A Stitch in Time
Pwyth mewn Pryd

An ecosystem services assessment of a conservation project

June 2017

Pembrokeshire Coast National Park Authority

Contents

1 Introduction

1.1 The Convention on Biological Diversity defines an **ecosystem** as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."

1.2 Ecosystems are usually defined in terms of their dominant vegetation or environmental features. Describing the natural world in terms of ecosystems allows us the environment to be scaled to suit. As such, ecosystems can be of any size depending on the question being asked or the decision being made[1].

1.3 The UK National Ecosystem Assessment describes **ecosystem services** as "the benefits provided by ecosystems that contribute to making life both possible and worth living". It classifies services along functional lines into the following categories.

Provisioning services: The products obtained from ecosystems.

For example,

- food
- fibre
- fresh water
- genetic resources

Regulating services: The benefits obtained from the regulation of ecosystem processes.

For example,

- climate regulation
- hazard regulation
- noise regulation
- pollination
- disease and pest regulation
- regulation of water, air and soil quality

Supporting services: Ecosystem services that are necessary for the production of all other ecosystem services.

For example,

- soil formation
- nutrient cycling
- water cycling
- primary production

Cultural services: The non-material benefits people obtain from ecosystems.

For example, through

- spiritual or religious enrichment
- cultural heritage
- recreation and tourism
- aesthetic experience

Ecosystem services
(table from http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx)

1.4 The aim of an **ecosystem services assessment** is to understand the services a defined ecosystem provides and the impact that a policy or project has on the services.

[1]http://www.assembly.wales/Research%20Documents/Ecosystems%20and%20the%20Ecosystem%20Approach%20-%20Quick%20guide-08032012-231338/qg12-0006-English.pdf

1.5 This report describes an ecosystem services assessment of a catchment scale project. The project is *A Stitch in Time - Pwyth mewn Pryd*, which is aimed at controlling three invasive non-native plant species in the Gwaun Valley in Pembrokeshire Coast National Park[2].

2 A Stitch in Time – Pwyth mewn Pryd

2.1 Invasive Non-Native Species (INNS) are species which are not native to an ecosystem and whose spread within it is believed to cause harm. INNS are often spread by human agency, whether deliberately (e.g. the introduction of ornamental species) or inadvertently.

2.2 Plant INNS can alter fire regimes, nutrient cycling, hydrology, and energy budgets in a native ecosystem and can greatly diminish the abundance or survival of native species. INNS are second only to habitat loss in terms of causing global biodiversity decline and the degradation of ecosystem function and productivity.

2.3 INNS have been identified as one of the major drivers of ecosystem degradation in Wales (UK National Ecosystems Assessment, 2011) and the Pembrokeshire Nature Partnership places Himalayan balsam, Japanese knotweed and *Rhododendron ponticum* amongst the priorities for control in the county.

2.4 Williams *et al.* (2010) estimate the cost of removing INNS from agricultural, amenity or built land in the UK as £1.7 billion annually, with an annual cost to Wales of £125 million.

2.5 A number of organisations and individuals are involved with INNS control in Pembrokeshire and the Pembrokeshire Coast National Park, but the approach is often piecemeal. For example, due to land ownerships, treatment may not eradicate the target species at a particular site, only control it up to a certain boundary. Such containment efforts imply indefinite treatment costs and, by leaving a source of infection, do not necessarily prevent species spread to new areas. Systematic eradication (or near-eradication) from a defensible area is the most cost-effective solution in the long term, as management is reduced to preventing or treating any re-infestation.

2.6 Pembrokeshire Coast National Park Authority's (PCNPA) *Stitch in Time - Pwyth mewn Pryd* project, supported by the Sustainable Development Fund (SDF), sought to undertake control on a whole catchment basis of three priority INNS (Japanese knotweed, Himalayan balsam and *Rhododendron ponticum*) focussed on the Gwaun Valley, Pembrokeshire. The objectives were to:

- Develop a locally-adapted, catchment-based, invasive species control model, applicable in the National Park and wider Pembrokeshire, in even the most environmentally-sensitive areas.
- Map and reduce in extent of invasive species in the Gwaun valley catchment.
- Increase agency and individual/community awareness of and capacity to manage key invasive plant species.

[2] A report of the project can be found at: http://www.pembrokeshirecoast.org.uk/Files/files/Stitch%20in%20Time%20project/SiTEoP.pdf

- Document the project online as a reference resource, to include approaches to engagement with communities and partner organisations, invasive species survey, mapping, identification of transmission routes, treatment and lessons learned.

The Gwaun catchment in North Pembrokeshire

2.7 The project received approval for £25,318.25 of SDF funding in 2014 and ran from January 2015 to August 2016. PCNPA provided match funding of £6,000. Natural Resources Wales contributed £5,000 during the project. The actual drawdown of SDF was £24,140.45.

2.8 A post of Invasive Non-Native Species Project Coordinator post (2 days per week) was created within PCNPA to deliver the project. Volunteer time was an essential element of the project, with almost 141 person days contributed, plus almost 52 days of officer time, which together totalled £16,615.53 of in-kind contributions at the approved rates. The Project Coordinator accumulated more than 100 unpaid hours, 89 of which were subsequently included as an in-kind contribution.

2.9 The project has mapped and achieved a reduction in the extent of the three target species. Control of the three target species (and, where required, general vegetation clearance for access) was undertaken by volunteers, landowners, PCNPA staff and other partner organisations. Contractors were involved in Japanese knotweed and *Rhododendron* control. The project established survey and treatment methods although it was recognised that eradication would require a longer term investment of resources and time.

2.10 PCNPA funded a 15 month project extension to maintain project continuity while external funding bids were being prepared. In April 2017 the project received a further £100,000 from Welsh Government.

2.11 This report is intended to inform subsequent project phases and to determine the benefit and limitations of ecosystems services assessment in relation to the project to date.

