Restoration of natural capital: review of evidence

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1. Introduction

This review was established to bring together evidence on the potential for restoration of natural capital assets and to attempt to determine the rate at which assets can be restored in the event that thresholds and/or limits are crossed. The review also attempted to collate information on the costs of restoration.

The approach has been informed by the Natural Capital Committee's emerging conceptual framework (Natural Capital Committee, 2014) which recognises that assets come together to provide benefits in a complex way. The review focused not just on assets, but also on habitats to address this complexity and in recognition of the fact that rarely are assets restored in isolation. Although habitats do not map simply across to either natural assets or benefits, much of the ecological restoration literature addresses habitat restoration and hence this review tends to focus on the feasibility, timescales and costs for the restoration of a range of habitats.

2. Methods

The first task was to create a review structure; a spreadsheet in Excel was setup with the following column headings agreed with representatives of the Natural Capital Committee:

- Evidence source
- Geographical extent
- Size of study area
- Spatial configuration
- Pressure/driver impacting asset
- Actions taken to restore
- Other management information
- Initial state (Habitat type)
- Initial state (level of degradation
- Final state
- Evidence of threshold
- Target (community/ecosystem function)
- Frequency of monitoring
- Timescale of recovery
- Rate/type of recovery
- Cost
- Constraints to restoration

Then a review of the literature was carried out using the search term restor* and constraining by country and habitat (to restrict the search to the UK although studies outside of the UK were used for some habitats e.g. woodland where there was not much evidence). This was used in various search engines (Web of Science, Google scholar) and also on websites of NGO's (e.g. RSPB), government agencies, and the conservation evidence website. In addition, colleagues and contacts were asked to suggest material and evidence sources. Efforts were made to include both information from the scientific literature and evidence from practitioners and experts. Review material was collated and then used to populate the spreadsheet (Appendix 3), each evidence source was numbered; these numbers are included in the accompanying spreadsheets to help readers refer across.

This information was then used to create a summary spreadsheet (Appendix 2) where, for each asset/accounting unit, information on the potential for restoration, the time taken for recovery, the ease of restoration, actions taken to restore, constraints to restoration and costs of restoration has been summarised by asset component (e.g. invertebrates, vegetation, carbon sequestration). Each study from which evidence has been collated is identified in the spreadsheet. This spreadsheet has been summarised further and included Appendix 1 at the end of this report. Appendix 1 provides a high level overview, by habitat, for more detail please refer to the accompanying appendices

Information on costs was obtained from the literature where possible. However, the scientific literature did not generally include cost information and it was therefore necessary to look to other sources. Data on costs were taken primarily from the IEEP report (2013) which reported on a large number of studies across Europe. There was also some further research and inclusion of cost information from other sources (e.g. agri-environment scheme payment options). Costs have been included as a present value per hectare over a specified number of years.

Definition of restoration

Restoration has been defined in different ways; the CBD (2011) definition is:

> '*the process of actively managing the recovery of an ecosystem service that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity*'.

Whilst the European Commission Biodiversity Strategy Impact Assessment definition for ecological restoration is:

> *'the return of an ecosystem to its original community structure, natural complement of species and natural functions'*.

A recent study (Arcadis, 2012) proposes a four stage approach ranging from level 4: highly modified abiotic conditions, reduced ecological processes and functions with declining native species to level 1: where abiotic conditions are satisfactory and key species, properties and processes of ecosystems and their functions are in good to excellent condition.

This study initially set out with the definition of restoration as 'the return of a habitat/ecosystem to pristine condition' as in the European Commission definition, however, if this were the case then few of the studies would have been described as restored as they did not demonstrate a return to 'pre-disturbance or pristine conditions'. In identifying the potential for restoration of a habitat we used more flexibility, similar to the Arcadis (2012) report we considered that restoration represents a gradient from degraded to good condition (of abiotic conditions, species, functions and processes) and movement along this gradient needs to be demonstrated for some level of restoration to have occurred. However, full restoration requires the return of key species, properties and processes of ecosystems as measured by comparing the target to the final state.

3. Results

The initial collation of evidence and review of restoration literature can be found in Appendix 3. Appendix 2 is a summary of this information with links through to the numbered evidence sources in Appendix 3. Appendix 1 at the end of this report is a further summary of evidence within assets and habitats/accounting units for different restoration targets (components of assets) detailing the time taken for recovery, ease of restoration and constraints.

