Cyfoeth Naturiol Cymru
Natural Resources Wales

Review of the Wider Biodiversity and Ecosystem Benefits of Great Crested Newt Designated and Mitigation Sites, with specific reference to North East Wales

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Amphibian and Reptile Conservation Trust

Report No.344

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Report series: NRW Science Report
Report number: 344
Publication date: March 2021
Contract number: 20398621
Contractor: Amphibian and Reptile Conservation Trust
Contract Manager: Matthew Ellis

Title: Review of the Wider Biodiversity and Ecosystem Benefits of Great Crested Newt Designated and Mitigation Sites, with specific Reference to those in North East Wales

Author(s): K Haysom, D Driver, and J Foster

Technical Editor: M.A.R. Ellis
Peer Reviewer(s)
Approved By: Dr E Halliwell
Restrictions: None

Distribution List (core)

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Acknowledgements

The authors are grateful to:

The late Elizabeth Howe (NRW), to whom this report is dedicated, for inspiration and advice. Estelle Bailey, Chief Executive at Berks, Bucks and Oxon Wildlife Trust (BBOWT) for granting permission to reproduce information derived from work on ecosystem services undertaken by BBOWT, including the Kintbury Newt Pond case study. Kate Wilson (Wild Ground) and Mandy Cartwright (ARC) for information relevant to the Lane End, Buckley case study. Steve Spode for information on Welsh Government perspectives on natural capital. Matt Ellis (NRW) for information and enthusiastic advice. Liz Halliwell (NRW) and Nick Thomas (NRW) for comments on a previous draft report.

Recommended citation for this volume:

KA Haysom, D Driver, and J Foster. 2021. Review of the Wider Biodiversity Ecosystem Benefits of Great Crested Newt Designated and Mitigation Sites, with specific Reference to those in North East Wales. NRW Science Report Series. Report No: 344 pp 58, Natural Resources Wales, Bangor

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Cydnabyddir yn gynyddol bod amgylcheddau naturiol yn bwysig nid yn unig i'r rhywogaethau planhigion ac anifeiliaid sy'n byw yn wyllt, ond oherwydd eu bod hefyd yn darparu buddion uniongyrchol ac anuniongyrchol i bobl ar ystod o raddfeydd. Mae strategaeth gadwraeth fodern wedi esblygu i ymgorffori mwy o bwyslais ar ddeall a chyfathrebu'r manteision ehangach sydd gan natur i'w gynnig i gymdeithas, fel strategaeth ychwanegol wrth gyfathrebu pwysigrwydd cadwraeth natur i'r cyhoedd.

Mae Cyfoeth Naturiol Cymru yn sicrhau bod adnoddau naturiol Cymru yn cael eu cynnal, eu gwella a'u defnyddio'n gynaliadwy, nawr ac yn y dyfodol. Mae ganddo ddyletswyddau o dan Ddeddf Llesiant Cenedlaethau'r Dyfodol (Cymru) 2015 i gyflawni ei weithgareddau yn unol ag egwyddorion datblygu cynaliadwy. Mae hynny'n galw am gyflawni saith nod llesiant, gan gynnwys dau sy'n cyfeirio'n benodol at adnoddau naturiol neu ansawdd yr amgylchedd. Erbyn hyn, mae'n wybyddus fod gan ansawdd yr amgylchedd naturiol ddylanwad eang a phwysig ar sawl agwedd ar les pobl.

Amcan y prosiect hwn oedd nodi'r manteision ehangach posibl i gymdeithas sy'n gysylltiedig â chadwraeth madfallod dŵr cribog a'u cynefinoedd, yn enwedig manteision posibl safleoedd lliniaru sy'n ymroddedig i gadwraeth amffibiaid yn yr hirdymor. Mae'n asesiad rhagarweiniol neu'n astudiaeth gwmpasu. Nod y prosiect oedd: gwerthuso'r rhesymeg dros, a dichonoldeb defnyddio gwasanaethau ecosystemau/dulliau cyfalaf naturiol o ran lliniaru madfallod dŵr cribog a safleoedd dynodedig; nodi manteision posibl sy'n gysylltiedig â madfallod dŵr cribog a'u cynefinoedd a chynnig argymhellion ar gyfer gwaith pellach.

Astudiaeth ddesg ansoddol oedd y prosiect, gan ddefnyddio dim ond dogfennau cyhoeddedig a heb eu cyhoeddi a oedd ar gael yn rhwydd o fewn amserlen fer y prosiect. Ni chasglwyd unrhyw ddata sylfaenol yn y maes. Roedd yr adolygiad llenyddiaeth yn defnyddio adnoddau cyhoeddedig a heb eu cyhoeddi a oedd yn hysbys i'r awduron, ynghyd â chwiliadau am gyfuniadau o eiriau allweddol drwy lwyfannau chwilio rhyngrwyd Google Scholar. Fe wnaethom chwilio am lenyddiaeth berthnasol ar fadfallod dŵr cribog ac amffibiaid cysylltiedig, gan ehangu'r chwiliad i herpetoffawna eraill cyn symud ymlaen i rywogaethau a chynefinoedd eraill, gan gynnwys enghreifftiau nad oeddent yn y DU lle bo angen.

Diffiniwyd rhai cysyniadau allweddol (gwasanaethau ecosystem, cyfalaf naturiol, asesiad o wasanaethau ecosystem, a mathau o asesiad gwasanaeth ecosystem). Archwiliwyd y rhesymeg dros, a'r defnydd o wasanaethau ecosystem a dulliau cyfalaf naturiol i gefnogi cadwraeth natur. Crynhowyd rhai profiadau blaenorol o'r dulliau gweithredu, o ran bioamrywiaeth a chadwraeth rhywogaethau.

Cyrchwyd un ymgais gynhwysfawr flaenorol i adolygu'r dystiolaeth ar gyfer darparu gwasanaethau ecosystem, sef adolygiad o lenyddiaeth fyd-eang gan Hocking a Babbitt (2013). Daeth yr awduron hyn o hyd i dystiolaeth o amffibiaid wrth gyflawni'r pedwar gwasanaeth ecosystem. Roedd y rhan fwyaf o'r ymchwil yn eu hadolygiad yn ymwneud ag amffibiaid digynffon. Er iddynt ddod o hyd i rywfaint o ymchwil ar salamandrau, nid oedd yr un o'r astudiaethau a broffiliwyd yn mynd i'r afael â

madfallod dŵr cribog. Roedd y rhan fwyaf o astudiaethau a ganfuwyd gan yr awduron yn ymwneud â rôl amffibiaid yn y gwasanaethau ategol.

Crynhowyd diet madfallod dŵr cribog. Nid ydym yn ymwybodol o unrhyw astudiaeth sydd wedi meintioli effaith reoleiddiol madfallod dŵr cribog ar unrhyw rywogaeth ysglyfaethus, neu wedi gwerthuso effaith y rhywogaeth ar lif maetholion neu ynni, ond mae'n amlwg bod rhyngweithio rhwng rhywogaethau priodol yn bodoli, ac mae'n rhesymol rhagdybio bod rhywfaint o gyfraniad yn debygol.

Archwiliwyd gwasanaethau diwylliannol sy'n cael eu darparu gan fadfallod dŵr cribog a madfallod eraill. Roedd y rhain yn cynnwys cyfeiriadau llenyddol (gyda'r enghraifft fwyaf adnabyddus mewn stori glasurol i blant gan Beatrix Potter). Mae madfallod hefyd yn ymddangos mewn idiomau ieithyddol, mewn addysg ac yn cyfrannu at werthfawrogiad pobl o fioamrywiaeth yng nghefn gwlad.

Crynhowyd dwy astudiaeth a oedd yn edrych ar y posibilrwydd o ddefnyddio madfallod dŵr cribog fel dangosyddion bioamrywiaeth.

Casglwyd gwybodaeth am y prif gynefinoedd a ddefnyddir gan fadfallod dŵr cribog. Crynhowyd y gwasanaethau ecosystem posibl a gyflenwir pan gaiff y cynefinoedd hyn eu cynnal, eu hadfer neu eu creu.

Cyflwynwyd dwy astudiaeth achos o gyflawni gwasanaethau ecosystem posibl o ganlyniad i gynlluniau cadwraeth madfallod dŵr cribog. Yn y gyntaf, ym mhyllau madfall Kintbury yn Berkshire, crynhowyd canlyniadau archwiliad o wasanaethau ecosystem posibl ar y safle a gynhaliwyd yn flaenorol gan Ymddiriedolaeth Bywyd Gwyllt Berkshire, Swydd Buckingham a Swydd Rydychen. Roedd yr ail yn canolbwyntio ar ddarparu gwasanaethau posibl gan warchodfa natur Lane End ger Bwcle yng ngogledd-ddwyrain Cymru, a oedd yn safle lliniaru ar gyfer datblygiad tai. Daethpwyd o hyd i wasanaethau posibl o ddisgrifiad o'r cynefinoedd a grëwyd, a chofnodion o weithgareddau a gynhaliwyd a rhywogaethau bywyd gwyllt eraill.

Argymhellir gwaith pellach.

Executive Summary

It is becoming increasingly recognised that natural environments are important not only to the plant and animal species that occur in the wild, but because they also deliver direct and indirect benefits to people at a range of scales. Modern conservation strategy has evolved to incorporate greater emphasis on understanding and communicating the wider benefits that nature brings to society, as an additional strategy in communicating the importance of nature conservation to the public.

Natural Resources Wales (NRW) has duties under the Wellbeing and Future Generations (Wales) Act 2015 to carry out its activities in accordance with the principles of sustainable development. This requires the delivery of seven well-being goals, including two that explicitly refer to natural resources or quality of the environment. Quality of the natural environment is now understood to have a wide-ranging and important influence on many aspects of human well-being.

This project aimed to identify the potential wider benefits to society associated with the conservation of greater crested newts and their habitats, especially the potential benefits of mitigation sites dedicated to the long-term conservation of amphibians. It is a preliminary assessment or scoping study. The project aimed to: evaluate the rationale for, and feasibility of applying ecosystem services/natural capital approaches to great crested newt mitigation and designated sites; identify potential benefits associated with great crested newts and great crested newt habitats and provide recommendations of areas for further work.

The project was a qualitative desk-study, using published and unpublished documents that were readily accessible within the short project timeframe. No primary data were collected in the field. The literature review drew on published and unpublished resources known to the authors, supplemented with searches for combinations of keywords through the Google Scholar internet search platforms. We searched for relevant literature on great crested newt and related amphibians, broadening the search to other herpetofauna and progressively to other species and habitats, including non-UK examples where necessary.

Some key concepts (ecosystem services, natural capital, ecosystem services assessment, and types of ecosystem service assessment were defined. The rationale for, and use of, ecosystem services and natural capital approaches to support nature conservation was examined. Some previous experiences of the approaches with regard to biodiversity and species conservation were summarised.

We accessed one previous attempt to review comprehensively the evidence for ecosystem services delivery, a review of global literature by Hocking and Babbitt (2013). These authors found evidence for delivery of all four ecosystem services by amphibians. Most research in their review related to anurans. Although they found some research on salamanders, none of the studies profiled addressed great crested newt. The largest number of studies found by these authors related to the role of amphibians in the supporting services

The diet of great crested newt was summarised. We are not aware of any study that has quantified a regulatory effect by great crested newts on any prey species, or evaluated the impact of the species on nutrient or energy flow, but it is evident that appropriate species interactions exist, and it is reasonable to presume that some contribution is likely.

Cultural services delivered by great crested newts and other newts were explored. These included literature references (most recognisably within a classic children's story by Beatrix Potter. Newts also feature within the English language, in education and contribute to people's appreciation of biodiversity in the countryside.

We summarised two studies that explored the potential application of great crested newts as biodiversity indicators.

Information on the main habitats used by great crested newts was compiled. The potential ecosystem services delivered when these habitats are maintained, restored or created were summarised.

Two case studies of potential ecosystem services delivery resulting from real-world conservation for great crested newt conservation were presented. The first, Kintbury Newt Ponds in Berkshire, summarised the results of an audit of potential ecosystem services at the site that was undertaken previously by Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust. The second focused on potential delivery of services by the Lane End nature reserve near Buckley in northeast Wales, which was a mitigation site for a housing development. Potential services were inferred from a description of the habitats created, and records of activities undertaken and other wildlife species.

Recommendations are made for further work.

Introduction

Natural Resources Wales (NRW) has duties under the Well-being of Future Generations (Wales) Act 2015 to carry out its activities in accordance with the principles of sustainable development. In overview, the seven well-being goals that the Act seeks to deliver are: a prosperous Wales; a resilient Wales, a healthier Wales, a more equal Wales, a Wales of cohesive communities, a Wales of vibrant culture and thriving Welsh language; a globally responsible Wales (Welsh Government 2015). Two of these goals explicitly reference natural resources or quality of the environment. A prosperous Wales is described as being “a low carbon society which recognises the limits of the global environment and therefore uses resources efficiently and proportionately (including acting on climate change)”. A resilient Wales is “a nation which maintains and enhances a biodiverse natural environment with healthy functioning ecosystems that support social, economic and ecological resilience and the capacity to adapt to change (for example climate change)”. It could however, be argued that the quality of the natural environment is also a direct or indirect influence on the achievement of several of the other goals including a healthier Wales, a more equal Wales, a Wales of cohesive communities and a globally responsible Wales.

It is becoming increasingly recognised that natural environments are important not only to the plant and animal species that occur in the wild, but because they also deliver direct and indirect benefits to people at a range of scales. In an increasingly urbanised world, mankind’s connectedness to, and dependence on, nature has become less apparent to many people. Traditional conservation arguments, based on the “intrinsic” value of species, while still fundamental, may have less impact on audiences that have more limited personal experience of nature. For this reason, and because steep declines in biodiversity have continued, modern conservation strategy has evolved to place greater emphasis on understanding and documenting the wider benefits that nature brings to society and extending the range of arguments used when communicating conservation messages to the public. In particular, these wider arguments for nature conservation have been directed at those who have the greatest influence on future land use and management. Terms in this modern framework of communication include the concepts of “ecosystem services”, “the ecosystem approach”, “natural capital” and “green infrastructure”. Such terminology adapts the language of economics and the corporate world in order to make consideration of the natural environment as part of decision-making a mainstream government and business activity. That is to say, rather than delegating responsibility for nature solely to traditional conservationists, it shares the responsibility with society in general. Further-more it aims to encourage more holistic thinking, so that decisions that affect land-use or land management are taken with greater visibility given to the potential wider “benefits” and “losses” to society. Environmental economics has developed methods of valuing “assets”, “goods” and “services” derived from nature more tangibly, so that the impact of decisions on nature, and its subsequent impact on people, is not overlooked.

Concepts in the ecosystem services, ecosystem approach and natural capital frameworks have been explored extensively in academia, followed by qualitative and quantitative analyses and the development of tools to support their wider application.

This has led to the principles becoming adopted and applied practically in government, in large corporates, and by the conservation sector and for ongoing dialogue in respect of cross-sectoral adoption e.g. see https://www.naturalcapitalinitiative.org.uk/. In Wales, the concepts are integrated within both the Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015.

While the concepts are clear in overview, the multi-disciplinary nature of the topic can be challenging to address in detail; practitioner networks such as Ecosystem Knowledge Network https://ecosystemsknowledge.net/ exist to demonstrate and share experience of the applications. The approaches usually focus on the impact of land use, management and land-use change on ecosystems and habitats (natural capital), the goods and services that flow from these habitats to people, and the qualitative or quantitative valuation of these goods and services. As they are integral components of ecosystems and contribute to ecological function, it is also valid to extend these approaches to recognising, even quantifying economically, the benefits delivered by species. In order for such frameworks to be applied to species conservation, however, species conservationists must have sufficient understanding of species ecology and distribution to facilitate the identification of potential services delivery either by the species directly, or by the habitats that are maintained, restored or created to support them. Despite the obvious challenges of performing such analyses for species, the field is evolving rapidly, and the need to develop the evidence base of case examples, is resulting in the importance and benefits of species becoming more recognised within this framework e.g. Gascon et al. (2015).

