a certain group over a short period of time we could assume it is due to one of these factors. However, what I will say in relation to this is that even though some of the records are concentrated, the fact that they have been split into larger groups, in terms of pre-management and after management was introduced means we compared data over many years not individual ones. So the data isn’t extremely biased to outside factors like funding but it should be considered as influential to the data gathered. However we do know that in the late 90’s large bird surveys were completed due to funding of North Wales Wildlife Trust. Also relevant agencies may change their priorities when it comes to which specific plant or animal species is the most endangered, or which sites are most in need of management or changing laws which may require an altering of procedures. Taking these issues into account is part of the reason I will suggest more surveys.

The main goal of the biodiversity aspect of the study was to determine how diverse the site is and what could be done to improve it. However before doing this we had to consider what factors may be causing a decline in species. Wetland species throughout the UK are declining, the main reason for this is the reduction in wetland habitats nationwide. The wider factors involved in this decline includes some natural and human influences including: climate change, physical modification, pressures from rural land management and agriculture, pollution from wastewater discharged from water treatment works, pollution from rural areas and towns, cities and transport, changes to water levels and flows, invasive non-native species and habitat fragmentation. Population changes around the world are being driven by climate change, habitat loss and degradation, pollution, predation, disturbance and food availability (Eglington, 2014). The main factors affecting Cors Goch are likely to be changes to water levels and flows, climate change and pollution and pressures from rural land management and agriculture. Muck spreading on neighbouring fields can lead to excess nutrients which can have adverse effects on the water quality which can in turn alter the chemistry of the site and change what species grow and in what numbers. This then obviously has knock on affects for the entire food web. Throughout my review of the COFNOD data for Cors Goch we only selected species that had a number of records over a period of years as this allowed me to examine changes in populations and locations for individual species and species groups. The sites in Cors Goch where we took our core samples from where on the firebreak (FB), in the sawgrass (SAW) and in Shrub mosaic (SH) which will be identified on the map of Cors Goch. Four core samples were taken from each area and a number of grab samples. We then carried out the procedure which is outlined throughout the methods section. Comparisons between the sites to see the differences in total species are also undertaken. Another essential element of examining the COFNOD data is to see if the trends for the major species have increased or decreased over time. This will help us look at the areas of the site that have been cut and determine whether the correct management techniques are in place to increase the diversity of the site. When determining what methods of management are operating best on the site it is first important to have knowledge of all of the species on the site and in what numbers they dwell. This will help us identify the species that will be affected due to changes to particular parts of the site. When species are recorded and the data sent to COFNOD many times there are not records of the amount of a species recorded during that visit. This may be because many species are difficult to record due to their ability to move rapidly and therefore increase the chances of recording the same animal twice. Also many of the species recorded on the site lack sexual dimorphism so it is hard to differentiate between males and females. The only way to tell the difference was by looking at changes in size and this may only help identify the growth stage of an animal. Therefore many records just state the species and year recorded while some will also mention the number of individuals recorded, specific details about individuals that can be identified and activities that some species may be performing.

The tables in the results section were inserted to know the variety of areas that are on the site and also to demonstrate the diversity of the site. Table 7 shows a list of species that were recorded in horse and donkey dung on the site. As mentioned previously it seems that there hasn’t been a count of the species that have been found living in horse and donkey dung recently. Due to the fact that there are still a number of large herbivores that are put out to graze the site including horses, donkeys and cattle means that it may be time to carry out a survey of these species to see how many still remain on the site and if there are any new species residing on Cors Goch. As can be seen in Table 8 there are a number of species that are found on gorse, hawthorn and hazel on Cors Goch. These shrubs are found dotted around the site. Gorse is found in larger clumps on the outskirts of the wetter parts of the site. While the Hawthorn and Hazel is found mixed in with the grasses, sedges and rushes in the waterlogged basins of the site. Some species such as *Erigone atra, Tenuiphantes tenuis* and the Speckled Wood (*Pararge aegeria*) have a significant number of records in which they have been found on the mentioned species. *Erigone atra* has 14 records between 1973 and 2003 with a total of 73 individuals recorded and *Tenuiphantes tenuis* has 17 records between 1973 and 2011 with 21 individuals recorded which includes 5 males and 10 females. The Speckled Wood (*Pararge aegeria*) has 32 records between 1995 and 2019 with many of them found on hazel wood. A number of other species including Gorse Weevil (*Exapion ulicis*), *Protopirapion atratulum* and *Stenopterapion scutellare* have been recorded on *Ulex europaeus* (Gorse). The amount of species relying on the gorse, hawthorn and hazel shrubs shows how important it is to keep these plants present on Cors Goch. There doesn’t need to be any significant changes to the current management tactics being employed for these particular species, but they can’t be allowed to spread too much on the site as this could affect the diversity in other areas.

The main reason Table 9 was inserted is to show how important these parts of the site are. A large proportion of Cors Goch is made up of *Carex* beds, Black Bog Rush and *Juncus* tussocks and *Juncus/Phragmites* swamp. These areas represent an important and deeply diverse area which is home to many animal species. These include *Gnathonarium dentatum* which has 16 records between 1988 and 2011; there have been 15 males, 30 females and 10 individuals recorded in that time. Also the spider species *Pardosa pullata* was recorded 13 times between 1973 and 2011 with 5 females, 18 individuals and 1 egg being recorded. Another species with a number of records is the *Pirata piraticus* which was recorded 15 times between 1973 and 2011. There were 2 males, 7 females and 34 individuals recorded of *Pirata piraticus*. These species along with many others recorded in these areas show the necessity of these plant sections for maintaining the diversity of the site. Many of these species were last recorded in 2011, which means a count may be necessary to establish the current populations and overall health of these groups on Cors Goch. These invertebrates are integral aspects of the food web so maintaining their populations is of critical importance for the whole site.