Table 1 contains a summary by asset and accounting unit[1] of the potential for restoration, the time taken for recovery of different components and the cost as present value. The evidence upon which the conclusions are based is indicated in the evidence column, this is coded 1-4 according to the evidence index: 1 = low agreement, limited evidence; 2 = low agreement much evidence; 3= high agreement limited evidence; 4=high agreement, much evidence.

Many studies were not monitored for sufficient time to determine whether full restoration had been achieved. The timescales required to monitor from restoration action to full recovery can be long (years) and therefore not suited to short- term research projects. Many studies made use of chronosequences (sets of sites with similar characteristics but of differing ages) and a lot of the information extracted is based on these studies. However, it is not possible to control for all variables when using chronosequences or possible to ensure that the initial state is comparable.

There was a great deal of variation in the availability of evidence between asset/habitat types. There are a lot of detailed studies on the restoration of semi-natural grassland and a reasonable number on heathlands (particularly lowland heaths), bogs and wetlands. There are a limited number of woodland studies; probably due to the long timescales involved (although as mentioned chronosequences have been used by some researchers). We have included some non-UK examples of woodland restoration due to the difficulties in finding UK studies. There are many studies on the restoration of freshwater and a recent meta-analysis of hundreds of freshwater papers was very useful for reporting (Verdonschot *et al*., 2013). There is a need to search further for material on soils, some literature has been included but there is more on restoration from heavy metal or oil polluted land that has not been covered. There could also be more consideration of individual soil components e.g. soil nutrients, soil carbon and their rates of recovery. The restoration of agricultural soils has not been well covered, there is likely to be a lot of information on this in different sources (i.e. beyond the ecological literature) and this could be investigated. For the species asset; vegetation and invertebrates have been well covered in this review but information on restoration for birds and mammals was limited, there are likely to be sources of information that were missed. We haven't covered the restoration of all assets- a large amount of literature was reviewed but given the breadth and complexity of the subject it was not possible to cover everything. Significant gaps in this review include the following assets: Oceans, Urban and Atmosphere.

For some habitats the focus or language is not about restoration e.g. heathland; there are some examples of re-creation and restoration of lowland heath but upland heath management is more concerned with rehabilitation, removal of trees and scrub, bracken, responding to over or undergrazing. It is useful to be aware of the variation in terminology when reviewing literature and interpreting results.

[1] In the final Natural Capital Committee State of Natural Capital report, these accounting units are termed major land use categories

Many of the targets set for restoration in these studies were biodiversity targets such as vegetation composition and richness, invertebrate composition and richness, return of fish populations, (fewer studies on birds and none on mammals). There were a reasonable number of studies that targeted water quality, water quantity, soils or other non-biodiversity variables but it is possible that a search of different literature sources e.g. engineering journals would have resulted in more studies on a wider range of ecosystem services. There were also quite a lot of studies that didn't set a target for restoration, perhaps working more with the CBD definition that actively managing a habitat for restoration was sufficient rather than having a pre-determined outcome to work towards.

Table 1: Summary table of potential and cost of restoration of natural capital

Evidence index: 1 = low agreement, limited evidence; 2 = low agreement much evidence; 3= high agreement limited evidence; 4=high agreement, much evidence

Asset	Accounting unit	Potential for restoration	Time taken for recovery	Evidence	Present Value per ha (unless stated) over x years [Upper and Lower values from IEEP 2013 study]
Freshwater	Lake	Partial- some restoration of chemical and biological components but issues with both	15-25 years (invertebrates 10-20 yrs, macrophytes- 2-40 yrs, fish-2 to >10 yrs, water quality 10-15 years)	4	e.g. one-off £8.1 million for Loch Leven (recovery from eutrophication) Unit costs not available
Freshwater	Rivers and streams	Partial- higher success for abiotic, +ve biological responses but not full restoration	15-25 years for biotic composition, diversity and functioning	4	£27,000 one-off cost[2]
Freshwater	Wetlands	Partial- Hydrology, birds, short time scales, vegetation and invertebrates some recovery but full takes long time	Hydrology 1-2 years, birds 1-2 years open water habitats, Vegetation and invertebrates beneficial changes <10 years, >60 years still not full recovery,	2	Upper: £23,738 over 60 years Lower: £6,223 over 10 years
Ecological Communities	MMH: Blanket Bog	Partial	Hydrology 1-2 years, Carbon improvement 3 years, Vegetation re-colonisation 2 years but community takes 20-50 years	4	Upper: £15,161 over 50 years Lower: £5,720 over 10 years
Ecological Communities	MMH: Upland Heath	Partial- practical constraints	Increases in Dwarf Shrub species in few years but overall diversity takes longer.	3	Upper: £7,111 over 50 years Lower: £4,381over 20 years
Ecological Communities	Lowland heath	Partial- recovery rather than full restoration, both rehabilitation and re-creation considered	Vegetation improves after 2 years but not comparable to non-restored heathland from either re-creation or rehabilitation. Pollinators 11-15 years full recovery of function.	4	Upper: £2,503 over 15 years + one-off cost of £450 for creation Lower: £900 over 11 years + one-off cost of £290 for creation
Ecological Communities	Semi-natural grasslands	Partial- some relatively species poor grassland communities (e.g.MG5) can be restored, for others restoration to 'ancient grassland' will take a long time. 80% similarity in invertebrate	MG5 and acid grassland vegetation 4-5 years, other grasslands (calcareous and species rich meadows)>100 years, soil < 10 years, Pollinators 4-15 years, Butterflies 10 years.	4	Upper: £6,509 over 15 years Lower: £2,430 over 4 years