3 A profile of the Gwaun catchment

3.1 The SDF-funded project phase focussed on the Gwaun Valley catchment, covering 4,546 hectares. Direct ecosystem service beneficiaries include the Cwm Gwaun community (approximately 250 people), many of whom rely on the integrity of the land and appearance of the landscape for income from agriculture and the visitor economy. Much of the catchment is privately owned.

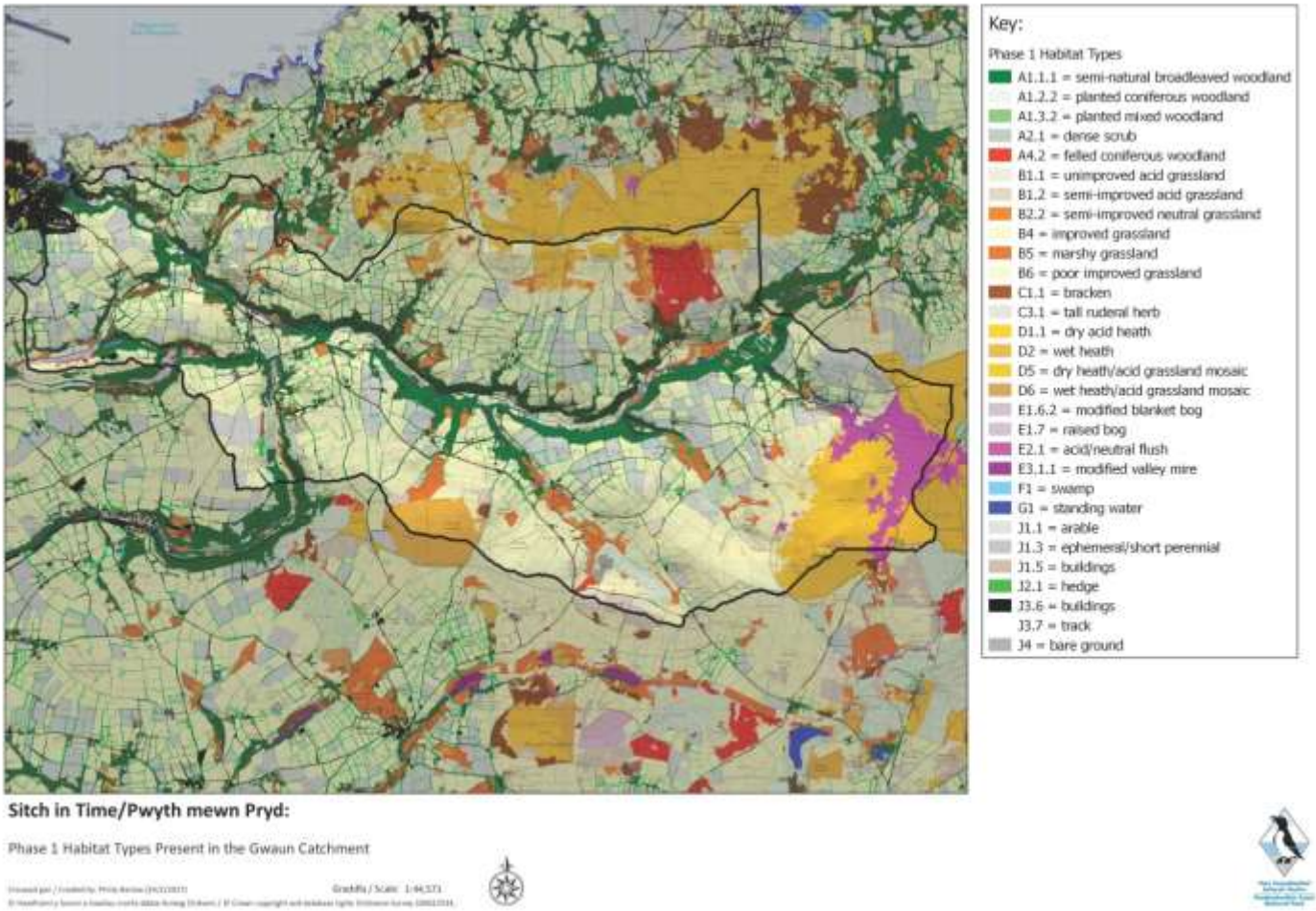
3.2 PCNPA owns or leases a number of sites (predominantly woodland) for conservation and recreation and manages rights of way within the National Park area. Natural Resources Wales has management influence over designated sites. Pembrokeshire County Council has responsibility for some sites, transport routes maintenance and Council-managed access. There is a disused Dŵr Cymru Welsh Water treatment works in the catchment.

3.2 The catchment also includes the River Aer headwater within Trecwn Valley, under the management of Renewable Development Wales. This area has additional strategic importance for INNS (which are present at Trecwn) as it includes headwaters of the Eastern Cleddau.

3.3 The Phase 1 Habitat Classification is a standardised system to record semi-natural vegetation and other wildlife habitats. The catchment has the following Phase 1 profile[3]:

- 61% improved grassland
- 12% semi-natural broadleaf woodland
- 8% dry acid heath
- 4% hedges
- 3% marshy grassland
- 2% wet heath
- 2% planted coniferous woodland
- 2% acid neutral flush
- 1% bracken
- 1% dry acid heath
- 1% semi-improved neutral grassland
- 1% semi-improved acid grassland
- 1% standing water

[3] excludes 171ha of felled woodland, tracks, buildings and unresolved data.