The great crested newt *Triturus cristatus* is protected under the provisions of Section 9 of the Wildlife and Countryside Act 1981 (as amended) and Regulation 43 of the Conservation of Habitats and Species Regulations 2017 (as amended). Sites in Britain and Europe have been designated and/or notified for the species. There is an obligation on Member States of the European Union to monitor and report on the conservation status and trend of this, and all other European Protected Species and habitats that occur in their territory. As a European Protected Species, it is also subject to the provisions of Schedule 1 of the Environmental Damage (Prevention and Remediation) (Wales) Regulations 2009. In assessing the impact of damage on a species or habitat achieving or maintaining favourable conservation status, the services provided by the species or habitat is one of several explicit considerations to be taken into account (see http://www.legislation.gov.uk/wsi/2009/995/schedule/1/made). In addition, under Section 6 of the Environment (Wales) Act 2016, there is a duty on public authorities to “seek to maintain and enhance biodiversity in the exercise of functions in relation to Wales, and in so doing promote the resilience of ecosystems, so far as consistent with the proper exercise of those functions.” This is known as the “biodiversity and resilience of ecosystems duty” and effectively replaces and enhances the duty that previously existed in Wales under Section 42 of the NERC Act 2006. Under Section 7 of the 2016 Act, Welsh Ministers must also “prepare and publish a list of the living organisms and types of habitat which in their opinion are of principal importance for the purpose of maintaining and enhancing biodiversity in relation to Wales”. They must also “take all reasonable steps to maintain and enhance the living organisms and types of habitat included in any list published under this section, and… encourage others to take such steps.” The current Section 7 list includes the great crested newt.

Great crested newts breed in water-bodies and outside of the breeding season forage for invertebrate prey in a broad range of terrestrial habitats (see section 7.5 and Appendix 1). As they utilise both the aquatic and terrestrial environment, and a variety of habitats, this species may be affected by a range of schemes associated with land use or land use change. Implementation of land use or change proposals may require the long-term provision of mitigation, offsetting or compensation areas for the species, subsequently referred to in this report as mitigation areas. In North East Wales, one of the strongholds of the species (Haysom et al. 2018), a network of mitigation sites has been created since 1992, covering both small and large great crested newt populations in both urban and rural areas. These complement the network of statutory sites notified for the species.

Both great crested newt designated and mitigation sites are subject to targeted management for the species. However, these sites also support a range of other species and habitats, which are likely to benefit, now or in the future from the protection and management of such areas. Furthermore, these sites may contribute to the local provision of green infrastructure and provide a range of ecosystem services. This project is a preliminary investigation of the potential wider biodiversity and environmental benefits likely to be associated with great crested newt mitigation areas and designated sites, sites that are specifically dedicated for the long term conservation of amphibians.

Aim and Scope of the Project

This project aimed to identify the potential wider benefits to society associated with the conservation of great crested newts and their habitats, in particular the potential benefits of mitigation sites dedicated to the long-term conservation of amphibians.

The project constitutes a preliminary assessment, or scoping study, to examine what evidence is currently available, and predict any benefits that appear likely to flow to society from efforts to conserve great crested newts at mitigation areas and designated sites.

The project was a short-term, qualitative desk-study, using published and unpublished documents that were readily accessible within the project timeframe. No data was collected in the field.

Within these constraints, the project aimed to: evaluate the rationale for, and feasibility of applying ecosystem services/natural capital approaches to great crested newt mitigation and designated sites, identify potential benefits associated with great crested newts and great crested newt habitats and provide recommendations of areas for further work.

Methods

The work was undertaken through a short review of relevant literature. We aimed to find examples of ecosystem services/natural capital literature pertinent to the conservation of great crested newts and their habitats.

The literature review drew on published and unpublished resources known to the authors, supplemented with searches for combinations of keywords through the Google Scholar internet search platforms. The terms used to identify relevant publications were:

> Ecosystem services and [great crested newt; *Triturus**; newt; urodele; amphibian; herpetofauna; species conservation; biodiversity]

Natural capital and [great crested newt; *Triturus**; newt; urodele; amphibian; herpetofauna; species conservation; biodiversity].

We expected that due to the very specific nature of this study, we might find relatively few publications explicitly focused on great crested newt. The approach planned was therefore to focus initially on great crested newt and related amphibians, broadening the search to other herpetofauna and progressively to other species and habitats, including non-UK examples where necessary. Similarly, we aimed to prioritise information derived from studies in Wales, especially north-east Wales, accepting examples from wider UK or other countries where necessary.

Introduction to Some Key Concepts:

To best understand the work undertaken in this contract, it is necessary to understand several widely-used terms, and since use of terminology varies, the context in which they are used in this report.

The ecosystem services framework

The *ecosystem services framework* or *ecosystem services approach* documents the ways in which people derive benefits from nature, or in the very simplest terms "what nature does for us". The information captured resembles what, in ecology, would be termed ecological functions, with an important difference in framing, that the processes are those that benefit people. Awareness and subsequent use of this framework was raised considerably in 2005, with the publication of the Millennium Ecosystem Assessment (MEA 2005) which sought to describe the links between well-functioning natural systems and human well-being. MEA (2005) defined ecosystem services as the "outputs of ecosystems from which people derive benefits". The ecosystem services framework is a way of understanding and measuring the benefits to people that come from nature (Waylen & Blackstock 2014). Academic research in this framework straddles many different disciplines including ecology, geography, spatial modelling, soil, climate, social sciences and economics. There is an emphasis on applied science to influence land-use and management including decision support, with the ultimate ambition being to stem and reverse the degradation of natural habitats and biodiversity loss.

Although it is common to see some terms used loosely and interchangeably, another term the Ecosystem Approach is actually a different concept. Waylen & Blackstock (2014) describe the 'Ecosystem Approach' as a holistic approach that is "a way of doing". According to these authors, the approach has become well-known since the Convention on Biodiversity in 2000, where it was used as a framework for adaptive, ecosystem-based management that is inclusive of, and empowering to people (see http://www.cbd.int/ecosystem). The ecosystem approach defined at the CBD 2000 is founded on 12 Malawi principles (Annex 1).

This report is based on the "ecosystem services framework" because it draws primarily on academic literature to understand the potential functions delivered by sites where great crested newts are conserved, or by the great crested newts themselves, rather than developing new management objectives for those sites through discussion with local stakeholders. Both approaches are, however, potentially relevant to the conservation management of the Welsh landscape generally, and in the formation of conservation sites for great crested newts near urban communities in the context of mitigation for development. The Welsh Government drew directly on the UN CBD Ecosystem Approach in the development of recent environmental legislation (Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015) reflecting an interest in all the benefits ecosystems provide to well-being as well as the intrinsic value of species and habitats (pers. comm. Steve Spode, Head of Ecosystem Management and Implementation, Welsh Government, May 2019).

Natural Capital

Further terms in wide use are “natural capital” and the “natural capital approach”. Natural capital is the “stock” of natural resources such as waters, land, species, air, minerals and oceans. Ecosystem services arise or “flow” from this stock and the flow of ecosystem services depends of the sustainable management of natural capital. The same natural resources are sometimes also referred to as ecological assets. Both terms refer to that part of the natural environment that produces value to people, as opposed to the services, or ecological functions as they benefit people, themselves. In the context of newt mitigation or conservation sites, the term natural capital might be used to refer collectively to habitats such as ponds, grasslands, woodland, hedgerow etc. In contrast, the term ecological services would refer to outputs that benefit people e.g., in this situation, local and global climate regulation including through carbon storage, or regulation of water quality through water filtering or the actions of natural habitats in countering soil erosion.

The evolution and use of the term natural capital relates to Malawi principle number four, the principle of understanding ecosystems in an economic context and internalising costs and benefits. The rationale of the approach is that, by adopting the language of business (“stocks”, “capital”, “assets”), features of the natural environment are made more visible and relevant (“internalised”) by businesses and government. Historically the decisions taken by these sectors, though often impacting on the environment, have taken little account of it, ostensibly because habitat conservation issues were traditionally “externalised” (seen to be the responsibility of other sectors). This is a very active area of work. Prominent actors include the Natural Capital Committee (NCC) (https://www.gov.uk/government/groups/natural-capital-committee), an independent advisory group that has a remit to advise the UK government on the sustainable use of natural capital such as forests, rivers, minerals and oceans and the associated public benefits. NCC was established to advise Defra on the implementation of its White Paper, The Natural Choice, and the achievement of its central objective “to be the first generation to leave the natural environment of England in a better state than it inherited”. NCC advice was for government to develop a 25-year environment plan, subsequently published in 2018 (HM Government 2018). NCC has published a series of annual reports, the latest of which decried the absence of progress towards the ten goals in the 25-year plan, the general further deterioration of the environment and the urgent need to take redressive action (Natural Capital Committee 2019). It has also published guidance on using natural capital approaches in decision making (Natural Capital Committee 2017b) and promoted the use of valuation approaches (Natural Capital Committee 2017a). The Natural Capital Initiative (https://www.naturalcapitalinitiative.org.uk/) has a mission to support decision making that results in the sustainable management of natural capital. It is a partnership of four leading environmental research organisations in the UK (the Society of Biology, the British Ecological Society, the Centre for Ecology and Hydrology and the James Hutton Institute). Two strategic approaches are deployed toward achieving the mission, namely initiating and facilitating cross-disciplinary dialogue and solution sharing among different sectors (specifically academia, policy, business and civil society) and communicating independent, authoritative synthesis and evaluation of the scientific evidence base including. It organises a Natural Capital Summit, Valuing Our Life Support Systems on a three yearly cycle, next scheduled in May 2019.

The central message to the non-environmental sectors is that natural capital underpins all other types of capital and forms the foundations of society, economy and well-being. In order to make these approaches mainstream, and available to practitioners operating outside academia, there has been significant investment in developing approaches and tools. The numerous examples include natural capital mapping exercises (used for example in the South Downs National Park), natural assets registers and natural capital accounts. A pilot of a Corporate Natural Capital Account framework ran in 2015 supported by four large land-owning organisations Lafarge-Tarmac, United Utilities, National Trust and Crown Estates, who each tested the approach on part of their estates (Provins *et al*. 2015). There has also been work on demonstrating the application of economic valuation exercises to specific habitats, locations, or contexts, expanding the breadth of capital and services for which it is possible to attempt valuation, or improving the accessibility of these techniques outside the academic sector. In Wales, references to natural resources within the Well-being of Future Generations (Wales) Act 2015 roughly equate to natural capital, although the term is not used explicitly (pers. comm. Steve Spode, Head of Ecosystem Management and Implementation, Welsh Government, May 2019)

Types of ecosystem service

The Millennium Ecosystem Assessment (MEA 2005) sets out four categories of ecosystem service: provisioning, regulating, cultural and supporting services (Table 1). Each of these categories encompasses a number of different individual services and to bring greater standardisation to activities such as ecosystem accounting, a common international standard for classifying the various services has been developed and adopted, called the Common International Classification of Ecosystem Services (CICES) (see Haines-Young and Potschin 2018).

Provisioning services are services that result in products, most of which are tradeable in traditional markets. Examples include food, fresh water, fibre, genetic resources, ornamental products derived from nature and medicine.

Regulating services are processes in nature that act to control perturbations of natural systems. For example, the regulation of water quality, climate regulation, control of pests and pathogens, pollination, regulation of air quality and erosion control.

Cultural services are spiritual and cultural responses to nature that contribute to human quality of life and well-being. This category is very broad and includes diverse recreational activities, religious, artistic, and spiritual connections to nature. It also includes education, knowledge and psychological and physical health and well-being.

Supporting services are biological processes and physical and functional aspects of ecosystems that underpin the three other categories, for example photosynthesis, nutrient cycling and the formation of soils. Although these are essential to the delivery of all other types of services, exercises to assess or value ecosystem services generally exclude supporting services. This is because assessments aim to avoid double counting.

An important part of the concept of the ecosystem service, is that there should be a human beneficiary; processes that occur without a beneficiary might be termed ecological functions rather than services. Thus assessments of ecosystem services (see section 6.4), often undertaken to guide a decision, attempt to describe and or quantify changes in the type or number of beneficiaries of a service, as well as change in the service itself. So it is relevant to understand whether the "environmental goods" provided are public, private, owned by a single individual or shared among many stakeholders.

Table 1. Examples of the four categories of ecosystem service described in the Millennium Ecosystem Assessment (MEA 2005).

Provisioning services	**Regulating services**	**Cultural services**
Food	Climate regulation	Aesthetics
Fibre	Water quality regulation	Landscape and heritage value
Fuel	Air quality regulation	Recreation and tourism
Water (for drinking, direct use etc.)	Erosion control	Cultural values
Ornamental resources	Pollination	Sense of place
Genetic resources	Biological control of pests and pathogens	Inspiration
Medicinal resources	Blank	Health & well-being
Blank	Blank	Education
Blank	Blank	Scientific knowledge

Supporting services: Photosynthesis, nutrient cycling, soil formation, soil fertility, habitat for wildlife, structural changes.

A further important point in the recognition of societal benefits from nature, is that ecosystems typically provide multiple services. So for example, depending on its geographic location (aspect, soil type, proximity to human settlements etc.), an area of woodland might provide various provisioning services (e.g. timber, wood-fuel), regulating services (e.g. global climate regulation through carbon sequestration and storage, local climate regulation through provision of shade, acting as a wind break; buffering noise pollution, countering soil erosion, contributing to water quality and flood regulation through slowing the flow of surface water and its interaction with water flow below ground) and cultural services (contribution to the aesthetics or the sense of place in an area, recreational space, heritage, health and well-being, education, scientific knowledge) at the same time. It is the task of ecosystem service assessment or valuation exercises to recognise the multiplicity of services delivered by the environment, since many of these benefits are normally taken for granted, and the potential "cost" of their replacement, not factored into decisions affecting land-use change, particularly in relation to new infrastructure or urban development.

Concept and application of ecosystem services assessment

Ecosystem services assessments have been developed, initially as proof of concept, to identify and document societal benefits that arise from nature, and more recently as decision support tools for practitioners, to properly consider the wider consequences of land-use change, particularly urban development or major infrastructure projects. The ecosystem services framework provides a structure against which to weigh the "value" of different land-use states. Although a number of digital tools have been developed to assist these processes (see https://ecosystemsknowledge.net/tool for reviews of a wide range of tools for analysing ecosystem services, natural capital and green infrastructure), the initial stages of qualitative assessments are simple enough to be performed manually. Guidance on the essential steps is provided by Everard and Waters (2013) and McCarthy and Morling (2014). The framework given in the latter text is based on the TESSA system (Peh et al. 2013).

Assessments are generally undertaken in two stages, and are used for the evaluation of two alternative states. The first assessment is termed rapid assessment. The very first step is to set the context (geographical boundary) and objectives of the assessment. It is common practice to identify stakeholders who may have an interest in the proposal; engagement with these stakeholders is a classic means of drawing out an understanding of the potential services, and relative importance of those services, provided in each state. Having defined the boundaries of the area to be assessed in the current and alternative state the type, extent and condition (quality) of habitats present within the boundary is examined. Based on a knowledge of literature, documentary evidence for the site where it exists, and through discussion with stakeholders who are able to provide information on how habitats are used, services flowing from these habitats are identified and listed in each of the two states. These are quantified or ranked in importance. The beneficiaries of each service are identified for each state. Changes in the area of habitat, the services delivered and the beneficiaries of each service between the two states are assessed, summarised and presented.

Why are these approaches advocated for promotion of nature conservation?

The use of these approaches has arisen out of increasing concern about the scale of human impact on the natural world and the repeated failure to meet previous conservation targets to arrest and reverse global declines in habitats and species. Traditional conservation arguments have included a focus on the "intrinsic value" of nature and while these still appeal to a core audience, the use of these additional terms has been developed in order to better connect people who have become more detached from nature, or at least, less aware of the importance of nature in their lives. Encouraging individuals and organisations to recognise nature's role in providing goods and services that people depend on is a tactic to engage wider audiences to conservation, particularly those that control or influence the

management of the large proportion of land in the UK that is privately owned. This strategy has been adopted by UK statutory conservation agencies, and by leading conservation Non-Government Organisation's (NGO's) including Royal Society for the Protection of Birds (RSPB) and other Wildlife Trusts.