[2] IEEP 2013

		communities but difficult to restore rare species.			
Ecological Communities	Enclosed farmland	Partial- capacity to improve natural capital (arable weeds, pollinators, birds, hedgerows) but ongoing conflicts	Improvements in plant species richness can be in a few years but fluctuation, pollinator abundance and richness can increase in 2-5 years. Hedgerows- establishment of structure 3-5 years but up to 30 years for species to colonise	4	Upper: £16,483 over 30 years Lower: £159 over 2 years
Ecological Communities	Woodland	Partial- can restore tree species given enough time but it is more difficult to restore the associated biodiversity.	20-30 years for restoration of full canopy cover from grassland, 30-40 years for shade tolerant species to replace light demanding, some studies shown full restoration still not taken place after 80-100 years. Soil fertility impacts restoration rate.	3	Upper: £89,590 over 100 years Lower: £45,637 over 20 years
Soils		Partial	Varies by ecological community type, woodlands took 75 years with poor restoration at shorter time scales, Heathland some changes in 10 years but not full restoration, grasslands showed a partial recovery in between 3-14 years. In wetlands although within 10 years soil properties for plant biomass and wildlife some soil properties critical for water quality take decades or centuries.	1	Distinct costs of soil restoration not identified. Costs for changes to soil management available, and change to soil integrity is part of other habitat costs.
Coasts	Coastal dunes and sandy shores	Partial- it is possible to restore dune systems, they are mobile systems which require frequent disturbance	5-20 years for semi-fixed dunes, over 40 years for fixed dunes, some vegetation colonisation within 3 years, up to 40 years for successionally young slack communities	3	Upper: £174,963 over 40 years Lower: £4,605 over 5 years
Coasts	Saltmarsh	Partial- easy to establish vegetation cover and increase invertebrate richness but difficult to restore biological equivalency	vegetation cover within 5 years but still not the same as non-restored community even after 100 years, invertebrates habitat re-creation long time scales required, restoration of degraded invertebrate	4	Upper: £33,100 over 5 years[3] (average of 19 UK schemes) Lower: £1,324 over 5 years

[3] IECS, 2005.

			restoration in 5 years, birds dependent on invertebrates		
Coasts	Transitional and coastal waters	Partial- can be confounded by re-release of contaminants, very difficult to control for all inputs to estuarine system.	In general periods of 15-25 years for attainment of the original biotic composition, diversity, and complete functioning. Fish can recover with 1-3 years though 1 study no recovery in 22 years, invertebrates >6 years, generally >10 years, bacteria 2 months, seagrass 10 years, Macroalgae 2 years, Phytoplankton 15-20 years	4	£195,000 to establish a marine protected area site and approximately £1.67m in running costs over 25 years thereafter (Feilen, 2006) (NB these are NOT costs per ha, and highly variable depending on size and features of MPA)