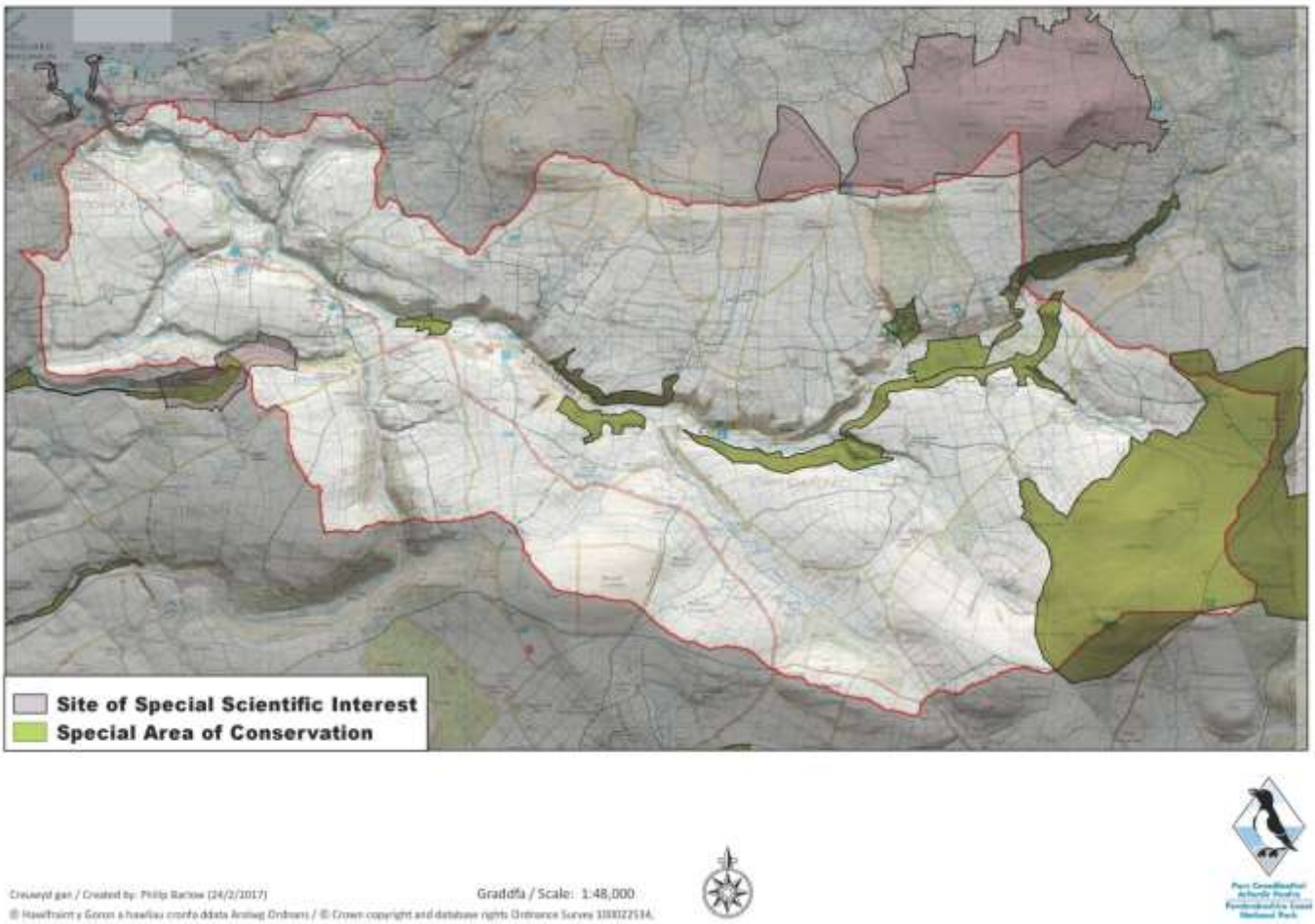
Phase 1 Habitat types present in the Gwaun catchment

3.4 The catchment includes the following woodlands (136ha):

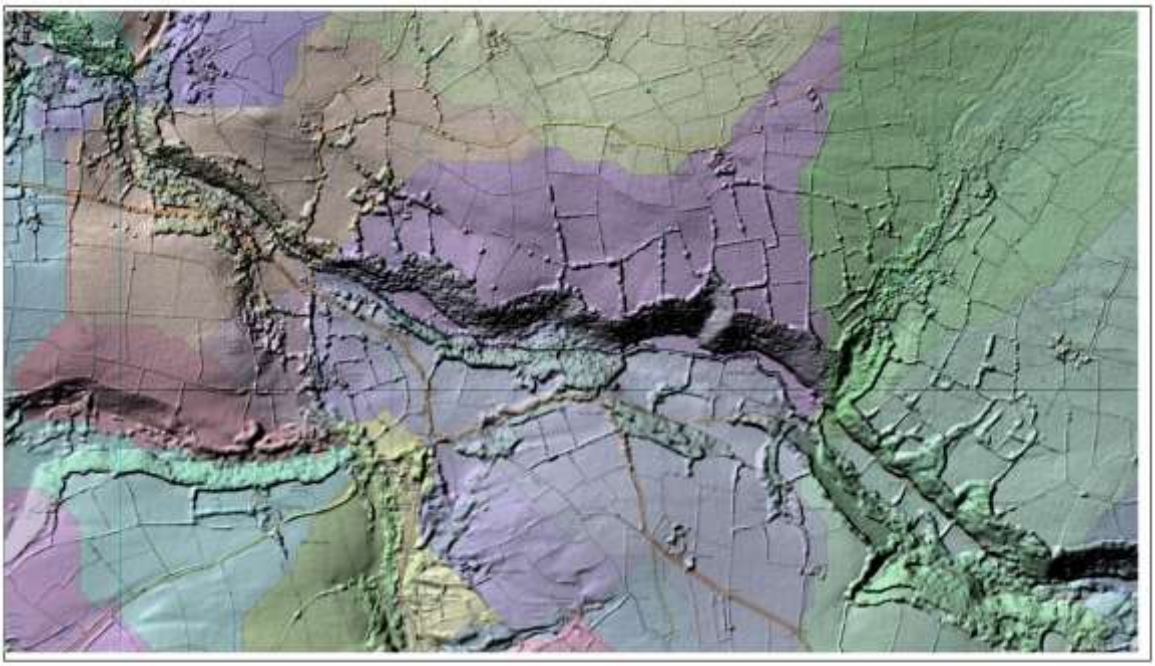
- Allt Garn Site of Special Scientific Interest, Ancient Semi-Natural Woodland *
- Coed Kilkiffeth and Allt Clyn Sites of Special Scientific Interest, Ancient Semi-Natural Woodland *
- Allt Pontfaen Site of Special Scientific Interest, Ancient Semi-Natural Woodland *
- Allt Pengegin Ancient Woodland Site (ancient woodland is land that has been continuously wooded since at least 1600)
- Sychpant Site of Special Scientific Interest, Ancient Semi-Natural Woodland*
- Coed Pentre Ifan, restored Planted Ancient Woodland Site, adjacent to Tycanol National Nature Reserve*

