OCTOBER 2016

Options for a New Integrated Natural Resource Monitoring Framework for Wales

Project Report - Phase I

Appendices

Welsh Government Contract No. C147/2010/2011
Agreed Additional Work Requirement Dated 8th March 2016
NERC CEH Project: NEC05945

Canolfan Ecoleg a Hydroleg
Centre for Ecology & Hydrology
Natural Environment Research Council
Prifysgol Bangor University
BTO Looking out for birds
WRc
JNCC Joint Nature Conservation Committee

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Options for a New Integrated Natural Resources Monitoring Framework for Wales

Phase 1 Project Report - Appendices

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Appendix A
Glossary of Acronyms

AGNPP	Above Ground Net Primary Productivity
AONB	Areas of Outstanding Natural Beauty
AURN	Automatic Urban and Rural Network
BBS	Breeding Bird Survey
BMS	Butterfly Monitoring Scheme
BRC	Biological Records Centre
BTO	British Trust for Ornithology Trust
BU	Bangor University
CBC	Common Birds Census
CEH	Centre for Ecology & Hydrology
COBR	Cabinet Office Briefing Rooms
CRN	Customer Reference Number
DCWW	Dŵr Cymru Welsh Water
DEFRA	Department for Environment, Food & Rural Affairs
EA	Environment Act
eDNA	Environmental DNA
EO	Earth Observation
EU	European Union
FERA	Fera Science Limited; formerly the Food and Environment Research Agency - a joint venture co-owned by Capita and DEFRA.
FSA	Food Standards Agency
FUW	Farmers' Union of Wales
GHG	Greenhouse Gases
GMEP	Glastir Monitoring & Evaluation Program
HEF	Historic Environment Feature
HNV	High Nature Value [farmland]
INNS	Invasive and Non-Native Species
IPPC	International Panel for Climate Change
IPR	Intellectual Property rights
JNCC	Joint Nature Conservation Committee
LERC	Local Environmental Records Centres
Lidar	Light Detection And Ranging - a surveying method that measures distance to a target with a laser light
LRCs	Local Record Centres
MoU	Memorandum of Understanding
Natura 2000	European network of protected sites {under the Birds Directive and the Habitats Directive}
NBMP	National Bat Monitoring Programme
NBN	National Biodiversity Network
NDVI	Normalised Difference Vegetation Index
NFI	National Forest Inventory
NFU	National Farmers Union Cymru
NGO	Non-Governmental Organisations
NNR	National Nature Reserves

NPMS	National Plant Monitoring Scheme
NRM	Natural Resources Monitoring
NRMF	Natural Resources Monitoring Framework
NRW	Natural Resources Wales
OGL	Open Government Licence
ONS	Office for National Statistics
PAH	Polycyclic Aromatic Hydrocarbon
PCBs	Polychlorinated Biphenyls
PES	Payments for Ecosystem Services
PROW	Public Right of Way
qPCR	quantitative Polymerase Chain Reaction
RAMSAR [site]	A wetland area designated for its conservation value under the 1971 UNESCO Convention on Wetlands of International Importance.
RCUK	Research Councils UK
RDP	Rural Development Programme/Plan
RIMNET	Radioactive Incident Monitoring Network
SAC	Special Areas of Conservation
SAGE	Scientific Advisory Group for Emergencies
SAM	Scheduled Ancient Monument
SoNaRR	State of Natural Resources Reports
SPA	Special Protection Area
SRO	Senior Responsible Officer
SSSI	Site of Special Scientific Interest
STAC	Scientific Technical Advisory Cell
TOMP	Toxic Organic Micro Pollutants Network
TPO	Tree Preservation Order
UKBMS	UK Butterfly Monitoring Scheme
UKEAP	UK Eutrophying and Acidifying Pollutants
UKEOF	UK Environmental Observation Framework
UKSO	UK Soil Observatory
WCBS	Wider Countryside Butterfly Survey
WFD	Water Framework Directive
WFG	Well Being of Future Generations Act
WG	Welsh Government

Appendix B
Who Was Involved – People and Organisations

This document provides a summary of the profile of the people and organisations involved in each of the project's core working activities. As large and diverse a group of stakeholders, contributors, reviewers and project-team members was included in this project as was possible with the brief given and the resources & timescales available.

Workshops

Attendees:
Workshop 1 : 27
Workshop:2 36
Workshop 3: 39

66 individuals (attended at least 1 event).

22 organisations (attended at least 1 event):

Bangor University	CLA	JNCC
Bat Conservation Trust	Cofnod	NFU Cymru
Brecon Beacons National Park Authority	Dŵr Cymru	NRW
	Environmental Systems	RSPB
BTO	Farmers' Union of Wales	WG
Butterfly Conservation	Freshwater Habitats Trust	Wildlife Trusts
CADW	FUW	WRc
CEH	Independents	

Bilateral Topic Meetings

12 focussed meetings, held between 4th March and 9th June 2106.

A set of bilateral meetings were conducted (although often involving more than two organisations), the objective was for each to focus on a specific topic, pull together relevant stakeholders and share and discuss status, current and planned activities and ways forward that were specific to that topic.

In the time available, the project team held 12 of these focussed meetings. For most, notes were taken and follow-up actions recorded. The meeting actions are outside the immediate scope of this project but the primary aim to share ideas and establish dialogue between stakeholders was achieved. In many cases, ideas and information from these meetings has informed and guided the resultant recommendations and other outputs of this project.

Index of meeting topics (chronological order)

1. NRW and CEH Monitoring Activities
2. Agricultural and climate change
7. Landscape & Landmap
8. Data and Informatics

3. Species and Habitat Monitoring (NRW/CEH)
4. Natural Resources Monitoring (NRM)
5. Developing Biological Indicators
6. Forest Policy
9. Water *(not minuted)*
10. RDP Monitoring and Evaluation
11. Cadw/Historic
12. Plant Health

Dates and attendees
The meetings were held in a series of events conducted between 4th March and 9th June 2106.

A total of 14 organisations were represented:

ADAS	CEH	JNCC	NFU Cymru
AHDB Dairy	FUW	Lantra	NRW
Bangor University	Hybu Cig Cymru	Menter a Busnes	WG
CADW	IBERS		

Over 38 people attended at least one of the meetings

Technical Briefing Papers

Six briefing papers – total of 51 authors and contributors from 14 organisations

- Earth Observation
- Citizen Science
- Molecular/eDNA
- Water
- Data & Informatics
- Emergency Response

Briefing Papers: Authors and Contributors (the full reviewer group is larger and has not been enumerated)

David Chadwick	Bangor University	Lawrence Way	JNCC
David L. Jones	Bangor University	Paul Robinson	JNCC
Simon Creer	Bangor University	Alun Attwood	NRW
Andy Musgrove	BTO	Barnaby Letheren	NRW
David Noble	BTO	Ben Wilson	NRW
Dawn Balmer	BTO	Dave Allen	NRW
Gavin Siriwardena	BTO	Dave Johnston	NRW
Kelvin Jones	BTO	David Allen	NRW
Nick Moran	BTO	Dylan Lloyd	NRW
Rachel Taylor	BTO	Dylan Williams	NRW
Bridget Emmett	CEH	Helen Millband	NRW
Clare Rowland	CEH	Kath Bollington	NRW
Dan Morton	CEH	Liz Howe	NRW
David Robinson	CEH	Tristan Hatton-Ellis	NRW
France Gerard	CEH	Cath Shellswell	Plantlife
Lindsay Maskell	CEH	Hayley New	Plantlife
Lisa Norton	CEH	Claire Horton	WG
Oliver Pescott	CEH	Colin Chapman	WG
Peter Henrys	CEH	James Skates	WG

Rob Griffiths	CEH	Martin Williams	WG
Simon Smart	CEH	Paul Guest	WG
Tara Froggatt	DCWW	Stuart Neil	WG
Katie Metcalfe	Environment Systems	Kate Lewthwaite	Woodland Trust
Jeremy Biggs	Freshwater Habitats Trust	Andy Davey	WRc
Havard Prosser	Ind.		
Chris Cheffings	JNCC		

Steering Group and Meeting Attendees

Four meetings conducted.

Catherine Duigan (Chair)	*NRW*	Steve Spode	*WG*
James Skates (SRO)	*WG*	Victoria Seddon	*WG*
Stuart Neil	*WG*	Howard Davies	*WG*
Dewi Jones	*WG*	Kathleen Mulready	*WG*
Betsan John	*WG*	Dave Jones	*WG*
Joanne Amesbury	*WG*	Alun Attwood	*NRW*
Clive Walmsley	*NRW*	Chris Lea	*WG*
Colin Chapman	*WG*	Jim Latham	*NRW*
David Allen	*NRW*	Claire Horton	*WG*
Fiona McFarlane	*WG*	Emily Finney	*WG*
Jenni Hartley	*WG*	Helen Minnice-Smith	*WG*
Bob Vaughan	*NRW*	Peter Jones	*NRW*
Dai Harris	*WG*	Susan Williams	*NRW*

(excluding project team members)

Project Team

Bridget Emmett (lead)	*CEH*	Dave Jones	*Bangor University*
Chris Bell (project manager)	*CEH*	Simon Smart	*CEH*
Havard Prosser	*Independent*	Gavin Siriwardena	*BTO*
France Gerard	*CEH*	Andy Davey	*WRc plc*
Chris Cheffings	*JNCC*	Pete Henrys	*CEH*
Dave Chadwick	*Bangor University*		