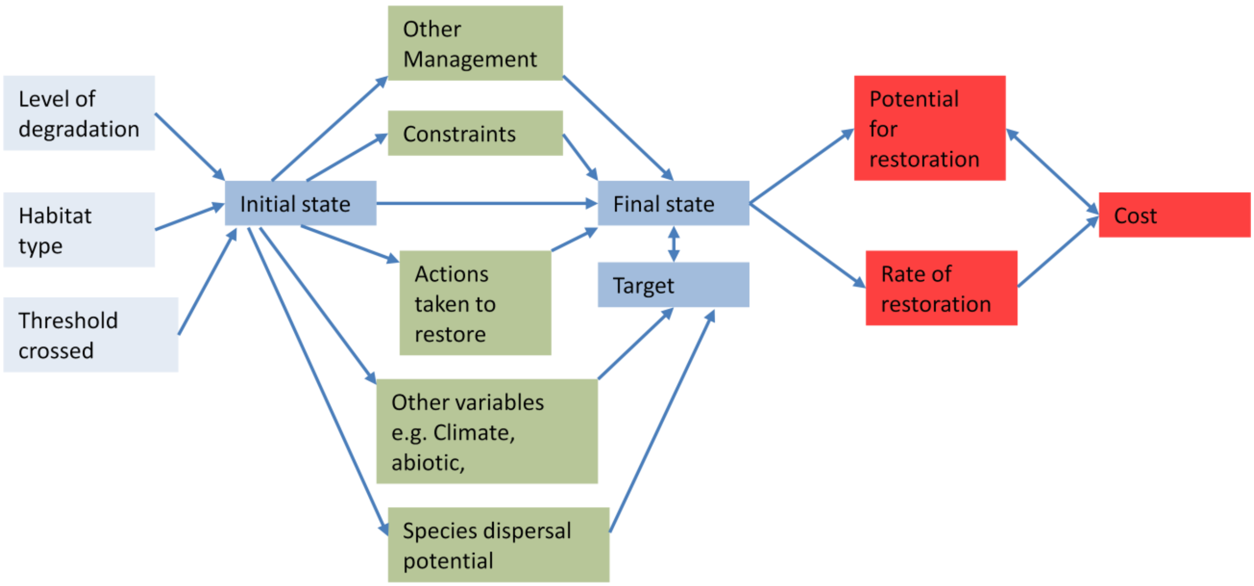
4. Conclusions

It is possible to achieve some recovery in components of most habitats however full restoration of species, abiotic components, functions and processes is very difficult. Eliciting the degree of recovery from the literature was also a challenge; it is very dependent on how recovery is measured (see methods) and what target/counterfactuals are set. Studies in the review used various definitions of restoration; from the improvement in ecosystem variables (without achieving pristine condition) to the application of restoration activity as an indicator of restoration (as in the CBD definition) even though no detailed analysis between initial and final states had taken place, to a return to pre-disturbance or pristine conditions. We tried to take these into account when summarising this information, however within a habitat if a number of studies felt that the difference between the final state and the target/control was still vastly different for at least one component then the potential for restoration was assigned as partial.

There can be such a lot of complexity in the process of habitat restoration, to understand it fully you need a knowledge of the initial state of the habitat (the degree of degradation, species composition, abiotic variables and whether a threshold has been crossed), the actions taken to restore (which can be very diverse), sources for species colonisation (from nearby habitat or within soil), ongoing management in addition to restoration facilitation, the final state, the target of restoration (which may be multiple from the same management actions), how closely the final state matches the target then the potential for restoration, costs and rate of restoration can be determined (Figure 1).

It would be very useful to create a detailed matrix to understand how variation in one of these variables affected the potential, rate and costs of restoration. Some of the material necessary to do this has been captured in this review but it would require more work to develop a complex matrix.

Figure 1: Relationships between factors determining cost and feasibility of restoration



References

(these are the references for this report, the citations for evidence used in the review of restoration can be found in Appendix 3)