Despite the wide adoption of ecosystem services and natural capital approaches to promoting care for the natural world, there remains an active debate on whether their use results in the engagement intended, or whether instead "the commodification of nature" encourages a more exploitative mind-set. A further concern frequently raised by conservationists is that while the approaches highlight the importance of nature in the general sense, it is less clear what it does, and how to use it, for the biodiversity element. For example, in November 2018 the Scottish Policy Group of the British Ecological Society held a debate evening on the theme "*Does a natural capital approach deliver for biodiversity conservation?*" (British Ecological Society Scottish Policy Group 2018). Those concerned with the conservation of individual species, particularly rare species, may feel side-lined by the strategy, because of the practical focus on habitat as the unit at which services are delivered, and also because there are still many aspects of ecosystem function and the roles that even common species play that have not yet been defined. Some conservationists have been optimistic about the framework, particularly about its emphasis on the opportunity to manage landscapes for multiple functions, ecological resilience and the wildlife that underpins this in contrast to narrow focus production systems e.g. Stoate (2011). Several authors have recently considered the pros and cons of these approaches variously from a general conservation perspective, and from the narrower lens of biodiversity and species conservation.

Schröter et al. 2014 synthesised the common arguments for and against the use of the ecosystem services concept, identifying seven recurring criticisms and counter-arguments. The criticisms they listed included that the concept is anthropocentric; that it encourages an "exploitative human-nature relationship"; that application may conflict with the aims of wildlife conservation; that it puts too great an emphasis on economic valuation; that it turns nature into a commodity; and that the definitions used are too vague. In rebuttal, they set out some alternative viewpoints including that the frameworks emphasise society's dependence on nature, that the concepts can be used in complement to and without contradicting biodiversity objectives, that many types of value are given recognition (not purely economic value), that it is also useable for natural benefits that do not have a "market" and that the vagueness of its definitions facilitates and encourages multidisciplinary partnerships.

Mace 2014 considered that the debating positions "nature for itself" or "nature for people" are too simplistic to convey the complexity of the relationship between humans and biodiversity, with a "people and nature" ideology being a better description. Pearce 2016 proposed an alternative framework of advocacy for the conservation of nature bringing both approaches together, and taking account of the level of biological organisation (e.g. gene through to ecosystem level) and spatial extent (local to global) to suggest the most appropriate combination of arguments to apply in different circumstances. Conservation practitioners may have mixed views on the benefit of concepts like natural capital for mobilising conservation efforts in society, but are united that nature is essential for humanity and that the continuing declines of species and populations, make the necessity of addressing this

effectively, ever more pressing (British Ecological Society Scottish Policy Group 2018).

Recognising the inherent challenge of assessing the value of individual species, in ecosystem service assessment approaches, Gascon et al. (2015) reviewed global literature to find examples of species for which benefits have been documented. These authors highlight the undesirability of creating a “sliding scale of species’ value” which fits badly with the concept of each species having “intrinsic value” and which is likely always to fail to quantify or fully recognise the potential contribution of species now and in the future as the environment, and human needs, change. Having identified benefits from even rare species that were until recently unknown, or certainly unexpected, they are strong advocates of taking the precautionary principle in all decisions affecting the future survival of species. Among the functions and species given profile in this review were: the beneficial impact of certain predatory species on plant action with regard to carbon storage; the multiple benefits delivered by burrowing fiddler crabs in mangrove systems (increased soil drainage, reduced soil oxidation, improved water quality, increased primary productivity); complex contributions to biocontrol of crop pests by predators; natural compounds as models for adhesives in challenging locations such as the marine environment; and a newly described catfish with gut bacteria able to digest wood, that may lead to innovations in the paper production industry. An important consideration in the conservation of species assemblages, is the concept of ecological redundancy by which multiple species in an ecosystem contribute to certain functionality; a shift in species composition may lead to a contributor species becoming dominant in future delivery of a benefit under changed environmental conditions.

Harrison et al. (2014) undertook a systematic review of literature to analyse linkages between various biodiversity measures and eleven ecosystem services. They found many positive associations between biodiversity and the delivery of services such as the regulation of water quality and flow, landscape aesthetics and commented on the complexity of interactions within the systems. The review included various species level traits and found that species abundance was important to pest regulation, pollination and recreation. They found few negative associations between biodiversity measures and ecosystem services delivery. Oliver et al. (2015) explored the potential impact of biodiversity loss on ecosystem functional resilience by analysing trends in the frequency of species known to contribute to several key ecosystem functions (decomposition, carbon sequestration, pollination, pest control and cultural values) in British ecosystems. They found significant declines in over four thousand species that contribute to pollination, pest regulation or have cultural value in a forty-year period, but groups that delivered decomposition and carbon sequestration were stable during the same timeframe, leading to a suggestion that prioritisation of conservation interventions also take account of organism contribution to functional resilience.

Finally, Eastwood et al. (2016) analysed case study nature conservation interventions to determine the impact of actions taken to maintain or enhance biodiversity, on wider benefits to society. They deployed expert opinion to make a comparative assessment of ecosystem services delivered by nine pairs of protected and unprotected sites. They found that the protected sites delivered higher levels of ecosystem services than non-protected sites, with the main differences being in the cultural and regulating ecosystem services. The authors were surprised that among

these case-study pairs, there was no consistent negative impact on delivery of provisioning services but they also emphasised the site and context specific outcomes of the interventions. In a much larger (and global) meta-analysis of 89 ecological restoration projects, Rey Benayas et al. (2009) reported that both biodiversity was increased by 44% and ecosystem services by 25% by restoration, but that values of both were lower in restored environments than in ecosystems.

The Case for Ecosystem Services / Wider Benefits Associated with Great Crested Newt and Other Amphibians Species

Services attributed to amphibians

To date, the most comprehensive case for amphibian delivery of essential ecosystem services that benefit human society has been made by Hocking and Babbitt (2014). These authors reviewed international literature covering a wide range of amphibian genera and species and found evidence for amphibian performance of, or a major or indirect contribution to, the delivery of all classes of ecosystem services. The largest number of studies found related to the role of amphibians in the supporting services e.g. by undertaking actions that changed habitats, ecosystem processes or functions. Some of the roles described have only become known due to recent developments in technology, and it is clear that the list of services reported will likely grow as a result of future research. Ominously, Hocking and Babbitt (2014) predicted that amphibian declines may deepen human understanding and recognition of their true contribution, through “natural experiments” as ecosystems change after species are lost.

Hockings and Babbitt are American authors, and although the paper constitutes a substantial international review, geographical coverage is uneven, somewhat weighted towards North American sources, with a notable paucity of European examples. Many of the cases profiled in Hocking and Babitt (2014) were from the tropics, in part reflecting patterns of species richness. At this point in time, the geographic composition of reported ecosystem effects is likely to be biased and be heavily influenced by the location of research activity i.e. it is not yet a true reflection of the spatial distribution of services delivered by amphibians. Neither is it likely to be a true representation of the dispersion of service delivery among amphibian genera. The literature collated by Hocking and Babbitt (2014) was dominated by studies of frogs, toads and to a lesser degree, salamanders. No European newt examples were showcased. It is also likely that the balance of services documented in aquatic versus terrestrial environments, and therefore also among life-stages (eggs, larvae or adults) does not mirror actual distribution, but is an artefact of fashions in research. It is clear that there are presently major gaps in our understanding of the wider benefits to society that have an amphibian association. This is expected to improve as more research is undertaken. Indeed Hocking and Babitt, postulated several mechanisms constituting probable service delivery by amphibians, for which they were unable to find confirmatory literature. This is all indicative of opportunities, and a need for, further research and a strong likelihood that new arguments for species protection and recovery will become available to conservationists, if attention is directed to this topic.

Accepting these limitations, the evidence collated by these authors, of which selected examples are summarised in Table 2, illustrates the likely breadth of effects, and is a useful background for considering the potential wider benefits to society contributed

by the great crested newt in Wales. Some of the examples listed in the table are services that amphibians provide to society, in clear conflict with the future viability of their own populations. This is particularly true of some provisioning services, where a market has been established, especially the trade in amphibians for food. The research cited in Hocking and Babbitt (2014) e.g. Kusrini and Alford 2006; Warkentin et al. 2009; Valencia-Aguilar et al. 2013, documents overexploitation at levels already linked to, or predicted to drive, the decline of wild populations. Some parts of this trade, though technically classifiable as an ecosystem benefit to humans, are nonetheless illegal. Hocking and Babbitt (2014) also identify a market in amphibians for the pet trade. Though these authors classify this as a cultural service, the existing market mechanism and tangible good traded, would lead many other authors to classify this as a provisioning service. Regardless of typography, it is another case of a good that is liable to be over-exploited to the detriment of wild populations; these types of benefits align poorly with conservation messaging, but are unarguably evidence that society has derived economic benefits from certain species, albeit unsustainably. Hocking and Babbitt (2014) also draw attention to the potential future, and largely underexploited, value of naturally produced amphibian chemicals as a model for future medicines; some of those that have already been identified and exploited are noted to have originated from species whose fragile populations have subsequently become extinct.

With regards to regulating services, Hocking and Babbitt were able to point to plausible mechanisms by which amphibians might contribute to suppression of pests and diseases, but the complexity of ecosystems means that there are relatively few examples where this has been demonstrated conclusively in the field. This is an area of research, (for many taxa), where advances in technical approaches look set to expose relationships among species in greater detail in the near future; undoubtedly a challenge is that interactions among species in natural conditions are highly-complex and often context specific. In terms of general nutrient and energy cycling (both of which are supporting services), amphibian behaviour, because it involves a life-history that is dependent on both aquatic and terrestrial environments in different life-history stages, means that amphibians play a role in exchanging energy and nutrients between terrestrial and aquatic habitats.

It was easy for Hocking and Babbitt (2014) to demonstrate amphibian cultural services due to the plethora of examples of different amphibian species in high and low, archaic and contemporary culture. For example, these authors cite Kenneth Grahame's The Wind in the Willows, a classic work of children's literature that features Mr Toad as a leading character (Grahame), but omit the work of an equally well known children's author, Beatrix Potter whose stories included frogs, toads, and an instantly recognizable great crested newt (see below).

Hocking and Babbitt (2014) also fail to include nature appreciation, from casual visits to nature reserves through to participation in citizen science and the involvement of expert volunteers in national (or local) species surveillance activities. In western countries at least, these activities involve considerable numbers of people, provide data in quantities that would be well beyond the scope of what could be afforded through contracting paid researchers, and in the case of nature reserves in remote areas, sometimes draw in important economic benefits through wildlife tourism.

Table 2. Summarised examples of societal benefits attributed to amphibians, selected from a review of global literature published by Hocking and Babbitt (2014)

Service: Provisioning	Provisioning Service: Species	Provisioning Service: Summary description	Provisioning Service: Geographic location	Provisioning Service:Example citations
Food	Various e.g. Mountain chicken *Leptodactylus fallax*	Frog leg consumption. [Hocking and Babbitt 2014 detail examples of heavy trade of frogs for consumption, noting that harvesting from the wild has driven population declines and husbandry in captivity is often associated with disease, poor water quality and poor animal welfare]	Many locations, especially southeast Asia West Indies	Kusrini and Alford 2006; Warkentin et al. 2009 Valencia-Aguilar et al. 2013
Medicine and medical support	*Xenopus laevis* and other species	Human pregnancy testing (historic application)	No geographic area stated	Jensen and Camp 2003

Service: Provisioning	Provisioning Service: Species	Provisioning Service: Summary description	Provisioning Service: Geographic location	Provisioning Service:Example citations
Medicine and medical support	Various including Rhinella jimi, Leptodactylus labyrinthicus, L. vastus.	Traditional medicines Amphibian chemicals as a model for development of western medicines e.g. epibatidine from poison dart frog *Epipedobates tricolor* as painkiller; Gastric-brooding frogs from Australia (*Rheobatrachus* spp., now extinct) for medical understanding of acid reflux and stomach ulcers; amphibian limb and tail regeneration as a model for cell regeneration	Neotropics and throughout the world	Jensen and Camp 2003; Valencia-Aguilar et al. 2013 Cury and Picolo 2006; Calvet and Comollón 2005); Tseng et al. 2010.

Service: Regulation	Regulating Service: Species	Regulating Service: Summary description	Regulating Service: Geographic location	Regulating Service: Example citations
Predation (and competition)	Tiger salamander Ambystoma tigrinum	Suppression of pests and vectors of disease such as mosquito-borne diseases through direct consumption Contribute to control of mosquitoes in ephemeral ponds that cannot support fish	USA	Brodman and Dorton 2006

Service: Regulation	Regulating Service: Species	Regulating Service: Summary description	Regulating Service: Geographic location	Regulating Service: Example citations
Predation (and competition)	Frog Lysapus limellus	Eats flies *(Ephyridae)* that carry neotropical diseases	South America	Valencia-Aguilar et al. 2013
Predation (and competition)	Rhinella arenarum, Leptodactylus latinasus, Leptodactylus chaquensis, Physamaemus albonotatus	Documented to consume arthropod pests of soybean crops	Argentina	Valencia-Aguilar et al. 2013
Influence on pollination and seed dispersal	Various	Proposed mechanism through predation of adult amphibians on arthropods that act as pollinators e.g. flies, butterflies and moths, beetles	No geographic area stated	No reference stated
Direct seed dispersal	Treefrog Xenohyla truncata	Eats fruits and defecates viable seeds	Brazilian rainforest	Silva et al. 1989

Service: Cultural	Cultural Service: Species	Cultural Service: Summary description	Cultural Service: Geographic location	Cultural Service:Example citations
Art	Toad	Aztec art	Central Mexico	DeGraaf 1991
Art	Frogs and toads	Jade, ceramic and gold representations in carved artefacts and jewellery	Costa Rica	DeGraaf 1991
Literature including children's literature	Toad	Mr Toad a lead key character in children's book *The Wind in the Willows*	No geographic area stated	Grahame 2012.

Service: Cultural	Cultural Service: Species	Cultural Service: Summary description	Cultural Service: Geographic location	Cultural Service:Example citations
Popular culture: television, film and advertising	Frog	e.g. Kermit the Frog (The Muppets) Budweiser frog television commercials to advertise alcohol	No geographic area stated	No reference stated
Popular culture: television, film and advertising	Red-Eyed tree frog (*Agalychis callidryas*) and other dendrobatids	Frequent use of photographs, images, magazines, calendars, travel advertising etc.	No geographic area stated	No reference stated
Popular culture: electronic games	Frog	Various examples given including arcade game *Frogger* (Konami Corporation, Tokyo, Japan) and games for iPhone e.g. *Slyde the Frog*^{TM} (Skyworks Interactive, Inc., Glen Head, New York, USA).	No geographic area stated	No reference stated

Service: Cultural	Cultural Service: Species	Cultural Service: Summary description	Cultural Service: Geographic location	Cultural Service:Example citations
Knowledge / entertainment / research	Frogs Salamanders	Hocking & Babbitt link the ability of people to experience these taxa in zoos, museums and television with a subsequent motivation to keep the animals as pets and pet trade sales. [Note: other groups including Urodeles may also be observed in zoos and museums. Many researchers would classify use in the pet trade as a provisioning rather than cultural service].	No geographic area stated	No reference stated
Education	Amphibians ("especially large *Rana* spp. And *Necturus maculosus*")	Resource in education e.g. to teach anatomy as part of biology education.	No geographic area stated	Jensen and Camp 2003
Religion and beliefs	Frog	Bible Old Testament reference to plague of frogs in ancient Egypt	No geographic area stated	No reference stated

Service: Cultural	Cultural Service: Species	Cultural Service: Summary description	Cultural Service: Geographic location	Cultural Service:Example citations
Religion and beliefs	Toad	Aztec toad Tlaltecuhtli as Mother Earth figure that was torn apart to create the heavens and the earth.	Mexico	DeGraaf 1991
Religion and beliefs	Toad	Association of toads with magic, wisdom and eternal life in ancient Chinese and Japanese cultures	China/Japan	DeGraaf 1991
Religion and beliefs	Toad	Toadstone “extracted from head of mature toad to protect the wearer from poison”	Medieval Europe	DeGraaf 1991
Religion and beliefs	Salamander	Association with heavy rain, beliefs that they may extinguish fire and cause hair loss.	Ancient Rome	Pliny the Elder 1855

