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THE MARLOES COAST PROJECT CONSERVATION WORK AT TREHILL FARM, WEST WALES, 2003-2015

Ymddiriedolaeth Genedlaethol
National Trust

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EXECUTIVE SUMMARY

This twelve year review looks at the habitat conservation work carried out at Trehill Farm, Marloes, Pembrokeshire. In 2003, 76.5ha of National Trust owned coastal land were brought under a management agreement with Countryside Council for Wales (CCW), now Natural Resources Wales (NRW). Much of this area was being used to farm cereal crops.

Heathland re-creation was carried out on some 20ha of this arable land. Treatments involved stripping the surface soil horizon to remove nutrients and lime; acidifying soil using elemental sulphur, and introducing seed of heather and other key heathland species in the form of cut brash. Different combinations of these treatments were applied across the site.

The elemental sulphur applied was sourced free from the sulphur recovery unit at the Chevron-Texaco Pembroke oil refinery, and applied with a conventional lime spreader. The soil removed was used to reinstate hedge-banks, using a 19th century tithe map to inform their locations.

Experimental plots encompassing the range of different treatments were established in one heathland re-creation field. The developing vegetation and soil chemistry was monitored annually for the first five years. Soil processes, vegetation and invertebrates were studied elsewhere on the site. Results of this work are summarised here.

The initial monitoring work concluded that the combination of soil-stripping, a low rate of sulphur application (4tons/ha) and brash application was best suited to re-creating ericoid-rich heathland on this site. However, more recent surveillance suggests that soil-stripping in the absence of sulphur application may also lead to heathland establishment.

A range of open-ground species established well following soil stripping. An early flush of arable plants gave way to coastal grassland and heathland species, with both low and no sulphur treatments. Lichen establishment has imparted a distinctive feel to these areas, and several rare plants have colonised.

Heathland plants failed to establish in untreated, control areas. These instead developed a coarse-grassland vegetation. High sulphur applications proved detrimental to heathland development, at least in the short-term, and this treatment resulted in a high proportion of bare-ground. It is possible, however, that this treatment will provide open heathland habitat in the longer-term as successional processes result in mature, closed-canopy heath elsewhere.

The heathland re-creation was novel in its nature and scale, and various lessons were learnt. Recommendations are given for future projects of this nature, and for the ongoing management of this site.

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PART I – ORIGINATION TO INSTIGATION

Pen Picture of a Peninsula

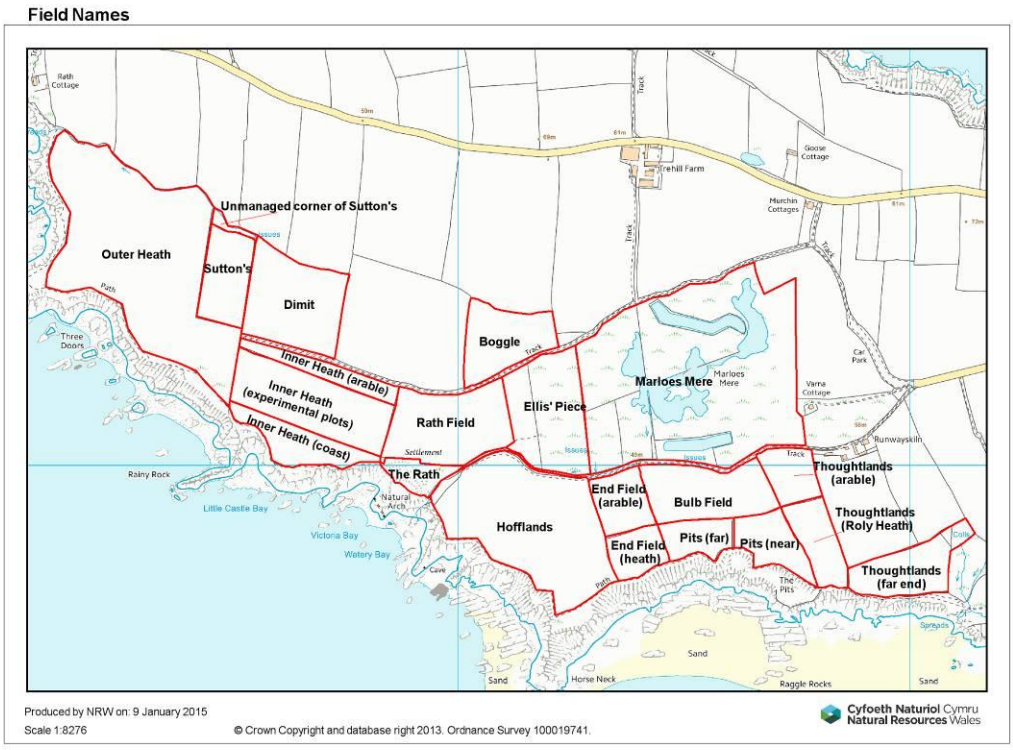
Trehill is a 180 hectare farm in Pembrokeshire, west Wales. As the location map illustrates, it lies at the tip of the Marloes peninsula – a tongue of Ordovician and Silurian age rock jutting out into the Irish Sea at the southern end of St Brides Bay. The gently sloping, south-facing plateau is overlain with drift material, deposited by the Irish Sea Ice at the end of the last glaciation. The heterogeneous nature of these deposits are reflected in the soils, which range from clays to sandy loams. They become deeper the further inland you travel. The coastline around the farm comprises rugged cliffs of sedimentary rock, which reach a height of 50 metres. These cliffs have names like 'Pitting Gales Point', a testament to the Atlantic storms that lash this corner of Wales. In winter, strong westerly winds whip the spindrift off breaking waves, sending salty froth drifting up across the farm like dandelion plumes. Summer, in contrast, can bring hot sunshine and drought periods.

Farming over the centuries has had to work around these extremes. Archaeological history tells us that Stone Age (Neolithic) people were in the area, but they were using flints as scoops for limpet shells and there is no evidence of agriculture from this time. The first recorded settlements here date from the late Bronze Age or early Iron Age. These comprise the 'cliff castles' of Watery Bay Rath and Gateholm Island - hut clusters in easily defendable positions, reinforced by steep earth banks. Permanent habitation here would presumably have led to some attempts at cultivation of the surrounding heath or scrubland. These settlements appear to have stayed in use into the Romano-British period, but little evidence survives from these times or the Dark Ages that followed. The first available maps of Trehill come from a 1767 survey. At the eastern end of the farm, a system of medieval strip field cultivation was, remarkably, still in usage. This contrasted with the western end of the farm, where a broad swathe of cliff land was still uncultivated. The 1847 tithe map and a parish map from 1932 then neatly demonstrate the fluctuating fortunes of arable farming on the peninsula. The strip fields all but disappeared during the nineteenth century, and it appears that much or most of the rough land was brought under the plough. However, the first half of the twentieth century saw significant areas abandoned - presumably to heathland again. The schedules with the 1847 tithe map indicate that the heath was used for grazing, and we can perhaps guess that this practice continued into the next century. The mere which dominates the shallow basin near the centre of the farm was certainly considered valuable grazing right up until the 1970s - cattle were brought down from surrounding farms to take advantage of the forage and water in hot

summers when their own pastures became too parched. A system of small fields to the west of the mere served to separate these cattle overnight.

As elsewhere in the country, the increased mechanisation and intensification of agriculture during the twentieth century overcame most of the remaining challenges to production. Although the National Trust purchased the farm in 1941, no specific protection was afforded to the areas of unimproved habitat and these continued to be cultivated up until 1981. Hedge-banks were pulled down with the aid of a chain stretched between two tractors. Mechanical stone-pickers were used to make the rockiest fields ploughable. Irrigation reservoirs were sunk in the edges of the mere to supply thirsty crops.

At the outset of the project, the farm was specialising in producing high quality potatoes for the supermarket shelves. Cereal crops – triticale and barley – were grown on the thinner soils towards the cliffs. These were undersown with rye grass to provide forage for the tack sheep, which had the run of the farm during the winter months. The coastal belt also had two fields of semi-improved pasture, one of which – known as Hofflands – had been developing since arable cultivation stopped in 1992. This ongoing experiment in coastal grassland reversion has been financially supported by CCW (now NRW). As well as providing a starting point for the current conservation efforts at Trehill, it serves as a counterpoint for the more interventionist techniques under consideration here.



Field Names, post-project, referred to in the report

Making a Mark

A pool in Ellis's Piece, west of Marloes Mere SSSI, 11 years after creation

Experience suggests that when a new owner or manager takes on a farm, changes to the old regime often follow. These changes can be environmentally damaging, as an energetic younger farmer looks to improve productivity and make his mark on the land. A change of tenancy at Trehill instead found the new farm manager receptive to the ideas being floated by the author, a newly appointed Senior Conservation Officer with CCW. Trehill was by now well accustomed to conservation management. Pete's father-in-law, Bill Ward, was the previous tenant, and he had forged good working relations with the National Trust, the Wildlife Trust, Pembrokeshire Coast National Park Authority and CCW. His work on and around the Mere was rewarded with a Silver Lapwing Award from FWAG in the 1980s. Making a mark here was clearly going to require something over and above the good work already achieved.

In 2003, The Wildlife Trust, struggling to get a grip on the management of the Mere, relinquished this role and a Section 15 Management Agreement was negotiated directly between CCW and the Smithies. An enhanced management regime was initiated and this quickly set about raising water levels, restoring marshy grassland and pools in both the SSSI and the adjoining field to the west, and re-introducing cattle grazing.

The management agreement on Hofflands then became due for renewal, as did a 'Coastal Slopes' agreement with the National Park which had re-aligned fencing alongside one field to facilitate management of the cliff land. Pete tasked the author with coming up with a new plan. The time seemed right to propose a scheme for the whole sweep of coastal land here, bringing some 70 hectares into a more conservation-orientated management regime.

A Blank Canvas

Although casual observation suggested that the arable land within the intended project site was of little ecological interest, consideration had to be given to its existing and potential value. Arable is a relatively uncommon habitat in Wales, and Pembrokeshire holds a significant proportion of the national total. It can be of considerable botanical interest, supporting a specialised higher and lower plant flora including a suite of 'archaeophytes'. Cereals, particularly spring-sown crops, can be utilised by various farmland birds including the declining skylark, and harvested fields that are left as unploughed 'stubbles' over the winter are an important foraging resource for the chough in coastal parts of west Wales. For both ecological and agricultural reasons it was decided to retain the greater proportion of the project site as arable, but to apply various simple management prescriptions to enhance its conservation interest (leaving margins unsprayed or uncultivated, and retaining stubbles late into the winter).

We had no specific information about the ecological history of the fields, but rough ground symbols on the old maps combined with the anachronistic field names (Outer Heath, Inner Heath) strongly suggested that they had supported heathland for long periods prior to and in-between cultivations. Further circumstantial evidence came from the farm records showing the quantities of lime that had been used to raise the pH of these predominantly light, sandy soils. Finally, the survival of heathland on nearby cliffs and headlands gave additional justification and reference points for the work. We targeted five fields for heathland creation or re-creation, totalling around 13ha. Four of these fields were under conventional arable cropping, and the fifth was fallow land, managed in accordance with government set-aside regulations.

Taking these fields out of conventional agriculture would also have added benefits for the cliff slopes themselves. Fencing against parts of the coast path – a national trail walked by thousands of people every year – would no longer be imperative, and permissive access could be granted to the new heathlands in due course. Without fencing and the consequent 'pinch-points' formed, stock would be able to safely access the cliff-slopes and help to maintain these in an open condition. Grazing management was not considered appropriate along the eastern section of cliffs though, due to the steep, narrow slopes and the presence of well-developed species-rich scrub communities here.

Elsewhere, management of the pasture was re-focussed to enhance the reversion to unimproved or coastal grassland, and to cater more specifically for chough. Two further fields were to be converted from arable to grassland, primarily to buffer the mere against fertiliser and pesticide run-off, and to provide hay for the herd of cattle soon to be introduced. Details such as re-creation of field ponds within the pastures, rough grass areas and small areas left to scrub up were also included within the plans.

Using Oil, Losing Soil….

A tanker collects liquid sulphur from the sulphur recovery unit at the refinery

The big challenge was to turn arable land into heathland. Experience of schemes both here and elsewhere on the Pembrokeshire coast suggested that it would not be enough simply to abandon cultivation and turn animals out to graze the naturally regenerating vegetation. Spontaneous heathland regeneration may have occurred here in previous centuries, but the legacy of lime, phosphorus, nitrogen and potassium applications from decades of intensive crop production would, by now, have profoundly altered the soil chemistry of these fields. The initial vegetation response – important in setting the pathway for longer term succession and stability – seemed likely to be characterised by those species in the agricultural seed-bank which would compete well in a soil with artificially high pH and nutrient levels. Although nitrogen and calcium would begin to leach away through the soil profile, phosphorus is a notoriously 'stubborn' element. A non-interventionist approach would perhaps continue to favour competitive species such as rye-grass, couch and bramble for a long time to come.

Several English projects had already looked at heathland re-creation from arable. Various techniques for reducing soil pH had been investigated (summarised in Tibbett and Diaz, 2005). Owen et al (1999) compared bracken mulch, pine chippings and sulphur, and found the latter to be far and away the most successful soil amendment technique. This works as naturally occurring soil bacteria, predominantly in the genus *Thiobacillus*, oxidise the sulphur to produce sulphate. This then combines with hydrogen to produce sulphuric acid, which dissolves calcium and allows it to be mobilised and lost down the soil profile. They succeeded in reducing pH from 7 to below 3, using quantities in the region of 8 tons/ha. However, the high cost of

processed, elemental sulphur (£200-250/ton in 2000) was felt to limit its practical applicability.

Soon after contemplating this, the author was at an 'environmental liaison' meeting at Chevron-Texaco's Pembroke refinery, where the aptly named David Heath gave a presentation on the new Sulphur Recovery Unit. The plant has made great strides in capturing sulphur from its emissions, exceeding legal requirements brought in to prevent the damaging atmospheric deposits known popularly as 'acid rain'. Talk of several hundred tons of sulphur being extracted from the crude oil on a weekly basis provided the required inspiration for the heathland re-creation. After some initial bemusement, David and Texaco gamely accepted the challenge of providing - free of charge - up to a hundred tons of raw powdered sulphur for the project.