Another area of the site that covers a large part is the *Cladium* fen pools which are generally made up of *Cladium mariscus*. The *Cladium mariscus* is usually found with other species such as Purple Moor-Grass (*Molinia caerulea*) and sometimes Black Bog Rush (*Schoenus nigricans*). Many species survive in these pools as seen in Table 10. Some of the species recorded in the pools with significantly more records include *Enochrus coarctatus* which has 22 records between 1997 and 2004 with 12 males, 5 females and 10 individuals. The Larger Noterus (*Noterus clavicornis*) has 20 records between 1997 and 2004 with 8 adults and 13 individuals and also *Paederus riparius* which were recorded 14 times between 1985 and 2012 with 11 adults and 6 individuals. The nature of *Cladium* fen pools means that any changes to the delicate water table in these areas can have severe negative effects on the diversity of these micro-habitats. Once again many of the species seen in Table 10 haven’t been recorded since the early 2000’s which means that a count of species in *Cladium* fen pools should be a priority as it will help determine the necessary action that needs to be taken in order to increase diversity. The main reason that we am pushing for up to date knowledge of species populations on Cors Goch is because of the research I have done in relation to analysing the COFNOD species data. The North Wales Wildlife Trust has done extensive management on the site over the last decade. This means that records taken before this may not take into account how the management techniques have affected the biogeochemistry of an area and thus the plant life found there and as a result of this the population of animals that reside there.

Table 11 shows invertebrate species that were known to be breeding on Cors Goch due to the discovery of larvae/pupa, larval/pupal cases, juveniles and some ovipositing females. Some other invertebrate species that weren’t included in Table 11 which are thought to be breeding include the Four-Spotted Chaser (*Libellula quadrimaculata*0 which has 56 records between 1955 and 2017 and includes records of 2 ovipositing females and 6 copulating pairs as well as the Large Red Damselfly (*Pyrrhosoma nymphula*) which was recorded 109 times between 1979 and 2015 and again includes evidence of ovipositing females and copulating pairs. Another animal believed to be breeding on the site is the Medicinal Leech (*Hirudo medicinalis*). The Medicinal Leech (*Hirudo medicinalis*) survives in freshwater pools that have a high amount of weed growth and is a rare animal in the UK. It is only found in a few places in the whole of the UK with Anglesey being a hotspot for their population. Kutschera and Elliott (2014) suggest that the loss of freshwater ecosystems and the decline in amphibian populations such as frogs, newts and toads which are the most popular host for the juvenile leeches. Cors Goch itself has a number of these species that have been recorded on the site. These include the Common Frog (*Rana temporaria*) which has 22 records from 1975 to 2018, the Common Toad (*Bufo bufo*) has 17 records between 1975 and 2018 and there are also a few records of the Great- Crested Newt (*Triturus cristatus*) and the Palmate Newt (*Lissotriton helveticus*). Some of the records for the Common Frog and Common Toad include sub-adults, juveniles and frog spawn which likely indicates they are breeding on the site also and is a significant boost to the Medicinal Leech populations in the area. The Medicinal Leech was recorded 27 times between 1977 and 2016, with 5 eggs/ovum being recorded throughout this period.

Table 12 also shows some bird species that are believed to be breeding on Cors Goch. Many of the bird species that are thought to be breeding on Cors Goch are generally located in close proximity to open water as it is an essential part of their life histories. Species such as the Coot (*Fulica atra*) with 70 records between 1972 and 2018, the Great Crested Grebe (*Podiceps cristatus*) has 39 records between 1985 and 2007, the Greylag Goose (*Anser anser*) which has 38 records between 1985 and 2018, the Moorhen (*Gallinula chloropus*) which has 36 records between 1975 and 2018, the Little Grebe (*Tachybaptus ruficollis*) with 62 records between 1972 and 2018, the Ruddy Duck (*Oxyura jamaicensis*) with 33 records between 1985 and 2003 and the Water Rail (*Rallus aquaticus*) which has 17 records between 1975 and 2013 and are all generally aquatic birds and rely on areas of open water to live and breed. Some of these species also build their nests on the water or on the lake edge. As can be seen in Table 12 each species has some form of evidence that leads the recorders to believe they are effectively breeding on the site. Some species like the Coot (*Fulica atra*) and Little Grebe (*Tachybaptus ruficollis*) have huge numbers of records with 16 individuals, 112 juveniles, 44 broods and 105 adults of the Coot and 89 adults, 54 juveniles and 25 broods of the Little Grebe being recorded. Many areas of the fen and accompanying grassland could be used as nesting sites for these species. Species like the Chiffchaff (*Phylloscopus collybita*), Dunnock (*Prunella modularis*), Grasshopper Warbler (*Locustella naevia*), Linnets (*Linaria cannabina*), Long-Tailed Tits (*Aegithalos caudatus*), Moorhen (*Gallinula chloropus*), Reed Buntings (*Emberiza schoeniclus*), Sedge Warblers (*Acrocephalus schoenobaenus*), Stonechats (*Saxicola rubicola*) and Willow Warblers (*Ohylloscopus trochilus*) all tend to build their nests in dense vegetation on the ground which makes up vast areas of Cors Goch. The Long-Tailed Tit and Dunnock like to build their nests in hawthorn and bramble, Reed Buntings nest in reed beds or wet and marshy areas and Stonechats nest in dense vegetation usually gorse. As well as that the Sedge Warbler tends to build its nests in bunches of Common Reeds (*Phragmites australis*). These plant species are all found in abundance on Cors Goch which is probably one of the key factors as to why these bird populations prosper and grow on the site. This evidence leads us to conclude that the species and areas these birds call home must be carefully managed and maintained. Appropriate planning and caution must be taken when considering changes in these areas, specifically any removals of the mentioned plant species which can sometimes out compete other species and grow rapidly. One of the most important species in UK and European terms is the lapwing (*Vanellus vanellus*). Breeding populations of lapwings have declined massively over the last number of decades. Chamberlain *et al,* (2000) suggested that this was due to major changes in agricultural techniques. These changes could lead to alterations of adequate nesting sites by changing the height and density of vegetation which are important factors when it comes to lapwings selecting potential nests (Klomp, 1954). As seen from Table 12 there were 12 records of lapwings on Cors Goch from 1972 to 2007 with the total number spotted at 36. Surveys of lapwing populations in England and Wales showed a decline of 49% between 1987 and 1998 (Wilson *et al,* 2001). There was also a decline of 38% for lapwings in lowland wet grassland between 1982 and 2002 in England and Wales (Wilson *et al,* 2005a). Farming and changes to land including alteration to cutting rotations, increased drainage and increasing use of pesticides. Lapwings prefer mosaic areas with a mixture of plants and shrubs so the current plan for Cors Goch should help entice more lapwings to return. However there hasn’t been a record of lapwings on Cors Goch since 2007 so new bird surveys especially ones that focus on rare or declining British species are essential. Some of the species in Table 12 were selected because they are used by Noble *et al,* (2008) as freshwater wetland indicator species. They are used to determine the overall health of the wetland. Birds are a good animal group to use as indicator species as many are well known throughout the UK, are easily visible, there are many census datasheets for populations and also improvements in analytical methods that allow for better estimates. As a result of this birds are extremely useful for assessing the quality of the environment. Noble *et al,* (2008) used years of population trends for wetlands across the UK in order to designate the species that they did. Analysing the trends led to the selection of a number of species that reflect the health of various wetland types throughout the UK. The selected species include common sandpiper (*Actitis hypoleucas*), curlew (*Numenius arquata*), dipper (*Cinclus cinclus*), lapwing (*Vanellus vanellus*), redshank (*Tringo tetanus*), reed bunting (*Emberiza schoeniclus*), sedge warbler (*Acrocephalus schoenabaenus*), snipe (*Gallinago gallinago*) and yellow wagtail (*Motacilla flava*). The common sandpiper and dipper haven’t been recorded on Cors Goch. There are also very few records for redshanks and yellow wagtails. Although there are a number of records for curlews and lapwings, the last ones were recorded in 2008 and 2007 respectively. This could be due to a lack of available recorders, however there are numerous records for reed buntings, sedge warblers and snipes which all date to 2018 and shows that current management seems to not be adversely affecting these populations. These species are the best indicators available for birds in UK wetlands, however it should be noted that up to date surveys for the site are still the best way to closely examine management effects on Cors Goch.