Service: Supporting	Supporting Service: Species	Supporting Service: Summary description	Supporting Service: Geographic location	Supporting Service:Example citations
Structural components that support other organisms	Tadpoles	Aquatic systems: Alteration of physical structure of aquatic macrophytes and periphyton	No geographic area stated	e.g. Wood and Richardson 2010
Structural components that support other organisms	Burrowing amphibians	Aquatic Systems: Potential to change soil bulk density and permeability to water	No geographic area stated	No reference stated
Structural components that support other organisms	Hypsiboas spp.	Aquatic systems: Gladiator frogs dig breeding pools (temporary structures) in stream mud, which may act as habitat for species of invertebrate larvae	Peru	Burger et al. 2002

Service: Supporting	Supporting Service: Species	Supporting Service: Summary description	Supporting Service: Geographic location	Supporting Service:Example citations
Direct / indirect contribution to ecosystem functions	Larval amphibians	Aquatic systems: Nutrient cycling and impacts on food webs in aquatic systems: - Larval salamanders in aquatic systems acting as predators (and also as primary consumers, detritivores, and cannibals) - Cumulative impact of larval amphibian feeding on food webs through season - Impact on algal community structure/biomass/productivity	No geographic area stated	No reference stated
Direct / indirect contribution to ecosystem functions	Atelopus zeteki, Rana warszewitschii, and Hyla spp.	Aquatic systems: Tropical anuran tadpoles decreased decreased algal abundance, biomass, changed algal community composition, reduced sediment	Panama	Ranvestel et al. 2004

Service: Supporting	Supporting Service: Species	Supporting Service: Summary description	Supporting Service: Geographic location	Supporting Service:Example citations
Direct / indirect contribution to ecosystem functions	Tadpoles	Aquatic systems: Variation in tadpole abundance affects nitrogen flux and balance of particulate to dissolved nitrogen; tadpoles thought to regulate primary production and algal and phytoplankton standing crop	Missouri, USA.	Seale 1980
Direct / indirect contribution to ecosystem functions	Ambystomatid salamander assemblages (eggs, larvae, adults)	Aquatic systems: Contribution to energy cycling as prey for predators or carcasses for decomposers	Illinois, USA.	Regester et al. 2006
Direct / indirect contribution to ecosystem functions	Plethodon cinereus	Terrestrial systems: Indirect impact of red-backed salamanders on decomposition rates through the impact of predation on leaf-fragmenting invertebrates [Hocking & Babbitt comment that this effect may be context specific, as other studies cited did not confirm this result].	USA (experimental study)	Wyman 1998

Service: Supporting	Supporting Service: Species	Supporting Service: Summary description	Supporting Service: Geographic location	Supporting Service:Example citations
Direct / indirect contribution to ecosystem functions	Bufo bankorensis	Terrestrial systems: Toad impact on litter chemistry (increased phosphorous concentration)	Taiwan	Huang et al. 2007
Direct / indirect contribution to ecosystem functions	Eleutherodactylus coqui	Terrestrial systems: Coqui frog reduces leaf litter C:N ratio and increases K and P through deposition of excreta and carcasses.	Puerto Rico	Beard et al. 2002

Potential contribution to pest regulation and nutrient/energy cycling: the diet of great crested newt

As great crested newts live in a range of terrestrial and aquatic habitats, the precise composition of the prey available to the species will vary among populations and ponds (Edgar et al. 2006), as well as by season (Fasola & Canova 1992). Great crested newts are considered predatory generalists (Jehle et al. 2011, Roşca et al. 2013), and are opportunistic predators (Fasola & Canova 1992, Roşca et al. 2013) with small and large prey items consumed. A wide variety of invertebrates are eaten including water lice (*Asellus* sp), snails (Langton et al. 2001, Roşca et al, 2013) water shrimps, lesser water boatmen (*Corixa* spp.), fly larvae (Langton et al. 2001), biting midges, mayflies (Roşca et al. 2013) leeches and water beetles (Beebee & Griffiths 2000). Other aquatic prey items include tadpoles (of both frogs and toads) and even adult smooth and palmate newts are sometimes taken (Langton et al. 2001). At the opposite end of the spectrum, but a notable food source, are zooplankton, including water fleas (*Daphnia* spp.), and as highlighted by Langton et al. (2000), these species, though very small, are important prey for the species due to the sheer number that can be found in ponds.

The terrestrial prey items eaten by the species are less well understood, but these are known to include earthworms (Roşca et al. 2013; McInerny & Minting 2016), weevils, beetles, spiders (Roşca et al. 2013) and molluscs (McInerny & Minting 2016). Juvenile great crested newts are believed to prey on small invertebrates located within leaf litter (Jehle et al. 2011), including species such as springtails and mites (Jehle et al. 2011, McInerny & Minting 2016) and worms (McInerny & Minting 2016).

Great crested newt larvae are also predatory, feeding on a number of small invertebrates including small crustaceans (Langton et al. 2001, Inns 2009, Jehle et al. 2011, McInerny & Minting 2016) dipteran larvae (Langton et al. 2001, Jehle et al, 2011), small tadpoles, water fleas (*Daphnia* spp), water lice *(Asellus* spp) and mayfly nymphs etc. (Langton et al, 2001).

While we are aware of no study that has quantified a regulatory effect exerted by great crested newts on any prey species, or evaluated the impact of the species on nutrient or energy flow, it is evident that appropriate species interactions exist, to presume that some contribution is likely. The scale of any effect would be expected to be context specific, depending on factors such as the size of the local great crested newt population and the density and composition of other great crested newt prey and predator assemblages.

Cultural services delivered by the great crested newt

In literature newts appear in several children's stories. The character of Sir Isaac Newton, a friend of the leading character, a frog named Jeremy Fisher is clearly recognisable as a great crested newt in Beatrix Potter's illustrations for her much-loved book *The Tale of Jeremy Fisher* (Figure 1). Sir Isaac Newton is described as wearing his black and gold waistcoat to attend a dinner party, where he shares a feast of roasted grasshopper and ladybird sauce (Potter 1906). The second witch in Shakespeare's Macbeth speaks the famous line "eye of newt and toe of frog" as she lists the ingredients the witches put into the cauldron to concoct their spell (Macbeth IV i, 14-15).

Figure 1. Illustration of Sir Isaac Newton, characterisation of a great crested newt in children's literature, in *The Tale of Mr. Jeremy Fisher* by Beatrix Potter.

The phrases "tight as a newt", "drunk as a newt" "or pissed as a newt" are well-known British idioms, all referring to somebody who is very drunk. Various explanations of the origins of this phrase are given, one being that newts roll from side to side when they walk on land, like a drunken person. Another suggests that the person is saturated like an animal that lives in water. Other explanations have nothing to do with the amphibian, but whatever the truth, it is a measure of familiarity with the animal, (and possible affection), that its name has been cemented into the English language in this way.

Dragons are a more visible part of Welsh culture. A red dragon appears on the national flag of Wales, and is the logo of the Welsh Government (https://en.wikipedia.org/wiki/Welsh_Dragon). The dragon has been part of Welsh culture for a long time; it appeared on the flags of Welsh kings in the fifth century (https://www.visitwales.com/info/history-heritage-and-traditions/dragon-spirit-legend-welsh-dragon). Several recent projects have popularised British newt species to the public by likening them to dragons e.g. the Heritage Lottery Funded project Connecting the Dragons in South Wales for which a development phase ran from 2018 (https://www.arc-trust.org/News/new-project-connecting-the-dragons-cysylltur-

dreigiau), a Big Lottery Fund project Dragonscapes which began in 2015 (https://www.arc-trust.org/dragonscapes) and the public information booklet *Dragons in your Garden* (Baker et al. 2009).

Newts and other pond creatures have featured in education and educational resources, and pond-dipping has been used as a way of teaching children about aquatic wildlife and inspiring a love of nature. The naturalist Chris Packham often quotes encounters with (smooth and palmate) newts as a boy, as one of the inspirations for a lifelong love of wildlife and a career presenting the natural world on television. Amphibian and Reptile Conservation's Great Crested Newt Detectives Project used eDNA technology to involve children and adults in citizen science surveys of waterbodies to improve knowledge of great crested newt distribution in Scotland and, at the same time, improve public knowledge of the uses of DNA technology. *Amazing Animals Brilliant Science How DNA technology is being used to save Scotland's Wildlife* (Minting 2018) was a published output of this project.

Great crested newts and other amphibian species also contribute to biodiversity appreciation, people's enjoyment and interest in species in the natural world, either directly in active participation or indirectly through nature documentaries and publications and "existence value". Evidence for this includes participation in expert volunteer programmes such as the National Amphibian and Reptile Recording Scheme NARRS, attendance at public events run through awareness and engagement programmes included within projects such as Connecting the Dragons and Dragonscapes (see above) or in the case-studies (see 8.2). Further evidence includes membership or support of voluntary groups (e.g. local Amphibian and Reptile Groups and networks of which there are several in Wales), local wildlife trusts, species conservation NGOs including Amphibian and Reptile Conservation (ARC) and wildlife tourism. While the latter usually addresses broader nature, or taxonomic groups that have a particularly large audience (birds, butterflies), examples of study tours and wildlife holidays that focus on amphibians exist. In some parts of the world, revenue from nature and wildlife tourism contributes importantly to local and national economies.

In the UK, the European Protected Species status of great crested newts (and other European Protected Species such as bats), and national/European/international obligations to conserve wildlife and redress biodiversity decline is the background for the development of ecological consultancy as an active part of the service sector. Ecologists who are qualified to provide expert guidance on the species in the context of developments and land-use change are able to derive a financial income, directly related to the legislation and policies linked to this species.

Great crested newts as a biodiversity indicator species

Two major classes of biodiversity indicator have been distinguished; the role of the first is to "reflect community composition" while that of the second is to "reflect environmental change" (Leader-Williams 2000, Sewell & Griffiths 2009). Refer to Annex 3 for summary definitions of indicators and related terms that are commonly used in single species conservation after Leader-Williams and Dublin (2000).

Sewell & Griffiths (2009) used great crested newts to consider how successfully one species may be used as an indicator for multiple taxa, by comparing macrophyte and macro-invertebrate assemblages in ponds where newts were present or absent. A second element of their study assessed the great crested newt as a biodiversity indicator against specific criteria derived from academic literature, and a third aspect investigated whether amphibians, in general, are suitable for use as indicator species.

For the first aspect, Sewell & Griffiths (2009) found that the average number of plant species recorded was substantially greater in ponds that were occupied by great crested newts, than in ponds without the species. The survey work also revealed that occupied ponds contained a greater percentage cover of aquatic vegetation. A similar study in Sweden corroborated these results (Gustafson et al, 2006). This correlates with what is known regarding the species' ecology, in that great crested newts prefer well-vegetated ponds (Langton et al. 2001, Baker et al. 2011, Jehle et al. 2011) and also to some extent, a diversity of vegetation, as indicated by Oldham et al. (2000) based on the results of the National Amphibian Survey (Swan & Oldham, 1993). This revealed great crested newt occurrence was highest in ponds where the emergent vegetation covered between 25 and 50% of the pond and cover of submerged plants was between 50 and 70%. Gustafson et al. (2006) suggested that ponds with a diverse range of macrophytes may provide optimal conditions for cover, prey, temperature and availability of egg laying substrate. However, Sewell & Griffiths (2009) found no difference in the diversity and abundance of macroinvertebrates between occupied and unoccupied ponds.

Sewell and Griffiths (2009) concluded that great crested newts met various of the eight biodiversity indicator criteria identified from previous studies to some degree, including that "*the species should be easy and effective to observe, identify and monitor*", although the authors noted that repeat surveys would be required. Great crested newts were also considered to satisfy the criterion "*The species should be distributed over a broad geographic area, if the indicator is at family or higher level the distribution should ideally be worldwide*" but only when examining this criterion at a suitable geographic scale. Sewell & Griffiths suggested that the species might be suitable as an indicator species for this specific criterion within a European context.

As outlined by Sewell & Griffiths (2009), the use of great crested newts, or any single species, as an indicator is immediately problematic for two criteria that necessitate consideration of multiple species. This includes "*Patterns of species richness should be closely correlated with those of other, non-related groups*". Great crested newts were also considered unable to meet another indicator criterion, "*the species should be sufficiently sensitive to provide early warning of change in the environment*". This is because great crested newts may persist in degrading habitat for several years, and therefore do not respond sufficiently quickly to reflect environmental change Sewell and Griffiths (2009).

The work also concluded that, based on our current understanding, individual amphibian species are unlikely to be suitable for use by themselves as indicators of "community composition" indicator or to "reflect environmental change". The overall research conclusion, pertinent to both types of indicator, was that a combination of

several species is more likely to be effective as an indicator, than any single species in isolation.

Principal habitats used by great crested newts

Great crested newts use a range of diverse habitats, with the majority of these being lowland habitats (Beebee & Griffiths 2000, Inns 2009, McInerny & Minting 2016), reflecting the range of the species in the UK. Appendix 1 summarises the main Phase 1 National Vegetation Classification (NVC) types that great crested newts use as primary or secondary habitat at some point in their lifecycle.

Appendix 1 serves to illustrate the breadth of habitats in which great crested newts may be found. The species overwinters, forages and disperses on land, migrating to ponds in the spring to breed. The presence of both good quality terrestrial and aquatic habitats close to each other is therefore important. Where key breeding and terrestrial habitats are not contiguous, good connectivity between the habitats is essential.

Pond clusters are often preferred by the species, as the presence of a number of well-connected ponds enables meta-populations to develop (Langton et al. 2001); these linked populations are likely to be more resilient to changes in the environment, such as pond desiccation or the introduction of fish.

Due to the loss of many natural wetland habitats, the predominant habitats used by great crested newts today are those that have been developed, or changed by human activity (Langton et al. 2000, Jehle et al. 2011). Some of the largest newt populations exist at abandoned or partially disused mineral extraction sites (Langton et al, 2001, Jehle et al, 2011), including those worked for clay, chalk or stone. The resulting waterbodies can be large and open or consist of numerous smaller workings. Within both urban and urban fringe environments, great crested newt and other amphibian species may occupy terrestrial and aquatic habitats that may also function as green and blue infrastructure. However, a wide range of suitable natural and semi-natural habitats may be used by the species. These include ponds on spring lines, and those found in sand dune slacks (Langton et al, 2001, Jehle et al, 2011), ox bow lakes, pingos, bog pools, marshes (Langton et al, 2001) and kettle holes, all of which are important habitats to conserve.

Good terrestrial habitat needs varied structure, providing cover and opportunities for hibernation and foraging. Ideal habitats include deciduous woodland (Edgar et al. 2006, Jehle 2011) and scrub (Jehle et al. 2011), hedgerows (Beebee & Griffiths 2000, Oldham et al. 2000), and grassland (Jehle et al. 2011) including pasture, and rank areas of grass and tall herbs. Frequently overlooked (or completely disregarded), scrub can often be an important habitat component for great crested newts. Deciduous woodland is more suitable than coniferous woodland (Beebee & Griffiths 2000, Langton et al. 2001), as this habitat tends to have a more developed understorey (Langton et al. 2001) and opportunities for cover, including the presence of deadwood and a deep leaf litter. However, both coniferous woodland and mixed woodland can be utilised by the species.

A key habitat resource for great crested newts is the lowland farmland environment, where the pastoral landscape can still provide suitable breeding ponds and terrestrial

habitat. This habitat type is important, constituting around 50% of the lowland farmed land in Britain (Langton et al, 2001).

Agriculture ('utilised agricultural land') makes up around 85% of Welsh land area, compared to the 70% estimated in both England and Scotland (Wiseall, 2018). In Wales, permanent pasture is by far the dominant land-use, constituting around 75% of the agricultural area; the remaining area includes 'common rough grazing' (a further 10%) and 'croppable area' (14%). Wiseall (2018) notes the land-use percentages are comparable in Scotland, but in England crops dominate at 54%, permanent pasture at 41% and 'common rough grazing' at 4%.

The pastoral landscape is able to provide all the essential habitats required by great crested newts, including clusters of ponds in grassland habitats with hedgerows, copses, and drystone walls delivering ideal areas for the newts to breed, forage, disperse and over-winter.

Some habitats are used less commonly by the species. For example, lowland heathland typically has fewer ponds and the aquatic environment is more acidic, but under certain circumstances newts can be present (Langton et al. 2001). Great crested newts can also be found in ponds in dune slacks, and mire habitats.

In upland areas of Wales and Scotland, great crested newts can be found in more atypical habitats (in comparison to their 'core' range), including bracken moorland and temporary ponds in mid Wales (Beebee & Griffiths 2000), and conifer, heathland habitats in Wales and Scotland (Langton et al. 2001; McInerny & Minting 2016).