Acidification, then, was set to provide a focal point for the project, but another technique for manipulating soil chemistry seemed worth considering. Removal of topsoil is a drastic means of taking away nutrients, which had been tried in experimental projects. Work at Euston and Honington, Norfolk (Pywell et al, 1995) had demonstrated the effectiveness of soil stripping in decreasing soil nutrient status, if not in encouraging heather establishment. The authors conclude that it is not likely to be a practical option for large-scale re-creation projects.

It was clear that we would only use this technique if we were able to use the stripped soil as an asset within the project, rather than see it as a liability to be disposed of. A look at the First Edition Ordnance Survey maps of the farm provided the answer. Numerous field boundaries had been removed during the previous two hundred years, as fields were enlarged to accommodate agricultural mechanization. The previous tenant described how earth and stone banks were being pulled down through into the 1980's. This would be done by two tractors driving in parallel either side of the bank, with a chain stretched between them. Mechanical stone-pickers had also been used, so that there were none of the exposed field-stones that contribute to the ecology and character of our more ancient heathlands. In all, over two kilometres of boundaries had been removed within the project site since the first map was published. With a new, more intimate mosaic of extensively managed habitats being proposed, a return to smaller field sizes seemed appropriate. Attempting to restore something of the post-medieval landscape thus became another strand of the project, although archaeological opinion was divided as to the merit of this.

We could have had a series of assays done, to look at whether or how nutrient status decreased with soil depth, and what species we could expect to recover from the buried seed bank. As it turned out, the initial soil chemistry work was done through a student project, and the sampling technique used did not give us this information. However, we came to see the restoration and re-creation of boundary banks as a key part of the project, and were ultimately led by the more pragmatic concerns of volumetric requirements and financial constraints. We had around 1.6km of banking that we wanted to put back. A 1m length of bank takes 5.5 m^3 of soil, so we would require in the region of 8,800 m^3 for this. If we stripped to an average depth of 25cm, it would take just over 3.5ha to supply this. We also had at least 1km of low, eroded bank that we wanted to build back up, and the option to use some of the soil within the fields that were staying as arable. In all, we estimated that we would be shifting 14,000 m^3, at around £1/m^3.

Criticisms are often levelled at this kind of resource-hungry, interventionist conservation management. At Trehill though, the work was justifiable from a number of angles. Firstly, the 'carbon-equation' seemed to be in our favour. The soil moving operation alone was to burn around 5000 litres of diesel, but, over time, this will be offset by the cessation of annual ploughing and harvesting, and the higher carbon sequestration of semi-natural vegetation relative to arable. Secondly, we set this interventionist management within a context of less radical habitat reversion and enhancement, using the 'headline-grabbing' work with machines and industry to build a bigger project around. Thirdly, we viewed this work as a 'statement of intent'. Nature conservation within the agricultural landscape appears, at times, to be seen as a temporary, transient option – easily undone when the ten-year agri-environment agreement comes to an end. This clearly contrasts with the ecological importance of permanent, ancient habitats. We wanted to challenge this, effectively by sabotaging agricultural productivity in the short term and giving nature conservation the highest priority.

Soil Conservation

Soil movements in Outer Heath – topsoil stripped from the left of the picture is piled up to the right ready to be spread across the arable area here. A new hedge-bank separates the two areas

It would be fair to say that soil conservation was not paid much attention at the outset of the project. Concerns about what was in the soil focussed on archaeology, and the soil stripping plans were designed so as not to disturb the areas thought to have the highest potential for artefacts. The start of the project coincided, however, with the launch of the National Trust's Soil Conservation Policy and the spotlight fell on the ground-works being undertaken here.

Soil conservation essentially has two issues with the heathland recreation work. Primarily, the policy seeks to conserve soil productivity, structure and function for agricultural purposes. Clearly, this aim is in conflict with heathland and other habitat re-creation, and prioritising one over the other is an exercise best left to those engaged at strategic level within the Trust. We did receive a letter of concern from the NFU, but as Pete Smithies observed, their concerns don't extend similarly to the sale of arable land for housing, or the installation of solar panels. Secondly, the policy seeks to conserve soil biodiversity. This has been described as the last great frontier for biodiversity, with so much of the diversity of invertebrate, fungal and microbial species being very poorly understood.

Three points stand out in defence of this project. Firstly, the soil seems unlikely to have been in a particularly healthy state for biodiversity at the outset of the project. The annual farming operation entailed sixteen different applications of fertilisers, herbicides and pesticides, followed by removal of organic matter and ploughing. Secondly, the soil has not been destroyed, instead either being moved to the edges of the field (where some of it had been before the hedge-banks were levelled), or into the fields being retained as arable where it has provided a deeper, more fertile substrate for crop production. It would seem fair to assume that, in the former context, the soil fauna can flourish without the regular disturbance of agricultural operations. Thirdly, the stripped areas are now undisturbed and subject to entirely natural processes of soil development. However, areas subject to high rates of sulphur application, particularly where also stripped of soil, are perhaps too radically altered to be described in this way.

One might expect the soil biodiversity in this new context to become inherently more interesting than before, but the answer to this question would depend on the application of soil monitoring procedures more complex and tailored than those currently being trialled by European soil researchers (see for example Gardi et al, 2009). One further point worth making again here is that the rate of carbon sequestration will now be higher than under the previous arable regime. In summary, it seems conceivable that overall the project has been beneficial rather than harmful to soil conservation.

A funding challenge

The in-kind contribution of sulphur from Texaco was worth at least £30,000

Hiring machinery, providing fencing and water supplies, aftercare – these would all be costly operations. Some money was available from CCW, but this kind of innovative work - over and above CCW's statutory remit – seemed a promising candidate for external funding. Attempts were made to draw down funding from the

'Aggregates Levy Fund', then the 'Landfill Tax Fund'. Neither of these funds felt able to support the project, the latter questioning the biodiversity value of the work and stating that they would have been more inclined to support a tree-planting project. It seems possible that our 'government-sponsored' status may also have worked to our disadvantage here.

It is worth noting that the market value of the sulphur donated by Texaco was in the region of £30,000. Adding in Texaco staff-time would perhaps have added £18,000. In match-funding terms, this would have represented a significant 'in-kind' contribution. It is also worth noting that English heathland re-creation experiments continue to cite high sulphur costs as prohibitive to large-scale projects (see for example Walker et al, 2007).

On a different note, I also began to wonder whether the carbon-sequestration value of restored or re-created habitats could be factored in to funding bids as an in-kind contribution, using the shadow-price of carbon on European carbon trading markets coupled to the difference in annual sequestration between improved habitats and semi-natural habitats. This approach might have been of more value in peatland restoration projects.

In the end, CCW footed the bill for most of the project through a combination of its management agreement and research budgets. Approximate costs are given as Appendix 1. The National Trust contributed through staff time and a rent reduction in the tenancy. Using Objective 1 money, they were also later able to install a sustainable 'hydro-ram' water supply system to some of the project fields.

A management agreement was negotiated with the tenant, which looked carefully at the financial losses likely to accompany the habitat re-creation. The outcome was an agreement offering a realistic annual payment, structured according to the loss of productivity likely to be experienced. Hence the agreed rate was highest for the fields being taken from arable to heath. When the agreement was in place, we were ready to go.

Getting Going

Excavator loading trailers in Inner Heath

The land-forming was straightforward enough. Fields to be worked were first ploughed, to loosen the top-soil ready for stripping. The contractor assembled the machinery in late September 2003 – a JS130 360 degree tracked excavator, a bulldozer and up to four 12-tonne dumper trucks. The autumn start meant that we kept a wary eye on the weather - work started on the heavier clay soils to the west of the site before moving on to the lighter, sandier eastern fields. Blessed with dry weather and good ground conditions though, the work progressed quickly. We had planned to use the bulldozer to push topsoil into rows, for loading with the excavator. This technique was abandoned early on, when it became apparent that the bulldozer left an excessively smooth, compacted surface. We wanted an uneven surface, with hummocks, hollows and a range of micro-topographic features. This would be more ecologically diverse, and effectively increase the actual surface area available to the colonising wildlife. Although the operator took some convincing to do so, the excavator left the requisite rough finish, and could work backwards to avoid tracking over the freshly stripped and shaped surface. It took on both the stripping and loading, whilst the bulldozer worked on shaping the hedge-banks. The operation took almost three weeks and cost £17,000 + VAT. The depth of the stripping generally varied between 20 and 30cm. An archaeologist was employed to do a field walking survey after the work was finished, costing an extra £1000. No significant finds were made.

Bringing in the Brimstone

Discharging sulphur into bunded hard-standing

The sulphur operation needed some careful steering by Dave Heath and the rest of Texaco's Environmental Team. The Environment Agency were also supportive, confirming our exemption from waste management licencing requirements. Ordinarily, tankers collect the sulphur, which is piped in as a hot liquid directly from the plants sulphur recovery unit. The sulphur is taken to Avonmouth in England where it is used in the chemical industry. However, due to increased supply, haulage costs currently exceed the market return.

The novel procedures and rigorous safety standards involved in plant processes meant that it was August 2004 by the time the sulphur was ready. We had tankers filled in the usual manner, but then had them discharge their loads onto a bunded hard-standing in a corner of the refinery. This sulphur 'lake' quickly cooled and solidified. A combination of a 1.5 metre, ride-on vibrating roller and JCB were then used to break it down into a powder. The roller was only effective to a depth of 15cm. This processing operation took 60 man-days. We didn't mind that the 'rough-and-ready' approach to processing left us with some large granules and coarser lumps as well as the powder. These lumps would take longer to break down, and the ensuing slow-release effect would perhaps help us to maintain low pH into the long-term.

We had an agricultural contractor ready to spread our sulphur in a conventional lime-spreader. A JCB was used to loose fill a bulk transporter, and three 22 tonne loads were taken to the project site by a driver certificated in the transport of hazardous chemicals. Here, it was tipped onto a field corner, and a loading shovel was then used to fill the spreader. Sulphur is flammable, and in confined spaces could potentially ignite on contact with sparks. Using a mobile bowser, we kept it wetted throughout the handling process to minimise this combustion risk. Appropriate protective clothing, dust masks and eye protection were also used, and temporary signage was erected on adjoining footpaths asking the public to avoid the fields.

The spreader took 4 or 5 tonne loads, and was adjusted to apply different rates to the different fields. Most of the six heathland re-creation fields were treated at a rate of

about 4 tonnes per hectare. The range of particle sizes involved – from fine powder through to 10cm chunks – meant that this application rate was sometimes unevenly applied, varying particularly at the start and end of each load when the excess fell off the sides of the hopper, or the load remnants were being discharged. The powder drifted a little before being caught on the sward or ground, whilst the granules and larger lumps fell to the ground – often in partial aggregations. Our intended maximum rate – around 8 tonnes per hectare – was applied to fields or parts of fields with high rye-grass cover or clay-rich soil. Clay, with its small particle sizes, has a higher inherent buffering capacity and the previous work by Liverpool University (Marrs et al, 1999) had suggested a heavier application was needed on clay soils to counter this. In practice, 'Roly Heath' which was treated first also received a high rate in the centre as the lime spreaders hadn't adjusted to the discharge rate and spread of the sulphur. We also had an excess of 6 tons more than our planned requirements, which was spread in Rath taking the application rate over parts of this field above 8t/ha. We left wide buffers around the two ditches on the site, both of which discharge directly into the sea. The spreading work was all finished in one day.

Two areas which had received higher than desired rates of application were, on Pete's suggestion, subsequently rotovated. The intention of this operation was to 'bury' some of the excess sulphur. The largest rotovated area, the western third of Rath, has shown this to have been a mistake, as almost no plant growth occurred here until a second application of heather brash in 2012.

Sulphur spreading in Thoughtlands

Cutting and Seeding

Forage harvester cutting heather brash

There were no suitable sites in the immediate vicinity for collecting heather and other heathland plant seed – coastal heath does not lend itself to mechanical operations. We chose Plumstone Mountain, an inland common some 25 kilometres from the project site. This contained a large area of mature heathers *Calluna vulgaris* and *Erica cinerea* as well as western gorse *Ulex gallii*. It was also rather species-poor, with no locally distinctive species which would be out of place at Trehill. We opted to use a tractor with an old double-chop forage harvester, which could cut and shred the woody material and blow it into 14 tonne trailers drawn alongside. The owner of the common had asked us to assist with recovery management, so the operation would serve a dual purpose – providing seed to assist with the re-creation work at Trehill, and opening out stock paths and firebreaks to assist with the restoration work here.

The chief difficulty we faced was ensuring the safety of the machine, as the flails are vulnerable to damage if rocks are hidden in the vegetation. This necessitated the author wading through the waist-high, gorse-rich heath ahead of the tractor, checking for hazards. The operation was carried out in October 2003 and again in October 2004, and a total of 18 trailer loads were taken down to Trehill. These were tipped into piles on the fields, then loaded into a muck-spreader using the front forks of a Manitou. The muck-spreader proved to be a simple and effective way of spreading the cuttings in a relatively even fashion. We spread on to all the areas where we had applied sulphur, leaving perhaps a 50% cover of this heath mulch. The material was spread on the day of harvesting or as soon as possible after, in order to prevent the heaped material heating up. In hindsight, this may not have been necessary – a heat treatment akin to heathland burning could potentially have enhanced germination. The late October date, dictated by heather seed ripeness, meant that ground conditions at Trehill were soft. The tractor work cut the soil up in places, but we were generally able to view this as another exercise in niche creation.

A similar exercise was carried out in autumn 2013, using Tretio Common near St David's as the donor site. This material was used to seed the part of Rath which was struggling to vegetate following high sulphur application and subsequent rotovation. The muck spreader applied this in somewhat regular lines, but the subsequent ericoid establishment has been good.