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Appendix 1a: Freshwater

Asset	Targets/ response vars	Pressure/degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Freshwater: Standing open waters	Diatoms, Phytoplankton, zooplankton, algal growth, benthic invertebrates, water P and N, chlorophyll, turbidity, fish	Eutrophication and acidification	Liming, Removal of stressor (e.g. diversion of effluent), biomanipulation (removal of fish)	66% success in restoring for P and N, 64% biological response. Biological improvements following reduction in acidification but lags behind chemical recovery. Difficult to restore lowland lakes- diffuse pollution	15-25 years (averages across variation in times for different components), 10-20 years invertebrates, 2-40 macrophytes, 2 to >10 years fish, 10-15 years water quality	Medium	Natural recovery from acidification longer than after liming, changes after liming may not be stable. Shallow lakes- once plants lost and algal dominance with turbid water may need drastic action e.g. removing fish to stimulate algal grazing. Internal loading of P can delay lake recovery.	Total cost £8.1 million for Loch Leven restoration
Freshwater: Rivers and streams	Benthic invertebrates and fish most common, also algal biomass, bryophyte cover,	Eutrophication, acidification, Habitat modification	Habitat improvement, riparian buffer creation, restoring connectivity between rivers, natural recovery after catastrophic events	Higher success rate for abiotic conditions. Environmental improvement in 33% of projects, +ve biological response in 50%	15-25 years for biotic composition, diversity and functioning, some recovery after 1-2 years for density of invertebrates after single event e.g. oil spill, logging	Medium but high degree of variation	Water quality, duration of exposure to nutrient enrichment (and subsequent changes to dominant species), hydrological change, source populations, dispersal barriers, 2ndary pressures e.g. floods, droughts, catchment management, monitoring frequently <10 years	Total cost 22 578 £/ha for re-naturalisation of heavily modified river courses, (from IEEP report)
Freshwater: Wetlands	Vegetation, Invertebrates, Wildfowl	Re-creation from agricultural land or Rehabilitation: drought stressed, eutrophication, afforestation	Grazing hydrological management, cutting, scrub management, soil stripping, reed bed creation, removal of invasive species, removal of tree species	Partial- restoration often used as term when only one component e.g. water table has been restored, difficult to decide what to restore e.g. Leighton Moss managed as reedbeds but is on site of lowland raised bog, for birds Open water habitats develop interesting bird communities quickly	Hydrology restored in couple of years, Vegetation communities not completely restored after 60 years although some beneficial changes seen within 10 years, Invertebrate diversity restored within 10-12 years in some cases although rare species not always restored after 60 years.	Hard-medium, landscape scale projects to restore morphology and hydrology	Study length too short, restoration efforts limited to one or two components of the ecosystem e.g. water table, requirement to see fen as a component of a wider matrix of habitat	668 £ ha/yr (from IEEP report), HLS and Glastir reedbed and fen creation approx £400 ha. Restoration £60-£200.

Appendix 1b. Mountains, Moorlands and heaths

Asset/ accounting unit	Targets	Pressure/degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Ecological communities: Blanket bog	Water quality, hydrology, benthic invertebrate, Blanket Bog vegetation, Sphagnum cover	Drainage, succession, afforestation, peat extraction, water pollution, overgrazing, air pollution	Ditch blocking, stabilisation, peat re-profiling, reseeding, planting, gully blocking, vegetation removal, stock reduction, Sphagnum beading	Partial- Hydrology and carbon restoration but poor for biodiversity, although stream invertebrates full recovery after ditch blocking	Improvement in Carbon and water in few years, recovery, increases with number of years blocked, vegetation slower than hydrology 20-50 years. 3-11 years stream invertebrates after improved water quality from ditch blocking	Medium. Ditch blocking is intensive at outset but may not require regular management.	Vegetation restoration dependent on hydrological restoration. May not be possible to achieve renewed peat accumulation. Physical access to sites can be difficult. Climate important for vegetation establishment. Timescale of monitoring too short to assess full restoration	Ditch blocking estimated at £490/ha to £6500/km depending on technique. Average across a range of studies total cost per hectare approx. £1600. IEEP £614 ha yr
Ecological communities: Mountains, Moorlands and Upland Heaths	Vegetation (Calluna heath, heath./acid grassland mosaic, montane scrub)	Bracken invasion/ dominance, overgrazing	Bracken clearance, stock reduction, herbicide, cutting, seeding, cessation of burning, fencing, planting	Partial	Longest study of 10 years was not sufficient to observe full restoration, increase in cover and height of Dwarf shrub species in 4-5 years but not overall diversity	Medium. All studies require some element of long term management (bracken control, grazing, fence management)	Several studies did not measure a target to assess restoration success, absence of controls. Problem of maintaining fencing at high altitude for montane restoration. Requirements for propagule sources. Slope- steep slopes harder to colonise by veg. Recovery after reducing stocking rate affected by high deer populations in Scotland.	IEEP £288 ha yr, HLS maintenance of moorland £40 ha, restoration £40 ha, creation £60, maintenance for birds £80
Ecological communities: Lowland heath	Vegetation, Invertebrate, species rich heathland	Afforestation, scrub invasion, agriculture	Tree felling, cutting, burning grazing, fencing, scrub clearance, mowing, soil stripping, herbicide, cultivation, soil addition, deturfing, acidification, seeding, translocation	Partial most successful restoration treatment 87% similarity to target after 17 years	Vegetation improves towards target within 2 years but does not entirely reach target after 17 years, pollinators full restoration of function in 11-15 years but incomplete restoration of higher trophic levels	Hard - medium	Restoration trajectory towards different habitat from target. Initial state and dominant species e.g. more difficult to restore after birch invasion than *Pinus sylvestris*. Requirement for hydrological management, soil chemistry. Initial changes may not reflect long term restoration trajectory so long term monitoring required. Unwillingness to graze livestock where tick infestation high,	Glastir monitoring Lowland heath management £89.74 ha, HLS maintenance £200, restoration £200
Ecological	Vegetation,	Re-creation on forest,	Various including	Partial- re-	Change occurred over		Initial community- Forestry sites had	One study