Appendix C – Bilateral Meeting Notes

Bilateral Meeting - NRW and CEH Monitoring Activities

Title	**NRW and CEH Monitoring Activities**
Date	4/3/2016
Participants	David Allen (NRW), Alun Attwood (NRW), Bridget Emmett (CEH), Kathryn Monk (NRW) and Bronwen Williams (CEH)
Aim	To raise awareness of the NRW monitoring review and CEH's position with regard to future monitoring.
Topics	Discussion • NRW have been conducting an internal review of their monitoring activities since March 2015 to ensure they are fit for purpose and aligned with the Well Being of Future Generations and Environment Acts. • NRW are in the process of understanding what their evidence needs are, and targeting them to NRN duties, whilst meeting their advisory and statutory reporting requirements. • Future monitoring priorities will include their statutory reporting requirements and core business needs. • WFD is NRW's largest monitoring programme and steps have already been taken to reduce costs. The frequency and spatial extent of current monitoring is being explored and there are plans to look at the statistical robustness of the monitoring programme. • CEH are also reviewing their monitoring activities and are in the process of putting together a portfolio of terrestrial and freshwater monitoring for the UK. • CEH have been asked to scope out an integrated monitoring programme for natural resources, building on the integrated monitoring approach developed by GMEP. A phased approach of recommendations will be given. Phase 1 immediate opportunities which can be out in place by 2017, phase 2 medium term opportunities which can be achieved over a 3 year period and phase 3 to long term opportunities which could be achieved over a 10 year period. • The 'Future Options' project team includes an external consultant with a strong statistical background, WFD experience and assessing sampling needs and efficiencies which may be useful for NRW's future needs.
Implications for Future of Natural	The Future Options project will be mapping monitoring activities against policy requirements and identifying gaps; identifying monitoring and indicator/metric

resources Monitoring Programme	overlaps; re-balancing monitoring activity according to reporting requirements and looking for opportunities for new technologies and citizen science. It is important for the project team and NRW to continue sharing information to ensure there are no overlaps in activity.
Agreements and Actions	A proforma for identifying monitoring activity for policy requirements has been drafted for circulation to the 'Future Options' stakeholder group. David Allen agreed to lead and co-ordinate the NRW response.

Bilateral Meeting - Industry Stakeholder - Tackling climate change in the Agricultural Sector

Title	**Industry Stakeholder - Tackling climate change in the Agricultural Sector.**
Date	22/3/2016
Participants	Industry stakeholders for Agriculture Climate Change sector including reps from WG, Bangor University, ADAS, Institute of Biological, Environmental & Rural Sciences (IBERS), Hybu Cig Cymru, AHDB Dairy, NFU Cymru, Farmers' Union of Wales, Menter-a-Busnes, Lantra.
Aim	• To identify monitoring activity and reporting requirements within the agriculture and climate change sector. • To agree a set of indicators to track progress with tackling climate change issues.
Topics	Discussion: • Identified regulation, targets and policies which the industry reports to currently. • A number of monitoring activities were identified (e.g. AHDB C footprinting of 430 farms across GB) and opportunities for enhancing current activities to fulfil other reporting requirements were highlighted. E.g. soil samples are analysed for N, P, K and pH. Could C be included? Could info from the fertiliser practice survey be used? • Identified current regional and national scale indicators for tracking climate change • Possible indictors for the future were considered e.g. livestock weight, animal health, livestock numbers • Indicators for efficiency of production were discussed e.g. biomass and concentrate onto farms, grass growth, livestock product / unit of time. • Considered the importance of farm behaviour in driving CO_2e per unit production of X,Y,Z • Incentivising landowners for providing key data sets, self-reporting etc.
Implications for Future of Natural resources Monitoring Programme	The policies, reporting pathways and monitoring activities identified will be fed into the Future Options mapping exercise. Alignment with other monitoring activities undertaken by other organisations will be considered in respect to the new Natural Resources Monitoring Programme and SoNaRR reporting.
Agreements and Actions	To ensure continued engagement with the stakeholder group. The proforma for collating evidence on reporting requirements, evidence needs and monitoring activity has been distributed to the group for their consideration.

Bilateral Meeting - Species and Habitat Monitoring (NRW/CEH)

Title	**Species and Habitat Monitoring (NRW/CEH)**	
Date	23 & 24/3/2016	
Participants	NRW -David Allen, Dylan Lloyd, Pete Jones, Liz Howe, Claire Burrows, Stuart Smith, Jim Latham, Julie Creer, Heather Lewis (part session), Jean Matthews. CEH – Lindsay Maskell, Simon Smart, Bronwen Williams, Bridget Emmett	
Aim	Review GMEP habitat and species results and evidence needs of NRW for reporting on designated sites.	
Topics	Discussion: • Results from Broad and Priority Habitat estimates • Remote sensing • CSM indicators • Overlap with Annex 1 habitats • Natural Capital • Section 42 species • Grasslands • Woodlands • Peatlands • NRW evidence needs	
Implications for Future of Natural resources Monitoring Programme	Important to ensure future remote sensing activities within organisations do not overlap, but complement and make best use of resources for work e.g. use of GMEP data for validation.	
Agreements and Actions	Create Priority Habitat estimates for additional habitats; wood pasture, ponds hedgerows	Lindsay/CEH
	CEH should get hold of the new data for Phase 1 and Phase 2, this will be particularly for Peatlands and grassland	Lindsay to arrange formal request through GMEP data manager for data
	CEH to request NVC data for Peatlands, grasslands and woodlands	Lindsay to arrange formal request through GMEP data manager for data
	CEH should compare phase 1 data directly with CS and GMEP.	Lindsay/CEH

	CEH should take another look at how NRW estimates were derived and check same definitions e.g. size of patch	Lindsay
	Consider Fridd- discuss further with Claire, use Fridd mask to look at overlap with GMEP squares	Lindsay to check whether we have Fridd map
	Provide guidance given to Phase 2 grassland surveyors.	Liz Howe/NRW
	CEH should continue discussions with NRW on remote sensing to complement and make best use of resources for work e.g. use of GMEP data for validation N.B. there may currently be issues with data confidentiality and non-disclosure of GMEP squares.	CEH/NRW
	CEH to circulate CSM list to habitat specialists Arable indicators and other relevant habitats to Claire Burrows Upland habitats to Pete Jones?	CEH
	Lindsay to talk to Dan Guest about Welsh approach to CSM and to obtain any relevant guidance documents	Lindsay
	CEH should overlap the Annex 1 spatial layer with GMEP squares and look for where there is coincidence. CEH could also explore further mapping Annex 1 habitats from mapping data,	CEH
	CEH to get hold of unified Peatland layer map and overlay with plots/habitats	Lindsay to check with data manager
	CEH should get hold of Ancient woodland inventory data in GMEP database	Lindsay to check with data manager
	Further exploration by CEH of discrepancies in classification of grasslands, Blanket bog and Woodlands, Joint analysis of NRW/GMEP quadrat data to assess differences.	Lindsay/CEH
	Analysis of peatland data to compare degraded vs non-degraded blanket bog	Simon, Lindsay, Pete Jones, Chris Evans
	Jim to send report on how Annex 1 maps were determined	Jim
	NRW to provide copy of map of 1920's data for the Lleyn peninsula	Liz/NRW
	Jim to send ancient woodland associates list that he has? CEH can exchange lists and send our current AWI list	CEH/Jim
	CEH to discuss connectivity metric with Jim	CEH/Jim
	Could we use method for species (surrogate environmental variables) to look at potential for invasion by non-natives? Would be very interesting	CEH to look at potential
	CEH/NRW to explore ways of getting better monitoring data for species, liaison with LRC's, use of license returns,	Simon/NRW
	Table mapping GMEP options to GMEP metrics for section 42 species will be sent to NRW for input on metrics suggested and whether there might be better measures that haven't been considered	Simon to send to Liz for circulation to Claire, Jean, others?

	CEH contact Steve Bladwell at the RSPB who has been working on matrices of habitat management and impacts of species, looking at cross cutting issues and cross referenced to Glastir.	CEH
	Re-run woodland priority habitat estimates without masks	Lindsay/CEH
	Didn't really discuss other indicators but there is a lot happening on this elsewhere, NRW and CEH should consider joint contributions to indicators?	
	Prioritise the list of potential extra analyses	CEH/NRW

Bilateral Meeting - Natural Resources Monitoring (NRM)

Title	**Natural Resources Monitoring (NRM)**
Date	8/4/2016
Participants	Steve Spode (WG), Emily Finney (WG) James Skates (WG), Bridget Emmett (CEH), Bronwen Williams (CEH)
Aim	To ensure future options project includes future NRM policy needs
Topics	• Welsh legislation. • NRM policy • SoNaRR
Implications for Future of Natural resources Monitoring Programme	Future NRM monitoring programme will be the primary evidence provider for SoNaRR.
Agreements and Actions	WG to present SoNaRR and NRM to the steering group and brief Catherine Duigan. James to review SoNaRR draft report in relation to GMEP data and findings to identify possible contributions and potential conflicts of messages / evidence and report to the WG/NRW core evidence group.

Bilateral Meeting - Developing Biological Indicators

Title	**Developing Biological Indicators**
Date	15/4/2016
Participants	Range of WG, NRW, JNCC staff & Bridget Emmett (CEH) and James Skates (WG)
Aim	To better align and understand biological indicator work across the UK and their use within Wales
Topics	Presentations: • Resilience reporting in SoNaRR and links to other reporting requirements • Development of biodiversity and ecosystem health indicators for WFG • GMEP overview • Connectivity metric work by JNCC/CEH Bayesian modelling of unstructured third sector data Discussions: • First round of SoNaRR and WFG indicators are the start of the conversation. • Sources of bias, limits and opportunities. • The need to reduce duplication and identify gaps • How to balance mix of species data and linking this to sustainable development goals which go beyond priority species to ecosystem / resilience. • Step change needed in Wales beyond traditional biodiversity reporting metrics and making use of all data sources e.g. on common species important for function/services and ecosystem condition • Finding challenges for everyone including JNCC • Need to make better use of LRC data by CEH/JNCC modelling work
Implications for Future of Natural resources Monitoring Programme	Future options programme will report reporting pathways and existing indicators which could help inform NRW thinking on future indicators for WFG, and SoNaRR. Future NR monitoring programme will be a key evidence source for SONaRR and WFG biological indicators.
Agreements and Actions	To identify alignments in indicator developments making sure we link to the higher level NRM goals. A combined approach is required to data collection and modelling i.e. structured, unstructured and modelling. A need to consider Macpherson recommendations re modelling. Agreed to work with NRW and identify opportunities and potential conflicts and gaps in evidence and indicators. Agreement to share lessons learned from developing Glastir indicators. Recognition that all evidence costs and those costs can often be hidden as a mix of internal and external sources.