Applying brash with muck spreader (above), brash lines in Rath (below)

Community Involvement

Building a 'clawdd' end to hedge-bank at entrance to Roly Heath

Although not a community-led project, we were keen to ensure that there was both community understanding and benefit from the outset. The farm manager served on the local community council, and was able to promote the project successfully within the local village and the wider farming community. The intention to remove fencing and allow access to the newly created habitats would be the main benefit, but some incidental economic benefits through increased eco-tourism were anticipated. Pembrokeshire contractors were used for all the land-forming, sulphur spreading and fencing work.

We produced temporary bilingual interpretation for the car parks, youth hostel and bird hides alongside the project site and ensured that these were up well in advance of the work starting. We left it until the sulphur was being spread though before putting out a press release. This was picked up by the national Western Mail as well as the county paper, and BBC Wales did a radio interview. We did a separate article for the community newsletter, and included within it a 'field-naming competition', with a sack of Trehill's finest potatoes as a prize. This gave us some positive feedback, as well as names including 'Roly Heath' for our ridge and furrow field (where we mis-interpreted the archaeologist's advice and reversed the ridges and furrows….).

Lastly, as a team-building exercise, staff from the local Field Studies Centre at Dale Fort and the Countryside Council for Wales spent a day with a hedge-banker from the village, and the result was a fine stone bank end at the entrance to the project site. The turf for this was dug with a spade from Pits, and even this small-scale disturbance activated a buried seed bank of a rare plant, hairy bird's-foot trefoil *Lotus subbiflorus*.

PART II - AGRICULTURAL AND FARM BUSINESS IMPLICATIONS

Conservation Grazing Regime

Trehill Welsh Black cattle on the Deer Park

Philbeach had a commercial beef herd before the project, but there was no cattle grazing at Trehill. A conservation grazing beef herd was then started at Trehill, to graze the mere and the coastal grassland and heath. Conversely, the commercial herd was wound up. The new suckler herd has been built up to around 25 plus followers. The stock were initially dairy bred Welsh Black calves, then a semi-pedigree mixed group of Welsh Black was purchased. These have been bred on from using pedigree bulls. A Hereford bull (from the author's herd) was used around that time, but there has been a subsequent cull of mixed stock. A pedigree Welsh Black bull has been used since.

The cows are autumn calving on fields near the Mere, and are then housed over the worst part of the winter at Philbeach. They are turned out on to the cliff fields or Deer Park in spring – by this time they are large enough, and the cows are not too protective. Public perceptions, for example of bulls or lively steers, makes the grazing of this land a difficult balancing act. All non-breeders are kept until they are ready for the abbatoir. They are pretty much left alone to get on with it – it may take three and a half years to finish them, but Pete is not concerned by this as a simple, low cost system is the aim. A few, perhaps five per year, are sold off-farm as 30kg meat boxes. Other Herefords have been going to Waitrose at Dovecote Park via a local dealer. The Hereford heifers finish in about 30 months, and 12 steers are currently also going out at about 30 months. No particular efforts are made to make this deadline though – the

animals are not corn fed because the home-produced corn is not organic (even though the animals are not sold as such). The Organic scheme rules complicate things here.

A few sheep are kept as well. Pete buys in new lambs and sells them on as yearlings. There are perhaps 350 at Trehill, running on farmed land and cliff ground (which they only graze lightly).

Sheep on the cliffs below Rath

Grazing Issues and Constraints

Welsh black yearlings above the Outer Heath cliffs

Forage quality is certainly a consideration. The Mere is relatively good, and animals come off fat and in good condition. It is dedicated to the cows and calves, although it could alternatively be used to finish steers. Finishing can be a difficult task as the conserved forage is not high quality (the crop has all 'gone to head' with the late-cutting dates specified by the S15 Agreement). Hofflands provides reasonable quality forage, but the productivity is low here and salt burn can be an issue, checking the grass growth. The heathland fields, even those with well-developed heath like End Field, don't provide useful grazing.

The extensive area of open ground means that ragwort is frequent, though not of immediate concern as the animals don't eat it and the neighbours aren't impacted. It is now encroaching into adjoining more intensive fields though.

Out-wintering has been a problem as the cliff land is surprisingly wet. The restrictions of the Organic scheme, prohibiting the use of the conventional land for grazing, has exacerbated this. It would make more sense to 'trash' the cereal fields and recondition them in spring.

The Organic scheme has created other issues and complications. Technically the beef animals are certified Organic, but they are not sold as such as there is not much of a premium. The Organic Scheme hasn't worked with conservation. In its absence, cow numbers could be built up, the increased number of young stock could go to Philbeach legitimately, then go on to graze at Trehill where the coastal areas could be hit harder (or pressure relieved more easily if necessary as well). There has been a

tendency for the Deer Park to be prioritised for grazing, at the expense of the Trehill fields. The Deer Park has been well restored, but the Trehill fields are perhaps under-grazed in places.

The Deer Park, and the cliff land round to Gateholm, presents some problems with fallen stock. There have been two cliff losses in seven years. The loss is compounded by the need to recover the dead animal or explain the loss of the animal to Welsh Government. One corpse was intentionally sunk, and the Coastguards retrieved the other. An insurance claim was only made on the first. The first loss was of a young (five month old) animal; the second was a yearling. Pete suspects that the animals gather on the cliffs on a sunny evening, and start bucking in excitement – the less sure-footed young animals can then fall. There is always plenty of grazing ahead of the animals so that they don't have to push hard and go down the cliffs in search of forage. There is one pinch-point by the Rath where dog walkers could cause problems, but this tends to affect sheep more than cattle. Pete is mindful of busy times, particularly on the Deer Park, and animals are generally brought off here around Christmas, New Year, and the summer holidays. This isn't a problem to do.

There are no specific disease or husbandry issues. Foul in the foot has been encountered, and there are potential problems with common complaints like grass seed in the eye, but this doesn't affect the placement of stock in the further reaches of the farm. Vigilance is constantly maintained, and problems can't be allowed to develop with the land being so clearly in the public eye. Routine treatments are few, and Ivermectin is only used when the cattle go into the sheds in Philbeach.

Management Agreement prescriptions are flexible, and have been well administered by Project Officers. There are no set stocking rates. Welsh Government audit requirements are more of a constraint, and the record keeping and inspections have an impact on the ease of management delivery. Pete was able to get agreement on Heathland as an eligible crop for SFP purposes, but negotiations such as this, and regarding the Organic scheme and dual funding issues, have been quite onerous. Trehill appeared to be targeted for a year for routine inspections.

Financial Considerations

At the outset, Pete knew that there would be CCW support, perhaps equating to current earning, but the rates were not set so finance couldn't be the primary driver. Cereal farming was tough - prices were low, and margins weren't great. The potential for steady earnings at a reasonable level was attractive as a business decision. Potato farming is notoriously volatile, and as the business was 80% skewed towards this, the guarantee of money from the conservation scheme would serve to counteract this.

Initially, with cereal prices low, not having the cliff land to work meant that there were savings in labour costs, and activities could be intensified on the improved land on the farm. Although hard to quantify, this has perhaps resulted in better production. Pete strongly believes in this ethos – farming the good land well, and releasing the more marginal land for environmental schemes. Trehill is part of the LEAF (Linking Environment and Farming) scheme, as Pete feels that they promote this ethos well.

Single Farm Payment entitlements were bought in, and now form the core of the farm subsidy received. Two CCW / NRW Section 15 Management Agreements covering the Mere and the Project fields also provide annual payments, and have clearly been crucial to the successful delivery of conservation work here. Turning in a profit from cattle requires numbers, skill, time and shrewd judgement – Pete's herd runs at a loss. The conservation grazing required by the S15 agreements has been completely dependent on the associated payment.

The S15 Agreements have been 'topped-up' by Tir Gofal, which has paid for the access elements of the project. The Organic Scheme has generated further payments, however, it has proved ill-suited to the farm and the marketing of Organic produce has not realised a premium. The environmental benefits of the grazing have instead been a better selling-point for the beef boxes – farm-gate perceptions have been important for the beef as with the potatoes.

An application to Glastir Advanced has recently been refused, with dual funding issues with the S15 seeming to be the problem. Pete feels that there should have been targeted support for areas adjacent to S15/SSSI. There has been some discussion with NRW as to the future of support following the 20 year S15 agreement term, and it seems likely that Pete will have to go into whatever agri-environment scheme is operational at the time. This could have implications for the conservation work, as flexibility is often sacrificed to audit requirements in these more generic scheme agreements.

The potential for deriving a significant income directly from the heathland and coastal grassland is low. A small beekeeping enterprise has been started, which could in time produce a surplus of heather or coastal wildflower honey for sale at the farm gate, or perhaps through NT outlets. As well as assisting with this, the author has explored the possibility of harvesting heather seed and green roofing plants (*Sedum anglicum* and other native coastal plants), for sale to other conservation or sustainable building projects. Seed was harvested from the coastal grassland in Hofflands for the first time in 2014. These income streams may not demand much investment, but returns may not justify the time involved.

PART III – ECOLOGICAL OUTCOMES

First Flowerings

Scentless mayweed in Inner Heath

Following site preparation, the initial vegetation response was dramatic. The arable fields were noteworthy for the profusion of arable weeds that germinated from the seed-bank. The scraped and un-scraped areas produced some interesting contrasts. The scraped fields generally had a high proportion of less competitive annual weeds, with scentless mayweed *Tripleurospermum inundorum* and field penny-cress *Thlaspi arvense* particularly abundant on the clay soils and knotgrass *Polygonum* species dominant on the sandier soils. Seeds of less common species such as weasel's snout *Misopates orontium* and corn marigold *Chysanthemum segetum* may have been buried around the plough horizon, and found the newly exposed bare ground in the scraped areas to their liking. Un-scraped areas tended to have a high proportion of perennial weeds such as rape *Brassica napus* and sow-thistles *Soncus arvensis* and *asper*. Couch grass *Elytrigia repens* quickly formed a thick sward on un-scraped sandier fields. As well as the arable weeds, a suite of coastal species quickly appeared in the scraped areas, including English stonecrop *Sedum anglicum*, thrift *Armeria maritima* and buckshorn plantain *Plantago coronopus*.

The heather cuttings spread in October generally formed a thin, patchy mulch over the ground. Western gorse *Ulex gallii* appeared the following summer, but it took a full year for ling *Calluna vulgaris* and bell heather *Erica cinerea* to start sprouting. The sulphur application, carried out a few months before the first sowings, had a dramatic impact. Even the gorse seedlings were challenged by the falling pH, perhaps combined with the salt deposition from winter storms. Heather seedlings flourished in scraped, sandy areas with a light sulphur application, but struggled to germinate elsewhere. The following summer saw many of the arable weed species disappear as the sulphur worked its way into the soil and the pH dropped below 4.

Heathland Vegetation Monitoring

IGER

Heather spreading from an unstripped, brash-applied, low-sulphur plot on the left, into the discard area to the right – a change occurring after the end of the monitoring

A monitoring contract, central to the CCW funding, was awarded to the Institute of Grassland and Environmental Research (IGER) and led by Mike Hayes. Mike completed the contract through his own consultancy business. We had set up sixty 10 x 10 metre plots in Inner Heath, using a fully randomised block design. Treatment combinations thus range from control plots with no intervention, through to soil stripped, sulphured and seeded plots. For the first five years, IGER monitored the changes in soil chemistry and vegetation associated with each combination of treatments. Full results are presented in the final report, Hayes & Spiridonova (2008).

Monitoring of soils indicated that soil stripping had no direct effect on nutrient levels due to the former mixing of nutrients throughout the whole plough layer through tillage. It did, however, change soil physical conditions by reducing the total nutrient pool available to colonising plants and by the greater exposure to the influence of the underlying dense, stony clay loam BG soil horizon.

Applications of elemental sulphur (S) were highly effective at rapidly lowering soil pH to target levels, attaining lowest mean pH values of 4.7 and 3.4 for the Low (approximately 4t/ha) and High (approximately 8t/ha) S rates respectively by 2007. However sulphur applications also led to large increases in soil extractable phosphate levels which is known to be one of key potential constraints for successful heathland re-creation. Initial levels of exchangeable calcium recorded were also high as a result

of regular past liming yet these were rapidly leached under the influence of the high soil acidity conditions created by sulphur applications. Sulphur applications also induced leaching of other exchangeable cations, although leaching of potassium was generally offset by the dissolution of residual fertilizer, and losses of sodium and magnesium were compensated probably as a result of the input of sea-spray onto the site. The less well drained soils on stripped plots tended to hinder all the leaching processes and thereby favoured the greater accumulation of salts from sea spray.

In terms of development of coastal heathland vegetation, results clearly demonstrated that at this site the addition of brash was essential as a seed source for the introduction of a number of key ericaceous/dwarf shrub species such as *Calluna vulgaris*, *Erica cinerea* and *Ulex* gallii. None of these established on plots without the addition of brash. However there was no need for the active introduction of seed of target maritime forb species as many of these were capable of naturally colonising suitable treatments.

The early development of heathland communities only occurred where sulphur was applied. The low rate of sulphur application of 4t/ha appeared to be the most effective within the timescale of the study. The high sulphur rate of 8t/ha was generally excessive due to toxic effects on plant growth although conditions may become more favourable over time. Although sulphur applications led to much elevated extractable phosphate levels, this did not prevent the early establishment of ericaceous dwarf shrub species. These were first recorded in 2007 and already attaining low mean cover values by 2008 on suitable treatments. Under the Low S treatment, it was still too soon to predict which of the topsoil stripping treatments would lead to the most successful re-creation of heathland. However, some interesting and contrasting trends in the successional development of vegetation had already emerged. On the unstripped low-S treatment, ericaceous species grew well under the protection of high levels of grass cover, but otherwise these plots had only poorly developed forb cover and thus resemble early-successional stage 'grass-heath' (i.e. NVC 'H8b' community). In contrast, on the less well-vegetated, grass-poor thin soils of stripped low-S plots, ericaceous plants were relatively small but frequent with the more open conditions far more receptive to the establishment of wind-blown seeds of target maritime forb species thus giving a generally more 'maritime heath' (NVC 'H7') character to the establishing community.