Table 13 shows birds of prey species that had been recorded on Cors Goch. We felt it was important to show that these species are present on the site and many of them have been recorded in the past three years. This is a promising sign that their populations are flourishing. Birds of prey are generally the top of the food chain which means their populations fluctuate depending on the availability of prey in the area. Birds of prey help balance the populations of amphibians, reptiles and mammals. Birds of prey are used to measure the overall health of a habitat. Birds of prey are relatively sensitive to changes to their environment which includes any alterations to prey populations or pollutant levels, which in turn could lead to a decrease in their overall populations. These species are extremely important for Cors Goch as they are essential for monitoring the health of the site and give a good indication of the populations of other species in the food web.

There have been a number of bird, invertebrate and even some reptile and amphibian surveys carried out on Cors Goch over the years. The lack of mammal records indicates that an accurate site specific survey has likely not taken place. With mammals being such an integral part of the food web and occupying so many ecological niches it might be prudent to make the suggestion that one be carried out on the site. This will help gain a better insight into the populations of mammal species on Cors Goch and a better overall view of the health of the site. It will also allow us to see if the current management techniques are influencing mammal populations in any way.

As mentioned previously and as shown in Table 13 there are a number of birds of prey species that live, breed and hunt on Cors Goch. These include the Barn Owl (*Tyto alba*), Buzzard (*Buteo buteo*), Hen Harrier (*Circus cyaneus*), Kestrel (*Falco tinnunculus*) and Tawny Owl (*Strix aluco*). Barn Owls are the most widespread raptor species on Earth (Kross *et al,* 2016). The mice species (*Mus musculus* and *Reithrodontomys megalotis*) were the most numerous prey caught by Barn Owls (Kross *et al,* 2016). They are also known to prey on other small mammals such as voles, shrews and rabbits. Buzzards are not known to be picky eaters; they will eat various things ranging from rabbits and rodents to invertebrates such as worms and beetles. Hen Harriers usually prey on small birds and mammals. They prefer hunting in areas with high densities of Field Voles (*Microtus agrestis*) and Meadow Pipits (*Anthus pratensis*) which are generally associated with tall ground vegetation and shrub layers (Madders, 2003). Hen Harriers eat Meadow Pipits which are also found on Cors Goch. There are 23 records from 1972 to 2018 of Meadow Pipits found on the site. Common Kestrels (*Falco tinnunculus*) are known to feed on voles and other small mammals and birds, A study by Korpimaki, (1985) shows that the Field and Common Vole (*Microtus agrestis* and *Microtus arvalis*) populations are the regulating factor for Kestrel population numbers, clutch sizes and the production of young Kestrels.