Bilateral Meeting - Forest Policy (National Forest Inventory)

Title	**Forest Policy (National Forest Inventory)**
Date	10/5/2016
Participants	Fiona McFarlane (WG) and Bill Macdonald (WG) James Skates (WG)
Aim	To identify Forest Policy evidence needs and future alignment of the (National Forest Inventory) NFI with the Natural Resources Monitoring Programme
Topics	Forest Policy evidence needs was discussed and the main evidence providers identified, currently with no future change expected NFI or its successor programme is the primary source of evidence, NRW evidence is more focussed on the operational side of things. GMEP currently fill a NFI gap in the provision of small woodland and on woodland evidence. FC restructuring and implications for the NFI was discussed, it is expected that the location / management of the NFI may change but the actual process of evidence capture is still required and a commitment to maintain exists. Currently DEFRA fund NFI and as such the cost to WG (domestic or programme) is zero. There is NO appetite to take responsibility for any evidence capture which falls within the remit of NFI due to additional cost. NFI is robust and practical, sample based approach, it does not really satisfy the evidence needs associated with small woodlands or on-farm woodlands and it does not lend itself to programme (intervention) evaluation. The current GMEP fills these gaps and as such the respective programmes are well aligned. Future opportunities were discussed and better working models identified with the emergence of a co-production / integrated approach as a clear theme.
Implications for Future of Natural resources Monitoring Programme	No significant change / action identified and it was agreed that the current NFI and GMEP satisfy the majority of forest policy evidence needs in the short to medium term Evidence gaps relating to WFG may exist and domestic emergency response and associated monitoring capacity raised as an issue. Urban tree cover is another gap currently addressed by the NRW Tree Cover in Wales' towns and cities – based on aerial photography. PAWS restoration – little data on this or monitoring of progress towards a more natural state resulting from interventions. It was agreed 2 recommendations should be developed around the themes of co production and more coordinated engagement, a more integrated NFI GMEP successor data pool should be established /agreed allowing for interrogation of a

	single data set and NFI should be represented on the future natural resources monitoring programme steering group / coordination group
Agreements and Actions	Bill / Fiona to collate a list of high level forest policy evidence needs The contractors to review (high level) forest policy evidence needs against NFI and GMEP activity and identify any significant gas Bill / Fiona to provide information on NFI activity and review Bill to provide some lines of emergency response / domestic monitoring capacity concerns to be included in the emergency / natural disasters paper Fiona to send Bill GMEP future options papers as these develop James / contractors to develop draft recommendations and consult with Bill, Fiona and possibly NFI

Bilateral Meeting - Landscape & Landmap

Title	**Landscape & Landmap**
Date	12/5/2016
Participants	Jill Bullen (NRW); James Skates (WG); Bridget Emmett (CEH)
Aim	To explore possible future synergies in activities in the landscape to contribute towards an integrated national monitoring programme
Topics	A detailed description of how Landmap was constructed and used was provided. There are 5 aggregated layers (geology; habitat; landscape; visual and sensory and historic) which can be aggregated but information can be lost doing this. In England their equivalent 'Character Map' a much larger resolution is used and using aggregated approach only. The map goes down to low tide. It does not include Cardiff and Swansea although a simple urban approach could be developed. Some boundaries are absolute – others are variable (notes on maps explain why). Landscape map is Phase 1 and then questions on scenic quality and character (both most important) integrity and rarity to get overall rating. Visual and sensory uses landcover map. Historic are the dominant historic features now (not in the past which have been superseded – see cultural). Cultural is where we have influenced the landscape or where landscape has inspired us. Classification is; outstanding (international or national); high (regional or county); moderate (local); low (little; none). The importance of the level of QA and use of professionals was emphasised to ensure protection if challenged legally as used as the basis for development control. Original produced in 2003; revised in 2008. They have explored change e.g. removal of trees at Plylimon and they do pick up change in quality. Ca. £1M to develop (ca. £46/km2). Understood they need to do change or will go out of date but how to do economically? GIS identified as potentially useful resource. They tested in South Wales and now doing nationally looking at change from 2001 to 2009. They are exploring parcels which have incremental or cumulative change. They use NDVI to explore where land management/ use likely to have changed and then score parcels to explore further e.g. Phase 1 – is vegetation of a type known to have phenological cycles (grassland) or e.g. timber harvesting which could explain the change. No NDVI = soil sealing. A live link to the underlying database for Landmap has just been completed.

	Landmap has been used for a range of purposes beyond development e.g. in Spark where layers where used to identify low levels of light pollution for recreation (art/astronomy); scenic quality (for painting, etc.)
Implications for Future of Natural resources Monitoring Programme	Joint working combining methodologies of Landmap and GMEP and EO could provide national mapping of change in landscape to help inform: WBFG and SoNaRR reporting; Targeting development opportunities e.g. for recreation; HNV assessment; Tourism experience (see Spark initiative which exploited Landmap)
Agreements and Actions	There is significant complementarity between Landmap and GMEP's approaches to landscape assessment. First step is to compare VQI to Landmap classification in all sample squares with key hypotheses questions identified beforehand. There is a major opportunity to explore change using more extensive metrics than can be obtained through EO alone to get a time series using GMEP approach. Opportunity to explore a comparison between the professional assessment of quality (Landmap) with citizen assessment (GMEP VQI) and impact of Visual Access (GMEP). Then explore potential to use GMEP approach to create a public perception layer to Landmap? Could also approach local authorities to get 'added local layer'. Potential for joint initiative to develop methods on peri-urban and urban but would need a refresh of questions. (Use of no-NDVI for soil sealing.) Explore link to HNV areas once agreed. Exploration of EO products and data should be more generally shared to avoid duplication and enhance synergies.

Bilateral Meeting - Data and Informatics

Title	**Data and Informatics**
Date	12/5/2016
Participants	Colin Chapman (WG),Stuart Neil (WG), Paul Guest (WG) James Skates (WG), Bridget Emmett (CEH)
Aim	To explore future requirements and opportunities for data and informatics for a new integrated national monitoring programme and how to align that with other data and informatics initiatives ongoing in WG and NRW.
Topics	Gap in knowledge in public sector in understanding the needs for investment in data and informatics if data is to be transformed into useful evidence and knowledge products i.e. data by itself with transformation into evidence and knowledge is worthless. Need for a data development workstream where a) what data is needed is identified; b) transfer functions to convert this to useful metrics; c) include hierarchy of evidence (not all evidence is of equal quality – critical when integration data to have assessed this quality beforehand and not include if not appropriate level of quality); Separate out constraints for regulation, compliance and discretionary data – they often have very different constraints impacting use, transfer and aggregation; Learning from past experience – and manage expectation. There are many good reasons why not all data is in one place and/or available. One size does not fil all. Keep realistic and doable, mixed model likely outcome. Key issues surround ontologies / data standards – we need to use what has already been identified (e.g. Darwin for biodiversity). Other issues include quality (a range of definitions should be devised) and suitability. Sustainable ongoing resource allocation to the management of and coordination among user groups is critical if investment collecting data is to be fully realised. Open source software for data capture needs to be explored further and that information shared between organisations.
Implications for Future of Natural resources Monitoring Programme	This topic is essential to comply with the Opendata commitment by WG. A possible model to explore is; WG to host a central hub live linked to a range of data providers who retain ownership and responsibility for their data linked using a range of web services. A range of issues need to resolved / agreed to allow their sharing between data providers and into WG central hub including; standards, ontologies; quality tags; suitability for different uses etc. Data sharing priority to be done on merit

	according to their need and quality. Preference for integration of fewer schemes by better. Potential role of a data management NRMF coordination subgroup to bring all partners together and ensure ongoing improvement and adaptations take place. Due recognition of original data providers always need to be considered.
Agreements and Actions	Agreed to co-produce a briefing paper on data and informatics enhanced with case studies of both successes (e.g. UKSO; GMEP) and failures. Capture rationale for this need i.e. efficiencies; integration of data sources; accessibility; transparency etc and potential model to take forward; To work towards an overall strategy and identify particular issues associated with the new technologies (EO; eDNA; citizen science, etc.) and consider implications of all data (political; legal; social and cultural) Include all involved in this bilateral from WG plus Barnaby Leatherman as Terrestrial Data Manager Colin Chapman Paul Guest to attend GMEP Pilot training days.