The Nil sulphur treatment was judged unsuccessful in the short-term, in that ericaceous species such as *C. vulgaris* generally failed to establish due to the inherently high pH levels. Moreover, unstripped Nil S plots tended to acquire a dense cover of coarse grasses. Stripped Nil-S plots, on the other hand, supported a generally sparse, grass-herb cover but with high overall levels of species richness and total forb cover.

From the results of this monitoring, it was clear that all the above processes were still highly dynamic. The longer term effects of re-creation treatments will only be confidently assessed by continued monitoring of soils and vegetation. Such monitoring should concentrate on the growth and survival of ericaceous species particularly on the low sulphur treated plots together with further monitoring of soil pH and phosphate dynamics. Additional single determinations of sward P, soil extractible Fe and the extent of ericoid mycorrhiza colonization would also be highly informative. Such information would provide further guidance for heathland

restoration at other potential sites and have particular relevance to sites within the coastal zone of Wales where similar soils to this study site commonly occur.

Quadrat 1, Roly Heath 2006

High costs meant that the IGER work was limited to one field. The author established five fixed 2x2m quadrats in two other fields – End Field and Thoughtlands (Roly Heath). These fields have sandy soil in contrast to the stagno-gleys of Inner Heath. Vegetation has been recorded on a near annual basis, with only two years missed between 2005 and 2014. Data has been arranged sequentially for each quadrat, and is presented in Appendix 3. The changes in each quadrat can be summarised as follows.

Quadrat 1, in a low strip near the centre of Roly Heath, received a 'double dose' of sulphur. The initial pH recorded here was 2.6. Unsurprisingly, the development of vegetation here has been very slow. Until 2014, the ground was left virtually bare, with only a western gorse *Ulex gallii* seedling and a few plants of annual meadow-grass *Poa annua* establishing and persisting. The one or two young heather *Calluna* plants appearing in the first year did not establish, and the scattered plants of toad rush *Juncus bufonius* also succumbed. Rabbit grazing was postulated as a significant factor in the slow establishment of seedlings. In common with the bulk of the field, the perhaps less palatable English stonecrop *Sedum anglicum* has proved equal to the challenge of the dry sandy soil and low pH and by 2014 was frequent. Yorkshire fog *Holcus lanatus* appeared later, but by 2014 was achieving up to 10% cover. This colonisation of mesotrophic grasses has been a feature of the edges of the field.

Quadrat 2 samples a raised strip near the edge of the field, receiving a single dose of sulphur. The arable plants which appeared following the ground-works in this field persisted for the first summer after sulphur application, despite the pH falling to 3.7. Parsley-piert *Aphanes arvensis*, field woundwort *Stachys arvensis*, corn spurrey

Spergularia arvensis and wall speedwell *Veronica arvensis* were amongst these. Heather, bell heather *Erica cinerea* and western gorse all established quickly and successfully within the first year, and a suite of other calcifugous plants appeared alongside, such as English stonecrop, trailing St. John's-wort *Hypericum humifusum* and thyme-leaved speedwell *Veronica serpyllifollia*. Sea mouse-ear *Cerastium diffusum*, autumn hawkbit *Leontodon autumnalis* and common centuary *Centaurium erythraea* colonised quickly from the adjacent cliff land. Tormentil *Potentilla erecta* and sheep's-bit *Jasione montana* were among the few later colonists, appearing whilst there was still some open ground. After five years, most of these early colonists had disappeared under the dominance of the heathers and gorse. Grasses, never a prominent feature, became limited to a few individuals of purple moor-grass *Molinia caerulea*, Yorkshire fog, cock's-foot *Dactylis glomerata* and bent grass *Agrostis* sp. Foxglove *Digitalis purpurea* and bramble *Rubus fruticosus* are indicative of the increasingly rank nature of the heath.

Quadrat 3 samples a low strip at the seaward edge of this field. As with quadrat 1, the removal of soil and a low pH (3) following sulphur application proved challenging to plant growth. Annual meadow-grass, sand spurrey *Spergularia rubra*, sea plantain *Plantago maritima* and buck's-horn plantain *Plantago coronopus* were the only early colonists surviving this challenge. A shift from annual meadow-grass to Yorkshire fog in 2009 marked a transition to more favourable conditions, and this perhaps aided the subsequent establishment of foxglove, bell heather, heather and English stonecrop. By 2014, the latter two were covering over half of the quadrat. Rosette hemi-cryptophytes – cat's ear *Hypochoeris radicata*, autumn hawkbit *Leontodon autumnalis* and lesser hawkbit *Leontodon taraxacoides* – had also recently colonised. The two plantains had slowly become frequent, together with sheep's bit. Open ground species, including sheep's sorrel *Rumex acetosella*, still found enough open ground to arrive or persist, but the appearance of bramble *Rubus fruticosus* perhaps marks a turning point in the successional process and a looming management challenge.

Quadrat 4 sampled the stripped and lightly sulphured north-eastern corner of End Field. The initial pH recorded here was 5.5. A diverse open-ground flora colonised here, and 27 species were recorded in 2005. Yarrow *Achillea millefolium*, scarlet pimpernel *Anagallis arvensis*, mouse-ears *Cerastium* spp., sheep's bit, lesser trefoil *Trifoloium dubium* and field pansy *Viola arvensis* were amongst the more frequent species. Following brash application, western gorse quickly became dominant. English stonecrop also became abundant. Heathers established more slowly. The quadrat stayed relatively open until 2009, with small species such as meadow brome *Bromus hordeaceus*, squirreltail fescue *Vulpia bromoides* and wild thyme *Thymus praecox* still occasional. By 2010 western gorse was strongly dominant and most open ground species were on their way out. The quadrat has not been recorded since 2010, and this part of the field is now strongly dominated by western gorse and ericoids.

Quadrat 5, in the sulphured but unstripped half of End Field, had a pH of 3.3 following treatment. Couch grass *Elytrigia repens* was strongly dominant for the first three years, but had disappeared by the fifth year. The quadrat initially held little else other than some English stonecrop and heather. The latter spread quickly, whilst bell heather took five years to reach abundance. As the couch disappeared, it was replaced by Yorkshire fog and creeping bent grass *Agrostis stolonifera*. Tormentil, foxglove, common sorrel *Rumex acetosa* and ragwort appeared in small quantity around this time, but appeared to be disappearing under the closing canopy of heather by 2014.

Bournemouth University monitoring in End Field, 2006

CCW also made a financial contribution to research work carried out by Dr Anita Diaz and Dr Ian Green of Bournemouth University. In addition to the invertebrate work described in a later chapter, they looked at some of the initial effects of the sulphur treatment in all fields not covered by the IGER monitoring contract.

Their work addressed several related areas investigation. Firstly, they surveyed soil chemistry to see how levels of pH, nutrients and potentially toxic elements differed across the site in response to treatments. Secondly, they carried out survey of plant and surface-active invertebrate communities across the site. Thirdly, they looked at the growth conditions for heather to see how they compared to those on an established heathland, and followed this up by looking at the extent of mycorrhizal colonisation of establishing heather plants. Summaries of some key findings are as follows.

The significant correlation between the level of elemental sulphur in the soil and pH indicated that the sulphur quickly caused a substantial decrease in pH whilst being microbially oxidised to sulphate. pH levels were lowered beyond that of the established heathland (on the Deer Park). The lowest value recorded was pH 2.7 and was associated with a sulphur level above 800ppm. The relationship was particularly clear across a sulphur range of 0-180ppm (down to pH 4.7). At higher sulphur levels, pH continues to fall but less steeply. This levelling out of the relationship at around pH 3 coincides with the lower end of the optimum range for *Thiobacillus* species, which are chiefly responsible for the oxidation of soil sulphur. It may indicate that the low pH of the soil was inhibiting them. Furthermore, the adsorption of sulphate to clays and Al/Fe oxides is negligible above pH 6.5, leading to the ready leaching of

sulphate. The strength of sulphate adsorption increases as pH drops below 6.5. The results were thus explained by the amount of sulphur applied, the extent to which this was oxidised and to which sulphate was leached/adsorbed by the soil constituents.

Phosphorous is one of the most important plant macronutrients and high levels of P within soils are thought to be a significant obstacle to the re-establishment of heath on former agricultural sites. Both extractable and total phosphorous concentrations showed a large and significant variation amongst the sites. The lowest P concentrations was found in the stripped part of End Field, and these were significantly different from the next lowest concentration found in the unstripped part of this field. This would suggest that stripping has proved effective in lowering total and bioavailable P in the soil. However, total P concentrations in all of the re-creation fields were greatly above the concentration in the heathland control.

The heavily sulphured part of Rath was found to have by far the highest concentration of extractable aluminium, whilst the lowest concentration was found in the grassland reversion in Pits. Aluminium is a potentially toxic element which is readily mobilised into extractable forms at soil pH values below 5. This was true of the studied sites, which showed a significant negative correlation between the extractable concentration of Al in the soil and soil pH. Aluminium phytotoxicity is believed to be a key driver of biotic change in the restoration of acidic vegetation using acidifying soil treatments such as elemental sulphur (Tibbett & Diaz, 2005). Consequently, the change in Al extractability with pH was an indicator of the success of the sulphur treatment.

Heather roots and shoots showed significant differences in their P concentration between the sites. They showed some correlation with total P concentration in the soil but not with extractable P concentration. Soil stripping did not show any effect on P concentration in the heather plants. The concentrations in roots of plants growing in all of the re-creation sites were 87 – 145 % higher than in the roots of plants growing in the established heathland, possibly due to higher nutrient competition here. The concentrations found in the shoots of the plants growing on the re-creation fields were within the range typically recorded on lowland heaths, indicating that P levels would not be an obstacle to successful heathland re-creation.

Mycorrhizal colonisation of heather roots varied from around 25% in Thoughtlands to 65% in End Field. This compared with almost 100% in the Deer Park heathland.

NATIONAL TRUST

NT staff carried out a ‘rapid ecological survey’ of various areas within the project on September 11th 2013 (NT, 2014). 8 different teams, each with a botanist, listed species in their area. These were classed as positive, neutral or negative indicator species, and the relative proportion of each used to judge the success of the restoration.

The classification of indicator species (although based on generic protocols) is perhaps prone to subjectivity. However, in terms of indicator species targets, the project was judged to be a success. The survey noted visible progress towards the targets of 50% positive species and 95% positive and neutral species. The application of sulphur was judged to have been successful in recreation of heathland and restoration of species-diversity.

Arable and Grassland

Corn spurrey dominating the margins of Thoughtlands arable

The arable management prescriptions incorporated both fallow and ploughed margins, the latter sometimes unsown, and sometimes sown with cereals but left unsprayed. Concentration of the ploughed margins on the lighter, sandier soils to the east of the project area was encouraged. Initially, 3 or 4m wide strips were distributed across several fields. In recent years, the agreed area has tended to encompass whole fields such as End Field arable.

Corn spurrey *Spergularia arvensis*, corn marigold *Chrysanthemum segetum* and knotgrasses *Polygonum* species (including the scarce or under-recorded cornfield knotgrass *Polygonum rurivagum*) are among the more abundant species appearing following ploughing on the lighter soils. The more interesting associates include weasel's snout *Misopates orontium*, scented mayweed *Matricaria recutita*, henbit *Lamium hybridum*, round leaved-fluellen *Kickia elatine* and field woundwort *Stachys arvensis*.

In contrast, margins left fallow become grassy after the first year with species such as rye-grass *Lolium*, creeping bent *Agrostis stolonifera* or couch *Elytrigia repens*. Instead of the smaller annual plants, perennials such as lesser burdock *Arctium minus* and sow thistles *Sonchus* species are favoured. Arable bryophytes, including crystalworts *Riccia* species, are favoured by biennial ploughing, but not by longer term fallow land.

Given the availability of undisturbed rough grassland on the adjoining heath and meadows, a presumption in favour of cultivated and sown, unsprayed strips rather

than fallow strips was taken in 2009. This should ensure the continued displays of a colourful archaeophyte flora with abundant seeds and spilt grain for wintering birds.

The project encompasses four grassland reversion fields, in addition to the coastal grassland strips alongside the heathland in Outer and Inner Heath. The longest established of these, Hofflands, has been under extensive management since 1992. The open ground following ploughing allowed an early incursion of coastal species, notably abundant thrift *Armeria maritima*. The sward then closed over with grasses, and the less competitive coastal grassland species became more confined to the exposed seaward edge of the field (Hale, unpublished CCW monitoring report). The continued dominance of perennial rye-grass *Lolium perenne* over the bulk of the field during the 1990s could perhaps have related to some continued fertiliser usage during this period. Summer sheep grazing, rather than hay-meadow management, would also have encouraged a grass-dominated sward. The project introduced a switch to late hay-cutting with spring or autumn cattle grazing from 2004. The decade following this has seen a gradual decline in rye-grass, with common bent *Agrostis capillaris*, sweet vernal grass *Anthoxanthum odoratum* and Yorkshire fog *Holcus lanatus* now the prominent grasses in the sward. Typical coastal forbs such as ladies bedstraw *Galium verum*, wild carrot *Daucus carota* and thrift are still largely confined to the uncut edge, but the late mown sward has a patchy abundance of species such as red bartsia *Odontites verna*, yarrow *Achillea millefolium*, yellow rattle *Rhinanthus minor* and field bindweed *Convolvulus arvensis*. Leguminous plants are particularly abundant, with large patches of greater bird's-foot trefoil *Lotus pedunculatus*, some common bird's-foot trefoil *Lotus corniculatus*, hairy bird's-foot trefoil *Lotus subbiflorus*, tufted vetch *Vicia cracca*, common vetch *Vicia sativa* and hairy tare *Vicia hirsuta*. We harvested seed from parts of this field in 2014, and most was used on a NT grassland reversion project on Gower.