Many of the trend graphs we created using the COFNOD data show significant variation in the amount of individuals recorded from year to year and also give an overall view of the health of certain species populations and how they are affected by changes to the management techniques employed and the site biogeochemistry. The one significant issue we had was with the consistency of records being taken. For example we must assume from looking at Figure 13 that because Barn Owl sightings were recorded from 2015 through to 2019 and Buzzards and Kestrels weren’t that there has been a slight dip in these species numbers in recent years. However it could also be assumed that due to a lack of frequent site visits which focused on bird surveys that these records could be incomplete. It is extremely difficult to carry out site specific monitoring of a wide variety of species and especially species like birds which can cover vast areas in a day. Figure 8 demonstrates trends in water bird records on Cors Goch. The water birds represented on the graph includes the Great Crested Grebe, Greylag Goose, Little Grebe and Mallard. These species were recorded predominately in the late 1980’s to the mid 1990’s and there are very few records after 1995. In terms of any alterations to the site that would have caused this decline, as can be seen in Figure 2 most of the site management didn’t begin until 2010. During the 90’s the only active management scheme being undertaken was the annual cutting of the firebreaks. It seems that these changes didn’t have any effect on these particular species making their way to the site. Obviously a key aspect of the site is how biodiverse it is. A good metric for seeing how biodiverse a site is, is the Shannon index. We used the COFNOD data to work out the Shannon index for available species groups which had a significant amount of records. As mentioned above a Shannon diversity above 3 can be interpreted as diverse. Table 18 shows the Shannon diversity for birds, butterflies and moths, and other invertebrates which had numerous records. The data is split by us into pre and post 2009 due to the fact that most of the management on the site was initiated after 2009. There is a small decrease in Shannon diversity in the bird data from pre 2009 to post 2009. Also in the invertebrates the diversity is much higher pre 2009 than post 2009, but both datasets can be stated as diverse. The exception is seen in the butterfly and moth data. The diversity is actually higher post 2009 than pre 2009. This may signal that the management techniques employed on the site are actually benefitting butterfly and moth diversity. However we must ensure these changes can also be adapted to benefit other species groups to make sure that all organisms are benefitting from the current management schemes.

**6.3 Biogeochemistry and Biodiversity**

Using large herbivores for grazing is a current technique employed on Cors Goch but could be improved based on current knowledge. The general consensus on cattle grazing is that small amounts of it are good for plant species biodiversity but any increase could be detrimental. High levels of grazing could lead to the cattle trampling vegetation, removing leaves, changing soil structure or even soil degradation and crushing sedge tussocks which may allow the shrub population to increase (Middleton *et al,* 2006). Also in fens cattle will only eat certain plants meanwhile unpalatable plants such as alder (*Alnus glutinosa*) are allowed to grow uncontained. A major problem with this is that if tall woody species are allowed to develop they will absorb a large percentage of the available light and shorter fen species would suffer (Kotowski and Van Diggelen, 2004). Another possible outcome of high cattle stocking rates is that they could cause uneven distribution of plants and animals on a site due to destruction of certain habitats. A study by Kruess and Tscharntke, (2002) indicated that lower stocking rates in grazing areas lead to an increase in species numbers and populations of bees, wasps, grasshoppers and butterflies. Another study by Steinman *et al,* (2003) determined that grazing intensity doesn’t particularly affect invertebrate populations in freshwater wetlands. There is the possibility that grazers could increase seed dispersal in fens via their manure and fur. Large herbivores could move seeds from areas of high productivity (feeding sites) to areas of low productivity (resting sites), (Mouissie *et al,* 2005a).

A possible point to look into is how effectively grazers can transport nutrients between sites. We know that they can add nutrients to areas that need them via their manure (De Mazancourt *et al,* 1998). There are a number of things that can effect mineralisation rates such as manure production, stocking rates, herbivore size and removal of vegetation and things that alter nitrogen mineralisation rates like soil type (organic or mineral), grazing intensity and amount of flooding. A trend has been noticed where high levels of grazing leads to phosphorus mobilisation and this causes higher phosphorus levels in upper soil layers in fens. There is evidence to support the idea that cattle help other grazers by managing plant size and height. There is the possibility of using primitive breeds such as Heck cattle or Polish konik horses as they both tend to stay away from nutrient poor sedge vegetation if better food is available (Vulink, 2001). The grazing intensity of these animals depends on a variety of factors including cattle population, length of grazing period, vegetation energy concentration, food requirements of various breeds and the life stage of each animal (Proulx and Mazumder, 1998). If there is a high amount of grazing then biodiversity may increase but soil degradation as a result of trampling could become a factor as it is often difficult to reverse. Much of the knowledge on cattle grazing in fens illustrates that having the appropriate stocking rates must be achieved in order to obtain credible results and useful benefits. Effects of grazing may change depending on the site and the productivity of different areas. Proulx and Mazumder (1998), suggests that species richness may increase in nutrient-rich areas with grazing and decrease in nutrient-poor sites. Burning is a common management practice in North America to remove high amounts of excess biomass. If a fen has not been harmed by grazing then burning could allow the growth of native non-woody species (Kost and De Steven, 2000). Burning is not a regular technique employed in Europe due to the risk of destroying peatland areas. However, could be carried out in winter months to reduce the chance of an uncontrollable fire and before vegetation growth starts properly. Periodic burns don’t seem to alter the dominance of sedges and grasses because they are long-lived clonal perennials. Fire however can increase sedge meadow diversity for short periods of time by allowing plants with different life histories to flourish. The most likely benefit of periodic burns is the introduction of seeds to seed banks rather than maintaining sedge meadow diversity (Kost and DeSteven, 2000). Mowing has been proven to create a higher species richness than grazing in calcareous fens (Stammel *et al,* 2003) and fen meadows (Hald and Vinther, 2000). Mowing is effective at reducing litter and increasing the availability of light which in turn allows for better seed recruitment and species growth (Kotowski *et al,* 2001). One example of this is the marsh violet (*Viola palustris*) which develops much better at higher light availability.