*part of the North Pembrokeshire Woodlands Special Area of Conservation

3.5 The catchment includes parts of the Preseli Special Area of Conservation, Mynydd Preseli Site of Special Scientific Interest and Carn Ingli Site of Special Scientific Interest. Local Biodiversity Action Plan species include lichens, dormouse, bats, marsh fritillary and damselfly species.



Special Areas of Conservation and Sites of Special Scientific Interest in the project area



Half-drainage basins in a section of the Gwaun Valley

Half-drainage basins in a section of the Gwaun Valley

3.6 Watercourses are a major dispersal pathway for INNS. Catchments, and sections of catchments, are therefore an appropriate scale at which to work. Geographic information systems (GIS) enabled the project to take a tactical approach within the catchment, based on stream order and drainage basins. Essentially, this means working from the top of a drainage unit down and from the outside in as the most cost-effective way to protect the largest area and the most ecologically-sensitive parts of the catchment, while minimising reinfection risk along watercourses.

4 Ecosystem services deriving from the principal habitats

Provisioning services

4.1 Rivers, streams, lakes and wetlands support a diverse range of species essential for maintaining ecosystem health, provide drinking water and contribute to human enjoyment through leisure and amenity. Watercourses and wetlands are important for the sustenance of other ecosystems. The Afon Gwaun has no commercial fishing and little recreational although trout are present and sea trout may have used the river in the past.

4.2 Semi-natural grasslands in the catchment mostly lie within farming systems (dairy/beef/sheep) but are distinguished from improved grasslands by lack of recent cultivation, re-sowing or heavy fertilisation, and lower-intensity management. They are species-rich and support a range of pollinators.

Regulating services

4.3 Freshwater systems help to control runoff from the land to rivers, floodplain inundation, groundwater recharge and water quality. These processes are vital for the regulation and supply of water, nutrients, energy flows, solutes, sediments and migratory organisms. Freshwater systems remove and dilute pollutants and capture carbon. They are therefore critically important in supporting the functioning of social and economic systems and the ability of humans and other species to adapt to climate change.

4.4 Grasslands provide climate regulation through sequestration and storage of carbon and other greenhouse gases. They help the purification of pollutants and storage of water. Grasslands can closely interact with wetland systems (in particular, water meadows which were traditionally managed so that they stored seasonal floodwaters). The positive management of enclosed farmland is important to help safeguard against soil loss, to reduce impacts on water quality from pollution and siltation and to address localised flooding.

4.5 Woodlands provide timber, are a valued recreational resource, help to regulate climate stress at a local level, provide carbon sequestration, regulate water flow, safeguard soils and improve air quality.

4.6 Upland habitats play important roles in water regulation and purification (e.g. storing water reducing flooding downstream and maintaining river base flows during periods of

drought), and in carbon storage and carbon sequestration. Upland habitats are amongst the most species-rich habitats in the UK.

Supporting

4.7 Woodlands play a major role in pollination, soil formation and stability, nutrient cycling, water regulation and cycling and oxygen production, all of which are crucial in supporting our health and well-being. Woodlands and scrub play key connectivity roles; oak woods are the most species-rich habitat in the UK, home to UK and European protected species and a range of pollinators for example.

4.8 Semi-natural enclosed farmland is a distinctive landscape in which plants, animals and other organisms live and through which they travel. Hedges provide physical landscape connectivity; those with a diversity of native woody species e.g. ash, hazel, holly are generally more species-rich with a good bottom flora.

Cultural

4.9 The Gwaun Valley community (approx. 250 people) has a unique culture and the majority are first language Welsh speakers.

4.10 Rivers and streams provide a sense of place, defining specific landscapes, and support 'charismatic' protected species such as otter.

4.11 Enclosed farmland supports functioning of social and economic systems in a number of ways, being a focal point for relationships within and between rural communities.

4.12 Uplands are archaeologically and historically rich, inspirational, and contribute to Wales' distinctive landscapes and national identity. People are more likely to identify mountains and moors as the places they would like to visit more often for recreation. There is extensive access to the coast and to land of high nature conservation value and high scenic value. There are three Landscape Character Areas of relevance to the project boundary (Annex 1).

6 Impacts of the target species on ecosystem services

6.1 Each of the target species outcompete native species, degrade commercial land potential and compete for pollinators from native species. Untreated, the cost of control for each becomes cumulative (NRW, 2016). The target species also have plant-specific impacts.