Pits, under similar late hay management but with less aftermath grazing, is developing a broadly similar but somewhat coarser grassland vegetation with frequent hogweed *Heracleum sphondylium*. Dimit was sown with a low productivity grass mixture and a robust red clover *Trifolium pratense* variety; it initially had a marked abundance of dandelion *Taraxacum officinale*. Turf was stripped from a narrow swathe along two edges, and some hay from a relatively species-rich field between Trehill and Marloes was strewn here. Although no monitoring has taken place here, recent signs have been encouraging and the appearance of several hundred spikes of southern marsh orchid *Dactylorhiza praetermissa* in 2013, together with other damp grassland species including sneezewort *Achillea ptarmica* and fleabane *Pulicaria dysenterica*, was indicative of a successful shift to low-productivity semi-improved grassland. Boggle has been treated as something of a sacrificial grazing field, and has remained grass-dominated and species-poor. Its inclusion within the project was largely as a buffer to the wetland vegetation on the mere.

Hofflands, late summer 2014

Brush-harvesting seed from the seaward edge of Hofflands, 2014

Rare Plants

Prostrate Broom Cytisus scoparius ssp. maritimus on an Inner Heath monitoring plot

Plants classed as rare in the following account are those included in the BSBI Rare Plant Register for VC45 Pembrokeshire (Evans, in draft 2007). Locations are mapped in Appendix 1.

The initial soil disturbance through stripping in the heathland recreation fields in 2004 presumably exposed buried seed-banks of weasel's snout *Misopates orontium* and corn marigold *Chrysanthemum segetum*. These species persisted in Outer Heath for one or two years, but in 2014 were instead associated with the arable margins, most notably in End Field arable. This field also produced a specimen of cornfield knotgrass *Polygonum rurivagum* in 2007, the first county record of this difficult to identify and presumably overlooked species. The arable, particularly to the east of the project area, also holds corn spurrey *Spergula arvensis* in quantity, and frequent field woundwort *Stachys arvensis.*

Several rarities subsequently colonised the heathland areas. Common broomrape *Orobanche minor*, appeared in 2005 as 2 or 3 dead spikes in the End Field heath. The host plant was not determined, and no further plants have been found. Similarly transient was a single plant of the hybrid St. John's wort *Hypericum humifusum* x *linariifolium* in Outer Heath (7638 0843) in 2005. One plant of this cross between the common trailing St. John's wort and the rare flax-leaved St. John's wort had recently been discovered in the county by the author. The latter parent is not known to be present, and plants differ somewhat in their characters. The plant here was not as distinct as those on the Solva cliffs. Portland spurge *Euphorbia portlandica* appeared as one vigorous plant in Roly Heath in 2005; a more established colony has been

known from the cliffs below Pits since 1989. Close by on the northern edge of Roly Heath was a single plant of what was initially taken to be bristle bent grass *Agrostis curtisii*. This was hitherto unknown from the county, the nearest recorded colonies being on the humid heaths further east in Glamorgan. The plant has subsequently disappeared as the field edge has vegetated with gorse and bramble. No specimen has been retained, although the photo below was taken. The record is perhaps best considered uncertain, as although it was confirmed by two BSBI recorders at the time, the possibility of it being a tightly-rolled leaf form of *Agrostis vinealis* was not considered.

The original plant of putative Agrostis curtisii

Some colonists of the heathland have established longer-lived populations. Seed of prostrate broom, *Cytisus scoparius* ssp. *maritimus*, has blown up from the adjoining cliffs to establish new plants in Thoughtlands, Hofflands and several in Inner Heath. Outer Heath has a significant population (hundreds of plants) of lesser centuary *Centaurium pulchellum*, first noted in 2007 in the damp ground by the broken drain. These tiny 1-2cm plants are now particularly frequent in the compacted area, stripped by bulldozer, in the south-east of the field. By 2014, plants had also appeared in the scraped areas of Inner Heath, although the presence of common centuary *Centaurium erythreae* in various forms (including diminutive plants and plants intermediate with seaside centuary *Centaurium littorale*) make identification less certain. Allseed *Radiola linoides* is a distinctive but easily overlooked plant, noted by the broken drain on Outer Heath in 2007 but not seen on a recent search. Another characteristic wet heath plant, three lobed-water crowfoot *Ranunculus tripartitus* was found by the water trough in the eastern gateway to Outer Heath in 2007; although not seen in recent years it has a long-lived seed-bank and may reappear with suitable disturbance and ground conditions.

Centaurium pulchellum, Outer Heath

Three rare plants are present in the grassland reversion. Chamomile *Chamaemelum nobile* has been known from the seaward edge of Hofflands since 1995. There were around 8 clumps and 200-250 flower heads in 2006. Hairy bird's-foot trefoil *Lotus subbiflorus* was also found in Hofflands that year, and has subsequently also appeared in Pits in 2005 and Roly Heath in 2007. It has been abundant on the middle slope of Pits in dry summers. Southern Marsh Orchid *Dactylorhiza praetermissa* is a more recent colonist of the hay meadow in Dimit. 2013 saw the appearance of hundreds of plants here.

The cliff land of the project is known to support rarities, most notably shore dock *Rumex rupestris* by the waterfall in Watery Bay, long-bracted sedge *Carex extensa* and the sea lavenders *Limonium binervosum* and *L. procerum*.

Marloes Mere also has rarities. Pool digging work done on the Mere and adjoining Ellis's Piece has enabled the colonisation or spread of red goosefoot *Chenopodium rubrum*, tubular water-dropwort *Oenanthe fistulosa*, pillwort *Pilularia globulifera*, three-lobed water crowfoot *Ranunculus tripartitus* and frog rush *Juncus ambiguus*. The latter was first noted, new to the county, in the new pond in Pits in 2007.

Bryophytes

Winter-wet hollows in Roly Heath, November 2014. Campylopus introflexus dominates.

Sam Bosanquet thoroughly recorded the Inner Heath monitoring plots in 2004 and 2006. His findings are presented in spreadsheet form, with accompanying summary report. By the second year of monitoring, the heathland recreation areas still mostly supported arable and waste ground species, such as *Barbula convoluta* and *Tortula truncate*. However, calcifugous species such as *Ceratodon purpureus* and *Pleuridium acuminatum* had started to appear. Low doses of sulphur did not impact much on the bryophytes, and helped to retain open ground suitable for many species. High sulphur doses, in contrast, prevented almost all bryophyte colonisation. The soil-stripped plots displayed the greatest abundance and variety of lower plants, including notable species like *Drepanocladus polygamus, Acaulon muticum* and the hornworts *Anthoceros punctatus* and *Phaeoceros laevis.* The former is likely to be a colonist from the nearby coast, whereas the latter species are more likely to have grown from dormant spores.

Inner Heath was revisited by Sam and the author in late January 2015. Unfortunately it proved too difficult to relocate individual plots, and we opted instead to make general records and observations on the bryological changes. Most obviously, the non-native *Campylopus introflexus* has arrived of its own volition and spread across the soil-stripped areas to become the dominant bryophyte. This is not always to the exclusion of other bryophytes however, and less competitive species including frillworts *Fossombronia* are established within the *Campylopus* mats. Most notably, the rare *Fossombronia husnotii* was found. This is restricted to southern and western coasts of the UK, and in Pembrokeshire was previously known with certainty from a

handful of sites on the southern limestone. Other developments in the heathland element included the colonisation by *Polytrichum juniperinum*, *Cephaloziella divaricata*, *Lophozia excisa*, *Archidium alternifolium* and *Fissidens incurvus* var. *tamarindifolius*. Soil stripping rather than sulphur additions seemed to be favouring these species. An arable element persists in the form of a few species such as *Didymodon insulanus* and *Bryum dichotomum* on the stripped ground. Unstripped plots, particularly the untreated controls, generally held just a few common pleurocarpous mosses beneath the coarse grass growth.

The only other bryological records come from my own casual observations (determined or confirmed by Sam). The uncommon liverwort *Riccia subbifurca* was found in Thoughtlands prior to soil stripping; *Polytrichum commune* var. *commune* – characteristic of the north of the county – appeared in End Field following heather seeding, and was presumably introduced with the brash. The flushed area of Outer Heath where a drainage pipe was broken now has *Drepanocladus aduncus*, a colonist from the Mere.

Polytrichum juniperinum

Lichens and Fungi

Rock exposed by soil stripping, colonised by species such as Ramalina siliquosa

No monitoring of these groups has been carried out. Recording effort has been limited, with no visits from specialists to my knowledge. The British Lichen Society Database holds no information on the site; the rare *Degelia ligulata* on the lower cliff slopes of Gateholm is the only record from the immediate area.

Jon Hudson and I collected ten lichen species from the heathland recreation areas in 2009, half of them widespread *Cladonias*. On a visit in 2014, I noted the development of fairly extensive patches of 'lichen heath' in the soil-stripped areas of Outer Heath and Inner Heath. As well as the cushions of *Cladonia* (including *fimbriata*, *rangiformis* and *cervicornis)*, various other species occur within the turf and on soil and stones here. The uncommon *Catapyrenium cinereum* was also found in association with the acidic puddles in Roly Heath. This lichen heath would appear to be a good emerging example of a scarce habitat, poorly represented elsewhere in Pembrokeshire where tall vegetation, burning or grazing limit the lichen flora. It would certainly merit further survey.

My observations on fungi are limited to several common waxcap *Hygrocybe* species in the grassland areas. The heathland re-creation areas, as might be expected, do not appear to have a great diversity of fungi as yet. The moor club *Clavaria argillacea* has been abundant under the heather in End Field since this established, perhaps arriving with the brash although there are no other county records. The orange mosscap *Rickenella fibula* occurs amongst moss in Inner Heath, and the blackening waxcap *Hygrocybe conica* – often considered a pioneer species – was recently noted here too. *Agaricus litoralis* has colonised stripped areas in Outer Heath.

Birds

Wheatears have benefited from the creation of open, stony ground

Changes in the bird usage of the project fields was recorded over a 6 year period (2003-2009) by local volunteer Steve Sutcliffe. Birds were recorded as numbers observed on a field-by-field basis during two summer visits. Breeding evidence was not recorded, and the data cannot be used to define numbers of pairs or territories. Despite this, some inferences can be made regarding trends in populations. Steve's records were similar to my own casual observations during this period.

Skylarks were perhaps the most obvious beneficiary of the project. Numbers, which generally relate to singing birds, showed a clear upward trend. Outer Heath and Inner Heath accommodated multiple territories, with the grassy experimental control plots in the latter perhaps providing good breeding sites within a matrix of seed and insect rich vegetation.

Wheatears were encountered with increasing frequency, finding the stripped areas of Outer and Inner Heath to their liking. Breeding was not proven, but was suspected by 2008.

Choughs were regularly encountered on the project fields, with those towards the western end being favoured. Pairs are present in close proximity to the site at Watery Bay and the Deer Park, and a large flock of non-breeders has become a feature of the Deer Park and Trehill coast where an extensive range of foraging opportunities now exists. My casual observations suggest that favoured areas include the grazed open maritime grassland above the cliffs of Outer Heath, the close-grazed winter swards of the hay meadows in Dimit and Hofflands, and the arable part of Inner Heath. Birds

have been observed feeding in the heathland recreation areas of Outer and Inner Heath, for example turning over small stones in search of ants or other invertebrates. It seems probable that the heathland and coastal grassland is used more in summer, whilst the arable and hay meadows fields are used in winter. Some heathland areas, notably End Field, are now too closed to provide foraging opportunities.

Two birds associated with heathy scrub and hedge-banks – stonechat and whitethroat – fluctuated in numbers during the period, but showed an overall decrease. The gorse on the site is perhaps not yet mature enough to hold nests of stonechats or Dartford warbler, but End Field could prove attractive to both in the near future.

Increased usage of the fields by meadow pipits and linnets was noted, but the observations perhaps related only to passage birds. My own observations of passage birds on the heathland recreation fields have included short-eared owl roosting on Inner and Outer Heath, tree pipit foraging on the stripped area of Outer Heath, jack snipe by a seasonal pool in Inner Heath, ringed plover, lapwing and oystercatcher on the bare ground of Rath and, most curiously, two shorelarks on Roly Heath the first winter after the sulphur had been spread. Records from other birders have included Lapland bunting and whinchat on Outer Heath.

The arable fields within the project have been enhanced for birds, with weedy fringes and stubbles retained late into the winter. They are lightly under-sown (with a late-heading rye-grass), and sheep grazed, but they still prove attractive to good numbers of birds such as skylark, meadow pipit, chaffinch, linnet, goldfinch, reed bunting, starling, rook and jackdaw.

Arable areas provide spilt grain and weed seeds for typical farmland birds

Invertebrates

Bare ground in heathland recreation, with burrows of green tiger beetle

In association with their research on vegetation and soils, Bournemouth University researchers carried out pitfall trapping to sample invertebrates. Initially this was to correlate invertebrate communities with the vegetation structure of the heathland recreation areas. Their work identified a dozen beetle species, all generalist grassland species rather than heathland specialists (subsequent beetle surveys of the heathland fields by a volunteer, David Search, took this total to 31 species with ground beetles *Carabidae* the principal group). No other groups were identified to species. The pitfalls, as expected, caught surface active predators, with ground beetles, wolf spiders *Lycosidae* and hymenoptera making up the bulk of the samples. Compared to controls in Pits and the Deer Park, the numbers of these predators was low, reflecting the lower abundance of prey such as Diptera and Hemiptera. The ratio of herbivores to carnivores was, unsurprisingly, lowest in the bare areas impacted by sulphur application.

Subsequent trapping was carried out in order to investigate the impact of potentially toxic metals on beetle and spider abundance (Diaz et al, 2011). The results of plant metal uptake analyses demonstrated that zinc and aluminium, both potentially toxic metals, were mobilised by the sulphur treatment and entered the food chain. No direct measurements of the Al or Zn concentration were made in beetles and spiders as the inter-specific variation in metal accumulation renders such measurement meaningless in samples where different species are bulked together. However, correlations showed that there was a significant relationship between the abundance of spiders and the available Al concentration in the soil. Beetle abundance showed no affect. Thus, there

were greater numbers of surface active beetles than spiders in the sulphured, low pH soils with higher Al levels.