One of the animals that could be introduced as a management tool is the Konik horses. Konik horses can survive harsh conditions and on limited food supply. They digest grass much more efficiently than common breeds and can therefore survive on coarser diets. They require little management as they have self-trimming hooves and aren’t usually wormed. They have been shown to improve vegetation structure and enhance biodiversity in wetland habitats. They tend to eat grass in the summer months but gradually move to sedge, rushes and reeds as the seasons progress. They often browse on a some tree species including willow (*Salix alba*), brambles (*Rubus fruticosus*) and oak (*Quercus* spp.). Their varied diet creates a diverse plant population which allows for a variety of species to develop. They can become very selective feeders and can damage single plant species if not carefully watched. They have been introduced to Stodmarsh and Ham fen in Kent. They have created a mosaic of diverse vegetation and are confined and rotated on the site to reduce the chance of overgrazing (Gerard, 2002). There has also been an uptick in invertebrate biodiversity as they regularly visit the horses dung heaps (Northover, 2005). They should be introduced along with another large grazer such as Heck cattle for best effects. However, their trampling can lead to the growth of elder (*Sambucus nigra*) patches which the horse won’t eat so this should be carefully managed. As well as using continental breeds of cows and horses, native species such as belted galloways and highland cattle may be a better alternative. A study by Ausden *et al,* (2005) used highland cattle to see what effect it would have on fen vegetation. Some of the benefits of grazing include maintaining open species-rich fen communities by reducing plant biomass, control scrub invasion to maintain or restore open habitat, contribute to the diverse wetland surface in terms of structure and species composition, keep the effects of nutrient enrichment in check by removing vegetation biomass and preventing the dominance of nutrient-demanding species or reducing the development of scrub and wood on sites that are drying out (and therefore have increased mineralisation rates). Also the re-establishment of grazing, especially by cattle can reverse the successional progress and also suppress scrub encroachment by cropping seedlings or by taking off the regrowth from cut stumps. This may not be the most useful benefit because as discussed earlier the woody litter from the shrub will help prevent decomposition during drought. Cattle are useful for trampling bracken and low scrub, breaking up mats of dead litter and creating pathways through tall, dense vegetation, however cattle may also cause turf damage and dung will accumulate. As part of the report Ausden *et al,* (2005) also did a case study for highland cattle on a wetland in Mid Yare Reserve in the Norfolk Broads. They discovered some of the negatives for this type of management included flattening of dead reed which impacts breeding birds and overwintering invertebrates. Also it would be more beneficial to establish a mixed age structure with the management herd as it will allow site knowledge to be passed between animals. Some noticeable benefits of the highland cattle include increased plant species richness, reduced inflorescence density of common reed (*Phragmites australis*) and increased dominance of reed sweet-grass (*Glyceria maxima*) at the expense of the common reed (*Phragmites australis*). Light grazing with highland cattle is useful for increasing plant species richness and likely to slow the rate of succession to scrub. Breeding densities and species diversity of wetland passerines increased following grazing and exceeded those in a nearby mown fen. There is also the added benefit that fen grazing is significantly cheaper than mowing and burning and requires less active management.

There is also the possibility that when large herbivores are completely removed from a site that there could be other issues. *Typha* species have a tendency to become dominant by choking other vegetation out of a site which creates negative habitats for waterfowl and other birds. If given a chance cattail (*Typha domingensis*) can completely take over a site like it did on a seasonal, freshwater marsh in Palo Verde national park in Costa Rica. The site was previously managed by cattle grazing which maintained diversity but when the cattle were removed as a result of the site being labelled a wildlife refuge the cattail (*Typha domingensis*) infestation began. Eventually it covered around 95% of the marsh. To manage the site many different techniques were tried including cattle reintroduction, burning, disking, below-water mowing and mechanical crushing to control the cattail. The most effective control method appeared to be crushing the cattails (Trama *et al,* 2009). Any introduction of new species or site management techniques that could allow species such as *Typha* to thrive must be carefully monitored, especially on our site on Anglesey and in many other sites throughout the UK. Earlier in this report I discussed what the current management plan from the North Wales Wildlife Trust and SAC (Wilson, 2008) intended for Cors Goch was. The plan is set-up to maintain the current spatial diversity of the site by not allowing existing areas such as the shrub to encroach on the mixed mosaic of flora thus allowing the rare plant and animal species to thrive in their existing areas. Plant species such as the pale heath violet (heathland) and green-winged orchid (calcareous grassland) which are found on very few sites in the UK are given significant attention and this limits what management can be undertaken as there is the risk that slight changes to these areas could be exceptionally detrimental to the rarest species on the site but benefit more common species. The same can be said for rare invertebrate species such as the pearl-bordered fritillary butterfly and a number of dragonfly species that occupy the site. The current management plan seems to be benefitting these species as they are frequently recorded and the likelihood of significant changes to the plan is unlikely due to the success of these rare species.

One of the most successful examples of managed wetlands in Europe is the Oostvaardersplassen located in the Flevoland polder in the Netherlands was artificially created as a wildlife sanctuary. The site is 5,600ha in size and is an essential habitat for up to 250 bird species including herons, cormorants and spoonbills, and 90 species even breed on the site. The site has had horses and cattle on it for a number of years. It has Konik horses which are descended from the ancient Tarpan wild horses of Western Europe. The cattle that are used on the site are cross breeds of Scottish, Camarguais and Hungarian breeds in order to create animals that resemble old European oxen which are better for these sites due to the fact that they are known to help increase biodiversity. The Oostvaardersplassen as an artificial wetland area is an extremely popular birdwatching destination and is beloved throughout the Netherlands. This shows the importance of such sites as the Netherlands is a highly densely populated country and yet it still uses its valuable reclaimed land to create sites of significant ecological importance. This is one example of the possibilities that could be used to help develop wetland sites in the UK. More research needs to be undertaken on the possibility of using fire as a management technique in Europe. Information is needed on the best season to pursue burns and whether the hydrology of the site severely affects biodiversity when burns occur (Middleton *et al,* 2006). Controlled burns are an important factor in the Florida Everglades management scheme. They are used to manage large areas of plants and also to remove invasive species like Old World Climbing Fern (*Lygodium microphyllum*). We know that mowing and cutting is effective at increasing biodiversity if used in the right areas but maybe we can develop a less active management strategy through the addition of appropriate grazing.