Bilateral Meeting - RDP Monitoring and Evaluation

Title	**RDP Monitoring and Evaluation**
Date	24/52016
Participants	Catherine Lawton (WG), Victoria Seddon (WG) & James Skates (WG)
Aim	To explore future requirements and opportunities of the RDP monitoring and evaluation programme and the future integrated Natural Resources Monitoring Programme / Framework
Topics	New monitoring requirements and a newly constructed framework for monitoring and evaluating the RDP. Within programme evaluation critical to new approach AIR now considers impact, evaluation and policy development as a whole rather than as separate components, asks a fundamental question of evidence policy feedback. Alignment of objectives in some cases across respective pillars. Far stronger emphasis of the provision of monitoring data /evidence within the programme and a requirement to utilise evidence. A stronger focus on annual reporting of how evidence has been capture and used Discussion took place on the relationship between different EU funds and how the new monitoring programme could better service evidence needs across funds Financial consequence for sub standard monitoring and non release of full funds. Annual reporting takes place across a series of set questions within which indicators have been identified
Implications for Future of Natural resources Monitoring Programme	Emphasis on evidence provision and utilisation provides robust foundation for a future monitoring programme Future monitoring programme can and should deliver evidence needs across the RDP Potential for the monitoring programme to contribute to other EU funds evidence needs Given within programme evaluation being of importance the roles of models may become more prominent

	Future monitoring programme should consider monitoring and evaluation questions rather than individual schemes. The future monitoring programme will be the source of evidence for subsequent evaluation rather than undertaking functions, increases transparency and independence. Farm Practice survey potential vehicle for wider evidence capture No policy or programme lead should own the future monitoring programme, it should be and be seen to be independent of policy and programme influence BASIS OF A RECOMMENDATION The proposal for a Wales wide Monitoring coordination group supported by RDP M&E team
Agreements and Actions	James to review new monitoring and evaluation questions against the fundamental evidence capture within GMEP as a means to provide early site of what evidence contribution the future monitoring programme could make across the RDP James to become a member of the EU funds advisory Group, Victoria to provide more detail James to circulation HNV paper Ongoing dialogue and engagement required with RDP M&E Victoria to circulate RDP M&E plan

Bilateral Meeting - Historic/CADW

Title	Historic/CADW
Date	9/6/2016
Participants	Kate Roberts (CADW); James Skates (WG); Bridget Emmett (CEH; FO Project Lead)
Aim	Opportunities / Benefits for a future Integrated Natural Resources Monitoring Programme for the Historic Environment
Topics	Current support of the GMEP project from CADW and the Archaeological Trusts Policy requirements for reporting and gaps. Current monitoring of non-scheduled features and potential benefits of non-biased sample from a systematic survey for; • reporting of current condition; • assessing ongoing risks; • informing new support schemes; • benefits or otherwise of scheduling regarding reducing risk and improving condition. Current situation re sharing of data between CADW and Archaeological Trusts New developments re databasing by CADW Opportunities for shared data analysis by CADW and GMEP to improve evidence base.
Implications for Future of Natural resources Monitoring Programme	Current reporting requirement has been for scheduled features only. Significant value was highlighted by CADW as to benefit of the current unbiased sample delivered by GMEP for tracking change in condition of unscheduled historic environment features (HEFs) which is not currently delivered by any other mechanism. Why? CADW emphasised that it was important any national assessment did not just focus on problems and thus skew the message. This approach could also inform a risk-based / prioritisation approach for follow-up assessment by experts of HEFS by CADW and the Archaeological Trusts most at risk. It was also useful information as to whether land in / out of agri-environment scheme was in a better condition and at lower risk to inform future support schemes. The unbiased systematic monitoring approach of GMEP also had the potential to identify what benefits (if any) was conferred by scheduling i.e. are SAMs in better condition by HEFS? GMEP approach also enabled an assessment of ongoing risks e.g. erosion; grazing; scrub encroachment etc. CADW were keen to share data - particularly to link across to other information which could help inform on risks e.g soil condition; land use/management change. CADW are just completing a cloud based approach to database of condition of scheduled features. Data on condition is not currently shared with Archaeological Trusts as to date there has been no need. Keen to share with others in future to increase understanding of underlying risks and change in condition.

	Opportunities also to integrate information of historic environment with other features/services from the natural environment to increase economic and well-being benefits e.g. more joined-up information for tourism sector.
Agreements and Actions	For CADW to continue to attend Future Options Stakeholder Workshops to ensure these views were shared with the wider community. To develop ideas how to develop the integrated analysis (i.e. of the soil, vegetation, HEF condition) to gain a better insight as to underlying factors which determine current condition and ongoing risks and thus improve the evidence base for the Historic Environment. To consider how to better integrate data to enhance economic and well-being agendas.

Bilateral Meeting - Plant Health

Title	**Plant Health**
Date	9/6/2016
Participants	Martin Williams, David Martin & Nia Meddins (Plant Health); James Skates (WG); Bridget Emmett (CEH; Future Options Project lead)
Aim	To assess current potential value of a future Integrated National Natural Resource Monitoring Framework for Plant Health
Topics	**Policy context** Current monitoring carried out and gaps. Breakdown of UK data for Wales re pesticide use. Potential use of archived samples from GMEP to track spread of pests and disease
Implications for Future of Natural resources Monitoring Programme	**<u>Pesticides</u>** **Policy needs** Implementation of the Sustainable Use Directive (2009/128/EC) and the Plant Protection Products (Sustainable Use) Regulations 2012 (No 1657) – the sustainable use of pesticides to reduce the risks and impacts of pesticide use on people's health and the environment, including integrated pest management. **National Action Plans** EU countries adopt them setting objectives and timetables to reduce risks and impacts of pesticide use; Training - Professional pesticide users, distributors and advisors get proper training. Information and awareness raising - Member States shall take measures to inform the general public and put in place systems to gather information on acute poisoning incidents and chronic poisoning developments; Aerial spraying - Aerial spraying is prohibited. EU countries may allow it under strict conditions after warning people; Minimising or banning - EU countries minimise or ban the use of pesticides in critical areas for environmental and health reasons; Inspection of equipment in use – All pesticides application equipment will have to be inspected at least once by 2016 to grant a proper efficient use of any plant protection product; Introduce Integrated Pest Management **Potential for NRMF** There is currently no breakdown of UK pesticide use statistics for Wales. It was highlighted it would be very useful if the GMEP Farmer Practice Survey could include questions on this to fill the gap. An idea of how pest management in general is being carried out by farmers is needed. They suspect agronomists are not being used which would be needed for this to be successful.

	It would be useful to know the competence of the sprayers in your grid squares and compliance with the rules and regs, what is being sprayed and how to provide background evidence of the key areas we need to focus on as a policy team. Availability of training, greater info and advice etc, etc **<u>Invasive Non-Native Species</u>** **Policy needs** Implementation of Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species. Also, related UK Regulations (yet to come into force). • 12 months after the list of species of EU concern is adopted – keepers of commercial stocks of listed species may no longer sell such species, other than to approved ex-situ conservation or research institutes. • 18 months after the EU list is adopted, Member States shall have carried out a comprehensive analysis of the pathways of unintentional introduction and spread of those pathways, and identified priority pathways. • 18 months after the list has been adopted Member States shall have established a surveillance scheme for the species of Union concern. • 18 months after the EU list is adopted, Member States shall have in place effective management measures for the species of Union concern. **NRMF potential** The main INNS areas I could see GMEP / NRMF having a role would be to map INNS generally and in particular the ones of EU concern in the grid squares, spread and perhaps new introductions. Also perhaps the knowledge of INNS and again this could feed into policy decisions. **<u>Plant Health</u>** Note: Also a need to contact forestry colleagues for input from forestry sides. <u>Policy needs</u> The Plant Health Services act to safeguard the biosecurity of plants whilst facilitating sustainable economic growth. Plant Health policy area aims to safeguard the biosecurity of plants in Wales. This is achieved by attempting to prevent the introduction and spread of quarantine pests and diseases, and delivering, in partnership with others, biosecurity systems that meet EU and international obligations, to enable businesses to grow by trading in healthy plant material and grow. We always need to be looking for ways to improve surveillance and biosecurity, and provide new tools, including diagnostics, vaccines and interventions. and the Animal and Plant Health Agency provide surveillance in line with EU requirements and this is essentially focused on plant nurseries and garden centres with some limited wider env monitoring. GMEP could supplement this wider env monitoring at their grid squares and provide added value. Plant Health Strategic Aims: • Development and implementation of policy to prevent harmful plant pests entering Wales.

	• Prepare a viable response to outbreaks of new plant pests (eradication, containment, management adaptation) to reduce losses to the economy and our natural environment.. • Develop partnerships with stakeholders including landowners, woodland managers, the horticulture sector, academics and the public to enhance biosecurity practices. • Commission and use evidence effectively to underpin policy and operations and to sustain plant health capability and capacity to respond to future threats. • Preventing the entry of harmful pests and diseases via enhanced horizon scanning for new threats, strengthened nursery checks. • Prioritising risks and action against the most harmful pests (priority pests) relevant to Wales via intensified checks, surveillance and mandatory contingency plans for dealing with outbreaks. • Improved Control measures in dealing with outbreaks wither through eradication or containment controls aimed at preventing further spread via the introduction of harmonised mandatory controls reflecting unfirmed standards. • Better pest management and biosecurity practices and develop approaches to raise awareness and enhance engagement with the general public. • Development of an integrated plant health monitoring network / expertise hub. Local forums developed to communicate and raise awareness on all levels (locally, regionally, nationally and internationally) and with a whole array of different interest groups including individual residents, business owners, land owners, councils, researchers, consultants and volunteers. • Increased awareness of invasive plant, pests and diseases and good biosecurity measures in the nursery and garden centre trade and of consumers through inspection, educational and awareness programme and the development and transfer of best practice protocols with stakeholders. <u>NRMF potential</u> PH Outbreak Example; P. ramorum is one of the main non-native fungus that causes diseases on a wide range of trees and shrubs in the Wales' woodlands affecting a range of environments, including nurseries, woodlands, heathlands, parks, private gardens and heritage gardens and is found widely across the UK (and Europe). NRMF/GMEP could help strengthen the information base available when surveying and monitoring and could add value to the networks of agencies that deal with the management and containment of diseases. The availability of working closer with NRMF/GMEP could offer up access of complementary skills and expertise in a different sector. Having access to this type of monitoring data could help us mange diseases, help with the development of an inventory of plant and tree species and also assist with certain research agendas. It could also help identify new diseases and help prediction of spread specifically if we had sporulating hosts present. NRMF/GMEP could be a tool that would help deliver and protect the current and future impact of pests and diseases on trees/plants in the wider environment of Wales and also assist in the understanding of factors driving pathogen spread and disease development, and the need to understand the risk to heathland environments, wider biodiversity and the overall health of ecosystems.