Little other work has been carried out with respect to invertebrates. My own scant observations have included casual records of Lepidoptera (light-trapping several local coastal species in Hofflands such as netted pug *Eupithecia venosata*), the striped slender robberfly *Leptogaster cylindrica* and orthoptera (great green bush cricket *Tettigonia viridissima* in End Field and Outer Heath hedge-banks).

Colonies of solitary bees are apparent in the bare ground, for example in Thoughtlands, and visiting English Nature staff commented that the extent of bare ground was a key feature of importance here. In their experience, English heathland schemes had been too successful in establishing high ericoid cover and had quickly lost the more highly valued invertebrate fauna of the early successional stages. They also appreciated the attention to micro-topographical detail which we took here.

Great Green Bush Cricket, Outer Heath hedge-bank

PART IV - LESSONS LEARNT

A key thing to note is that the project site selection came about as the result of intuition and opportunism, rather than a strategy defined by spatial modelling of connectivity and habitat recreation 'opportunity' mapping. Such exercises have theoretical merit, but are not necessarily practical and perhaps divert significant resources from real action.

Secondly, the project development was almost entirely the result of a committed individual working in a positive relationship with a receptive landowner. Several CCW staff members provided support where needed to facilitate project delivery. The style of line management (from Dr David Worral) was of particular importance. Creating space around individuals, trusting and empowering them, and allowing them to take risks are qualities associated with skilled managers.

Although National Trust ownership was key to the delivery, there was no formal partnership created to determine actions. No wider partnership of conservation bodies was established – such partnerships may often be politically necessary but excessive inclusivity can cause projects to stagnate.

Two potential administrative hurdles were side-stepped. Firstly, the pragmatic and supportive position taken by the Environment Agency locally gave us an exemption from Waste Management Licencing Requirements and the attendant bureaucracy that would have been entailed by an application. Secondly, the planning authority was uncertain whether or not the engineering works, particularly the creation of hedge-banks, required planning permission. In the light of this uncertainty, we decided to proceed without an application. Similar projects in future should be aware of such

potential hurdles, and also those encountered by the tenant in the form of Welsh Government Agriculture Department scheme requirements.

We learnt lessons regarding funding applications. The project was perhaps too innovative for its own good, and failed to connect with the preconceptions of what constituted 'good conservation' prevalent amongst the funding bodies that we approached. It wasn't clear whether the late involvement of CCW's External Funding Department was a blessing or a curse. They specified increased costings to cover staff time and overheads, considerably inflating the bid. However, a skilled funding officer could have helped to fashion an application in language tailored to the funder.

A well-presented funding bid for a similar project would need to ensure that the nature conservation philosophy inherent in this project is well-aligned with the 'ecosystem goods and services' philosophy now prevalent in the environmental sector. Benefits to access and tourism, long-term soil carbon storage, pollinator benefits and seed dispersal are among the themes that could be explored.

The soil stripping and sulphur application have perhaps been seen as cavalier in some quarters, and that perception won't have been helped by the over-application of sulphur in some places. As explained previously, this was primarily due to logistical reasons as processing of refinery sulphur and field-scale application had not been attempted before. An imprecise understanding of the soil chemistry, and the limited and imperfect nature of the experimental evidence at that time were also contributory factors. Collecting our own evidence from experimental applications would clearly have helped to guide applications, but this would have taken years and the project would have lost its 'moment'. That evidence will now be available to guide other projects.

The varied treatments have helped to fashion a diverse heath with a range of vegetation structures. At this stage, it seems that the 'light' sulphur application has most favoured the development of good ericoid heath. High sulphur application plots have ericoid growth, but are less species-rich. Plots without sulphur had little ericoid establishment in the short-term, as noted by Hayes and Spiridinova (2009). However, it is interesting to note the subsequent development of *Calluna* heath in the 'discard' areas around some plots which only had an (inadvertent) very light application. It is not clear yet which treatment will prove to be the most successful in supporting heathland vegetation in the long-term.

Although an essential part of the monitoring experiment, the control plots are serving as entry points for undesirable plant species such as couch grass *Elytrigia repens*, creeping bent grass *Agrostis stolonifera*, bramble *Rubus fruticosus* and creeping thistle *Cirsium arvense*. These have the potential to colonise the good quality heath emerging across the rest of the field.

The soil stripping treatment has proved to be very successful, and it could be argued that this treatment alone would have sufficed to create a desirable ecological outcome. The addition of a light sulphur application to these stripped areas aided heather establishment in the short-term, but was not necessarily essential. Given the logistical difficulties associated with procuring and applying sulphur, my recommendation would be to look at possible soil stripping projects in isolation.

It is worth noting here the development of two much smaller heathland re-creation projects carried out by CCW near St David's in the same year as the Marloes work. Firstly, the author instigated a soil-stripping project on one acre of ground at Clegyr Boia, adjacent to Trefeiddan Moor SSSI. This was soil stripped to c.30cm and seeded from the same heathland source as Marloes. It was not acidified, although the landowner experimented with salt addition over small areas. The growth of heathers and western gorse was initially a little slow, but has since been excellent. The heath now has a good structure, some species-rich open ground, and is a valuable piece of habitat extending habitat around the SAC and removing a previous source of eutrophication.

Heathland re-creation at Clegyr Boia, St David's, January 2015

Secondly, the Tir Gofal scheme attempted heathland re-creation on a coastal field at Porthlysgi (SM73472362). No soil stripping or disturbance was employed, but sulphur was added in the form of an agricultural ferrous sulphur compound, 'Tiger 90'. Despite heather brash addition, ericoids failed to establish. When last visited by the author, the field was poor semi-improved grassland.

Future projects should follow the approach that we took with regard to micro-topographical detail. Leaving an irregular, 'hummock and hollow' terrain dramatically increases surface area and niche diversity. This is particularly evident in Outer Heath, but is also demonstrated by the strips in Roly Heath, creating features such as ridges and temporary pools. Projects should also incorporate vertical bare-ground where sloping terrain allows small 'quarries' to be excavated.

Lastly, potential projects should note the importance of a realistically financed, long-term (at least 25 year), tailored Management Agreement. It is worth reiterating here that management 'plans' need to be flexible and adaptive and should be predicated on trust and understanding, not adherence to generic prescriptions for grazing. Most project funding is only available for one-off capital works – this could be set alongside a Management Agreement but may be of little use without it. Current Glastir Advanced funding is not sufficiently generous or long-term to be appropriate for ambitious projects of this nature. Project officers with a good ecological skills, at least a degree of agricultural knowledge and a pragmatic approach are also essential.

The irregularly contoured surface, ten years after soil stripping in Outer Heath

PART V – FUTURE DEVELOPMENT AND RECOMMENDATIONS

Retention of the current open lichen-heath should be a management priority

At the outset of the project, I was clear that we were kick-starting a process rather than building a vegetation community. Although 'heathland recreation' was the stated aim of the soil stripping, sulphuring and seeding, the term was used in its widest sense and I was relaxed about the outcome in terms of such things as heather dominance and NVC type. To my eye, development of an open-structured vegetation which was receptive to stress-tolerator rather than competitor plant species was the principal aim. In some fields, this could be judged successful within the first season or two. Where sulphur applications were heavy, even stress-tolerators were initially struggling to survive and success looked perhaps less certain. Now, with even these areas generally supporting good *Calluna* growth, the project is starting to meet the expectations of other observers. This would seem an opportune time to examine the concept of a desired ecological state and refine any management necessary to achieve or maintain this.

The heathland on the site currently encompasses all stages from barely vegetated to closed canopy heathers and gorse. However, several areas intuitively stand-out as holding particular promise to a naturalist. These are the stripped areas of Outer and Inner Heath, particularly where sulphur application was light or avoided, and the 'advancing front' of heathland vegetation in Roly Heath. These tend to have a varied structure, often with small *Calluna* bushes, a short turf of species such as *Leontodon autumnalis*, *Centaurium* species, *Sedum anglicum* and *Thymus serpyllifolia*, interspersed with patches of bare ground, stones and an abundance of lichens.

This developing 'lichen heath' is an uncommon habitat in the county, where recovery management of senescent coastal heaths has had to rely on grazing and burning as tools rather than excavators. These techniques tend to leave a soil surface still enriched with the residues of decades or centuries of plant growth, and prone to grass dominance rather than lichen establishment.

In addition to the inherent interest of the lichen communities, the heath at Trehill is youthful, dynamic, and receptive to chance colonisation events and species range expansions. In an era dominated by discussion over climate change impacts, the requirement of our semi-natural habitats and wildlands to accommodate such range expansions is a key conservation concern. The less competitive plant species (such as the rarities described earlier), and the animal species dependent on the infertile or stressed habitats where they are found, are perhaps of paramount concern here. Trehill could be expected to provide habitat in future for species such as silver-studded blue or shrill carder bee, colonising from the Castlemartin peninsula to the south (the recent find of the liverwort *Fossombronia husnotii* may be the first evidence of this). In turn, it could provide a springboard for species to colonise the St Davids peninsula to the north. One challenge will be to create new dynamic habitat on the latter peninsula, or ensure that some of the more static heaths here are receptive to chance colonisation events. The opportunity to do this at Treginnis may have passed for the time being, but the coast between Solva and Newgale may provide an alternative focus should funding be available to widen NT holdings on the coastal belt here.

With pond management, it is desirable and often possible to employ rotational management. One is allowed to mature, whilst a fresh one is dug nearby. Species associated with each successional stage are catered for in this way. The challenge to re-create further coastal heathland nearby is unlikely to be met so easily, and the early successional stages of heathland currently available here will fast succeed to established ericoid heath. End Field, a decade on, has matured to the extent that there is strong heather and gorse dominance and little bare ground. Although currently providing habitat variety within the project site, it would seem undesirable for all of the heathland to succeed to the same stage in the future. With this in mind, the desired ecological state or states should be defined now before recovery management becomes necessary.

Following definition, a clear vision should be communicated to the Smithies. This should define parameters rather than prescribe management. End Field, for example, has proved difficult to manage effectively using a traditional conservation grazing approach. Would it be desirable, or permissible, to perhaps site a ring-feeder here for one winter? Pete notes that it is important to use the grazing animals available on the farm to achieve the desired vegetation structure. Finding a way of providing additional disturbance as a natural part of the agricultural management system would appear to be a difficult challenge, and one that should be addressed in conjunction with the Smithies.

A more robust approach, using mechanical management, may have a role to play here. It is worth noting that early successional stages were sometimes maintained in Breckland heaths by seemingly drastic techniques such as plough-cleaning. The only recent local example of this would perhaps be on Plumstone Common, where ploughing in the early 1990s has resulted in the restoration of open, species-rich heathland with *Viola lactea* and small plants of *Ophioglossum azoricum / vulgatum*.

The new heaths at Trehill may provide an opportunity to trial soil disturbance as a management technique, providing it is applied judiciously and with appropriate monitoring. It is unlikely to prove necessary in the next five years, as early successional habitats should remain frequent in at least the high sulphur areas.
An alternative approach would be to extend the areas of heathland across the coastal belt here, perhaps through further soil stripping but without new sulphur application. Unstripped areas of Outer Heath, and the arable parts of Inner Heath and Thoughtlands, could prove suitable for this approach. Compensatory arable areas would ideally be provided elsewhere nearby.

In the short-term, arable margin management would benefit from being refocused on the sandier fields to the east of the project area. This would ensure maximum benefits for more valued annual plant communities

Monitoring and research should continue. The plots in Inner Heath should be remarked and vegetation recording repeated. Ideally, this would perhaps be carried out now at the 10 year point then again at 5 yearly intervals. Introduction of light grazing, perhaps initially with sheep rather than cattle (to conserve lichen communities), may soon require consideration and monitoring prior to this would be sensible. If monitoring is not to be repeated, then consideration should be given to removal (by soil stripping) of some or all of the control plots. This would remove the undesirable species which could establish more widely in the field, and also create fresh bare-ground as discussed above.

Lichen recording should be carried out, either as an add-on to the monitoring brief, with in-house resources, or through liaison with the FSC lichen course at Orielton. Recording by other visiting specialists should be encouraged, perhaps through groups such as the Dipterists Forum.

Lastly, there are interesting questions to be answered with regard to soil biodiversity. Determining the relative biodiversity of stripped ground, hedge-banks and ploughed arable would be a complicated undertaking requiring PhD sponsorship as a minimum, but it may perhaps be necessary to provide justification for future projects of this nature.