communities: Lowland heath	Invertebrate, species rich heathland	arable or grassland sites	acidification (S or bracken litter), seeding, addition of heath shoots, tree felling	creation most successful on previous conifer plantations due to availability of seed and abiotic conditions	3-17 years but length of restoration was not included in the analysis		higher similarity to target heath vegetation, arable and grassland sites were more similar to acid grassland	estimated £13,600 for translocation of a 620 m2 area of heath so £219 354 per ha. Glastir: expansion onto grassland £283.69 ha, HLS creation from arable £450 ha.

Appendix 1c: Semi-natural grasslands

Asset/ accounting unit	Targets	Pressure/degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Ecological communities: Semi-natural grasslands	Vegetation biodiversity/ composition often NVC (MG5, MG4, MG3b), or HAP, Invertebrates- Butterflies, carabid beetles	Reversion from arable	Turf translocation, natural regeneration, seeding, grazing, cutting, herbicide, liming, cultivation, nurse crop, Rhinanthus, molluscicide , deturfing, soil translocation, farmyard manure, fertiliser cessation, fertiliser reduction , acidification , conservation headland	Full- to produce MG5, Partial- MG3b closer to target. Partial- Calcareous grassland, restored sites very different to ancient	Perennial vegetation 2 years, MG5- 4-5 years. MG3b- 14 years not sufficient to restore (proposed 20 years). 60% similarity to CG3 after 3-20 years. Complete restoration to a previous 'ancient grassland' state will take over 100 years or may be impossible. Restoration of soil conditions can occur in 10 years if modification is not too severe and some recolonisation can occur within 20 years, particularly if helped by seeding. Acid grassland restoration can be very quick, with recovery within 5 years following seeding and sulphur addition.	Easy- medium	Modification of soil and lack of local species pools and mixed landscape structure. Isolated arable fields. High soil fertility less of a barrier than seed availability. Translocation more likely to succeed. Monitoring/study period too short. Natural regeneration did not produce target communities in timescale- sowing required but long term this may affect successional processes. Adjustment of grazing management-Cattle grazing better than sheep- more heterogeneous structure. Some species rely on specialist associations e.g. Thymus polytrichus and ants. The difference in P and pH from the target may determine the timescale of restoration (under 10 years if less than 10 mg/l P and 0.5 units pH different from target, more than 10 years if more than this)	IEEP £520 ha/yr, Glastir and HLS £161-£280 (not including capital)
Ecological communities: Semi-natural grasslands	Invertebrates- Butterflies, carabid beetles	Reversion from arable/landfill/ grassland	Turf translocation, natural regeneration, seeding, grazing, cutting , scrub removal	Partial- arable reversion, poor- grassland reversion	4-15 years pollinators, 20 year study of invertebrate communities showed up to 80% similarity in communities with no further improvement. Butterflies similarity to reference after 10 years from reversion from arable, less similar in grasslands		restoration produces a different community to the target, restored sites do not include rare species	IEEP £520 ha/yr, Glastir and HLS £161-£280 (not including capital)