	Improved linkages with the protocols of the requirements of contingency planning would provide an improved readiness to respond to further large outbreaks. Potential to act as a vehicle to exchange survey information with key agencies ie: NRW & APHA
Agreements and Actions	Plant health to send information on current policy needs; drivers and how a NRMF could support their work. – this is now included in text above. FO to ensure invites go to Plant Health to FO Stakeholder Workshop 3. The potential value of the NRMF highlighted the need for Plant Health would need to have a representative on any future Coordination Board. The need for Plant Health to input into the Future Options Emergency Response Briefing Paper.

Appendix D1
Stakeholder Workshops
An Introduction & Who Was Involved

Workshop 1

3rd May 2016 - Welsh Government Offices, Ladywell House, Newtown

Topic: Policies, Drivers, Evidence Categories, Evidence and Data Sources

Invitation emails to: approx. 104 names across 29 organisations

Emails publicising the event and the date: 25/4/16, 28/4/16

On the day:
28 attendees
13 organisations

Jo Amesbury	WG
Alun Attwood	NRW
Jill Bullen	NRW
Dave Chadwick	Bangor University
Chris Cheffings	JNCC
Catherine Duigan (Chair)	NRW
Chloe Elding	Wildlife Trusts
Bridget Emmett	CEH
Ian Halfpenney	CADW
Dai Harris	WG
Peter Henry	CEH
Liz Howe	NRW
Peter Jones	NRW
Rachel Lewis-Davies	NFU Cymru
Bernard Llewellyn	NFU Cymru
Fiona McFarlane	WG
Stuart Neil	WG
Charlotte Priddy	FUW
Havard Prosser	Independent
Paul Sinnadurai	Brecon Beacons National Park Authority
Gavin Siriwardena	BTO
James Skates	WG
Simon Smart	CEH
Steve Spode	WG
Roy Tapping	Cofnod
Clive Walmsley	NRW
Emma Waters	CEH
Dylan Williams	NRW

Workshop 2

23rd May 2016 - Welsh Government Offices, Ladywell House, Newtown

Topic: "Technologies" – review/discuss briefing papers covering Molecular/eDNA, Citizen Science, Earth Observation and Land/Water Monitoring

Invitation emails to: approx. 122 names across 39 organisations

Emails publicising the event and the date: 28/4/16, 3/5/16, 11/5/16, 19/5/16

On the day:
36 attendees
16 organisations

Catherine Duigan	NRW
Gavin Siriwardena	BTO
Pete Henrys	CEH
Bernard Llewellyn	NFU Cymru
Jill Bullen	NRW
Lawrence Way	JNCC
Clive Walmsley	NRW
Dylan Lloyd	NRW
Steve Lucas	Bat Conservation Trust
Si Creer	Bangor University
Davey Jones	Bangor University
Clare Horton	WG
Dylan Williams	NRW
Tara Froggatt	Dŵr Cymru
Stuart Neil	WG
Andy Davey	WRc
Jenni Hartley	WG
Dai Harris	WG
Dave Chadwick	Bangor University
James Skates	WG
, Havard Prosser	Independent
Bridget Emmett	CEH
Chloe Elding	Wildlife Trusts Wales
Chris Cheffings	JNCC
Ian Johnstone	RSPB
Chris Bell	CEH
Dewi Jones	CEH
Bernard Griffiths	FUW
Tristan Hatton-Ellis	NRW
Fiona McFarlane	WG
Katie Medcalf	EnvSys
David Allen	NRW
Simon Smart	CEH

Liz Howe	NRW
Jeremy Biggs	Freshwater Trust
France Gerard	CEH
Emma Waters	CEH

Workshop 3

22nd June 2016 - Llandinam, Powys

Topic: Recommendations and Benefit Realisation

Invitation emails to: approx. 126 names across 39 organisations

Emails publicising the event and the date: 28/4/16, 3/5/16, 11/5/16, 10/6/16, 13/6/16,

On the day:
39 attendees
16 organisations

David Allen	NRW
Joanne Amesbury	WG
Alun Attwood	NRW
Chris Bell	CEH
Jill Bullen	NRW
Clare Burrows	NRW
Dave Chadwick	Bangor University
Colin Chapman	WG
Andy Davey	WRc
Catherine Duigan	NRW
Chloe Elding	Wildlife Trusts
Bridget Emmett	CEH
Ian Halfpenney	CADW
Dai Harris	WG
Jenni Hartley	WG
Russell Hobson	Butterfly Conservation
Liz Howe	NRW
Betsan John	WG
Ian Johnstone	RSPB
Peter Jones	NRW
Dewi Jones	WG
Steve Lucas	Bat Conservation Trust
Lindsay Maskell	CEH
Nia Meddins	WG
Louise Mees	CADW
Stuart Neil	WG
Katie Orford	JNCC
Charlotte Priddy	Farmers' Union of Wales
Havard Prosser	Independent
Katherine Raymond	WG
Paul Sinnadurai	Brecon Beacons National Park Authority
Gavin Siriwardena	BTO
James Skates	WG
Simon Smart	CEH
Steve Spode	WG

Bob Vaughan	NRW
Emma Waters	CEH
Bronwen Williams	CEH
Dylan Williams	NRW

Combined Workshop Invitation Lists and Responses

The distribution list expanded as time went on. To confirm attendance, see the workshop lists in Appendix D1 (parts 1-3).

Name	Surname	Organisation	Responded to WS1 invite	Intend to Attend WS1	Responded to WS2 invite	Intend to Attend WS2	Responded to WS3 invite	Intend to Attend WS3
David	Allen	NRW	Yes				Yes	Yes
Joanne	Amesbury	WG					Yes	Yes
Karen	Anthony	CLA					Yes	
Alun	Attwood	NRW	Yes	Yes			Yes	Yes
Kevin	Austin	WG						
Chris	Bell	CEH	n/a	n/a	Yes	Yes	Yes	Yes
Nick	Bialynicki-Birula	NRW					Yes	
Jeremy	Biggs	Freshwater Habitats Trust	n/a	n/a	Yes	Yes		
Martin	Bishop	Confor	Yes				Yes	
Julian	Bray	WG					Yes	
Steve	Bromley	Keep Wales Tidy						
Alan	Brown	NRW	n/a	n/a			Yes	
Helen	Buckingham	National Trust	n/a	n/a			Yes	
Jill	Bullen	NRW	Yes	Yes	Yes	Yes	Yes	Yes
Clare	Burrows	NRW	Yes	Yes			Yes	Yes
James	Byrne	Wildlife Trusts					Yes	
Dave	Chadwick	Bangor University	Yes	Yes	Yes	Yes	Yes	Yes
Colin	Chapman	WG					Yes	Yes
Colin	Cheesman	PlantLife	n/a	n/a	Yes		Yes	
Chris	Cheffings	JNCC	Yes	Yes	Yes	Yes	Yes	
Simon	Creer	Bangor University	n/a	n/a	Yes	Yes	Yes	
Jonathan	Cryer	RSPB						
Andy	Davey	WRc	Yes		Yes	Yes	Yes	Yes

Delyth	Davies	Dairy Co					Yes	
Keith	Davies	NRW	Yes	Yes				
Trevor	Dines	Plantlife						
James	Dowling	WG						
Catherine	Duigan	NRW	Yes	Yes	Yes	Yes	Yes	Yes
Trystan	Edwards	National Trust						
Chloe	Elding	Wildlife Trusts	Yes	Yes	Yes	Yes	Yes	Yes
Bridget	Emmett	CEH	Yes	Yes	Yes	Yes	Yes	Yes
Mike	Evans	NRW					Yes	
Susan	Evans	Wales Environment Link					Yes	
Sinead	Evans	Wales Environment Link			n/a	n/a	n/a	n/a
Emily	Finney	WG						
Ben	Fitch	Riverfly Partnership	n/a	n/a	Yes		Yes	
Tara	Froggatt	Dŵr Cymru	Yes		Yes	Yes	Yes	
France	Gerard	CEH	n/a	n/a	Yes	Yes	Yes	
Emma	Giles	WAO						
Tim	Green	Gwent Wildlife Trust					Yes	
Mick	Green	WDC, Whale and Dolphin Conservation	n/a	n/a	Yes		Yes	
Bernard	Griffiths	Farmers' Union of Wales	n/a	n/a	Yes	Yes		
Rob	Griffiths	CEH	n/a	n/a	Yes		Yes	
Bernard	Griffiths	FUW			n/a	n/a	n/a	n/a
Andrew	Gurney	Farmers' Union of Wales						
Ian	Halfpenney	CADW	Yes	Yes			Yes	Yes
Nathalie	Hall	NRW					Yes	
Tony	Harrington	Dŵr Cymru			Yes		Yes	
Dai	Harris	WG					Yes	Yes
Jenni	Hartley	WG	Yes		Yes	Yes	Yes	Yes
Tristan	Hatton-Ellis	NRW	n/a	n/a	Yes	Yes	Yes	