There are some examples of mutualism in wetland areas where both parties benefit. The main example of this in UK wetlands is the mutualistic relationship between alder trees (*Alnus*) and fungi, (Grosse *et al,* 1990). Levels of nitrogen fixation increased in the trees due to the fungus *Frankia alni.* This is most likely due to the thermal pumping of oxygen down through the roots. An interesting aspect could be investing more research into learning about mutualism in wetlands. This research could possibly show us ways of increasing biodiversity in wetlands by planting alder groves in particular sites.

Monitoring the population and more specifically the changes in population of common bird species in the UK is a viable way to understand the overall health of the habitats that these birds call home. Another aspect of this is keeping a keen eye on individual species. This is important as it allows us to see how particular species are coping with changes to their environment and in which areas we need to focus our conservation efforts and also to truthfully examine the successes and failures of these efforts.

A number of species aren’t just located on the main part of Cors Goch, some are found on the paths and roads that lead to the site. Along the tracks and roads that lead to the site, there a number of houses. This means that any means of pollution that could possibly come from a property must be carefully managed and monitored so as it doesn’t have any adverse effects on the site. Liquid waste from sewage from nearby houses to the site is one of the major forms of pollution available from domestic properties. Sewage from houses is a mixture of human waste, water and wastewater. The likely sources of these pollutions would be from overflowing septic tanks or latrines which could leak onto the site and cause major issues. However food waste and oil from cooking are also sources of pollution from a house that could have significant implications on a site. Carefully monitoring point and non-point sources of pollution from the nearby properties is important for maintaining biodiversity and the current biogeochemical properties of the site. Another possible implication of the location of Cors Goch is its proximity to groups of nearby fields. Improper farm management in local fields could have indirect effects on Cors Goch. The main issue with the proximity of agricultural practices is that many of these practices could have huge influences if not monitored correctly. Any run-off from fertilisers, slurry or chemicals could lead to a reduction in water quality and a decline in the overall health of the site. A keen example of this is the spreading of slurry which if done incorrectly can run-off onto the site and cause eutrophication. This could lead to serious problems as it causes a rapid and excessive growth of plant life that chokes waterways and destroys other forms of plant life. Wetland studies in Western Europe have shown that large influxes of nutrients can cause changes in the composition of the species, decreases in the biodiversity of plant species and a loss of rare species (Bedford *et al,* 1999). This shows that even just closely monitoring changes to the site might not be enough to maintain or improve the biodiversity. This shows the necessity for not just managing the site but being aware of outside interferences that could have serious detrimental effects on the site.

There are a number of theories that display how common species seem to occupy the central areas of sites and rarer species reside elsewhere. One idea is the centrifugal organisation concept model where rare plant species are generally confined to the peripheral habitats and therefore much of the biological diversity may be centred around these zones. This means that there is the possibility that this model could be used to aid in the protection of rare and endangered plants and could be integral for the conservation of biodiversity on a range of sites (Keddy, 2010). The centrifugal model applied to freshwater marshes showed rarer species and the highest marsh diversity was present in the peripheral habitats (Keddy, 2010). Throughout freshwater marshes rarer species were found predominantly in infertile areas on the outskirts of the areas. This means that these areas should be carefully managed and not altered as they promote site biodiversity. The core habitats of these sites are dominated by relatively few species including *Typha, Phragmites, Scirpus* and *Papyrus.* Another thing that seems to affect species diversity in freshwater marshes is the period of flooding throughout the year. More species were found in marshes that had continuously moist soils rather than being inundated for parts of the year. High amounts of annuals and low populations of obligate wetland plants were found on these sites as well.

The importance of wetlands as a global ecosystem cannot be understated. A study by Davidson *et al,* (2019), estimates the global value of natural wetland ecosystem services as 47.4 trillion US dollars per year, which is 43.5% of the value of all other biomes. One of the modern factors that have to be taken into account when discussing management techniques is the effects of ecotourism. Ecotourism has become a valuable way of attracting money to wetland areas. The benefits of ecotourism are that it provides income for the site and the country without any resources being subtracted from the area. However the problem with ecotourism is that if the site becomes increasingly popular then the site could be damaged by higher footfall. A large amount of people these days visit wetlands in order to get a view of the variety of wildlife that lives there particularly birds. Birdwatching has become a significant source of income and is believed to be a $41 billion per year business in the United States (U.S. Fish and Wildlife Service, 2013). Obviously it would be difficult for wetlands in Europe to compete with sites such as the Florida Everglades but there is room for growth in the UK for developing ecotourism hotspots.

There are a number of risks associated with changing management techniques without having full disclosure of the possible consequences for the site. Knowing what negative effects your influence could have on an area and its species is essential for good management practices. A number of possible outcomes have been discussed for the management techniques mentioned. There is another outcome of trying to increase species biodiversity that has not being appropriately discussed. The growth and development of invasive species could become a problem in the UK, like it has in a growing range of other countries. Invasive species has become a problem in the Wisconsin sedge meadows as a result of sediment accumulation. This sediment helped promote the growth of *Typha* species and reed canary grass (*Phalaris arundinacea*) which of course then reduces species richness (Werner and Zedler, 2002). Invasive species have also become a serious problem in the Florida Everglades and a varying array of management techniques have been employed in order to stunt their population growth. Large numbers of species have invaded the Florida Everglades and caused severe damage to the area. Some of the major invasive species include Cuban tree frogs (*Osteopilus septentrionalis*), Burmese pythons (*Python bivittatus*), Old World climbing fern (*Lygodium microphyllum*) and hydrilla species particularly *Hydrilla verticillata.* Annual hunts of Burmese pythons are initiated in order to manage their population. Controlled burns and herbicide use are the main controls for Old World climbing fern. Hydrilla is difficult to control as it spreads extremely rapidly. Mechanical removal and biological controls are the main methods used to try contain the population. Cuban tree frogs have no effective control but repellents are used to deter them from entering areas where they have been known to cause damage.