Appendix 1d: Enclosed farmland

Asset/ accounting unit	Targets	Pressure/degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Ecological communities: Enclosed farmland	Vegetation	Agricultural intensification/ eutrophication	Conservation headland, natural regeneration, grass seeding, wildflower seeding pollen and nectar mix seeding, cutting, herbicide	Partial- capacity to improve natural capital but ongoing conflicts with nutrient runoff and management	Initial improvements in species richness in first year or so but then some declines over time. 13 year study showed complex patterns, suggests recovery may be long term and fluctuating	Medium- some long term management (cutting) was required	Natural regeneration can lead to colonisation of injurious weeds, no target site measured to compare to so difficult to measure progress.	Seed mixes vary from £55/ha to £850/ha depending on composition
Ecological communities: Enclosed farmland	Pollinators	Agricultural intensification/ eutrophication	Conservation headland, natural regeneration, grass seeding, wildflower seeding, pollen and nectar mix seeding, cutting	Partial- improvement in pollinator populations observed	Studies show increases in pollinator abundance and richness within 2-5 years but no targets used to assess degree of restoration	Medium- some long term management (cutting) was required	No studies measured a target area and therefore restoration success cannot be assessed. Direct sowing provides more forage plants for bees than natural regeneration and may be used if bees or other pollinators are the target of restoration.	Seed mixes vary from £55/ha to £850/ha depending on composition, HLS options around £400 ha, IEEP £167 ha
Ecological communities: Enclosed farmland	Birds	Agricultural intensification/ eutrophication	Bare patches in fields, game cover for granivorous birds,	Partial		Medium	Creating habitat doesn't mean that birds will colonise	Seed mixes vary from £55/ha to £850/ha depending on composition, HLS options around £400 ha, IEEP £167 ha
Ecological communities: Enclosed farmland	Hedgerows	Hedgerow removal or lack of management	Hedgerow creation, laying hedgerows, management	Partial- hedgerow structure can be restored, longer timescales may be required for colonisation and connectivity function	3-5 years for shrub establishment, Time for colonisation of mobile species 30 years	Medium	Capacity for species dispersal, Eutrophication, Continuation of management	£5-£7m for laying and creation = £400/ha/yr

Appendix 1e: Woodland

Asset/ accounting unit	Targets	Pressure/degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Ecological communities: Woodland	Vegetation- includes canopy and ground flora	Clearfell or creation from arable/grassland	Woodland creation- Natural regeneration or planting,	Partial- can restore tree species given enough time but more difficult to get ground flora	Tree regeneration - longer than most studies, 10 years for woody species, 20-30 years for full canopy cover from arable/grassland., ground flora - variable, studies suggest 30-40 years from light demanding to shade tolerant, but others have shown full restoration does not occur even after 80-100 years	Variable- can rely on natural succession, then minimal effort but takes a long time, can plant in which case more effort	Very difficult to monitor- long timescales! Chronosequences frequently used. Cover of competitive ground flora species e.g. Ivy, bramble, bracken restricts tree seedling growth and other herbaceous species enhanced by high nutrients with slower restoration rates. Proximity to species pool, some woodland species can survive in hedgerows, otherwise species move from nearby woodlands. Lack of required soil conditions e.g. moist soils, suitable pH, acidification of soil.	IEEP £3592 for woodland restoration, Glastir re-stocking £2300 ha, HLS £100 ha restoration
Ecological communities: Woodland	Vegetation- includes canopy and ground flora	Succession, eutrophication, acidification	Woodland management to improve condition- felling, planting, thinning, fencing			Variable- natural or managed	Browsing, grazing or lack of it, nutrient deposition,	HLS Maintenance £100 ha
Ecological communities: Woodland	Invertebrates: beetles, ants, spiders and arthropods	Felling, Succession, eutrophication, acidification			Ants - over 100 years, beetles - more than 27 years, spiders/arthropods - more than 80 years	Variable- natural or managed		
Ecological communities: Woodland	Birds	Felling, Succession, eutrophication, acidification				Variable- natural or managed	Size and spatial configuration of woodland patch	
Ecological communities: Woodland	Nutrient cycling: N and P	Felling Succession, eutrophication, acidification			Restoration of N cycling in 75 years, 2 year study of P cycling showed some improvement	Variable- natural or managed		

Appendix 1f: Soils

Asset/ accounting unit	Targets	Pressure/ degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Soils: Woodland	Soil C, N, P, Microbial, SOM, soil structure, minerals	Logging, agriculture	Fallowing	Partial-full	Full recovery observed in one study after 75 years partial restoration over 80-100 years, however poor recovery at one site after 120 years, All short term studies had poor restoration. Likely to be 100 years or more for full restoration			
Soils: Heathland	Soil fertility and Chemistry	Invasion, Eutrophication	Felling, cutting, bulldozing, litter stripping, chemical treatment, natural regeneration	Partial	Some changes in 10 years but not full restoration	Easy-hard	Restored sites can have soil properties further from the target than degraded sites. Soil properties were most easily restored where litter stripping was used or the start point was close to the target. The absence of soil restoration did not prevent vegetation restoration, although full restoration was not achieved	
Soils: Grassland	Microbial communities, pH	Fertilisation	Grazing, seeding, manure, cutting, acidification	Partial, plant species diversity lower than target	Partial recovery over 3-14 years	Medium	No assessment of target microbial communities	
Soils: Wetlands	SOM, bulk density, CEC, nutrients and chemicals	Drained		Partial	Although <10 years for plant biomass and wildlife usage some soil properties critical for water quality functions take decades or centuries to reach natural reference levels. In top 5cm of soil SOM, bulk density and CEC achieved <50% of reference levels 50 years after restoration began. rate of soil development slow for first 14 years then increased,		role of different successional phases. Degree of openness in each system, connectivity with external sources, In hydrologically open systems (reverie or tidal marshes) external inputs of mineral sediment and organic particles may act to subsidise wetland. High	