Impacts of Himalayan balsam

Impact on provisioning services	Promotes soil erosion along riparian zone, increasing nutrient rich sediment entering aquatic environment which could impact catchment water quality; impacts on spawning fish.
Impacts on supporting services	Diversity of primary production species (photosynthesis) is reduced due to monoculture; habitat loss/ fragmentation impacts genetic diversity reducing overall site, landscape/catchment resilience. The Poppit Himalayan balsam eradication project noted over 90 species recolonising a dense balsam stand covering 30 acres. Modification of nutrient regime. Below and above ground disruption of soil formation, communities and composition.
Impact on cultural services	Restricts access to forage sites - berries, timber, freshwater fish food sources. Decreases aesthetic value of landscape. Impacts on cultural heritage e.g. condition of monuments, ancient woodland. Prevents access for recreation activities (fishing, walking) which could impact tourism. INNS spread/control may lead to disputes within communities.

Impacts of Japanese knotweed

Impact on regulating services	Reduced carbon sequestration potential of other species. Habitat alteration due to increase in annual rainfall reducing stability, increasing erosion, increased sedimentation in water environment invaded sites (Kurose et al 2006).
Impacts on supporting services	Diversity of primary production species (photosynthesis) is reduced due to monoculture; habitat loss/ fragmentation impacts genetic diversity, localised extinction reducing overall site, landscape/catchment resilience. Modification of nutrient regime, homogenisation of soil conditions in invaded landscape at site scale (Dassonville et al 2008). Novel Weapon Hypothesis - allelochemicals produced, may remain in situ after control/eradication (Widenhammer and Callaway, 2010. Understory devoid of vegetation. Below and above ground disruption of soil formation, communities and composition.
Impact on cultural services	Restricts access to/existence of forage sites - berries, timber. Increased sedimentation may impact freshwater fish spawning capability. Decreases aesthetic value of landscape. Impacts on cultural heritage e.g. condition of monuments, ancient woodland. Prevents access for recreation activities (fishing, walking) which could impact tourism.

	May compromise social relations and community cohesion due to impacted livelihoods, costs of control and difficulty of achieving integrated control. Degradation of hard standing structure overtime Kurose et al 2006). Devaluation of property and mortgage refusal.

Impacts of *Rhododendron*

Impact on provisioning services	Livestock death by ingestion. Host of diseases and pathogens such as *Phytophora* facilitating wider catchment spread through disturbance and airborne dispersal threatening resilience and prosperity of ecological and commercial woodland. Mad honey disease (from species common in Black Sea area)
Impact on regulating services	Invaded sites may have lower carbon sequestration potential. Erosion, sedimentation and increased run off.
Impacts on supporting services	Modification of nutrient regime impacting soil formation and soil health increasing acidity and reduction in soil communities such as earthworms. Invasions into oak and holly woodland inhibit woodland generation. Invasions into lowland heath vegetation and soils changed enormously (Manchester and Bullock, 2000)
Impact on cultural services	Impacts on cultural heritage e.g. condition of monuments, ancient woodland. Prevents access for recreation activities (fishing, walking) which could impact tourism.

7 Infestation, treatment extent and effects

7.1 The total extent of Himalayan balsam, Japanese knotweed and *Rhododendron ponticum* is 28 hectares. The coincidence of each of the target species with Phase 1 habitat types was determined using Quantum GIS.

7.2 The habitat types with the most instances of the three target species are:

1. Semi-natural broadleaf woodland
2. Improved grassland
3. Watercourses and standing water
4. Hedge
5. Buildings
6. Marshy grassland
7. Poor improved grassland
8. Dense scrub
9. Semi-natural coniferous woodland
10. Semi-improved neutral grassland

7.3 The ranking does not seem to be a simple function of habitat extent (for example there is five times more improved grassland than broadleaved woodland in the project area).

7.4 Approximately 55% of INNS records identified during the project received treatment during 2015 and or 2016.

Himalayan balsam

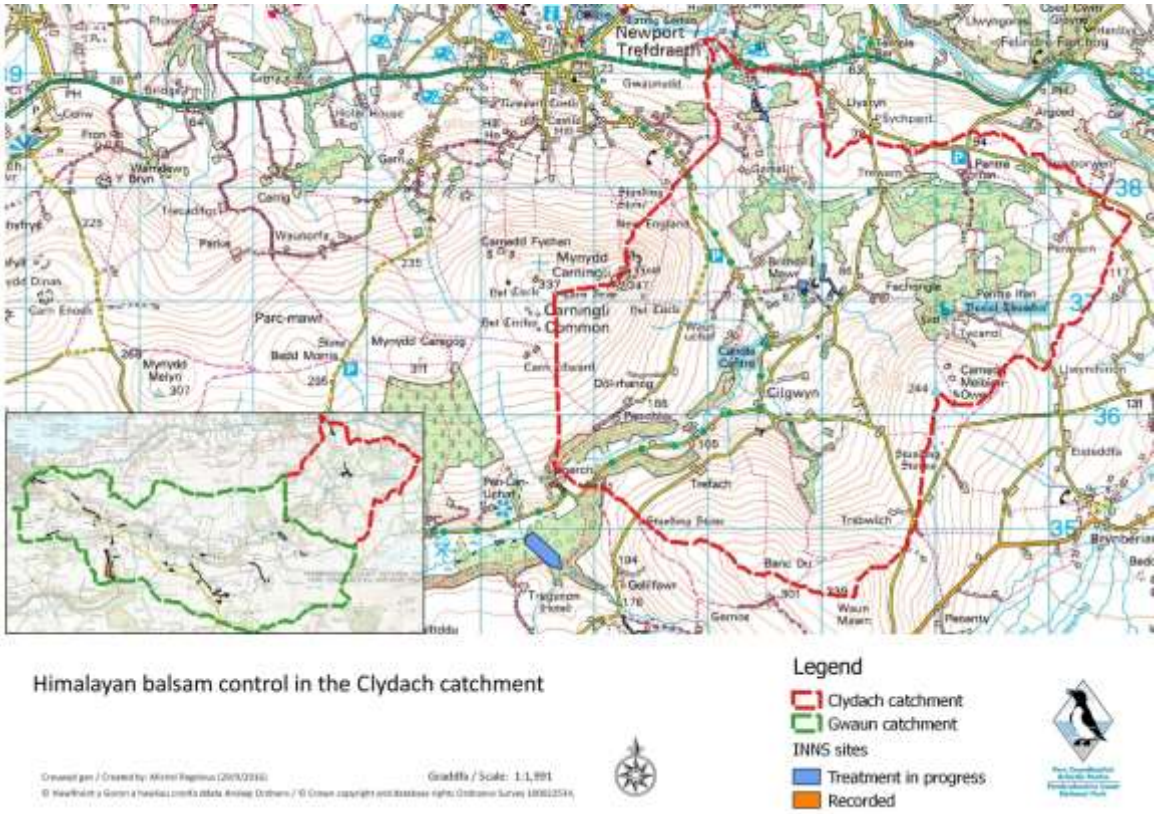
7.5 The project recorded approximately 30 instances of Himalayan balsam within the catchment covering a total land area of approximately 4.5ha. Himalayan balsam was found to have formed monocultures in springs, ditches and tributary banks and has colonised farm land (some with conservation value) at tributary sites feeding the Afon Gwaun.