Peter	Henrys	CEH			Yes	Yes	Yes	
Russell	Hobson	Butterfly Conservation	Yes		Yes		Yes	Yes
Claire	Horton	WG						
Liz	Howe	NRW			Yes	Yes	Yes	Yes
Alaw	Hughes	Gwent Wildlife Trust						
Kirsten	Hughes	HCC						
Ann	Humble	WG	n/a	n/a			Yes	
Ann	Humble	Welsh Government	Yes		n/a	n/a	n/a	n/a
Dafydd	Jarrett	NFU Cymru					Yes	
Ruth	Jenkins	NRW			Yes		Yes	
Betsan	John	WG					Yes	Yes
Dave	Johnston	NRW	n/a	n/a	n/a	n/a	Yes	
Dave	Johnstone	NRW	Yes				n/a	n/a
Ian	Johnstone	RSPB	n/a	n/a	Yes	Yes	Yes	Yes
Chris	Jones	NRW						
Geraint	Jones	Pembrokeshire Coast National Park Authority						
Rhianne	Jones	CLA	Yes				Yes	
Sarah	Jones	Dŵr Cymru						
Dave	Jones	WG	Yes		Yes		Yes	
Dewi	Jones	WG			Yes	Yes	Yes	Yes
Laurence	Jones	CEH	Yes		Yes		Yes	
Peter	Jones	NRW			Yes	Yes	Yes	Yes
David	Jones	Bangor University	n/a	n/a	Yes	Yes	Yes	
James	Latham	NRW	Yes				Yes	
Catherine	Lawton	WG						
Rachel	Lewis Davies	NFU Cymru	Yes	Yes	Yes		Yes	
Bernard	Llewellyn	NFU Cymru	Yes	Yes				
Dylan	Lloyd	NRW	n/a	n/a	Yes	Yes		
Steve	Lucas	Bat Conservation Trust	Yes		Yes	Yes	Yes	Yes
Sinead	Lynch	Bumble Bee conservation /WEL						

Alexander	Makovics	Keep Wales Tidy						
Stephen	Marsh-Smith	Wye and Usk Foundation	n/a	n/a			Yes	
Lindsay	Maskell	CEH	n/a	n/a	n/a	n/a	Yes	Yes
Fiona	McFarlane	WG	Yes	Yes	Yes	Yes	Yes	
Katie	Medcalf	Environmental Systems	n/a	n/a	Yes	Yes	Yes	
Nia	Meddins	WG	n/a	n/a	n/a	n/a	Yes	Yes
Louise	Mees	CADW	Yes				Yes	Yes
Helen	Minnice-Smith	WG					Yes	
Kathryn	Monk	NRW					Yes	
Dan	Moreton	CEH			n/a	n/a	n/a	n/a
Vicky	Morgan	UKEOF					Yes	
Dan	Morton	CEH	n/a	n/a				
Kathleen	Mulready	WG						
Stuart	Neil	WG	Yes	Yes	Yes	Yes		Yes
Katie	Orford	JNCC	Yes		Yes		Yes	Yes
Rhys	Owen	Snowdonia National Park Authority						
Eurgain	Powell	Moved	n/a	n/a	Yes		n/a	n/a
Eurgain	Powell				n/a	n/a	n/a	n/a
Charlotte	Priddy	Farmers' Union of Wales	n/a	n/a			Yes	Yes
Charlotte	Priddy	FUW	Yes	Yes	n/a	n/a	n/a	n/a
Havard	Prosser	Independent	n/a	n/a	Yes	Yes	Yes	Yes
Katherine	Raymond	WG	n/a	n/a	n/a	n/a	Yes	Yes
Kate	Roberts	CADW						
Carole	Rothwell	NRW						
Adam	Rowe	LERC's	Yes					
Clare	Rowland	CEH	n/a	n/a	Yes		Yes	
Victoria	Seddon	WG					Yes	
Cath	Shellswell	Plantlife/Wales Environment Link					Yes	

Paul	Sinnadurai	Brecon Beacons National Park Authority	Yes	Yes	Yes		Yes	Yes
Gavin	Siriwardena	BTO	Yes	Yes	Yes	Yes	Yes	Yes
James	Skates	WG	Yes	Yes	Yes	Yes	Yes	Yes
Simon	Smart	CEH	Yes	Yes	Yes	Yes	Yes	Yes
Steve	Spode	WG	Yes	Yes			Yes	Yes
Mark	Squire	NRW	n/a	n/a	n/a	n/a	Yes	
Roy	Tapping	Cofnod	Yes	Yes				
Ruth	Tipping	NRW					Yes	
George	Tordoff	Butterfly Conservation						
Michelle	Van Velzen	NRW						
Bob	Vaughan	NRW					Yes	Yes
Clive	Walmsley	NRW	Yes	Yes	Yes	Yes	Yes	
Emma	Waters	CEH	Yes	Yes	Yes	Yes	Yes	Yes
Lawrence	Way	JNCC	n/a	n/a	Yes	Yes	Yes	
Bethan	Webber	WG	Yes	Yes	Yes		Yes	
Bradley	Welch	Brecon Beacons National Park Authority	Yes		Yes		Yes	
Karen	Whitfield	Wales Environment Link	n/a	n/a	Yes		Yes	
Lizzie	Wilberforce	Wildlife Trusts						
Arfon	Williams	RSPB						
Sarah	Williams	NRW	Yes					
Susan	Williams	NRW					Yes	
Bronwen	Williams	CEH	Yes	Yes	Yes		Yes	Yes
Dylan	Williams	NRW	Yes	Yes	Yes	Yes	Yes	Yes
Martin	Williams	WG	n/a	n/a	n/a	n/a		
Sarah	Wood	NRW						

Appendix D2

Stakeholder Workshop 1 - Output tables detail

Workshop 1 participants were invited to provide their input to several tables of:

- Policies/evidence requirements – what needs what monitoring and reporting
- Evidence categories and evidence providers
- Sources of reporting and monitoring data

Although not every thought and suggestion will have been fully captured in the attached tables, the project team developed multiple lines of further inquiry and research and provide these tables as further input to the project as it progresses. These are a working documents – an output of the workshop 1 sessions and an attempt to capture the observations of the participants during that session.

Read these appendices in conjunction with the workshop notes captured and attached as Appendix O (workshop 1) and further analysis in the main body of the report and in Appendix D3.

Policies and Reporting Pathways – Workshop Observations

This is a working document – an output of the workshop session and an attempt to capture the observations of the participants during that session. **Shaded boxes denote items added or significantly amended during the workshop1 sessions;** these are the comments and observations of workshop participants and this is a draft working document – not all policies/pathways will be represented in this table and some inaccuracies and outstanding questions will remain in this version.

General suggestion:	General suggestion: Policies need to be nested under each other Matrix/grid of policies and eco topic areas

Policy "Evidence Requirements" (group2)	Policy Number	Primary Wales Domestic Legislation	Secondary Legislation now captured by Primary Domestic Legislation	Reporting Activity in place (Y/N)	Reporting Pathway	Notes
PHASE 1						
Well Being of Future Generations Act	1	W		Y	WBFG annual report	
Environment Act	2	W		Y	SoNaRR	1. SoNaRR 2. climate change
					SoNaRR --> National Resources Management Plan	First will be what we have/baseline. cf aspiration for the future
Planning Act and Local Well being Plans	21	W	relates to Well Being of Future Gen Act	Y	Local Area Statement	not reporting Local Well Being Plans NOT Planning Act ?
EU Habitats Directive	3		UK/EU	Y	SACs (Article 17 Habitat Directive)	reports on conservation status of each species and habitat type at biogeographical level, species' population sizes and habitat surface areas

EU Birds Directive	4		UK/EU	Y	SPAs (Article 12 Birds Directive)	reports on size and trend in individual bird species' populations and distributions, including main threats and pressure
Convention on Wetlands	5		UK/EU	Y	RAMSARs	RAMSARs - Not unique, same as SSSIs
RDP	6		EU	Y	CMEF	
SEA directive						
EIA directive						
CROW act						
W+C act						
NEC act						
Nitrates Directive						
1949 act						
Forestry act						
Agriculture Act						
Countryside act						
Design Scheme Roads and Bridges/Highways Act						
EU climate change directive		EU				
Climate Change Act		E & W				CCRA
UNFCCC (Climate Change)	7		UK/EU	Y	GHG Inventories	

SSSIs	8		UK/EU	N	Ideally would be done annually for UK biodiversity indicator	Better alignment with GMEP?
					Further notes on SSSI's (group 2) National systematic programme needed - not currently in place. Reporting process ongoing, but not monitoring Protocol in place, not a programme	SSSI monitoring (terrestrial) : critical to multiple policy drivers, cover majority of welsh habitats and species assembles, critical measures of health Welsh ecosystems and major focus of NRW and WG expenditures. Greater focus needed, stratified protocols, include rapid assessment component. SSSI resources approx. 12% Wales. Also reflects state of geological reserves.
Historic Environment Act	9		W	?	CADW	
HEAct - closed loopholes - more power to CADW - more consistency - more democratic process (eg right to appeal and exceptions)						
Woodlands for Wales Strategy	10	Forestry Act 1967 (group1)	D	Y	WG	WFW Indicators annual repeat
Sustainable Management Scheme	11		D	N	None currently	
National Parks	12		D	N	None currently focussed on Natural Resources	
AONBs	13			Y	Reporting to WG	

					Statutory Management Plans for 10 years - cultural, history, bio diversity state of play special qualities	
Special Landscape Areas	14				NRW criteria to implement	Not NRW - reported on by local authorities
Heritage Coast	15					
World Heritage Sites	16		D	N	Cadw/ RCAHMW	
Biosphere Reserves	17				NRW	
Carbon budget and trading	18		?	N	None developed to date	
Local Authorities	19		?	?	Unknown	
CAP Greening	20					
Nature Recovery Plan	21					
Other?					SoNaRR / Habs directive	
EU INNS Directive						
Tan 5						
CBD				Y	National reports	
S6 environmental IoT (?)						
Floods Directive						
Invasive Aliens Directive				Y	SIP ?	Need to engage with plant health policy and NRW lead
Plant Health Directive				Y	APHA for England and Wales	

Heather & Grass Burning Directive				N	Areas potentials / lost	
NVZ					NRW/GMEP via DEFRA	
European Landscape condition						
National Habitat Creation Scheme (saltmarsh only). NRW run it.					Not statutory. Report back on what's been done.	
Pollination Action Plan						
PHASE 2						
WFD		??				
WFD / Marine Strategy (?) Framework Directive						
Air Quality Strategy		??				
EU Waste and Landfill Directives		??				
Marine (MCZs; MPAs; MNRs)		??				
Nitrates Directive		??				