Maturing heath in End Field

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Presentations and Guided Walks

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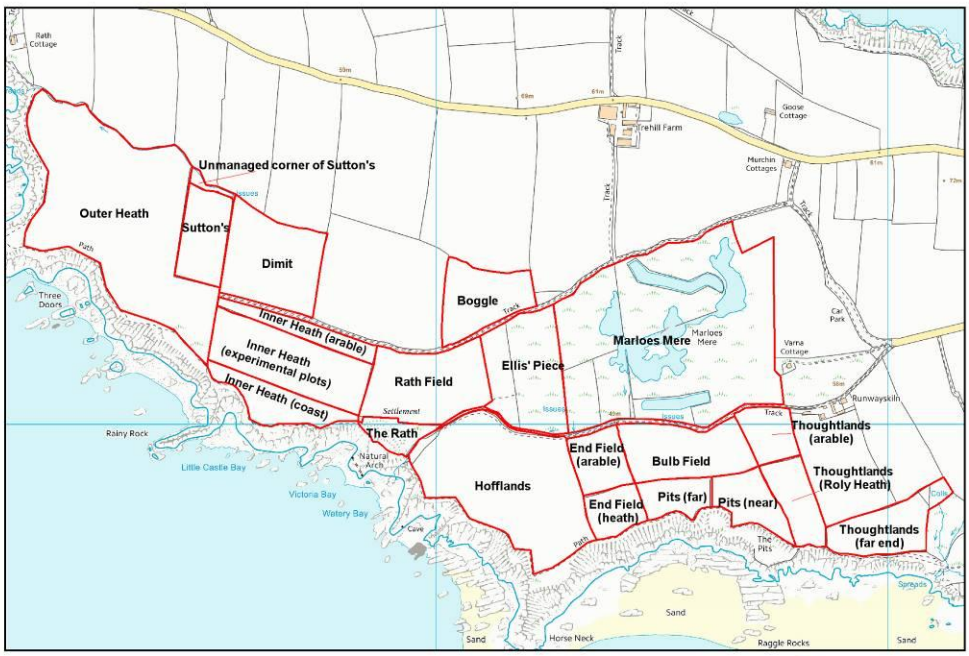
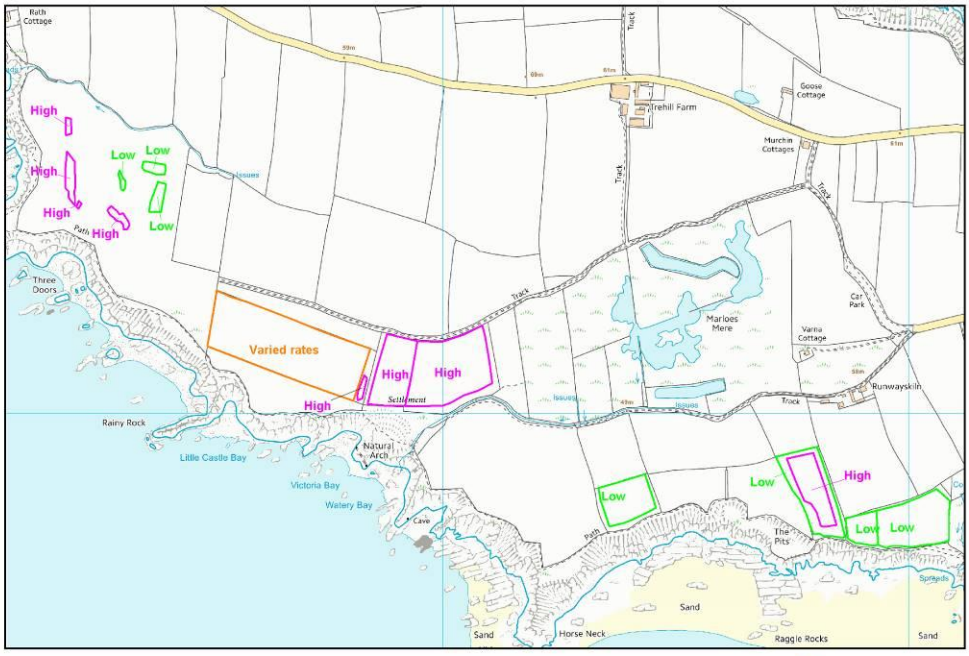
Heather Society
NT Soil Conservation Workshop
BSBI
CCW Council
National Parks

APPENDIX 1: Maps

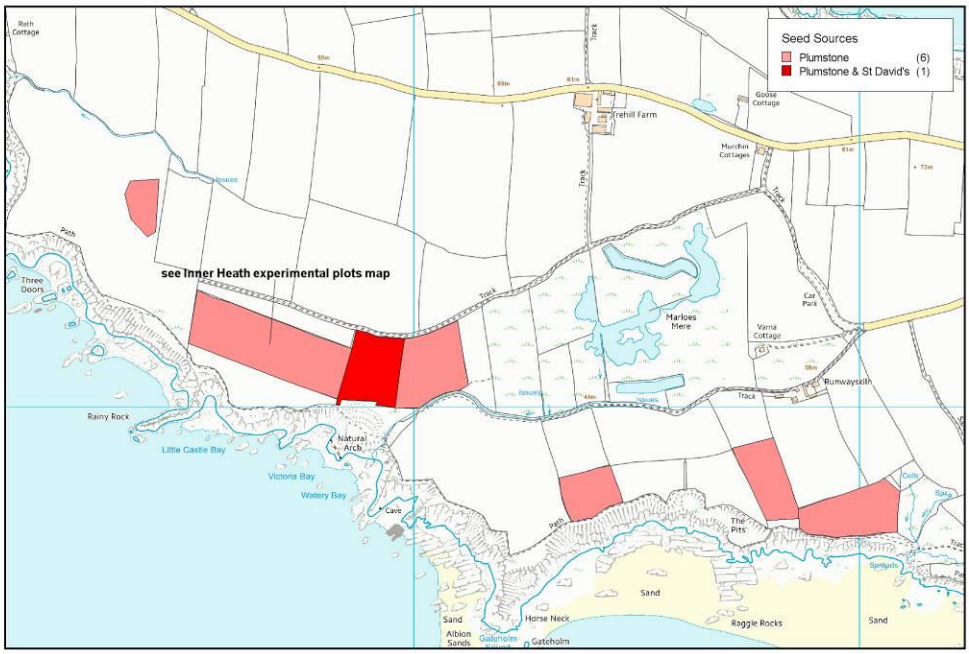
Field Names



Sulphur Applications



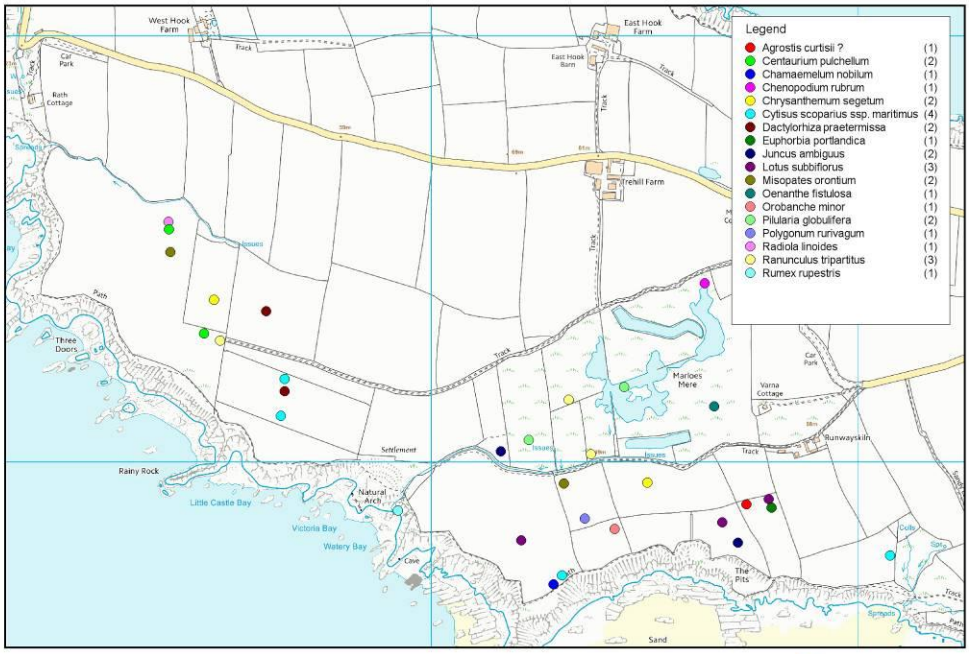
Seed Sources



Produced by NRW on: 9 January 2015
Scale 1:8380

Cyfoeth Naturiol Cymru Natural Resources Wales

Rare Plants



Produced by NRW on: 9 January 2015
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Cyfoeth Naturiol Cymru Natural Resources Wales

APPENDIX 2: Costings for Heathland Re-creation Work

	£/Per Ha	£/Per Hr	£/Per day	Actual Total
Ploughing / Subsoiling	35			320
Soil Stripping	*1355*			17,625
Hedge-banking	*179*			2,325
Archaeological Field Walking	*77.5*		200	1008
Sulphur Processing	Operation resourced by Chevron-Texaco, 60 man-days involved			
Sulphur Haulage & Spreading	*204*			2,650
Heather Harvesting & Transport	*118.5*			1,540
Heather Spreading (tractor with muck-spreader, Manitou for loading)		28		392
Topping		14		140
TOTAL CAPITAL EXPENDITURE	***2000***			**26,000**
Management Agreement	400			5,200
TOTAL ONGOING EXPENDITURE	**400 / year**			**5,200 / year**
Monitoring				£50k?

APPENDIX 3: Interviews with Pete Smithies, 2014

Matt Sutton interviewed Pete Smithies initially in February 2014, as a 'dry run' for a series of interviews carried out as part of a 'Conservation Grazing Case-studies' project commissioned by NRW. This interview dealt with the detail of the conservation grazing regime on the Marloes Coast Project. A second interview was carried out in November 2014, as part of the review of the project commissioned by NT. This focussed on the heathland re-creation work and its position in the farm business.

The following summary has been compiled from both interviews. The MP3 files are archived under Marloes Coast Project 2014/Project Summaries, Papers and Press/Interviews.

Background to Farming Operation

Ward-Smithies farms 450 acres at Trehill, and 200 acres at nearby Philbeach. Bill Ward, Pete's father-in-law, began the business in 1968. At this point, the farm was extensive grazing – Bill fenced fields, ploughed and limed and the farm became predominantly arable land rather than grazing land. Pete started farming at Philbeach in 1994, swapping with Bill to take on Trehill in 2001. The business is now a partnership of 4, with 2 full-time employees. 100 acres of land are down to potatoes, 200 acres of corn are grown, and the rest of the land is grass or heath.

Background to the Project

One arable field – Hofflands – was entered into set-aside in the late 1980s. The subsequent display of thrift and other coastal grassland plants was noted by CCW District Officer Stephen Evans, and the field was entered into a Section 39 Management Agreement with CCW. As the field was alongside the SSSI rather than within it, this was perhaps quite an unusual agreement at the time and one that paved the way for the Marloes Coast Project. Coastal grazing – to benefit iconic species such as chough – was an emerging concept, and the cliffs here only had a few sheep in winter. The Deer Park was under-grazed.

When Pete and Gina took on Trehill in 2001, they recognised that Bill's conservation work on the mere and cliffs had been relatively conservative. They were willing to push things on, and their first involvement with me was to drive forward a S15 management agreement on the Mere. They were pleased that the Wildlife Trust had relinquished their role here, as they had not been active in their management of the site. Pete tasked me with coming up with an ambitious plan for the coastal land, and was suitably impressed with the vision and its innovative nature. Of course, there was an undercurrent of financial considerations but this was not the primary motive for taking the plan forward.

Financial Considerations

At the outset, Pete knew that there would be CCW support, perhaps equating to current earning, but the rates were not set so finance couldn't be the primary driver. Cereal farming was tough - prices were low, margins weren't great. The potential for steady earnings at a reasonable level was attractive as a business decision. Potato

farming is notoriously volatile, and as the business was 80% skewed towards this, the guarantee of money from the conservation scheme would serve to counteract this. With hindsight, the conservation income has been important, but dedicating the land to seed potato production would have perhaps provided an equivalent income stream. The management agreement certainly helps with budgeting, but wouldn't stand alone as a sole revenue generator.

Initially, with cereal prices low, not having the cliff land to work meant that there were savings in labour costs, and activities could be intensified on the improved land on the farm. Although hard to quantify, this has perhaps resulted in better production. Pete strongly believes in this ethos – farming the good land well, and releasing the more marginal land for environmental schemes. Trehill is part of the LEAF (Linking Environment and Farming) scheme, as Pete feels that they promote this ethos well.

Single Farm Payment entitlements were bought in, and now form the core of the farm subsidy received. The Section 15 Management Agreement over the scheme has clearly been crucial to its success. This has been topped up by Tir Gofal, which has paid for the access elements of the project. The Organic Scheme has generated further payments, however, it has proved ill-suited to the farm and the marketing of Organic produce has not realised a premium. The environmental benefits of the grazing have instead been a better selling-point for the beef boxes – farm-gate perceptions have been important for the beef as with the potatoes.

The conservation grazing required by the S15 agreements on the coast and mere has been dependent on the associated payment. Turning in a profit from cattle requires numbers, skill, shrewd judgement and a time investment that Pete can't give – his herd runs at a loss.

An application to Glastir Advanced has recently been refused, with dual funding issues with the S15 seeming to be the problem. Pete feels that there should have been targeted support for areas adjacent to S15/SSSI. There has been some discussion with NRW as to the future of support following the 20 year S15 agreement term, and it seems likely that Pete will have to go into whatever agri-env scheme is operational at the time.

Perspectives

Soon after the project was initiated, cereal prices hit £200/ton and there was speculation about global shortages. Pete had cause then to question the decision made – was it irresponsible? That is the word that comes back more often than not when he thinks about it (now cereal prices are down again, the economics favour the project).

NT had been initially reticent with their support, and there was subsequent pressure from the soil conservation policymakers. CCW were supportive but Pete felt that some people were keeping their heads down.

The criticism from NFU regarding top-soil stripping was given short-shrift though. Pete saw this as completely hypocritical, pointing out that if he'd sold land in England for a housing development, they'd be congratulating him for his entrepreneurial spirit. He does still sense a general feeling of hostility to project from some farming quarters, but true attitudes are not known.

It is clear to Pete that only NT or a large estate could have attempted such a project. The value of land is the key issue – 'irreversible' works wouldn't be done to a privately owned commercial farm, at least not in large swathes. The value of a farm acts, for example, as collateral to borrow money to run the farm; there may also be a need to 'cash-in' the assets some generations down the line. Anything that acts to devalue the asset would not be welcomed by most landowners. The valuation is tied into the prevailing subsidy system, which clearly favours good farmland for grazing or arable. The project here was the result of a peculiar opportunity between three partners.

Key advice for anyone attempting a similar project is that they should speak to WG and seek support and reassurance from the outset. Numerous bureaucratic difficulties were encountered with WG Agriculture Department as a result of the complex and novel field changes. They are unlikely, however, to give guarantees regarding subsidy payment, as politics make policies change.

Attitudes to the project are generally positive. Some people are polite, some farmers are intrigued (and want to know how much money he's getting), but most people don't care. Pete has received positive comments from various quarters – eg. locals liking the space after fence removed, and birders noting the perhaps increased numbers and varieties of birds on the mere and coast. He himself has developed his understanding of wildlife and is now genuinely interested, particularly in the birds. He confesses to not enjoying the barer parts of the heathland recreation fields, and finds it hard to explain them to other people.

He would do it again, but perhaps as a more targeted, less cavalier job, that would be more aesthetically acceptable. The random scars in Outer Heath, for example, would be avoided. The soil stripped areas are better appreciated.