7.6 Liaising with existing projects and groups within Pembrokeshire was key to identifying efficient methods of control with recorded success locally. Meetings with Gill Wisloki (Cymdeithas Llandudoch), the project coordinator for Himalayan balsam control initiatives at Poppet and at Cemaes Head (SDF funded) - was instrumental to advising on best practice in terms of Himalayan Balsam control. References are included at the end of this report.

7.7 Effective control took place on approximately 3.5ha of sites identified with source populations. The project has achieved a reduction from thousands of stems to hundreds at target sites, allowing for example the re-colonisation of native plant species such as the nettle family (an important invertebrate life cycle plant) and more generally increasing the local diversity and abundance of native flora. Himalayan balsam control helps prevent bank destabilisation and the consequences of increased sedimentation. Local site balsam seed banks will have been reduced, further reducing the numbers of plants able to colonise a local habitat as well as removing wider catchment source populations.

7.8 Some strategic Himalayan balsam sites have been adopted by the Friends of the Pembrokeshire Coast National Park. Others have been included in PCNPA's forward work programmes and those of partner organisations and volunteer groups. Landowners have a better understanding of Himalayan balsam spread and control. Effective eradication in the catchment may be achievable by 2019.

7.9 The Project Coordinator worked with members of the Newport Paths Group to create a catchment strategy of volunteer and contractor control works on the headwater system of the Clydach valley (adjacent to headwaters of the target catchment and a risk to it), assisted by a financial contribution by Natural Resources Wales.



Main map: The Clydach catchment (red outline)
Inset map: Clydach catchment (red) and Gwaun catchment (green)

7.10 Pembrokeshire Rivers Trust, Cymthedias Llandudoch, Keep Wales Tidy, PCNPA and Natural Resources Wales all contributed to the creation of a practical advice leaflet for Himalayan balsam control strategies. Leaflet planning and draft creation was undertaken throughout the duration of the project. The leaflet has been translated and published ready for the 2017 season.

Japanese knotweed

7.11 The project recorded approximately 75 instances of Japanese knotweed within the catchment, covering a total land area of approximately 9 ha. Japanese knotweed control has been focussed strategically on headwater tributaries, on sections of the main Afon Gwaun and in areas identified as an acute risk to catchment biosecurity (e.g. farmyards).

7.12 Stem injection in 2015 produced excellent results with knotweed vigour/extent reduced and/or rhizome dormancy evident in 2016. Pulling and drying was used on knotweed growing in river bank substrate during 2016. No regrowth was observed when revisited 14 days later. Treatment at one site was compromised due to flooding in 2015 and a tree fall disturbing knotweed further in 2016.

7.13 The short term local site benefits from Stitch in Time treating Japanese knotweed has been positive in that Japanese knotweed vigour/extent has been reduced and/or entered rhizome dormancy. All Japanese knotweed treatment is a long term (3-6+ years) process of continual treatment and site monitoring. The benefit of targeting this species within

the catchment is that the long term process has been initiated with some sites receiving at least two treatments during the project (and with the project's extension by PCNPA, at least one more treatment). The post-project focus of resources should be on high priority sites such as headwater tributaries, designated sites and their surroundings.

Rhododendron ponticum

7.14 The project recorded 36 instances of Rhododendron within the catchment covering a total land area of almost 14 ha.

7.15 Control work focussed on the River Aer tributary, which rises at the head of the Trecwn valley. Access was granted to a strategic section of Trecwn valley by kind permission of Valley Management Services Ltd, for Renewable Developments Wales Ltd (RDW), who also made an in-kind contribution to the project of 13 person days. Three hectares of Rhododendron was cut, treated and processed, at Trecwn and at an adjacent site. This part of the project also benefited from additional funding of £5,000 from Natural Resources Wales.

7.16 Coed Cymru and Tir Coed provided input and a remote sensing project (drone survey for INNS) was undertaken by a student of the University of Wales (Annex 2).

7.17 Activities within Trecwn Valley occupied the Project Coordinator in setting up the partnership by delivery of a management report, and contractor paperwork before and during operations. The Project Coordinator was requested by RDW to be present during all contractor and PCNPA woodland team Rhododendron operations (see Table 3).

7.18 The Project Coordinator accumulated more than 100 unpaid hours, many in this phase of the project, which stand as a voluntary contribution to the Stitch in Time project and reflect the strategic importance (two headwaters) of the resulting partnership with Trecwn Valley management.

7.19 Rhododendron is present to a lesser extent at other locations in the Gwaun. These instances are of limited size and it has been possible to include them in the PCNPA Woodland Team's 2016/17 work programme.