Potential ecosystem services delivered by great crested newt habitats

The Millennium Ecosystems Assessment (MEA 2005), the UK National Ecosystem Assessment and other local, national or habitat-focused exercises have reviewed and variously quantified the benefits that nature brings to society. Such initiatives have typically focused on stock (e.g. Brauman et al. 2007, Morris and Camino 2010, Firbank et al. 2013, Biggs et al. 2017) or the impact of changing from one habitat state to another, as in ecosystem restoration (e.g. Rey Benayas et al. 2009, Egoh et al. 2014). A common approach is to map habitats, and relate these to the delivery of services through inference, or by using primary data. For example, Burkard et al. (2011) used land cover data and other information to map and assess the match between ecological integrity, ecosystem service supply and demand. Natural England has recently undertaken a natural capital account of the National Nature Reserves (NNRs) it manages to document the holdings, the services and benefits they provide to people and the economic value of those benefits (Sunderland et al. 2019).

From the wealth of accumulated literature, potential services may be predicted from a knowledge of the habitat types present at a location, but the actual benefits that arise are often site and context specific, depending on the interactions of habitat, topography and the location in respect to human populations and the demand for the services. Some services such as a contribution to global climate regulation, via the sequestration and storage of carbon, may be realised in any location with suitable

habitat present. Other potential services such as recreation and biodiversity appreciation, (via leisure visits to view nature), will only be realised in practice if they are within travelling distance of a human settlement where there is demand for these benefits.

Table 3 summarises potential services associated with the primary and secondary habitats used by great crested newt, based on literature sources. The representation of these services in the table is simplistic, taking no account of the relative quantity of service delivered by different habitat types and it should be emphasised that it is indicative rather than fully comprehensive. Individual great crested newt sites might deliver fewer services than those listed in the table, depending on the composition of habitats present and the use to which land is put. From examining the management plans (CCW 2008a,b,c) available for this work, the great crested newt SACs incorporate a range of different habitats in Wales, including *inter alia,* grasslands (neutral*,* acid and calcareous, hay meadows, 'pasture' and marshy grassland), woodland (including mature broadleaved), scrub, hedgerows, lowland dry heath, wet heath and bracken. The water bodies found on the SACs include a kettle formation pond, pits and quarries from former mineral workings, and ponds set within pasture and grassland settings.

In overview, a site protected for the purpose of great crested newt conservation is likely, by virtue of the habitats that will be secured for that purpose, to deliver a number of other benefits to people. The mix of potential services is dominated by regulating and cultural services, but a contribution to provisioning services is possible. For example, if the woodland in the vicinity is managed for the production of timber, or wood fuel, then economic benefits from the sale of these products may follow. If grassland is present it may be managed to support either livestock, or for the production of hay or silage, or a combination of both; all these outputs have a market and may contribute to livelihoods. Hedgerows, because they provide enclosure and shelter, may make a contribution to livestock production, but traditionally these were also used for wood-fuel production and, in some quarters, this potential application is being re-visited (Baudry et al. 2000, Chambers et al. 2015). Any habitat management that results in the production of biomass, perhaps the arisings from cutting scrub, grass or heath on sites managed for conservation has the potential to contribute to energy production. Whether this is an actual outcome depends on local infrastructure (e.g. biomass digesters) and an effective business model for ensuring the biomass is harvested, processed and the energy or fuel product made accessible to the customer, but such initiatives have been trialled recently on nature reserves as enterprises for the benefit of local communities (e.g. Mills et al. 2015). Biggs et al. (2016) highlight that ponds contribute to the small-scale supply of freshwater and that within Europe, water supply was a historical driver for their creation. One provisioning service associated with some freshwater bodies (fish production), and the related recreational activity (fishing) has, however, been identified as an obvious conflict with great crested newt conservation, because fish predate larvae and eggs so ponds where fish occur are judged to score badly when habitat suitability is being assessed (Oldham et al. 2000). This has been further evidenced by studies that have shown the presence of fish to be a significant negative influence on newt occurrence leading to decline (e.g. Ranaap and Briggs 2006, Denöel and Ficetola 2008, Hartel et al. 2010, Denöel et al. 2013). These potential services must be forfeit if the driver for land management is great crested newt conservation.

Many natural and semi-natural habitats have the potential to contribute to global climate regulation, because of the ability of plants and soils to sequester and store carbon. Different habitats vary in their capacity to accumulate carbon, due to soil type, vegetation type, climate and typical disturbance pattern. The potential of different habitats to contribute to global climate regulation has been reviewed in greater depth than is possible here, including through life-cycle analysis of typical management operations associated with those habitats (see e.g. Broadmeadow and Matthews 2003, Warner et al. 2008, 2011, Ostle et al. 2009, Alonso et al. 2012). In summary, however, organic soils store most carbon. Soil carbon densities are highest under semi-natural habitats and woodlands, and lowest under farmland and urban areas. Any management that reduces vegetation biomass or disrupts soil is likely to lead to higher emissions of greenhouse gases. Converting land into built or agricultural land may lead to increased CO_2 emissions, while retention and restoration of natural and semi-natural habitats and woodland is usually predicted to stabilise or reduce emissions. Carbon storage in the soil is often found to be higher under vegetation that has higher species diversity, believed to be because of higher rates of turnover and the decay of root material, and the presence of legumes is also considered to result in higher rates of carbon sequestration. Due to the complex interactions of grazing livestock, vegetation and underlying soils, grazed grasslands may be either net emitters or net sequesters of carbon due to site specific factors such as whether animal housing is available, whether the soil becomes poached, the duration and intensity of grazing and how dung is managed. Hedgerows can contribute to climate regulation through the action of storing carbon in their woody vegetation and below ground in the soil, and through reducing carbon loss and greenhouse gas emissions by counteracting soil erosion.

Soils under waterbodies such as lakes and ponds can also be important stores of carbon, although most evidence has come from American studies (Thompson 2008). Drainage of soils is associated with higher levels of CO_2 emissions and rewetting (raising the water table), particularly of organic soils, has been an objective of some climate change mitigation strategies. The rewetting conservation approach is used in the restoration of peatland habitats such as bogs, fens, mires and reed-beds. In the first ten to thirty years after such an intervention, these restored habitats may be net emitters of greenhouse gases such as CO_2 and CH_4, but after that, carbon sequestration may outweigh emission (Smith et al. 2011). Creating ponds has been a much advocated conservation approach to restore the great crested newt to favourable conservation status (FCS) in Wales (e.g. Russell et al. 2017a,b,c) and this intervention may be a very effective way of capturing carbon, through the plants and algae that they contain, at least according to American literature. Downing *et al*. 2008 studied an intensively farmed agroecosystem in Iowa and estimated that farm ponds might accumulate sediment (therefore carbon) up to 500 times faster than lakes in natural environments depending on lake function and catchment size, with smaller ponds having greater deposition and accumulation rates per unit area. Biggs et al. (2016) collated other evidence that very small ponds can emit large quantities of methane and highlighted the need for further work to understand the factors that determine net sequestration or emission. A further cautionary point is that although restoring wetlands is likely to increase carbon stocks, the absolute levels achieved may not be as high as in undisturbed habitat so the preferred strategy should be to maintain the integrity of wetland systems where this is an option (Alonso et al. 2012).

Other potential regulating services performed by habitats used by great crested newts include nutrient regulation and pollution control. Biggs et al. (2016) collated evidence of pond systems being able to retain nutrients but commented on the uncertainty regarding the absolute contribution of ponds to addressing pollutants at catchment and landscape scale. Many of the possible examples of regulating services listed in Table 3 below are site and context specific, for example the shade and shelter contribution of features like hedges and tree lines to local climate or the availability of semi-natural habitats to provide resources to pollinators. In the latter case, effective delivery of the service depends not only on the production of insect pollinated plants, but also upon the presence of pollinator dependent crops within range of foraging pollinators. With regard to erosion control and water purification, many natural and semi-natural habitats contribute to these by slowing the passage of surface water and filtering the passage of water through the underlying soil. Both these processes may also contribute to flood protection.

Cultural services are often considered to be the most difficult to quantify or value economically. Only overarching categories of potential cultural ecosystem service are set out in Table 3. Many sub-categories of benefit could be identified or recorded. The services realised will be site specific and influenced by the landscape context, including proximity to human populations. For example, the category recreation might include walking for exercise, dog-walking, sports use, horse-riding and cycling, activities that are variously influenced by public access permissions, infrastructure such as footpaths and bridleways, the appeal of the landscape or habitat, parking provision or the distance to people's homes.

Access to many types of natural environments for recreation, or even just the experience of being in nature, has been associated with various positive physical and mental health and well-being outcomes (see evidence summarised in Sunderland 2012 and Sandifer et al. 2015). For example, more rapid recovery from illness by hospital patients who observed a natural or semi-natural view from a window (Ulrich 1984). In Wales, both designated sites (e.g. Connah's Quay Ponds and Woodlands SSSI) and long-term mitigation schemes, (e.g St Asaph Business Park) provide and contribute to the overall extent of publicly accessible green networks. Requirements for the provision of terrestrial and aquatic habitats for great crested newts as material components of mitigation and/or as part of the designation and management of statutory and non-statutory sites of ecological (or geological interest) can contribute, potentially significantly, to the overall provision of these green networks within defined geographical areas. Examples of this include the extent of publicly accessible areas within Deeside and Buckley SAC and at St Asaph Business Park. It can therefore be demonstrated that the protection of great crested newts provides tangible benefits for local people. It should be noted however that higher levels of public access may damage sensitive habitats and species so an appropriate balance needs to be maintained. Threats to newt populations from greater public access include increased likelihood of fish introduction, spread of non-native plants or amphibian disease (see Copp et al. 2006, 2010 and Price et al. 2010), all of which may have serious consequences.

Some features such as ponds, lakes or quarries might reflect former industrial archaeology, but a range of habitats might contain ancient archaeology or, as in the case of old hedgerows, may reflect ancient by-ways or landowner boundaries or cropping patterns. Sunderland et al. (2019) distinguished "thriving wildlife" as a

potential service provided by the national nature reserves that were the subject of their natural capital account; actual delivery is dependent on habitat condition and species distribution. Biodiversity appreciation is the opportunity for people to view or encounter nature, perhaps facilitated by resources such as hides, but certainly dependent on access.

Table 3. Example ecosystem services often associated with the broad habitat types used by great crested newt as primary or secondary habitat. See Appendix 1 for a full list of habitat types known to be used by the species, matched to the Phase 1 Natural Vegetation Classification. Sources used to list potential ecosystem services associated with these habitats include Alonso et al. (2012), Baudry et al. (2000), Biggs et al. (2017), Brauman et al (2007), McCarthy and Morling 2014, Thomson et al. (2011) and Thompson (2008).

Classification, with additional explanation of primary and secondary habitat use. 'LC' = Likely contribution to service. 'DC' = This service may be associated with this habitat, but is in direct conflict with great crested newt conservation. 'N' = No data

i) Provisioning services: Primary Habitat

Habitat	Crops	Livestock	Fodder	Fishery	Timber	Wood fuel	Energy	Freshwater	Construction aggregates
Woodland	N	N	N	N	N	LC	N	N	N
Scrub	N	N	N	N	N	LC	LC	N	N
Grassland	N	LC	LC	N	N	N	LC	N	N
Marsh	N	N	N	N	N	N	N	LC	N
Open water (standing)	N	N	N	**DC**	N	N	N	LC	N
Quarry	N	N	N	N	N	N	N	N	LC
Arable	N	N	N	N	N	N	LC	N	N
Ephemeral /short perennial disturbed land	N	N	N	N	N	N	N	N	N
Hedges	N	LC	LC	N	N	LC	N	N	N

Habitat	Crops	Livestock	Fodder	Fishery	Timber	Wood fuel	Energy	Freshwater	Construction aggregates
Drystone wall	N	LC	N	N	N	N	N	N	N

ii) Provisioning services: Secondary Habitat

Habitats	Crops	Livestock	Fodder	Fishery	Timber	Wood fuel	Energy	Freshwater	Construction aggregates
Heathland	N	LC	N	N	N	N	N	N	N
Mire	N	N	N	N	N	N	N	N	N
Swamp	N	N	N	N	N	N	N	N	N
Saltmarsh	N	LC	N	N	N	N	N	N	N
Sand dune	N	N	N	N	N	N	N	N	N
Coastal grassland	N	LC	N	N	N	N	N	N	N
Coastal heathland	N	LC	N	N	N	N	N	N	N
Gardens	N	N	N	N	N	N	N	N	N
Earth	N	N	N	N	N	N	N	N	N

Habitats	Crops	Livestock	Fodder	Fishery	Timber	Wood fuel	Energy	Freshwater	Construction aggregates
Bank									

iii) Regulating Services: Primary Habitat

Habitat	Local climate	Global climate	Flood protection	Air quality	Erosion control	Nutrient regulation	Water purification	Pollination
Woodland	LC	LC	LC	LC	LC	LC	LC	LC
Scrub	LC	LC	LC	LC	LC	LC	LC	LC
Grassland	N	LC	LC	N	LC	LC	LC	LC
Marsh	N	LC	LC	N	LC	N	N	N
Open water (standing)	N	LC	LC	N	N	N	N	N
Quarry	N	N	N	N	N	N	N	N
Arable	N	N	N	N	N	N	N	N
Ephemeral/ short perennial disturbed land	N	N	N	N	N	LC	N	LC
Hedges	LC	LC	LC	LC	LC	LC	LC	LC
Drystone wall	N	N	N	N	N	N	N	N

iv) Regulating Services: Secondary Habitat

Habitat	Local climate	Global climate	Flood protection	Air quality	Erosion control	Nutrient regulation	Water purification	Pollination
Heathland	N	LC	N	N	N	N	N	LC
Mire	N	LC	N	N	N	N	N	N
Swamp	N	LC	LC	N	N	N	N	N
Saltmarsh	N	LC	LC	N	LC	N	N	N
Sand dune	N	N	N	N	LC	N	N	N
Coastal grassland	N	LC	LC	N	LC	LC	N	LC
Coastal heathland	N	N	N	N	N	N	N	N
Gardens	LC	LC	LC	LC	LC	LC	LC	LC
Earth bank	N	N	LC	N	LC	N	N	N

v) Primary Habitat: Cultural services

Habitat	Recreation	Aesthetic value / sense of place	Thriving wildlife	Biodiversity appreciation	Historical value	Education	Science / knowledge
Woodland	LC	LC	LC	LC	LC	LC	LC
Scrub	N	LC	LC	LC	N	N	LC
Grassland	LC	LC	LC	LC	LC	LC	LC
Marsh	N	LC	LC	LC	N	N	N

Habitat	Recreation	Aesthetic value / sense of place	Thriving wildlife	Biodiversity appreciation	Historical value	Education	Science / knowledge
Open water (standing)	LC	LC	LC	LC	LC	LC	LC
Quarry	N	N	LC	N	LC	N	LC
Arable	N	LC	N	N	N	N	N
Ephemeral/ short perennial disturbed land	N	N	N	N	N	N	N
Hedges	N	LC	LC	N	LC	N	LC
Drystone wall	N	LC	N	N	LC	N	N

vi) Cultural services: Secondary Habitats

Habitat	Recreation	Aesthetic value / sense of place	Thriving wildlife	Biodiversity appreciation	Historical value	Education	Science / knowledge
Heathland	LC	LC	LC	LC	LC	LC	N
Mire	N	N	N	N	N	N	N
Swamp	N	LC	LC	LC	N	N	LC
Saltmarsh	N	LC	LC	N	LC	N	LC

Habitat	Recreation	Aesthetic value / sense of place	Thriving wildlife	Biodiversity appreciation	Historical value	Education	Science / knowledge
Sand dune	LC	LC	N	N	LC	N	LC
Coastal grassland	LC	LC	LC	N	LC	N	LC
Coastal heathland	LC	LC	LC	N	N	N	N
Gardens	LC	LC	LC	N	LC	LC	N
Earth bank	N	N	N	N	N	N	N

Example case studies

High-level audit of potential ecosystem services at Kintbury Newt Ponds, a nature reserve in Berkshire owned and managed by Berks, Bucks and Oxon Wildlife Trust (BBOWT).