Cattle Grazing Regime

Pete runs a suckler herd, numbering around 25 plus followers. The stock were initially dairy bred Welsh Black calves, then a semi-pedigree mixed group of Welsh Black was purchased. These have been bred on from using pedigree bulls. Capacity with cows and heifers was reached 2 years ago. A Hereford Bull (mine) was used around that time, but there has been a subsequent cull of mixed stock and a pedigree Welsh Black bull has been used since. There used to be a separate commercial beef herd at Philbeach, but no longer.

The cows are autumn calving on fields near the Mere, they are then housed over the rough part of the winter at Philbeach. They are turned out on to the cliff fields or Deer Park in spring – by this time they are large enough, and the cows are not too protective. Public perceptions (eg. of bulls) makes the use of this land a difficult balancing act. All non-breeders are kept until they are ready for the abbatoir. A simple, low cost system is the aim. They are pretty much left alone to get on with it – it may take 3.5 years to finish them, but Pete is not concerned by this. A few, perhaps 4 – 5 year, are sold locally off-farm as 30kg meat boxes. Others, at least the Herefords, go to Waitrose at Dovecote Park via local dealer Anthony Rees. Welsh Black can't go this route though, as the Waitrose licence is held by a north Wales business. The Hereford heifers finish in about 30 months, and 12 steers are currently

also going out at about 30 months. No particular efforts are made to make this deadline though – the animals are not corn fed because the home-produced corn is not organic (even though the animals are not sold as such). The Organic scheme rules complicate things here, as, for example, the non-Organic corn-fed cattle might get too old and need to go back on the organic land.

A few sheep are kept as well. Pete buys in new lambs and sells them on as yearlings. There are perhaps 350 at Trehill, running on farmed land and cliff ground (which they really just 'walk across').

Grazing Issues and Constraints

Forage quality is certainly a consideration. The Mere is good, and animals come off fat and in good condition. It is dedicated to the cows and calves – it could alternatively be used to finish steers, which is difficult. Conserved forage isn't great, as the crop has all gone to head with the late-cutting dates specified by the S15 Agreement. Hofflands is ok, but productivity is low – salt burn can be an issue checking the grass growth. Heathland fields, even those with well-developed heath like End Field, don't provide useful grazing. Ragwort is an issue, but one largely ignored as the animals don't eat it and the neighbours don't complain. It is now encroaching into more intensive fields though.

Out-wintering has been a problem as the cliff land is surprisingly wet, and the Organic scheme has exacerbated this. It would make more sense to 'trash' the cereal fields and recondition them in spring.

The Organic scheme has created other issues and complications. Technically the beef animals are certified Organic, but they are not sold as such as there is not much of a premium, and occasionally animals have had to go onto non-Organic land. The Organic Scheme hasn't worked with conservation. In its absence, cow numbers could be built up, the increased number of young stock could go to Philbeach legitimately, then go on to graze at Trehill where the coastal areas could be hit harder (or pressure relieved more easily if necessary as well). There is a tendency for the Deer Park to be prioritised for grazing at the moment, at the expense of the Trehill fields.

The Deer Park, and the cliff land round to Gateholm, present some problems with fallen stock. There have been 2 cliff losses in 7 years. The loss is compounded by the need to recover the dead animal or explain the loss of the animal to WG. One was intentionally sunk, and the Coastguards retrieved the other. An insurance claim was only made on the first. The first loss was of a c.5month old animal; the second was a yearling. Pete suspects that the animals gather on the cliffs on a sunny evening, and start bucking in excitement – the less sure-footed young animals can then fall. There is always plenty of grazing ahead of the animals so that they don't have to push hard and go down the cliffs in search of forage. There is one pinch-point by the Rath which could cause problems with dogs, but there are generally more problems with the sheep getting spooked. Pete is mindful of busy times, particularly on the Deer Park, and animals are generally brought off here around Christmas, New Year, and the summer holidays. This isn't a problem to do.

There are no specific disease or husbandry issues. Foul in the foot has been encountered, and there are potential problems with common complaints like grass

seed in the eye, but this doesn't affect the placement of stock in the further reaches of the farm. Vigilance is constantly maintained, and problems can't be allowed to develop with the land being so clearly in the public eye. Ivermectin is only used when the cattle go into the sheds in Philbeach.

Management Agreement prescriptions are flexible, and have been well administered by Project Officers. There are no set stocking rates and animals knock tall lush grass down to encourage smaller cliff plants. Welsh Government audit requirements are more of a constraint, and the record keeping and inspections have an impact on the ease of management delivery. Pete was able to get agreement on Heathland as an eligible crop for SFP purposes, but negotiations such as this, and regarding the Organic scheme and dual funding issues have been quite onerous. Trehill appeared to be targeted for a year for routine inspections.

Future Directions

Pete would like to see NT recognise that Trehill is now effectively a smaller farm than it was, and future tenants should be obliged to look after the coastal land.

A management response to maturing heath needs defining. It is important to use the grazing animals available on the farm to achieve the desired vegetation structure, but some fields present a challenge in terms of balancing grazing pressure with forage quality. Pete is somewhat unsure as to what the grazing objectives are for these fields and would appreciate parameters. Could or should he, for example, draw animals on to the mature gorse-rich heather of End Field by positioning a ring-feeder (with hay from Pits or Hofflands) on it? To date, attempts to get animals to knock back the vegetation here haven't met with great success. Outer Heath has also proved difficult to graze to a level where the spread of bramble across the un-stripped areas is checked. Cutting or grazing it hard in spring might be more effective, but would this then harm the skylark population? He is nervous of making mistakes which could inadvertently damage the ecological interest. He agrees though that no endpoint should be set – instead the results should reflect the interactions between the process started and the grazing management tool used. With this in mind, any parameters defined should perhaps be necessarily broad.

APPENDIX 4: CCW Fixed Quadrat Monitoring in Roly Heath and End Field

Q1	2005	2006	2007	2009	2010	2011	2012	2014
Date	14.6.05	13.6.06	17.8.07	19.5.09	20.7.10	5.7.11		
Holcus lanatus							3	4
Poa annua	1		1	1	1	1	1	1
Calluna vulgaris	1							
Cerastium fontanum							1	
Erica cinerea								1
Juncus bufonius	3			1	1			
Polgonum aviculare					1			
Sagina procumbens						1	1	1
Sedum anglicum				1	1	1	2	3
Ulex gallii							1	1
Ulex sp. seedling	1	2	1	1	1	1		
Bryophytes					1	1	2	4
Lichens							1	1
Bare Soil	0	7	10	10	10	10	9	8
Spread Heather Litter	3	3						
Dead Plant Thatch	9	8	3	4	4	3	2	2
Veg Height cm			0-3	0-3	0-5	0-5	0-5	0-10
Ph	2.6							

Q2	2005	2006	2007	2009	2010	2011	2012	2014
Date	6.7.05	13.6.06	17.8.07	19.5.09	20.7.10	5.7.11		
Agrostis canina							1	1
Agrostis capillaris	1	1						
Agrostis cf. stolonifera			1	1				
Dactylis glomerata							1	1
Holcus lanatus	1		1	1			1	1
Molinia caerulea			1		1	1	1	
Poa annua	4	3	3	1	1	1	1	
Aphanes arvenis	1	1						
Calluna vulgaris	3	5	5	7	8	8	8	8
Capsella bursa-pastoris	1							
Centaurium erythraea	1							
Cerastium diffusum	1	1						
Digitalis purpurea		1	3	3	1	1	1	1
Dipsacus fullonus			1					
Epilobium tetragonum			1					
Erica cinerea	3	2	5	5	6	5	6	5
Hypericum humifusum	1	1	1				1	
Hypochoeris radicata							1	
Jasione montana			1	1	1	1	1	
Juncus bufonius	4	2	1	1				
Leontodon autumnalis	2	4	2					
Leucanthemum vulgare	1							
Medicago lupulina							1	
Plantago coronopus				1				
Plantago maritima				1				
Polygonum aviculare	2		1	1				
Potentilla erecta							1	
Rubus fruticosus agg.					1		1	1
Rumex crispus				1				
Sagina procumbens				1	1			
Sedum anglicum	1		1	2				
Senecio jacobaea			1	2				
Sonchus oleraceus	3							
Spergularia arvensis	3		2					
Spergularia rubra		1		2				
Stachys arvensis	1							
Trifolium repens	1	1						
Ulex europaeus					1	1	1	1
Ulex sp. seedling	1		1					
Ulex gallii		1	2	2	4	4	4	5
Veronica arvensis	1							
Veronica serpyllifolia	1							
Vicia sativa					1	1	1	1
Hypnum			2	2	3	3	1	1
Peltigera				1	2	2	1	
Cladonia portentosa				1	2	2	1	
Total Bryophytes			2	2	3	3	1	1
Total Lichens				1	2	2	1	0
Bare Soil	8	7	6	6	5	5	5	3

Dead Plant Thatch			3				2	2
Height	0-5		0-10	0-10	0-30	0-30	0-30	
Ph	3.7							

Q3	2005	2006	2007	2009	2010	2011	2012	2014
Date	6.7.05	13.6.06	17.8.07	19.5.09	20.7.10	5.7.11		
Festuca cf. rubra					1	1	1	
Holcus lanatus				5	7	8	8	6
Poa annua	2	1	1	3				2
Vulpia bromoides								
Calluna vulgaris					2	2	2	5
Digitalis purpurea				2	2	2	3	2
Erica cinerea					1	1		1
Glechoma hederacea								2
Hypochoeris radicata	1	1					1	3
Jasione montana	1			1		2	3	3
Juncus bufonius	2			3	1	1	1	1
Leontodon autumnalis							1	2
Leontodon taraxacoides							1	2
Plantago coronopus	4	3	2		1	1	1	3
Plantago maritima	1	1	1		1	1	1	2
Rubus fruticosus agg.								2
Rumex acetosella								1
Rumex crispus	1	1	1					
Sedum anglicum	1	1			4	4	4	6
Spergularia arvensis	1		1					
Spergularia rubra	2	2	2		1	1	1	1
Taraxacum officinale agg.								1
Trifolium repens	1							
Bryum sp.					2	2	2	2
Campylopus introflexus							3	4
Total Bryophytes					2	2	3	4
Total Lichens (saxicolous)					2		2	1
Bare Soil	9	9	9	7	6	10	5	5
Dead Plant Thatch		5	2	2			4 (holcus)	2
Veg Height cm	0-5	0-2	0-2	0-5	0-20	0-20	0-20	0-20
Ph	3.0							

Q4	2005	2006	2007	2009	2010	2011	2012	2014
Date	6.7.05	13.6.06	17.8.07	19.5.09	20.7.10		not recorded	
Agrostis capillaris	4	4	4	2				
Agrostis stolonifera	1							
Aira caryophyllea		1						
Bromus hordeaceus		3		1				
Dactylis glomerata				1	1			
Elymus repens				2				
Festuca cf. rubra				1				
Holcus lanatus	1	1	4	5	4			
Molinia caerulea			1					
Poa annua	1	2	1					
Vulpia bromoides				1				
Achillea millefolium	3	3	3	2				
Anagallis arvensis	3	2	2					
Calluna vulgaris	2	2	4	5	5			
Centaurium erythraea	1	1	2	2				
Cerastium fontanum	3	3		1	1			
Cerastium diffusum		2		2				
Cerastium holosteoides	2	2		1				
Crepis capillaris		2						
Digitalis purpurea				1				
Epilobium tetragonum	1	1	1	1				
Erica cinerea			4	2	5			
Hypochoeris radicata	1	1						
Jasione montana	3	3	2	1	1			
Juncus bufonius	2	2						
Leontodon autumnalis	1	2	2					
Leontodon taraxacoides		2			1			
Leucanthemum vulgare	1 outside Q							
Orobanche minor								
Plantago coronopus	2	2						
Plantago maritima			1					
Polgonum aviculare	1	1						
Rubus fruticosus agg.	1	1	1		1			
Rumex acetosa					1			
Rumex crispus			1					
Sagina apetala		1						
Sagina procumbens				1				
Sedum anglicum	2	4	2		1			
Senecio jacobaea	2	3	5					
Senecio sylvaticus	1	1						
Senecio vulgaris		1						
Sonchus oleraceus	4	1						
Thymus praecox					1			
Trifolium dubium	4	4	4	1				
Ulex gallii		6	6	6	8			
Ulex sp. seedling	3							
Veronica arvensis		2						
Veronica polita		2						
Veronica serpyllifolia	2	1	2					
Vicia sativa				1	1			

Viola arvensis	3	3						
Total Bryophytes		3	2	2	2			
Total Lichens			1	1	1			
Bare Soil	5	5	3	0	1			
Dead Plant Thatch	4							
Veg Height cm		20	0-20	6-40	0-60			
Ph	5.5							

Q5	2005	2006	2007	2009	2010	2011	2012	2014
Date	6.7.05	13.6.06	17.8.07	19.5.09	20.7.10	5.7.11		
Agrostis cf. stolonifera					3	5	3	3
Dactylis glomerata					1	1		1
Elytrigia repens	8	8	8	4				
Festuca cf. rubra	1	1			1	1	1	1
Holcus lanatus			2	6	6	6	4	2
Poa annua	1							
Achillea millefolium					1			
Calluna vulgaris	1	3	5	6	7	8	8	8
Crepis capillaris					1			
Digitalis purpurea			4	4	4	3	2	
Erica cinerea		2	4	2	5	5	4	4
Juncus bufonius	1							
Potentilla erecta					1	1	1	
Rumex acetosa			1				1	2
Sedum anglicum	2		1		1	1	1	
Senecio jacobaea		1	1		2	2	1	1
Trifolium repens					1	1		
Riccia sorocarpa	1							
Polytrichum formosum				2		2		
Campylopus introflexus				3		3		
Total Bryophytes	2		3	3	2	3	2	2
Total Lichens	1							
Bare Soil	3	1	2	2	0	0	0	0
Dead Plant Thatch	5	9	5	2	2	4	3	3
Veg Height cm	65	40	0-40	0-20	0-40	0-40	0-40	20-55
Ph	3.3							