Draft working document – not all inputs will be represented in this table.

Shaded boxes denote items added or significantly amended during the workshop1 sessions; these are the comments and observations of workshop participants and this is a draft working document – not all policies/pathways will be represented in this table and some inaccuracies and outstanding questions will remain in this version.

Evidence Providers –Workshop Observations

This is a working document – an output of the workshop session and an attempt to capture the observations of the participants during that session. **Grey boxes denote items added or significantly amended during the workshop1 sessions;** these are the comments and observations of workshop participants and this is a draft working document – not all providers/drivers will be represented in this table and some inaccuracies and outstanding questions will remain in this version.

	Other Notes	Frequency	Spatial extent	Scale of sampling	Spatial Structure	Modelled	EO	Funding Support	Volunteers ?	
Monitoring Activity - FOR CHANGE		**Monthly, semi-annual, annual, rolling annual, unstructured, periodic (every N years)**	**e.g. Wales, list of regions, entire Welsh range of target taxa, specific habitats covered**	**e.g. 1km square, garden, county, point location only (typical for casual records), farm (holding)**	**Random/stratified random, standardized but observer-selected, unstructured but effort recorded, completely unstructured**	**Empirical data available, modelled product (specify method?), summarized data, interpolated data**		**Long-term secured (>5 years), term of current funding (eg 2013-2016), funding being sought, entirely voluntary; include funder name where applicable**	**Voluntary data unlikely to have been used in this SoNaRR**	**Comments**
GMEP		Rolling annual on a 4 year cycle	Wales	1 km square	Stratified random	Some		2012-2016		a. 50% of Priority Habitats reportable and Priority Birds likely to be reported on. Modelling for habitat condition for other priority species and also for GHG; water quality; future scenarios

BRC		Unknown	Wales	point	unstructured but effort recorded, if effort not recorded analysis attempts to incorporate this via proxy	Bayesian			Yes	Data mash-up for range of species. Method under development for UK and Wales. Unknown at present which species will have sufficient data. All species equally weighted.
National Recording Schemes		Unknown							Yes	Incorporated in BRC?? Schemes and societies and ad-hoc recodes
National Plant Monitoring Scheme		Annual							Yes	
Butterfly Monitoring Scheme		Annual	Wales	Site specific	Random? Self selected?				Yes	
Wider Countryside Butterfly Survey		Annual	Wales	1 km square	Random				Yes	
ECN including enhanced		5 years?		Site specific	unstructured but effort recorded		No?			
CEH EO Landcover map		8 years	Wales				Yes			Greater frequency into rolling product being developed
NRW EO Habitat map		?	Wales				Yes			Uncertain when will be released. Unlikely to be relevant for change
Env Systems EO products										Various under development… to fill in.
GHG inventories		Annual	Wales							

CADW			Wales	point location						To our knowledge GMEP has only change data currently for HEFS. CADW do SAMs?
ADAS		?	Wales							Look at NRW return for Agriculture data sources
BTO Breeding Bird Survey		Annual	Wales	1 km square	Stratified random				Yes	Terrestrial, random sample; uplands under-sampled, but coverage is increasing; suitable for large-scale average patterns, not site-level data
BTO Wetland Bird Survey		Annual	Wales	?	?				Yes	
BTO Bird Atlas		Periodic (c. 20 years)	Wales	10 km square	Stratified random				Yes	
BTO Waterways Breeding Bird Survey		Annual	Wales		Stratified random				Yes	
RSPB		Various							Yes	
NGO's/ Third Sector (WEL)		?							Yes	National hedgehog survey, Living with mammals, The Great British Bee Count, Welsh Rare Plants Project, Orchid Observers Project, National Water Vole Monitoring Programme, House Marten Count Survey, Make the adder count, Vincent Wildlife Trust mammal surveys
LERCs		?							Yes	
Stockholm Environment Centre		?							Yes	Ecological footprint identified as one potential metric

National Bat Monitoring Programme		?	Wales						Yes	long term trends for 11 species since 1996
National Amphibian & Reptile Recording Scheme			Wales						Yes	
British Bryological Society National Database										
UK Upland Waters Monitoring Network	some not sure about this one							NRW		
Historical data from CCW/EAW/ FC surveys										mammals, higher plants and fish
National Forest Inventory		Periodic (5 yr cycle)	GB and Wales - woodlands over 0.5 ha	I ha sample squares	Stratified random	data extrapolated		Under discussion at National level		15,000 1 ha sample squares across GB; 0.6% sample of all wood and extrapolated to represent 100% of all woodland regionally or GB level. Surveyed at section, component group and plot level.
Forestry statistics			GB and Wales					Under discussion.		Range of stats - including those on recreation, timber, woodland, public opinion of forestry related issues. Useful in connecting natural resources to public value.
Deer Survey			England and Wales					Deer Initiative	Yes	Data collection based on sightings; records geographical spread and no. of different deer species including INNS

Ancient Woodland Inventory			Wales					NRW		Based on OS map series, old records. Best available record of ancient woodland sites.
National Soil Carbon	Soils									
National Soil Nutrients	Soils									
Pathways and (can't read)	Soils									
National Soil biodiversity (baseline)	Soils									
National Soil contaminants	Soils									
(no data on physical attributes)	Soils									
Soil data from LUCAS	Soils									
WT habitat photos	Resilience									
Hedgerow surveys	Resilience									
Extent, urbanisation etc (connectivity and extent)	Resilience									LCM

Phase 1 maps	Resilience									
Pollination - forb diversity as a proxy	Hazards									
BGS Landslides (stability)	Hazards									
BGS Earthquakes	Hazards									
Public health wales - disease	Hazards									
Met Office - Drought (risk)	Hazards									
Met Office - Fire (risk)	Hazards									
Wales Coastal monitoring centre (LIDAR data for coastal erosion)	Hazards									
Earth Obs data	Hazards									
Digitized public health data for Wales (UNN)	Health									

Local authority noise and waste data	Health									
dark skies designation	Health									
GMEP VQI (Landscape quality)	Health									
Forestry Commission public use data	Recreation									
Economic data for tourism	Recreation									
Membership nums for environmental charities	Recreation									
Paleo archaeology	site specific, eg EIA evidence gathered through planning /EIA									Must be freely available once got through planning (OR perhaps not - copyright info issues!!?) Must have follow-up in 10-20 years Who owns it ?? (what's legal standing ? - Ask WG)
Countryside Survey		8yr	E + W + S +NI	1km squares				no funding		
SAC terrestrial Monitoring Proc		6 yr	Wales	site				NRW		subject to review
Nat. Inv. Woodlands and trees		4 yr maybe	E + W					NFI now		

SSSI condition monitoring		6 yr maybe	Wales	site				NRW		Link to SM planning timescale varied. CSM methods - subject to review (some done by others orgs)
Phase 1 and NVC surveys			Wales	census				NRW		Phase 1 complete, NV ongoing (grassland, peatland, sand dune, heathland, woodland)
New "Phase 1" (UK hab class scheme)			UK ?	?						
NVR monitoring		variable	Wales	site				NRW		
BARS		6 yr	UK ?	h + s				all	Yes	Biodiversity Action reporting system - priority h + s - projects
Tree cover in Wales, cities and towns			Wales							Urban - iTree (all trees in cities. Towns, villages) Need to include green bit of urban
Phenology network			UK							
SAF data: EFAs etc										
Red Tractor										
GFG Incentives										Building on industry working group
Farming Connect										Soils database
RDP Strategic Initiative										Early stages - data inputs led
FCW Farm woodland survey (one off)										
WFPS (GMEP)			4 yrs	NP	varies	existing data	Extrapolated			

NPs: State of the Park report			4 yrs							
Welsh Index of Multiple Deprivation (WIMD)	Annual data									Index updated periodically

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Evidence Categories – Workshop Observations

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Other general comments
1: Restructure by standard ecosystem typology
2: 'Resilience' fits naturally with Supporting Services

	BEFORE	AFTER	
Topic	**Category**	**Category**	**More Data sources**
Ecosystem resilience	Diversity	Diversity/Functional Diversity	
	Connectivity	Structural diversity	
	Extent/landcover/urbanisation	Connectivity	
	Condition	Extent/landcover/urbanisation	
		Condition or management	
		Forestry commission status	
		Trophic cascades (Duplicate: here and in Biodiversity)	
		Food webs (Duplicate: here and in Biodiversity)	
		Farm viability (economic)	
		HNV (here and under Biodiversity)	
		data needed for models and mapping tools	
		data of activities likely to enhance	
		data on evidence of response/vulnerability to an extreme	
		PES opportunity??	
Biodiversity	Priority Species - Declining and localised	Priority Species - localised (deleted 'declining')	

	Priority Species - Declining and widespread	Priority Species - widespread (deleted 'declining')	
	Functional / Widespread Species	Functional / Widespread Species	
	Priority Habitats	Priority Habitats	
	Habitats	Habitats (Broad)	
	Invasive non native species	Invasive non native species	
	HNV	HNV (here or under Resilience?)	
		Red lists	
		Statutory/non-statutory sites	
		Trophic cascades (Duplicate: here and in ecosystem resilience)	
		Food webs (Duplicate: here and in ecosystem resilience)	
		Favourable conservation status (global, EU, national)	
Greenhouse Gases	Agricultural Emissions	Agricultural Emissions	
	Soil and Biomass	Soil and Biomass	
	Global footprint	Global footprint	
	Woodland area	Woodland area	
	proportion of Woodland certified	questioned this	
	Energy generation	Energy generation	
	Energy efficiency	Energy efficiency	
	Adaptation/ Resilience measures	Adaptation/ Resilience measures	
	Farm woodlands	Farm woodlands	
	Farm biomass (hedges, corridors etc)	Farm biomass (hedges, corridors etc)	
	Anaerobic digestion	Anaerobic digestion	
	Carbon footprinting	Woodland carbon code	
		LULUCF	
		Agricultural productivity	
		Woodland management (monitoring woodland area)	