The information in this case study is kindly made available by permission of BBOWT. The information is summarised from the results of an internal BBOWT exercise that was undertaken by Karen Haysom, when employed by the wildlife trust between 2015 and 2016 as part of a review of potential ecosystem services across the wildlife trust's land-holdings which, at that time constituted a portfolio of 87 nature reserves (Haysom, BBOWT unpublished). The purpose of the review was to gain an understanding of the potential wider benefits to society of the wildlife trust's work conserving habitats and species, particularly with regard to demonstrating the impact of BBOWT's work, including to, but also going beyond, the traditional audiences who are already engaged to conservation. The audit was undertaken for all nature reserves managed by the wildlife trust. Due to the extent of this task it was necessary to use an approach that was less detailed than a more formal rapid assessment. Information for the review was gathered through inspection of site conservation management plans and interviews with land managers responsible for each site.

Site description

Kintbury Newt Ponds nature is a small (3 ha) nature reserve which is situated 5.5 miles west of Newbury in Berkshire. Most of the ponds at the site are the remains of clay pits, formed when the clay soil was exploited to feed the local brick industry. The original ponds are believed to be up to several hundred years old. Due to the presence of a breeding colony of great crested newts which had statutory protection, the site narrowly escaped being incorporated into urban housing development in the 1990s.

The parent soil is clay-silt-sand. Habitat present on the site comprises several ponds (eight are listed in the site management plan), reedbed, blackthorn scrub, grassland and woodland, including the presence of some ancient oaks. Other species recorded on the nature reserve include smooth newt, palmate newt, grass snake, slow worm, chiff chaff and the site provides breeding habitat for summer migratory birds including warblers.

Audit method

The potential ecosystem services delivered by the site were assessed using a desk-study. BBOWT GIS resources, the site conservation management plan and site maps were examined, and the land-manager and relevant BBOWT colleagues interviewed, to gather information on the type and area of habitats present, aspect, soil type, history of use, type of management practised, access arrangements and facilities for visitors, public rights of way, number of visitors where known, how visitors use the site (where known) and human population within defined radii. This information was used to infer likelihood of different ecosystem services being delivered by the site, taking into account the habitats associated with these potential services and the proportion of the overall site encompassed by each habitat. The potential for delivery of pollination took into account not only the type of vegetation present on the reserve, but also the presence of crops requiring pollination in the surrounding landscape within the typical range of pollinators. Expert opinion based on knowledge of relevant ecosystem servic46es literature was used to identify potential ecosystem services delivery at the site. A qualitative indication of the relative importance of that service at the site, was given using a minor, medium, major grading, taking into account the area of habitat supplying the service as a proportion of the whole site area.

Results

Table 4. Summary evaluation of potential ecosystem services delivered by Kintbury Newt Ponds nature reserve

Ecosystem Service	**Provisioning**
Hedgerow/non-timber forest products	Minor
Livestock production	Minor
Ecosystem Service	**Regulation**
Climate regulation	Major
Flood regulation	Medium
Water quality	Minor
Air quality	Unknown
Pollination	Minor
Ecosystem Service	**Cultural**

Conservation volunteering	Minor
Nature appreciation (biodiversity)	Major
Biological recording /monitoring (Knowledge)	Minor

This very coarse, desk-based review documented the potential delivery of ten ecosystem services at this small nature reserve (two provisioning services, five regulating services and three cultural services. The two provisioning services are both likely trivial. The hedgerow/non timber forest products service was identified in reference to the presence of brambles in the hedgerows in the management plan; any harvesting of products (blackberries) would be undertaken by local people as part of recreation (so the activity itself could also be regarded as a cultural service. Grassland at the site is managed through conservation grazing, with the management prescription noting the use of 2 to 4 Dexter cattle in spring and autumn. The site is therefore too small to support many stock and the activity is seasonal, but the animals are supplied by an external grazier, so it is possible that the site makes a small contribution to the production of meat and contributes to the livelihood of this stakeholder.

Of the regulating services, climate regulation was considered the most important due to the presence and overall coverage of woodland, grassland, scrub, and the ponds which are all habitats that sequester and store carbon. It is reasonable to assume that flood regulation is a relevant service due to the area of ponds, performing water storage, and the overall coverage of vegetation which would be expected to slow surface water flow. Indeed, the exercise revealed that one more recent pond had been dug in 1996, to alleviate the concerns expressed by some local residents about the possible risk of flooding in the vicinity. With regard to pollination, the contribution of the site was considered likely to be minor given that nectar resources would be limited to the areas of the reserve supporting scrub and grassland, and the actual realised service would depend on the quantity of pollinator-dependent crops in the surrounding area (nominally set at a 3-mile radius).

Relatively few cultural services were identified and this reflected the small size, location of the site in respect of human population centres and low-level provision for visitors. Aside from being open to public access with the presence of a permissive path, there is relatively little provision for visitors and the site is not among those in the BBOWT land-holding that regularly support public events. Visitor numbers were not actively monitored but it was estimated that there would be a low level of visits per annum, estimated at less than one thousand per year (or one to two per day). Were any of these factors to change, the site would have been rated more highly for the provision of cultural services. Arguably the site's industrial origin could be said to give it some heritage value. The cultural service of nature appreciation (biodiversity) was a pre-requisite for a site dedicated to conservation, however the major category in respect of appreciation is perhaps generous, given the low number of visitors believed to come to the site per annum. Strictly speaking, the biodiversity itself may be categorised as a supporting service, while the enjoyment of the biodiversity (nature appreciation) is a cultural service, dependent on the existence of

beneficiaries. A small number of volunteer work parties assist in the management of the reserve each year, providing another cultural service to the participants. Mention of reptile tin checks was used as evidence for the site making a small contribution to scientific knowledge.

Conclusion / lessons learned

Wider biodiversity benefits:

The establishment of this nature reserve was driven by the requirement to secure a population of great crested newts, due to their status as a protected species. It has however benefited a number of other species including amphibians, reptiles and migratory birds, all of which would have lost access to habitat providing their ecological requirements, had the land formed part of housing development in the 1990s.

Societal benefits:

This basic audit identified that even though this reserve was very small, it is likely to deliver a number of ecosystem services, and ten were specifically identified (excluding the constituent supporting services which were prerequisite for their delivery). Most of the services identified were likely to benefit local beneficiaries, however, climate regulation is considered to contribute to a global benefit.

This desk-study, though mainly qualitative, benefited BBOWT by raising awareness of additional reasons why wider society might value this reserve and provide an evidence base for making claims of how the wildlife trust's work benefits not only species but people.

Potential ecosystem services delivery at Lane End, Buckley, north Wales, a mitigation for the Heathlands Residential Scheme

The information for this case study is derived from previous reports (e.g. Haysom et al. 2018), organisation websites (TEP The Environment Partnership n.d., Tir Gwyllt Wild Ground n.d.), and personal communications (Mandy Cartwright 2019, Matt Ellis 2019, Kate Wilson 2019).

In this case, habitat for great crested newt was restored and created in mitigation for a 300-house development on the site of a former brick works. The industrial heritage of Buckley is dominated by brickworks, potteries and collieries. These industries were determined by a corridor of clay and coal that runs across the district from Ewloe in the north to Padeswood in the south. The gradual demise of the brickworks and associated clay extraction left various clay holes which eventually filled with water and were colonised by amphibians (Haysom et al. 2018). Parts of this site are listed as non-statutory North East Wales Regional Important Geological Sites (RIGS) designation (No, 584) for its Lower Palaeozoic stratigraphy interest (the locations can be accessed at http://lle.gov.wales/catalogue/item/Rigs).

Part of the site contributes to the Deeside and Buckley Newt Sites Special Area of Conservation (SAC) and Buckley Claypits and Commons Site of Special Interest (SSSI). Buckley Claypits and Commons SSSI is a composite site that includes Etna Country Park, Buckley Lower Common, Buckley Middle Common and Knowle Hill. These sites, together with great crested newt compensation areas at Fields Farm, Globe Way, Pentre Lane and Lane End contribute to the overall provision of designated and non-designated green infrastructure in Buckley. In terms of overall areas, designated sites provide 99.76 ha and non-designated mitigation sites contribute a further 20 ha of green infrastructure. This overall provision of 120 ha is significant, representing a material contribution to the provision of accessible green space within the town.

The non-designated site green infrastructure network also contributes to the implementation of conservation objectives for the SAC, since the SAC conservation objectives require the offsite provision of steppingstone and linear habitats that functionally connect component compartments of this designated site.

In recognition of the overall outcome of the residential development and nature conservation scheme, the project won the Landscape Institute Award for Science Management and Stewardship in 2017. In 2019 it was short listed for a Chartered Institute of Ecology and Environmental Management (CIEEM) award under the category “Best Practice – Large-scale Mitigation”. Material attributes of the overall scheme include consideration of long term issues.

Site description

Prior to the development of housing, this was a brownfield site at Buckley, northeast Wales constituting a former abandoned clay-pit that included a 1 ha steep-sided lagoon. Great crested newts had been present on the site since at least the 1990s, when it was still a working brickworks; clay quarrying for making bricks ended in 2000 (Tir Gwyllt Wild Ground n.d.). The site was part of the Deeside and Buckley Newt Sites SAC (see http://jncc.defra.gov.uk/ProtectedSites/SACselection/sac.asp?EUcode=UK0030132) which was designated in 2004 (European Environment Agency 2015). The great crested newt population was the primary reason for this designation, the designation schedule stating that “waterbodies created from the extraction of clay, sand and coal in north-east Flintshire provide breeding habitat for one of the largest great crested newt populations in Great Britain.” Habitat on the SAC schedule is described as rich and varied, including neutral and acid grasslands, *Molinia* mires, scrub, mature broad-leaved woodland and ponds created for nature conservation following post-industrial reclamation (JNCC 2018).

Planning permission was given on appeal for a scheme that included land within the SAC; housing development was restricted to land outside the boundary of the SAC, habitat creation and restoration in mitigation for the development included land within the SAC. Development and mitigation was undertaken by TEP for Redrow Homes with the design objectives: i) reclaim a derelict and unsafe clay-pit for beneficial uses including 300 houses, a nature reserve and public open space ii) enhance an internationally important colony of GCN iii) create biodiverse habitats of educational

value. The restoration and habitat management work undertaken as part of the housing development mitigation comprised filling in the steep-sided lagoon that had been deemed unsafe, vegetating an area of bare ground referred to as a “moonscape” and establishing a multi-pond nature reserve (Figure 2). A total of 2,261 great crested newts, 31,483 small newts, 55 common toads and 28 common frogs were found and translocated to suitable existing habitats in Knowle Hill, and once established, recreated habitats at Lane End (Tir Gwyllt Wild Ground n.d.).

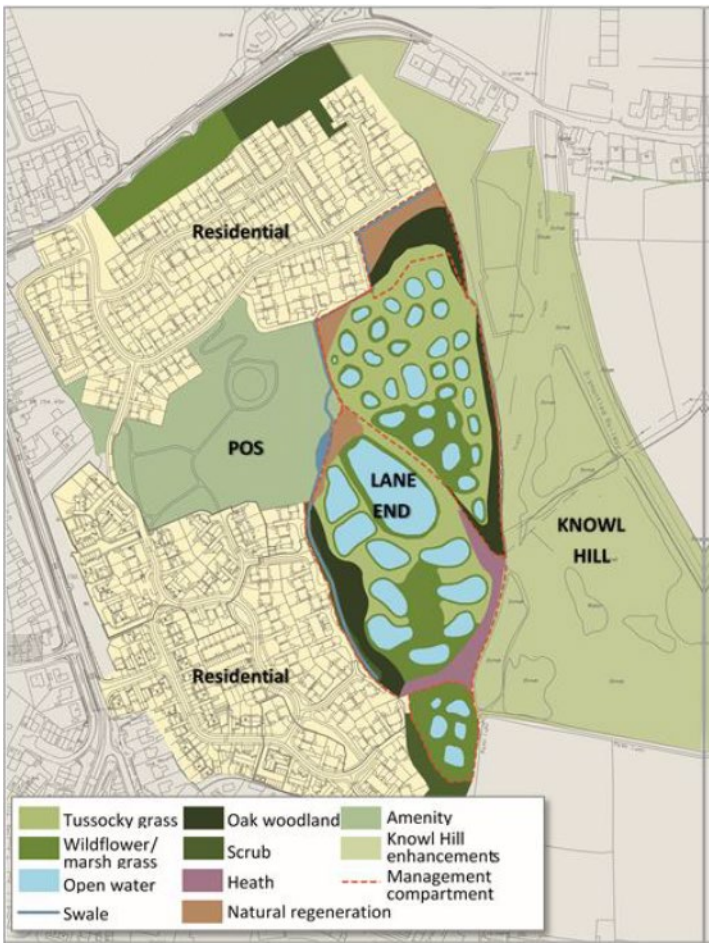

Figure 2. Map showing the layout of Lane End Nature Reserve and the contiguous Knowle Hill Reserve, Buckley, north-east Wales. Reproduced from Redrow Homes (Northwest) Limited.

The nature reserve is managed by Wild Ground, which was formerly known as North East Wales Wildlife (NEWW). Wild Ground also manages the adjacent reserve at Knowle Hill. The great crested newt population is monitored annually and recent peak counts have exceeded 1300 individuals (2019), making this one of the largest great crested newt breeding populations known in Great Britain. Visits to the site can be made by arrangement with Wild Ground, and periodically educational events are run for the public; the Lane End site is not open to the public outside of these events and arrangements. The contiguous Knowle Hill site is publicly accessible.

The overall scheme design considerations included the provision of resources for long-term conservation management surveillance and wardening, without reliance on public sector (exchequer) funding. The provision of financial resources in this case was based on the combination of commuted sum and index-linked ground rent service charges. This overall funding model enables blue and green infrastructure and their associated ecosystem service benefits to be sustainably managed in the long term.

To both highlight the industrial heritage of the area and to promote recreation, the Buckley Heritage Trail passes through Knowle Hill and traverses the boundary of Lane End (see https://www.flintshire.gov.uk/en/PDFFiles/Tourism/Buckley-Town--Heritage-Trail.pdf)

Potential ecosystem services delivered by habitat restoration and creation

Method

The general description of the site, its characteristics prior to the development, the map of habitats established and information on current use and management have been used to infer potential ecosystem services and public benefits that may have resulted from the conservation work undertaken. Results are not based on a formal ecosystem services assessment; the specific details of land-use and habitat composition were not measured in the two alternative states (before and subsequent to development and conservation mitigation) using GIS. Neither was any information collected through interview of local stakeholders or direct collection of data in the field. The predominant changes were instead deduced from the text descriptions in the above sources; the inferred changes in services should therefore be regarded as provisional, indicative of the type of benefits that could be explored further, rather than being comprehensive.

Results

The outcome of the mitigation was an overall increase in the quantity and quality of open water habitat. Before the development, the original lagoon was approximately 0.93 ha in size; after the development there were many more waterbodies with a variety of characteristics. The habitat management work produced 45 new ponds in Lane End nature reserve and also restored ponds in the adjoining Knowle Hill nature reserve, achieving 90 water bodies across the SSSI, with total area exceeding 1.2 ha after habitat creation. The original waterbody was a “steep sided” and “dangerous” lagoon. It was replaced by multiple waterbodies with shallow sides and varying size and depth. Before habitat creation, the clay-pit was likened to a “moonscape”, meaning it was largely bare of vegetation. The new habitats created included species-rich hedge (650m), grassland/heath (2.89 ha) and woodland (1 ha). The restoration achieved a landscape that was vegetated with a variety of habitats including several types of grassland (amenity grass, wildflower / marsh grassland), scrub, heath and oak woodland and areas of natural regeneration (Figure 2). These habitats could deliver various ecosystem services, particularly regulating, cultural and supporting services.

Potential provisioning services

The contribution of the mitigation area to provisioning services is likely to be negligible or minor, as there are few tangible “products” that have market value such as would be the case from cropped land. Some habitat management activities may occasionally generate marketable by-products, for example wood fuel, timber or other biomass resulting from the removal of scrub or trees as part of conservation management to maintain the early stages of succession. Likewise, if grazing or cutting management form part of grassland management, the livestock supported or hay-crop produced would be evidence of provisioning services. The waterbodies present at the site may contribute to freshwater provision. Biggs et al. (2016) state that it is becoming understood that ponds and wetlands that lack surface connections with other waterbodies still affect downstream waters, and contribute to water storage and the recharge of groundwater. Finally, though likely to be minor, local people might benefit from being able to forage for blackberries or similar wild foods from this area. Further investigation, through engagement with the current land managers or the local community would be needed to confirm the existence of such provisioning services.