Obviously the UK is not a hub for invasive species in the way that Florida is but we still need to be wary when considering introducing new species or when testing new management schemes in areas that could promote invasive species to flourish. There are a number of invasive species that have been introduced to the UK that have negative effects on wetlands. Invasive species in general are not a concern as they tend to be a part of balanced communities where a variety of species both native and non-native are able to thrive. The problem arises when non-native species establish themselves in areas with good condition for growth and reproduction but the area lacks a natural predator or the spread of disease is low. When this occurs invasive species can take over areas in a relatively short period of time. Some examples of species that have invaded British wetlands include the water primrose (*Ludwigia peploides*), quagga mussel (*Dreissena bugensis*), signal crayfish (*Pacifastacus leniusculus*) and the American mink (*Neovison vison*). The water primrose was introduced as an ornamental pond plant but spread rapidly. The plant can choke waterbodies by taking large portions of the available oxygen, light and space which can severely impact wetland communities. The quagga mussel spreads and creates dense populations quickly which consume micro-organisms and can alter the chemical make-up of waterbodies. The signal crayfish was part of an introduction to be included on restaurant menus; however they escaped and in turn destroyed large populations of the smaller, native white-clawed crayfish (*Austropotamobius pallipes*) through competition and disease. One of the most endangered and rare mammals in UK wetland systems are the water vole (*Arvicola amphibious*) and part of this population decline is due to the introduction of the American mink which hunt them voraciously.

Obviously one year of study on the site is not enough to gain the full picture of how the site functions. That’s why more study needs to be done on how different areas of the site are affected by the management techniques currently employed. Also testing of methods on the site that haven’t been previously used to see what affect they would have on the diversity and biogeochemistry of the site over a number of years.

The long term plan is to turn peatlands which have been degraded over the years into net sinks rather than net sources. Well managed sites and projects like the Peatland Carbon Code (PCC) are necessary. The PCC is a project that tries to get financial backing from investors who wish to see a reduction in carbon and mitigate its effects on the atmosphere. This project could benefit many sites around the UK as long as strong management strategies are present on these sites. We hopefully will also determine the plant and animal diversity on the site by doing biodiversity studies throughout the summer. Our studies on Cors Goch will hopefully show us if the current techniques being used are maintaining the sites to its optimal potential and what if anything needs adjusting. These ideas could then be employed on similar sites and could lead to the growth of better carbon sequestration models and increase the plant and animal biodiversity on UK wetlands.

**7. Suggested Management Plan for Cors Goch**

Wetlands are greatly affected by changes in environmental conditions such as climate change, removal of resources, development of land usage and urbanisation (Walpole and Davidson, 2018). Environmental changes in a wetland ecosystem can then lead to hydrological changes which in turn can have severe effects on the biogeochemical processes that define wetlands such as water storage and carbon sequestration (Rezanezhad *et al,* 2020). Wetlands are exceptionally sensitive ecosystems and even minor changes (whether that be natural or man-made) to the climate or hydrological conditions can alter the ecology and biogeochemistry of a site. Biogeochemical processes in wetlands are exceptionally complex and rely on interactions between hydrological processes, mineralogical transformations, soil stores of carbon and nutrients and bacterial and vegetation communities (Cherry, 2011). Changes to biogeochemistry can alter what plants are able to grow and in what densities. Changes to floral composition can in turn affect all later trophic levels and alter biodiversity to varying degrees. The biogeochemistry data shows that the site seems to be in fairly good health which means that the likelihood that the biodiversity is being adversely affected is low. However in a similar scenario to the biodiversity, more annual studies are required to test different areas of the site and see if there are any changes from year to year that could have knock on effects on biodiversity.

The overall management of Cors Goch seems to be working well. The main techniques being employed at the minute are annual cutting/mowing of the firebreaks, trimming and cutting back of areas that are becoming overgrown or dominant and the more passive technique of grazing by cattle. These techniques are the standard management tools for sites like this. However an overall suggestion for the site could be made from examining the biodiversity data. First we wish to examine the current techniques being employed. The annual cutting of the firebreak is necessary for the general health of the site and to protect it from any scenarios. With that in mind, we don’t believe that the firebreak has any significant negative effects on Cors Goch, A study by Bachinger *et al* (2016), suggests that firebreaks don’t seem to have a negative effect on plant diversity and even though carbon and nitrogen concentrations are lower in firebreaks than nearby areas it is unlikely to severely enhance soil degradation. The paper goes onto suggest that the development of firebreaks on the site is considered a sustainable management technique as it doesn’t affect plant diversity or range condition. Most years there is also active site management in terms of an area of the site that is trimmed and cut back. This is obviously a very important part of keeping the site healthy. The main suggestion we would have is that there are many key areas on Cors Goch that are essential for biodiversity and it is important not to over manage them. As seen in Table 8, 9, and 10 many species live in gorse, hawthorn, hazel, cladium fen pools, carex beds, black bog rush tussocks and *Juncus* tussocks. This means that altering these areas could significantly hamper biodiversity. Gorse and hawthorn in particular are fast growing and can take up huge areas of the site. These areas do need to be managed but not to the extent that it negatively affects biodiversity. The evidence from the Shannon index in Table 18 shows that the biodiversity hasn’t significantly declined since management was introduced and has even risen in butterfly and moth species since 2009.