7.20 Rhododendron control sites will require post-project monitoring for regrowth and restoration.

8 Impacts of the project on ecosystem services

8.1 The tables below describe the presumed effects of the project on ecosystem services: in each case these are positive. There is a discussion at section 9.

Impact of the project on provisioning services

Services and project impact	Examples	Values and beneficiaries
Impact on water, agricultural produce, wild food, fibre, biochemical, genetic resources and aesthetic resources: **neutral/ slight positive**	Recovered land safeguarded for food/fuel/fibre/conservation uses. Water can be accessed safely no spread, no extraction data available. Presumed improvement in ecosystem function (provision of habitat) indirectly safeguarding supporting services. Safeguard of biochemical and genetic resources.	**Direct and indirect uses, option values** Land owners and managers. Local authorities, charities, NGOs. Local producers and suppliers.

Impacts of the project on regulating services

Services and project impact	Examples	Values and beneficiaries
Impacts on air quality, climate regulation, carbon sequestration, water regulation (flooding, run-off, and therefore natural hazard regulation), pest and disease regulation, soil regulation (erosion control and therefore, water treatment), pollination/biodiversity: **neutral/ slight positive**	Increased stability, reducing erosion potential and river sedimentation, reducing further INNS spread and increasing biosecurity. Restoring capacity of sites to support species richness, increasing and safeguarding GHG sequestering potential and resilience (species multi-functionality rather than monocultures). Pollinators are free of invasive species dominance. Native plants are free of competition for light, space, nutrients and pollinators increasing pollination potential. Initiating disease regulation by reducing host tree (Rhododendron) disease (*Phytophora* species).	**Direct and indirect uses, option values** Land owners and managers. Local authorities, charities, NGOs. Local producers and suppliers.

Impacts of the project on supporting services

Services and project impact	Examples	Values and beneficiaries
Impact on soil formation, primary production, nutrient cycling, water recycling, provision of habitat/biodiversity: **neutral/ slight positive**	Improved soil health and formation, reduced disruption of nutrient cycling (although note concerns with the use of glyphosate on soil). Extinction or exclusion of native species mitigated as increased area for provision of habitat, increases biodiversity, increasing genetic diversity and ecosystem function and ecological process.	**Direct and indirect uses, option values** Land owners and managers. Local authorities, charities, NGOs. Local producers and suppliers.

Impacts of the project on cultural services

Services and project impact	Examples	Values and beneficiaries
Impact on heritage, recreation, tourism, aesthetic value, architecture and social relations: **neutral/ slight positive**	PCNPA footpath survey during 2015 in the Gwaun found that 90% of respondents were walking to 'enjoy the natural landscape, 55% to 'explore the area' and 44% to 'see wildlife'. Generally improved aesthetic value of landscape and important/well used habitats, woodland, stream and river foot paths are biosecure for recreational activities such as walking, exploration and wildlife watching. (Note there is also an appreciation of Rhododendron in bloom.) Architecture, buildings protected from structural degradation. Social relations/community cohesion increased as associated cost and boundary disputes for treatment cost settled.	**Direct and indirect uses, option values** Land owners and managers. Local authorities, charities, NGOs. Local producers and suppliers. Just over 140 volunteer days were contributed to the project. Three volunteers and one contractor received specialist training in safe use of and application of pesticides. Two community groups received equipment through the project to assist with control efforts within the

		project catchment and wider National Park. Members of the Newport Paths Group mapped, liaised with landowners, organised and led Himalayan balsam work parties in the Clydach Valley in 2016. Members of Cymdeithas Llandudoch and the Pembrokeshire Rivers Trust provided expertise throughout the whole project, including input to a Himalayan balsam leaflet.

9 Limitations

9.1 This assessment has attempted to apply a catchment scale, ecosystem approach but there are considerable gaps in the depth of service identification (e.g. the use of water in the catchment by sector) and quantification of ecosystem services and benefits. However the assessment does identify the broad landscape scale set of ecosystem services and implied improvements resulting from the project. For example, other things equal, biodiversity will increase following strategic INNS control, while INNS-related erosion/watercourse sedimentation will decrease.

9.2 INNS projects delivered on a catchment scale could in principle lend themselves to ecosystem services assessment due to the time frames required for INNS control/eradication species (3-10 years). This would require a wide engagement of stakeholders and partners through survey, workshops and consultation and use of ecosystem service mapping. Applying monetary values to services is problematic but has been achieved at larger scales.

9.4 The question however arises: how much additional evaluation weight or project justification would quantification add, especially since the margins of error would be relatively large at this geographical scale. There is recent legislative support[4] for projects that safeguard/restore catchment resilience, tackling INNS, regulate natural hazards, improve water quality and soil/nutrient cycles etc.

9.5 The economic and ecosystem impacts of INNS are well documented and researched in the scientific community, therefore with the wealth of scientific literature available the presence of target species within the Gwaun Valley alone is enough to warrant spending

[4] E.g. section 4 of the Environment (Wales) Act 2016 – in particular (h) take action to prevent significant damage to ecosystems, and (i) take account of the resilience of ecosystems - applies.

on control and prevention due to the known risks and forward costs. Quantification might however help to prioritise projects or focus within a project, or help inform the structure of payments for ecosystem services schemes. Comparison of management costs between local catchments might also be useful to identify project success/failure factors but this need not be an involved process.

10 Conclusions

10.1 Plant species richness is one of the most widely used measures of biodiversity. Primary producers, herbivorous insects and microbial decomposers are important drivers of ecosystem functioning, shown by frequently strong positive associations of their richness or abundance with multiple ecosystem services (Soliveres, 2016).

10.2 Isbell et al (2011) also suggest that high plant diversity is required to maintain ecosystem services and although species appear functionally redundant when one function is considered under one set of environmental conditions, many species are needed to maintain multiple functions at multiple times and places in a changing world.