Potential regulating services

Areas of land that changed from bare ground to various types of vegetation are likely to have increased their contribution to global climate regulation, as grassland, heath, scrub and woodland are usually net stores of carbon, whereas carbon release would be more likely by bare ground (Thompson 2008, Ostle et al. 2009, Alonso et al. 2012). The actual amount of greenhouse gas emissions averted versus carbon sequestration and storage achieved would be influenced by the management of the individual habitats (e.g. Thompson 2008, Warner et al. 2008, 2011, Alonso et al. 2012). Life-cycle analysis of management prescriptions used in agri-environment schemes has revealed considerable variation within habitat types (Warner et al. 2008, 2011) and relevant considerations include the use of fossil fuels in the machinery deployed for their management. In general, operations that minimise soil disturbance, and maintain vegetation growth in its active stages are more likely to result reduced greenhouse gas emissions or in net sequestration. Carbon sequestration rates in mature woodland with trees that have attained their maximum size may plateau in the trees themselves, but the habitat may continue to increase its overall store of carbon in living and dead wood and in litter and underlying soil (Alonso et al. 2012). Sediments below the waterbodies may also be net carbon stores, but note that in some conditions, such as in the early phases of restoration wetlands may be net emitters (see section 7.6). Conclusions on the contribution of land-use change and habitat restoration to climate regulation, that is to say, whether there is net sequestration or emission of greenhouse gases, also depend on the timeframe considered during an evaluation.

Increase in the overall area of waterbodies, and total water-storage capacity of the site, would likely enhance flood regulation; the proximity of the housing development indicates stakeholders who would likely benefit from this service. The waterbodies in the nature reserve have been designed to capture and store roof water from the areas of new housing.

Alteration to the topography (from steep to shallow sided), and the act of vegetating bare ground are both likely to have had positive benefits for reducing the potential for erosion and soil loss, with likely benefit for water quality (and reduction of carbon loss). The vegetated surfaces reduce the speed of surface water flow, and plant roots also uptake and filter water moving through the soils.

The heath (if containing flowering angiosperm species such as heather *Calluna vulgaris*), the wildflower/marsh grassland, and possibly plants within the scrub, may support pollinating insects. This will depend on species composition; some species that are attractive to pollinators e.g. rowan *Sorbus aucuparia* and bilberry *Vaccinium myrtillus* are stated to be present (Tir Gwyllt Wild Ground n.d.). The degree to which this results in pollination as an ecosystem service that benefits people, as opposed to pollination as an ecological function, may depend on the amount of pollinator dependant crops in the immediate vicinity, not known from the resources examined.

Potential cultural services

The benefits of the Lane End mitigation area to the health and well-being of the local community may not be fully realised because the nature reserve is a closed site, meaning that access is permitted only on a set number of days per year, rather than being open to all year-round. However, there is open access to Knowle Hill and the amenity grassland part of the mitigated land, which would supply some physical benefits of recreation and published literature includes evidence of benefits even for subjects who could only experience the natural environment from a distance. Public use of Knowle Hill for recreation, especially dog walking is likely to be in the order of 15,000 people per year (pers. comm. Kate Wilson September 2019). Potential well-being benefits from the restored landscape at this site might therefore be enjoyed by those who exercised regularly on land designated for amenity use, those who periodically have access to the reserve itself, and residents of the housing development who are able to observe these areas from a distance. Wild Ground also runs a weekly conservation group; similar groups have been equated to “green gyms” delivering physical fitness benefits and a sense of well-being. More than 6400 hours of volunteering work have been delivered on Lane End and Knowle Hill since 2016 including surveys, pond work, access work and invasive species control (pers. comm. Kate Wilson September 2019).

The nature reserve that was developed as mitigation for the housing development contributes to education. Wild Ground offers outdoor education and nature awareness activities to the local community, including through hosting regular school visits, providing ecological training for its volunteers and staff and publishing newsletters for local residents. Since 2017, educators have engaged with more than 900 children and over 300 adults including through events such as pond dipping, an Easter trail, fungi foray, “meet the amphibians”, great crested newt training courses, and education sessions with schools and scout groups (pers. comm. Kate Wilson September 2019). The area also facilitates science, as there is a programme of fully resourced long term ecological monitoring, which contributes data to national schemes (eg the online Wales Great Crested Newt Monitoring Scheme and to the local Cofnod record centre. The nature reserve will facilitate biodiversity appreciation, the act of observing and enjoying wildlife, even if the “closed site” status of the reserve, which opens for a limited number of days/events each year, reduces the possible number of human beneficiaries that could be realised.

The strong link to the industrial history of the site maintained through a heritage trail and through the work of the Wild Ground warden to engage with CADW and the local community to map the land's heritage features will contribute to a "sense of place". Specific examples of features that have been given profile include Victorian clay quarrying and brick-making locations and the Buckley Tramway, dating from the 1700s which is a Scheduled Ancient Monument.

Potential supporting services

The biodiversity of the reserve and green infrastructure is often classed as a supporting service (as opposed to the enjoyment of biodiversity by people, a cultural service). Ecological monitoring and species recording has produced evidence that the habitats on the nature reserve are used by other species, in addition to the great crested newts that drove the conservation efforts. The species recorded include four other amphibian species including the common toad (a section 7 list species) and other species shown in Table 5.

Table 5. List of notable species recorded at Lane End/Knowle Hill nature reserves. Source: Tir Gwyllt Wild Ground (n.d.). * denotes a species that appears on Section 7 of the Environment (Wales) Act 2016. This is a list of the living organisms of principal importance for the purpose of maintaining and enhancing biodiversity in relation to Wales.

Taxon	Species
Amphibian	Great crested newt *
Amphibian	Palmate newt
Amphibian	Smooth newt
Amphibian	Common frog
Amphibian	Common toad *
Bird	Black headed gull *
Bird	Herring gull *
Bird	Heron
Bird	Mallard
Bird	Tufted duck
Bird	Lapwing
Bird	Snipe

Bird	Common linnet *
Bird	Black redstart
Bird	Bullfinch *
Bird	Lesser whitethroat
Bird	Blackcap
Bird	Chiffchaff
Bird	Green woodpecker
Bird	Great spotted woodpecker
Bird	Sparrowhawk
Bird	Jay
Mammal	Badger
Mammal	Fox
Mammal	Rabbit
Mammal	Common shrew
Mammal	Grey squirrel (non-native)
Butterfly	Peacock
Butterfly	Orange tip
Butterfly	Gatekeeper,
Butterfly	Common blue
Butterfly	Dingy skipper *
Butterfly	Green-veined white

Reptile	Common lizard

Conclusion / lessons learned

Examination of literature about this location, supplemented with some direct communication with people who have personal knowledge of the site, suggests that Lane End development and mitigation is capable of delivering a range of ecosystem services, predominantly regulating, cultural and supporting services. Quantification of the area of individual habitats in the prior to and after establishment states and direct engagement with other local stakeholders and the community itself would be necessary to quantify or value these with more certainty. For example, an approach used in economic valuations that might be applicable here, were an economic valuation to be considered, would be to evaluate any premium associated with prices of houses that have views of the natural area in comparison with others without views (see example revealed preference methods and other approaches reviewed in Sunderland 2012 and Laurila-Pant et al. 2015).

Land at Lane End contributes both designated and non-designated land to the overall provision of green infrastructure in Buckley. Preliminary analysis of the combination of designated and non-designated sites in Buckley indicates approximately 120 ha of green infrastructure has been secured as part of the delivery of species conservation action (including site designation, compensation and off-setting). It is considered from preliminary assessments that this overall provision is significant in a Buckley spatial context. Reoccurring significant issues associated with the management of habitats and species within green networks concern the availability and security of long term financial resources. The financial funding model for Lane End could be relevant to the long-term management of some other ecological interests, e.g. for sites supporting non-designated habitats or species; managing greenspace; and for delivering targeted ecosystem service management. In this case, the presence of great crested newts, a strictly protected species, made it possible to set in place long-term funding arrangements that would also benefit wider biodiversity and local people. Other novel funding arrangements underpinned by similar rationale are being trialled or implemented in other parts of the UK.

Conclusions

The main findings of this report are:

The literature review discovered published studies on societal benefits (ecosystem services) associated with amphibians. A published global review that covered a wide range of amphibian genera and species found evidence for amphibian performance of, or a major or indirect contribution to, the delivery of all classes of ecosystem services.

The largest number of studies found related to the role of amphibians in the supporting services e.g. by undertaking actions that changed habitats, ecosystem processes or functions.

There are currently geographic and taxonomic biases in the published literature, likely reflecting the distribution of researcher interests rather than their actual occurrence in nature. A key text, a global review, mainly drew on North American sources and by studies of frogs, toads and to a lesser degree, salamanders. No examples of studies of ecosystem services associated with European newts were showcased in the global review.

There also appears to be an uneven balance of attention towards the aquatic and terrestrial stages of the amphibian life-cycle and consequently to the different life-stages. The global review, undertaken under the provisions of this contract, found more studies on the aquatic stages of the lifecycle, than on the terrestrial phases.

Since the amphibian lifecycle involves both aquatic and terrestrial stages, they are able to play a role in exchanging energy and nutrients between terrestrial and aquatic habitats. For many species this remains unquantified.

It is plausible that amphibians may contribute to suppression of pests and diseases, but the complexity of ecosystems means that there are relatively few examples where this has been demonstrated conclusively in the field.

Great crested newts predate a broad range of invertebrate prey. While we are aware of no study that has quantified a regulatory effect exerted by great crested newts on any prey species, or evaluated the impact of the species on nutrient or energy flow, it is evident that appropriate species interactions exist, to presume that some contribution is likely. The scale of any effect is expected to be context specific, depending on factors such as the size of the local great crested newt population and the density and composition of other great crested newt prey and predator assemblages.

There are many examples of amphibian cultural services including in art, religions, music and literature. A great crested newt features as a character in *The Tale of Jeremy Fisher*, a well-loved children's story by the author Beatrix Potter. Newts are also referenced in Shakespeare's Macbeth.

Several recent projects have likened amphibians and reptiles, including newts to dragons, a prominent emblem in Welsh culture, as a way of raising awareness of, and popularising herpetofauna.

Newts and other pond creatures have featured in education and educational resources, and pond-dipping has been used as a way of teaching children about aquatic wildlife and inspiring a love of nature.

Great crested newts and other amphibian species also contribute to biodiversity appreciation, people's enjoyment and interest in species in the natural world, including indirectly through nature documentaries and publications and "existence value".

Great crested newts use a range of diverse habitats, with the majority of these being lowland habitats; during different stages of their lifecycle and in different times of year they move between the aquatic and terrestrial environment.

In Wales, habitats that have been protected on the network of SAC sites that were designated for the protection of great crested newts include grasslands (neutral, acid and calcareous, hay meadows, ‘pasture’ and marshy grassland), woodland (including mature broadleaved), scrub, hedgerows, lowland dry heath, wet heath and bracken and water bodies including those formed in pits and quarries from former mineral workings and ex-industrial landscapes.

We used expert knowledge to list the main NVC vegetation classes that constitute primary or secondary habitat for great crested newts. By reference to the literature on potential ecosystem services delivered by different habitat types, we predicted potential ecosystem services that are likely to be delivered as a result of land being protected or managed for the benefit of great crested newts.

A site protected for the purpose of great crested newt conservation is likely, by virtue of the habitats that will be secured for that purpose, to deliver a number of other benefits to people. The mix of potential services is dominated by regulating and cultural services, but a contribution to provisioning services is also possible.

Potential regulating services delivered by a site managed for great crested newt conservation include contributions to global climate regulation (through carbon sequestration and storage), local climate regulation (e.g. through shelter belts or shade), flood protection (through water storage and slowing the rate of water movement on the surface and through soils), air quality regulation, erosion control, nutrient cycling, water quality and pollination (where flowering plants are present close to crops that require pollinators).

Potential cultural services delivered by a site managed for great crested newt conservation include recreational opportunities, contribution to aesthetics or a sense of place, enabling other wildlife that use the same habitat types to thrive, provision of opportunities for people to appreciate nature, preservation of historical heritage and opportunities for education and the generation of scientific data or other knowledge.

Potential provisioning services delivered by a site managed for great crested newt conservation include possible contributions to rearing livestock, production of fodder and other crops, wood for timber, fuel or energy, freshwater, construction aggregates but not use for fishery (e.g. angling) because of conflict between the persistence of great crested newts and the presence of fish.

We presented information on the results of simple audits of potential ecosystem services for two case study sites where land has been protected and managed for great crested newt conservation.

At Kintbury Newt Ponds, a Berks, Bucks and Oxon Wildlife Trust (BBOWT nature reserve in Berkshire the establishment of a nature reserve was driven by the requirement to secure a population of great crested newts on land threatened by a housing development. Site protection brought wider biodiversity benefits including to other amphibians, reptiles and migratory birds, all of which would have lost access to habitat providing their ecological requirements, had the land been developed. Although the reserve is very small, it is likely to deliver at least ten ecosystem services. The potential beneficiaries were mainly local, but also global (through contribution to climate regulation).

At Lane End, Buckley, north Wales, habitat for great crested newts was restored and created in mitigation for a 300-house development on the site of a former brick works. As a result of the mitigation, in addition to conservation of one of the largest populations of breeding great crested newts known in Great Britain, habitat has been secured for a list of other species including several that are listed on Section 7 of the Environment (Wales) Act 2016. Wider benefits for society (ecosystem services) are anticipated to include a range of ecosystem services, predominantly regulating, cultural and supporting services.

The combination of designated site and amphibian mitigation action is considered to contribute significantly to the overall provision of green networks within the environs of Buckley. Preliminary analysis of current and extant conservation action suggests this is in the region of 120 ha. Consequently, preliminary analysis of amphibian conservation action highlights its potential to function as a material mechanism for securing and managing green infrastructure and facilitating long-term ecosystem services management.

Due to the strict protection accorded to great crested newts, their presence made it possible to set in place a long-term funding model designed to sustain conservation management of the site, benefiting the newts, wider biodiversity and local people. This model may be relevant to further sites and alternative novel or innovative funding arrangements underpinned by similar rationale are being trialled or implemented in other parts of the UK.

In overall conclusion, we have used the ecosystem services framework to demonstrate a range of wider societal benefits that are likely to arise from measures to conserve great crested newts. In addition to those that that flow from the protection of habitats on which the species depends, examination of published literature also suggests that amphibians themselves may contribute to ecosystem services directly and indirectly. Research on how nature, and ultimately species such as great crested newts, impact human well-being is an active and developing field and there is scope for further work that would enhance public understanding and support the conservation of species and habitats.

Recommendations for Future Work

This report is the output of a brief scoping study that drew on existing knowledge and readily available literature. It therefore provides a general overview and rationale, rather than comprehensive detail, particularly in a specific Welsh context. Given more time and resources, there is scope for expanding the work begun here, to source improved evidence of how people and other species may benefit from mitigation and conservation provision for great crested newts, or other wildlife species.

Suggested areas for further work include:

- *Review the spatial correlation of great crested newt and other European protected species /conservation priority species at selected sites in Wales.* Building on the preliminary results available from the literature reviewed in this report, this task would review record centre data and local reserve species lists to determine the coincidence of clusters of species that may benefit from the protection and management of sites for great crested newt.

- *Potential ecosystem services audit of selected sites in Wales that are protected and managed for great crested newt.* This would involve review of site maps, and potentially management plans to infer likely services.

- *Rapid assessment of ecosystem services at selected case study sites in Wales protected and managed for the conservation of great crested newt.* Where suitable mapping resources and current/historic data on land-use and management allow, GIS would be used to quantify spatial changes in land-use before and after the establishment of mitigation/conservation sites for great crested newt. Desk-study and expert opinion would infer likely qualitative change in ecosystem services. This process also determines the degree of scope for economic valuation of services, where of interest, for separate later work. (Rapid, qualitative, assessment is a pre-requisite of any economic valuation, but the more detailed valuation step is not always required, and is only feasible where data allow).