							rates of soil development in salt marshes. Studies into use of soil amendments to jump start soil development. Initial addition of topsoil increases biomass growth, CEC, soil moisture, water-holding capacity, P sorption and denitrification in freshwater wetland soils. Conflicts in degree of success though.	

Appendix 1g: Coasts

Asset/ accounting unit	Targets	Pressure/degree of degradation	Actions taken to restore	Potential for restoration	Time taken for recovery	Ease of restoration	Constraints/issues for restoration	Preliminary costs estimates (see final table)
Coastal dunes and sandy shores	Early successional habitats	Over-stabilisation and eutrophication of dunes, scrub invasion	Turf stripping, remobilisation, deep ploughing, scrapes		5-20 years for semi-fixed dunes, over 40 years for fixed dunes, some vegetation colonisation within 3 years, up to 40 years for successionally young slack communities	Hard- all require landscaping- initial effort	Sand loss, study length not long enough, studies not documented	Between £3,600 and £7800 ha, presumably dependent on action and size of site. IEEP £835 ha
Saltmarsh	Spartina marsh, vegetation	Re-creation of saltmarsh	Managed re-alignment, removal of sea wall to allow tidal ingress, creeks dug to reflect old creek patterns	partial	Vegetation cover is usually established within 5 years - but differs in sp. composition and abundance may differ considerably even after 100 years from habitat creation vegetation composition still not the same	Medium- easy to establish vegetation cover, difficult to restore biological equivalency	Waterlogged soils (Redox) limits germination and retention of some species. Elevation limits species composition and extent. Restoration also limited by amount of land to enable full zonational range of saltmarsh communities.	From £620 to £100 000 per ha mean £33115. Glastir options pay £242.08 per ha for saltmarsh creation and £268.17 for restoration. IEEP £109ha but doesn't include managed re-alignment
Saltmarsh	Invertebrates	Re-creation of saltmarsh	Managed re-alignment, grazing to improve structure for breeding birds would facilitate invert colonisation	Partial	Species richness restored quickly but equivalent composition takes much longer when re-creating, less extreme action restoring degraded communities can result in restoration of invertebrates within 5 years.	Medium: relies on the restoration of vegetation structure and productivity	Differences in vegetation composition	From £620 to £100 000 per ha mean £33115. Glastir pays £242.08 and HLS up to £700 per ha for saltmarsh creation and £268.17 and £140 ha for restoration. . IEEP £109ha but doesn't include managed re-alignment
Saltmarsh	Birds	Restoration of vegetation	Managed re-alignment and Grazing	Full	After 5 years bird communities similar but	Medium	management to arrest vegetation succession required,	From £620 to £100 000 per ha

		structure			not the same as surrounding, densities lower,		invertebrate communities required	mean £33115. Glastir options pay £242.08 per ha for saltmarsh creation and £268.17 for restoration. . IEEP £109ha but doesn't include managed re-alignment
Transitional and Coastal waters	Many studies focuses on benthic invertebrates, also community composition of bacteria, seagrass, macroalgae, Phytoplankton, Fish	Excess nutrient inputs, overfishing,	Nutrient reduction in catchment	partial	Fish can recover with 1-3 years though 1 study no recovery in 22 years, invertebrates >6 years, generally >10 years, bacteria- 2 months, seagrass 10 years, Macroalgae 2 years, Phytoplankton- 15-20 years partial, In general periods of 15-25 years for attainment of the original biotic composition, diversity, and complete functioning	Hard	Estuarine and coastal recovery confounded by contaminants that can be released back into solution when in contact with toxic water causing toxic effects	£195,000 to establish a marine protected area site and approximately £95,000 in annual running costs thereafter (Feilen, 2006)