The other main tactic being used on Cors Goch at the minute is the grazing by cattle. This is a useful management tool but must be manged very well. The cattle will obviously stay away from the deeper areas of water of water in the fen and stick to the fen meadow/heathland areas on the outskirts of the fen valley. These areas are dominated by areas of gorse, woody shrubs and there is also significant amounts of black bog rush and other *Juncus* species. An overstocking of cattle can lead to soil degradation via trampling and can damage the site. However species like Konik horses and Heck cattle could be used as alternatives. Konik horses are an ancient breed and have many benefits for wetland habitats. As mentioned in the discussion, these animals require little to no management, help vegetation structure and biodiversity. They have an extremely varied diet which helps with plant diversity. We believe they could be a significant addition to Cors Goch along with Heck cattle, as long as they are confined and rotated they can provide many benefits to the site. The addition of hardy native breeds such as belted galloways and highland cattle could provide similar benefits as mentioned earlier. The idea that grazing, mowing and burning are the best management techniques is reinforced by Middleton *et al*, (2006), who suggests that if the use of these techniques is reduced then it can lead to a loss of biodiversity as well.

One technique that is not used in Europe as much as it is in North America, is burning. Burning is a common tool used in America for managing overgrown areas. It’s not used in Europe as there is the risk of peat catching fire. However, we believe that controlled burns in the winter time could be a viable management strategy. This can increase sedge meadow diversity for a short period of time. More seeds will also be added to the seed banks as a result of controlled burns. A study by Clay *et al,* (2010) found that a blanket bog in Northern England which had undergone management by both grazing and burning to varying degrees could lower carbon release. The study discovered that when the site was burned over 10 and 20 year periods that it led to these plots becoming lower sources of carbon than unburnt plots on the same site. It also showed that when burns are paired with appropriate grazing it created the plots with the lowest sources of carbon. The use of mowing on the site could be extremely beneficial to the calcareous grassland on the fen. Also with there being annual management on Cors Goch, the extra plant litter could be left on the site in order to create microhabitats for invertebrates and may increase population size and biodiversity. It may be best to leave the material in piles as leaving it on the main part of the site could reduce light availability and be detrimental to other plants. It is also important to actively manage every part of the site over the course of a couple of years. It’s important because Middleton *et al* (2006), suggests that if a fen is abandoned the vegetation within will shift to trees and shrubs after around 10-15 years. If this were to happen in a section of the site it is obviously difficult to reverse.

Overall Cors Goch seems to be a healthy site which could benefit from slight changes to the management plan. The additions of ancient species such as Konik horses and heck cattle, or more modern ones such as highland cattle and belted galloways, which are much better suited for the fen habitat and have proven benefits on similar sites as long as they are managed adequately. Controlled burns of overgrown areas during the winter months along with the current schemes in place could increase biodiversity. We have seen an overall increase in biodiversity for some species groups in the Shannon index. We believe that further studies to update some of the data that is currently available. From analysing the COFNOD data we noticed that there were limited records for certain plants, birds and invertebrates in recent years. A site survey to determine current populations and diversity could be an extremely useful tool and help focus management on the site in the future. This along with regular testing of enzyme activities, pH, and soil respiration can make sure the site is in the best position it can be to flourish. Completing annual surveys alternating between different groups will eventually lead to a database of species records that can be examined and tested to see if there are any significant changes caused by different management techniques. I understand this may not always be feasible due to available funding. However there are many local recorders and university students who with little training could become adequate recorders, similar to when volunteers are asked to help tidy the site. This is also not only a recommendation for Cors Goch, there are many sites across North Wales, specifically Anglesey that require this kind of attention in order to make sure current management is benefitting each individual site and if any potential changes could be identified.

**8. Conclusion**

The question we wished to answer before beginning this thesis was to see how current management techniques being employed on Cors Goch have affected or are affecting the biodiversity and biogeochemistry of the site and what if anything could be done to improve the management process and make it more effective and efficient. In order to do that we collected peat samples and analysed huge amounts of data from COFNOD to see if we could uncover significant details that would assist us. We used the data to compare changes in Shannon diversity before and after significant active management were introduced. This data did show us some information that led us to believe that the current management schemes are influencing some species both positively and negatively. More studies on the site are needed in order to gain more up to date population and diversity numbers in order to ascertain the significance of our findings for more species.

The main recommendations that we would have is that future research is needed on Cors Goch and on similar sites throughout the UK. On Cors Goch specifically, there is a lack of records for bird populations, certain invertebrate species and plant diversity which needs to be changed. A significant site survey could be undertaken in order to gather more data and therefore be able to more closely analyse and compare it. Comparisons with data gathered pre 2009 is necessary to see how species have adapted to the current management schemes. Through research of current techniques we discovered that use of ancient breeds of animals like Konik horses and Heck cattle and native breeds such as highland cattle and belted galloways can be beneficial to sites like Cors Goch if managed properly. Testing of the theory that their diet is more varied and they are less likely to cause soil degradation by trampling therefore increasing biodiversity sounds extremely promising and needs to be examined further on UK sites in order to determine its validity. Another possible technique that needs to be examined further is the addition of controlled burns to the management regime. It is an under used technique in Europe and the effects of it need to be examined more closely in order to see if it is a viable option for use in the UK.

In terms of what knowledge this paper has contributed to the overall knowledge, we believe it gives conservation institutions and trusts a basis for standard tests that can be run on many other sites. Cors Goch is not the only site managed by the North Wales Wildlife Trust; there are also similar sites all over the British Isles that could benefit from the ideas presented in this work. It can show them a number of tests that can be run or strategies that could be employed in order for their sites to flourish. It can also give ideas on whether population surveys are required and what other aspects of site management need to be looked out for. Things like nutrient influx, changes to water level and impacts of outside influences that could alter a site significantly. There is still much research needed into how small changes to these sites can have huge consequences and what these affects may be. Also the current issues which are being accelerated by climate change need to be investigated further. Important issues such as how climate alteration effects carbon sequestration are key for us being able to protect and sustain our peatlands worldwide.

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