- *Engagement with local stakeholders at selected great crested newt conservation sites to improve understanding of benefits to people.* Stakeholder engagement and participation is regarded as a “key part of conducting an ecosystem assessment” and McArthy & Morling (2014) recommend that rapid assessments engage with as wide a range of stakeholders as possible, and that relevant stakeholders be identified at a very early stage.

- *Workshop focused on Biodiversity, Ecosystem Services and Wales.* This would bring together researchers and practitioners to give profile to the wider benefits of species conservation activity and the species themselves, drawing on work led within and outside Wales. The basic format would include a programme of talks, but depending on locality, and organisational needs, could potentially incorporate some element of stakeholder discussion, focused on opportunities for improving outcomes for species and people, in a site or regional context including cross reference to Area Statements in Wales (see

https://naturalresources.wales/about-us/area-statements/area-statements-overview/?lang=en) and Local Nature Recovery Action Plans.

- *Provision of potential ecosystem services summary information for selected sites, for integration into site information resources.* Information on protected sites for visitors often focuses purely on the biodiversity interest of the site. Information on “taken for granted” services provided by nature is rarely provided. Where appropriate, and following a rapid assessment exercise, there is an opportunity to provide summary information suitable for incorporation into websites or signage, to support land manager engagement with local community audiences.

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Annexes and Appendices

Annex 1.

The 12 Malawi Principles that underpin the Ecosystem Approach

Information summarised from UN Environment Programme website Convention on Biodiversity. 25 Years Safeguarding Life On Earth.
https://www.cbd.int/ecosystem/principles.shtml

1. Management objectives are a matter of societal choice
2. Management should be decentralised to the lowest appropriate level.
3. Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems.
4. Recognizing potential gains from management there is a need to understand the ecosystem in an economic context, considering e.g. mitigating market distortions, aligning incentives to promote sustainable use, and internalizing costs and benefits.
5. A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning.
6. Ecosystems must be managed within the limits of their functioning.
7. The ecosystem approach should be undertaken at the appropriate scale.
8. Recognising the varying temporal scales and large effects which characterise ecosystem processes, objectives for ecosystem management should be set for the long term.
9. Management must recognise that change is inevitable.
10. The ecosystem approach should seek the appropriate balance between conservation and use of biodiversity.
11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Annex 2.

Short films explaining ecosystem services terms.

A series of short films summarising the different categories of ecosystem services and the concept of natural capital, from the viewpoint of environmental practitioners was produced in 2016 by University of Reading in association with the Loddon Catchment Partnership. Photographed and edited by Motion Blur productions.

Nature's assets: natural capital explained

Nature provides: provisioning services explained

Nature regulates: regulating services explained

Nature enhances lives: "cultural" services explained

Annex 3.

Definitions of common terms and roles in single species conservation after Leader-Williams and Dublin (2000)

Term	Ecological	Ecological & Strategic	Strategic
Keystone species	Vital role in ecosystem	Not relevant	Blank
Umbrella species	Shelter other species	Blank	Blank
Indicator species (i)	Reflect community composition	Blank	Blank
Indicator species (ii)	Blank	Chosen to reflect environmental change	Blank
Flagship	Blank	Blank	Chosen to raise public awareness, action & funding

Appendix 1

Notes accompanying Appendix 1 Phase 1 habitat classification

Introduction

The Phase 1 habitat classification system has been used for this work to highlight the broad habitat types used by the species (i.e. Phase 1 level 1 or level 2 categories). The Phase 1 system was chosen as it provides a defined list of habitats that is widely utilised and understood by the conservation community, with descriptions and unique coding for each habitat. In many instances, the Phase 1 system provides further fine-scale habitat classification e.g. sometimes as far as a fourth-level category. This report only refers to habitat types at the coarser scales, rather than attempting to define great crested newt use of fine-scale sub-categories. This is because the fine-scale preferences of great crested newt within the broad category are not always known and, similarly, the impact of fine-scale differences in habitat type on the potential delivery of ecosystem services is often uncertain. For example, the habitat Mire (E) has various vegetation sub-categories below those shown in the table below, but we have not commented on the potential use of these by the species.

Primary habitat

Great crested newts use a diverse range of habitat types, with some habitats being more optimal than others. For the purposes of this study, 'primary habitat' is defined as key habitat frequently used by the species throughout its range and therefore some of the natural habitats which are often ideal for great crested newts, but have a very restricted distribution, are classified in this report as 'secondary habitat' for this reason. For terrestrial habitat, the habitat type generally affords good refuge, hibernation, foraging and dispersal opportunities.

It is important to note that structure is important when determining the suitability of a habitat for great crested newts, so if a habitat is highlighted as 'primary' but does not provide structure and therefore refuge opportunities etc., it would not be considered as an optimum habitat for the species. This classification is only one aspect of assessment to determine whether a habitat is suitable for great crested newts.

Secondary habitat

For this study, 'secondary habitat' is either limited in extent, such as some natural or semi-natural habitats such as sand dune slack ponds, or may not provide optimal conditions for the species, such as coniferous woodland, but may still be used by the species.

It is important to note that sometimes 'secondary habitat' can be tremendously important for the species, particularly if it is situated close to ponds, forms connectivity between key habitats or provides good structure.

Ponds

This section has not been further broken down into sub-categories; this is because the assessment of whether a pond is suitable is based upon many aspects including,

the location and setting of the pond (habitat type), size of the waterbody, amount of vegetation and degree of shading inter alia.

Use of JNCC (2008) Phase 1 Habitat Survey Vegetation types to identify great crested newt habitat. Where applicable, habitat types have been assigned primary or secondary habitat status based on literature sources and expert judgement. The purpose of this summary is to demonstrate the breadth of habitat utilised and indicate the habitats in which the species occurs most frequently. However, it is not intended to be a comprehensive analysis of all habitats used by the species.

JNCC Phase 1 habitat survey handbook code	JNCC Phase 1 habitat survey handbook name	Phase 1 habitat survey of Wales code	Phase 1 habitat survey of Wales name	Primary habitat	Secondary habitat	Comments
A	Woodland and scrub	Blank	Blank	Yes	Blank	Blank
A1	Woodland	Blank	Blank	Yes	Blank	Blank
A1.1	Broadleaved woodland - semi-natural	Blank	Blank	Yes	Blank	Blank
A1.1.1	Broadleaved woodland - semi-natural	A.1.1.1	Semi-natural broadleaved woodland	Yes	Blank	Blank
A1.1.2	Broadleaved woodland - plantation	A.1.1.2	Planted broadleaved woodland	Yes	Blank	Blank
A1.2	Coniferous woodland	Blank	Blank	Blank	Yes	The species shows a preference for deciduous woodland, where there is generally more of a well-defined understorey, and ground cover including rotting/fallen logs etc.

A1.2.1	Coniferous woodland - semi-natural	A.1.2.1	Semi-natural coniferous woodland		Yes	The species shows a preference for deciduous woodland, where there is generally more of a well-defined understorey, and ground cover including rotting/fallen logs etc.
A1.2.2	Coniferous woodland - plantation	A.1.2.2	Planted coniferous woodland		Yes	The species shows a preference for deciduous woodland, where there is generally more of a well-defined understorey, and ground cover including rotting/fallen logs etc.
A1.3	Mixed woodland	Blank	Blank	Yes	Blank	Blank
A1.3.1	Mixed woodland - semi-natural	A.1.3.1	Semi-natural mixed woodland	Yes	Blank	Blank
A1.3.2	Mixed woodland - plantation	A.1.3.2	Planted mixed woodland	Yes	Blank	Blank
A2	Scrub	Blank	Blank	Yes	Blank	This is often an overlooked habitat for great crested newts, although it typically provides good cover and foraging opportunities.
A2.1	Scrub - dense/continuous	A.2.1	Dense scrub	Yes	Blank	Blank
A2.2	Scrub - scattered	A.2.2	Scattered scrub	Yes	Blank	Blank
A3	Parkland/scattered trees	Blank	Blank	Yes	Blank	Blank

A3.1	Broadleaved Parkland/scattered trees	A.3.1	Scattered broadleaved trees	Yes	Blank	Blank
A3.2	Coniferous Parkland/scattered trees	A.3.2	Scattered coniferous trees	Yes	Blank	Blank
A3.3	Mixed Parkland/scattered trees	A.3.3	Scattered mixed trees	Yes	Blank	Blank
A4	Recently felled woodland	Blank	Blank	Blank		The habitat is likely to offer little structure/cover;
B	Grassland and marsh	Blank	Blank	Yes	Blank	This is a key habitat grouping for the species; grassland with good structure – and with a thatch, are likely to deliver greater benefits for the species.
B1	Acid grassland	Blank	Blank	Blank	Yes	Blank
B1.1	Acid grassland - unimproved	B.1.1	Unimproved acid grassland	Blank	Yes	Blank
B1.2	Acid grassland - semi-improved	B.1.2	Semi-improved acid grassland		Yes	Blank
B2	Neutral grassland	Blank	Blank	Yes	Blank	Blank

B2.1	Neutral grassland - unimproved	B.2.1	Unimproved neutral grassland	Yes	Blank	Blank
B2.2	Neutral grassland - semi-improved	B.2.2	Semi-improved neutral grassland	Yes	Blank	Blank
B3	Calcareous grassland	Blank	Blank	Yes	Blank	Blank
B3.1	Calcareous grassland - unimproved	B.3.1	Unimproved calcareous grassland	Yes	Blank	Blank
B3.2	Calcareous grassland - semi-improved	B.3.2	Semi-improved calcareous grassland	Yes	Blank	Blank
B4	Improved grassland	B.4	Improved grassland	Yes	Blank	Blank
B5	Marsh/marshy grassland	B.5	Marshy grassland	Yes	Blank	Blank
Only used in Phase 1 habitat survey of Wales	Blank	B.5.1	Marshy grassland Juncus dominated	Yes	Blank	Blank

Only used in Phase 1 habitat survey of Wales	Blank	B.5.2	Marshy grassland Molinia dominated	Yes	Blank	Blank
B6	Poor semi-improved grassland	Blank	Blank	Yes	Blank	Blank
C	Tall herb and fen	Blank	Blank	Yes	Blank	This broad habitat type can be important as some of the communities are found scattered or in pockets in key habitat types, and often close to ponds. These habitats can be especially important where optimal terrestrial habitat is absent or limited.
C1	Bracken	Blank	Blank	Blank	Blank	Blank
C1.1	Bracken - continuous	C.1.1	Bracken	Blank	Yes	Blank
C1.2	Bracken - scattered	C.1.2	Scattered bracken	Blank	Yes	Blank
C3	Other tall herb and fern	Blank	Blank	Yes	Blank	Blank
C3.1	Other tall herb and fern - ruderal	C.3.1	Tall ruderal herb	Yes	Blank	Blank
C3.2	Other tall herb and fern - non ruderal	C.3.2	Non-ruderal herb	Yes	Blank	Blank

			and fern			
D	Heathland	Blank	Blank	Blank	Yes	Great crested newts can be found on heathland, particularly notable in parts of Scotland and Wales. This habitat grouping has not been broken down further.
Blank	Blank	Blank	Blank	Blank	Blank	Blank
E	Mire	Blank	Blank	Blank	Yes	Great crested newts do use mire habitats (secondary habitat). This habitat grouping has not been broken down further.
Blank	Blank	Blank	Blank	Blank	Blank	Blank
F1	Swamp	F.1	Swamp	Yes	Blank	Swamp habitats are used by newts, as 'swamp' is defined in JNCC (2010) "Swamp contains tall emergent vegetation typical of the transition between open water and exposed land. Swamps are generally in standing water for a large part of the year…". It is not considered helpful to break this habitat grouping down further.
G	Open water	Blank	Blank	Yes	Blank	Great crested newts use a wide range of waterbodies (both natural and semi-natural habitats), including ponds, ditches, ox-bow lakes, quarries & even more acidic pools. The species is typically associated with lowland ponds, where the water is around/close to neutral. The aquatic environment for great crested newts is frequently assessed via a number of factors, such as

						the amount of vegetation, degree of shading and size of the standing water, rather than the nutrient status of the water.
G1	Standing water	G.1	Standing water	Yes	Blank	Blank
G1.1	Standing water - eutrophic	G.1.1	Blank	Blank	Blank	Blank
G1.2	Standing water - mesotrophic	G.1.2	Blank	Blank	Blank	Blank
G1.3	Standing water - oligotrophic	G.1.3	Blank	Blank	Blank	Blank
G1.4	Standing water - dystrophic	G.1.4	Blank	Blank	Blank	Blank
G1.5	Standing water - marl	G.1.5	Blank	Blank	Blank	Blank
G1.6	Standing water - brackish	G.1.6	Blank	Blank	Blank	Blank
G2	Running water	G.2	Running water	Blank	Blank	The species is not typically associated with running water.
H	Coastland	Blank	Blank	Blank	Blank	Blank
H2	Saltmarsh	Blank	Blank	Blank	Blank	Blank
H3	Shingle above	H.3	Blank	Blank	Yes	Blank

	high tide mark					
H6	Sand dune	Blank	Blank	Blank	Yes	Blank
H6.4	Dune slack	H.6.4	Dune slack	Blank	Yes	Where these habitats exist, these can be very important habitats for the species.
H6.5	Dune grassland	H.6.5	Dune grassland	Blank	Yes	Blank
H6.6	Dune heath	H.6.6	Dune heath	Blank	Yes	Blank
H6.7	Dune scrub	H.6.7	Dune scrub	Blank	Yes	Blank
H6.8	Open dune	H.6.8	Open dune	Blank	Blank	Blank
H8	Maritime cliff and slope	Blank	Blank	Blank	Blank	Blank
H8.4	Coastal grassland	H.8.4	Coastal grassland	Blank	Yes	Blank
H8.5	Coastal heathland	H.8.5	Coastal heath	Blank	Yes	Blank
Only used in Phase 1 habitat survey of Wales	-	H.8.6	Coastal heath/coastal grassland mosaic	Blank	Yes	Blank
I	Exposure and waste	Blank	Blank	Yes	Blank	Blank
I2	Artificial rock	Blank	Blank	Blank	Blank	Blank

	exposure and waste					
I2.1	Quarry	I.2.1	Quarry	Yes	Blank	This is an important habitat type; large populations can be associated with ponds in quarries.
J	Miscellaneous	Blank	Blank	Yes	Blank	Blank
J1.1	Cultivated/ disturbed land - arable	J.1.1	Arable	Yes	Blank	Blank
J1.2	Cultivated/ disturbed land - amenity grassland	J.1.2	Amenity grassland	Blank	Yes	Blank
J1.3	Cultivated/ disturbed land - ephemeral /short perennial	J.1.3	Ephemeral/short perennial	Yes	Blank	Blank
J1.4	Introduced shrub	J.1.4	Introduced scrub	Blank	Yes	Blank
Only used in Phase 1 habitat survey of Wales	Blank	J.1.5	Gardens	Blank	Yes	Blank
J2	Boundaries	Blank	Blank	Blank	Blank	Important habitat grouping for the species, as often important for cover and connectivity between habitats.
J2	Hedges	Blank	Blank	Yes	Blank	Blank

J2.1	Intact hedge	Blank	Blank	Yes		
					Blank	Blank
J2.1.1	Intact hedge - native species-rich	J.2.1.1	Blank	Yes		
					Blank	Blank
J2.1.2	Intact hedge - species-poor	J.2.1.2	Blank	Yes		
					Blank	Blank
J2.2	Defunct hedge	Blank	Blank	Yes	Blank	Blank
J2.2.1	Defunct hedge - native species-rich	J.2.2.1	Blank	Yes		
					Blank	Blank
J2.2.2	Defunct hedge - species-poor	J.2.2.2	Blank	Yes		
					Blank	Blankl
J2.3	Hedge with trees	Blank	Blank	Yes	Blank	Blank
J2.3.1	Hedge with trees - native species-rich	J.2.3.1	Blank	Yes		
					Blank	Blank
J2.3.2	Hedge with trees - species-poor	J.2.3.2	Blank	Yes		
					Blank	Blank
J2.5	Wall	J.2.5	Blank	Yes	Blank	Particularly dry stone walls
J2.8	Earth bank	J.2.8	Blank	Blank	Yes	
						Blank

Data Archive Appendix

No data outputs were produced as part of this project.

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