10.3 Invasive species are widely acknowledged within the scientific community as drivers of biodiversity loss, reducing species richness and resilience of ecosystem functioning within landscapes, degrading land and causing local modifications of soil, nutrient and hydrological cycles disrupting ecosystem services and causing economic cost to society.

10.4 Taking action through projects such as *Stitch in Time – Pwyth mewn Pryd* to identify, prevent, control and eradicate INNS within the Gwaun Catchment will help to promote native vegetation cover, increase habitat area and restore/maintain biodiversity and contribute to catchment resilience and ecosystem service functioning, as well as reducing the inherited cost of control to future generations.

10.5 Site recovery in terms of recolonising plants can be measured and quantified in the short term whereas returning to natural formation and cycling of soils, nutrients and water would require baseline data and long term dedication of resources and monitoring. This would need to include the monitoring of other factors in order that they can be 'subtracted' to isolate project impact. While this exercise is unlikely to be cost-effective or accurate at the project scale, aspects of the approach could help prioritise effort within the project, or help inform the structure of wider payments for ecosystem services schemes.

11 References

Dassonville N. et al. (2008) Impacts of alien invasive plants on soil nutrients are correlated with initial site conditions in NW Europe. Oecologia 157, 1:131-140 http://link.springer.com/article/10.1007/s00442-008-1054-6

Isbell F. *et al.* (2011) High plant diversity is needed to maintain ecosystem services. Nature 477: 199–203. https://www.ncbi.nlm.nih.gov/pubmed/21832994

Kurose D. *et al*. (2006) *Fallopia japonica*, an increasingly intractable weed problem in the UK: Can fungi help cut through this Gordian knot? Mycologist 20(4):126-129

Manchester S. J. and Bullock J. M. (2000) The impacts of non-native species on UK biodiversity and the effectiveness of control. Journal of Applied Ecology, 37: 845–864 http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2664.2000.00538.x/full

Natural Resources Wales (2016) State of Natural Resources Report (SoNaRR): Assessment of the Sustainable Management of Natural Resources: Technical Report

Soliveres S. *et al.* (2016) Biodiversity at multiple trophic levels is needed for ecosystem multifunctionality. Nature 536 (7617):456-9 https://www.ncbi.nlm.nih.gov/pubmed/27533038

UK National Ecosystems Assessment (2011) UK National Ecosystems Assessment Technical Report. UNEP-WCMC, Cambridge. http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=ryEodO1KG3k%3d&tabid=82

Weidenhamer, J.D. and Callaway, R.M. (2010) Direct and indirect effects of invasive plants on soil chemistry and ecosystem function. J Chem Ecol 36(1): 59-69 https://www.ncbi.nlm.nih.gov/pubmed/20077127

Williams, F. *et al.* (2010) The economic cost of invasive non-native species on Great Britain http://www.cabi.org/VetMedResource/ebook/20123122024

Annex 1 – Landscape Character Areas (LCAs) of relevance to the project boundary

	Visual and Sensory Characteristics	Historic and Cultural Characteristics
LCA 22 Mynydd Carningli	The Mynydd Carningli is a relatively small yet distinctive area characterised by open moorland and heath, with rocky summits and scree slopes evident on the higher parts. As with the Preseli Hills, the extensive tracts of open moorland on Carningli give an exposed and mountainous feel to the landscape. Conifer plantations are also present, forming incongruous features and breaking the skyline in some places, with a notably discordant effect on the long curves of the summits punctuated by rocky outcrops. The upland area affords wide-ranging views across to the neighbouring Mynydd Preseli - with which there is a strong visual relationship - and along the coast.	There are Prehistoric standing stones, settlements and field systems, Medieval and post-Medieval structures and buildings of national significance. This archaeological wealth has led to the inclusion of part of the eastern section of this LCA - Carningli Common, Mynydd Carregog and the land sloping northwards down to Newport - within the Newport and Carningli Registered Landscape of Special Historic Interest in Wales. Extensive 19th and 20th century rectilinear enclosure of common land is evident on the southern flank of the mountain block. The boundary between cultivated land and moorland on the northern fringe, however, appears to have changed little since the early 19th century.
LCA 26 Cwm Gwaun/Afon Nyfer	A series of narrow enclosed and sheltered wooded valleys, overlooked by the Preseli hills, which provide a strong sense of place and accentuate the incised nature of these valleys. They are densely wooded valleys with small agricultural fields, often bounded by overgrown hedges, and there is rough grazing land on the upper valley fringes. The woodland blocks are composed of deciduous and mixed deciduous/coniferous species.	This LCA includes a very small part of the Preseli Registered Landscape of Outstanding Historic Interest in Wales. In addition, a small part of the LCA lies within the Newport and Carningli Landscape of Special Historic Interest in Wales, notably for the presence of Neolithic tombs in the vicinity of Nevern. There are Iron Age forts, Medieval and post-Medieval buildings and structures of national significance. The valley supports a traditional Welsh speaking community, and there is a real sense of community amongst local families that have lived in the valley for many generations and have retained aspects of Welsh rural life which date back centuries.
LCA 28 Mynydd Preseli	The Mynydd Preseli is a distinctive upland area characterised by open moorland and heath with rocky	The unenclosed moorland contains nationally important features, including Iron Age Hill forts, Round

	summits and scree slopes evident on the higher parts. Conifer plantations are also present, particularly on the southern flanks. The upland area affords wide-ranging views across to the neighbouring Mynydd Carningli, and along the coast.	Barrows and Deserted Settlements. This archaeological wealth has lead its designation as the Mynydd Preseli Registered Landscape of Outstanding Interest in Wales. Much of the hill area is common land - 19th & 20th century enclosure of common land is evident on the southern flank of the mountain block. The boundary between cultivated land and moorland on the northern fringe, however, appears to have changed little since the early 19th century. The rectilinear field shapes were formed following enclosure of common land.