Soil	Carbon/organic matter	Carbon/organic matter	
	Nutrients and pH	Nutrients and pH	
	Biodiversity	Biodiversity	
	Contaminants	Contaminants	
	Physical attributes	**Physical attributes** (erosion, compaction, etc.)	
		Peatland code	
		Planning policy Wales	
		Area of sealed soil surface	
		Rare soils	
Historics	SAMS	SMs and listed buildings	
	HEFS	HEFS	HEFS (with the trust?)
		Veteran trees	Local planning hold the register or CADW
		Tree preservation orders (TPOs)	
		Historic landscapes & Parks and Gardens	Historic Environment Records
		Ancient woodland inventory	*Employment*
		Buildings at risk register	
		Historic Environment Record/National Monuments Record	*Grant in aid --> stonemasons*
			Footfall counters
			Valuing the historic gardens report 2010 - repeated?
Landscape	Landmap	Landmap (biased/unreliable?)	
	GMEP VQI	GMEP VQI	
	Visitor numbers/appreciation of HEFs and SAMs	Visitor numbers/appreciation of HEFs and SAMs	
		Landscape character assessment	
		Hedgerows (preferred visual features)	
		Field trees (preferred visual features)	

Health and well-Being	Physical and mental health	Physical and mental health	
	social resilience	Social resilience	<-- it's about an opportunity issue Social resilience - connectivity, socio-economics conditions, diversity, poverty, age distribution
	waste	Waste	
	noise and litter	Noise and litter / fly-tipping	
	access to green space	Access to green space	
	hazards e.g. contaminated land	(link to)-> Green infrastructure access to green space =/= green infrastructure	
		hazards e.g. contaminated land	
		Deprivation (index of multiple deprivation indices)	
		Hirath (welsh word) (longing belonging sense of adventure)	
		clean air/pollution	
		Poverty and environmental quality	
		Access to clean soil	Cardiff/NRW done work on flooding and heat vulnerability
		Dark skies / Light pollution	
		Crime (arson eg of heathland, damage to historics, wildlife eg poaching, off-roading)	
		Access to water	
Recreation	PROW condition	PROW condition	
	Utilisation	Path length/condition	
	Tourism	Utilisation	
	Recreation	**Tourism** (contribution to GDP)	
		Recreation (sport & outdoor activities)	
		Landscape quality	

		Length of PROW per unit area	
		Accessibility/affordability	
Natural hazards / disasters **AND** **Manmade and Industrial**	Disease/vector/pathogen	Disease/vector/pathogen	notifiable and 'other' (less data)
	Volcanoes	Volcanoes	
	Radionuclides	Radionuclides	
	GMOs	GMOs	
		Wales Resilience forum	
		Forest fires (risk)	
		Heather/grass fires (risk)	
		Extreme weather	
		Coastal erosion	vegetation structure / soil moisture /climate (NP) -> farming and human health (NR)
		Acute air pollution	Frequency of extreme events eg climate inc social media/news
		Drought	
		Landslides/Earthquakes	
		Flooding	
Provisioning and supporting services	Pollination	Pollination	
	Agricultural Production	Agricultural Production	
	Timber Production	Diversity of Production	
	Energy Production	Timber Production	
	Renewables	Energy Production	
	Nutrient cycling	Renewables	
	Primary production	Nutrient cycling	
		Primary production	
		Food and drink action plans	
		Landscape services	
		Soil formation and remediation	Soil proxies and models

		Climate mediation (local)	Water regulation - land use and models
		Flood risk mediation	EO and survey
		Cultural services	

Note: Water and Air to be dealt with in Phase 2

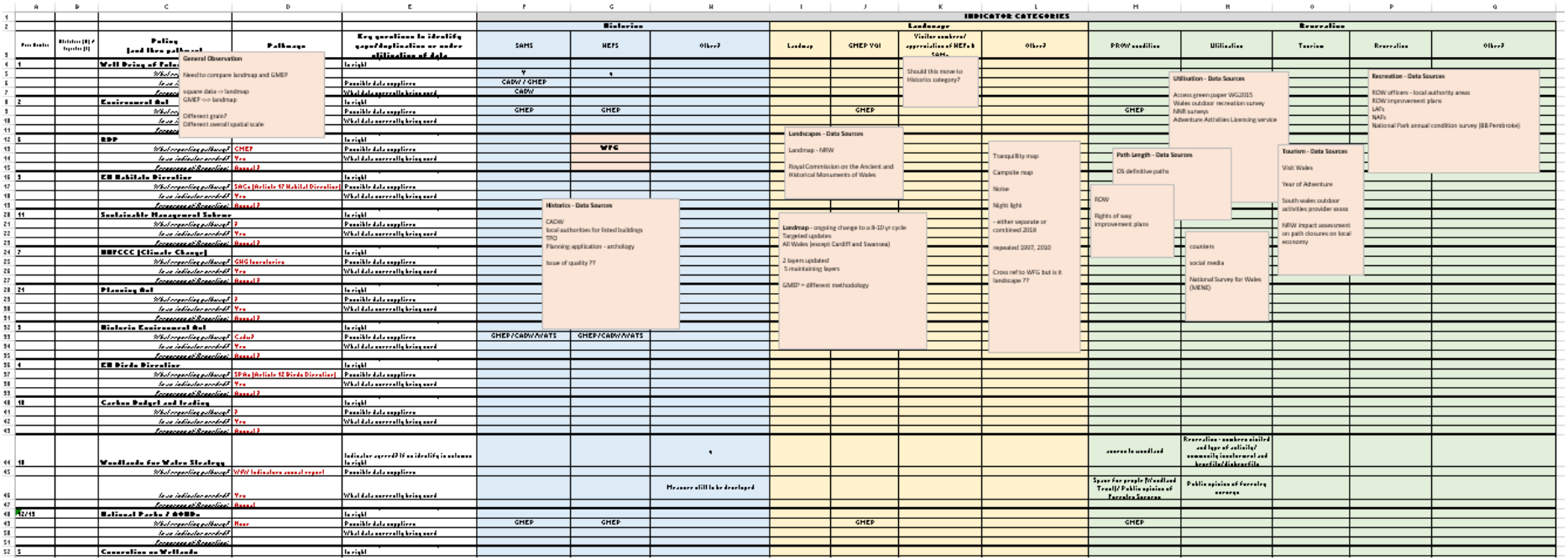
Draft working document – not all inputs will be represented in this table.

Shaded boxes denote items added or significantly amended during the workshop1 sessions; these are the comments and observations of workshop participants and this is a draft working document – not all evidence catagories will be represented in this table and some inaccuracies and outstanding issues will remain in this version.

Data Sources – Workshop Observations

The project team files also contains spreadsheet databases of the many actual and suggested data sources for the monitoring/reporting pathways discussed by the Workshop1 participants. There is no way to meaningful includes these pages in this document, but the data are available for continuing work. This is a working document – an output of the workshop session and an attempt to capture the observations of the participants during that session.

INDICATIVE SCREENSHOT OF "DATA SOURCES" SPREADSHEETS



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Appendix D3
Draft Matrix of Evidence & Category Assessments

This is a working document and should not be consider to be a final product. The version shown here has been subject to some updates since the production of the project report so may not match numbers in main report (section 3.4).
An assessment for sub-national was also attempted but is too incomplete to include here.
Does not include some citizen science activities.

Legend: GREEN: the scheme provides full national coverage and is well structured without major biases.
AMBER: the scheme could be developed to be a useful component with additional work.
RED: the scheme was set up for a different purpose and is unlikely to be useful as coverage is incomplete.
GREY (or blank): Unknown or insufficient information to assess.

			Type				Assessment of scheme			
Monitoring data/ categories	**Sub-category**	**Taxon/unit**	**Designed surveys**	**Record harvesting**	**Local surveys**	**Blind sampling**	**National**	**Representativeness/ Quality**	**Opportunities**	**Constraints**
Bio-diversity	Common species	Common birds	BBS					Stratified random hence misses rare occurrences.	Detection of large-scale management effects.	Low upland coverage, volunteer density limits growth
		Common birds	GMEP					Stratified random.	Detection of local and large-scale, long-term management effects.	Land access, no secure funding
		Common birds	WeBS					Censused estuaries and inland waterbodies	Improved inland coverage	Volunteer density limits growth
		Common birds	Bird Atlas					Complete coverage	Use as a baseline or for stratification of new sampling	Infrequent; 20 yr intervals.
		Common birds	WBBS					Stratified random hence misses rare occurrences.	Increased coverage	Not fully funded
		Common plants	NPMS					Weighted stratified random	Joint analysis with other datasets.	Low uptake at present in Wales.

		Common plants	GMEP					Stratified random.	Detection of managememnt effects.	No secure funding.
		Common plants	BSBI (Atlas)					Complete coverage.		
		Common plants	British Bryo Soc (Atlas)					Partial coverage		Check if enough recorders
		Common butterflies	UKBMS					Amalgam of stratified random and selected 1km squares.		
		Common butterflies	GMEP					Stratified random hence misses rare occurrences.		
		Common butterflies	BC (Atlas)					Complete coverage.		
		Common Bats	NBMP					Amalgam of stratified random and targeted roosts / hibernacula	Passive detector deployment may increase geographic coverage.	
	Rare species	Rare plants	BSBI (Atlas)					Complete coverage.		
		Rare plants	BSBI (TPP)					Representative sample of 50 threatened species.	Potential for detection of management effects.	Uncertain future.
		Rare plants			Plantlife (rare plants)			Targeted survey.	Potential for detection of management effects.	Uncertain future.
		Rare plants			BSBI (rare plant registers			Targeted survey.		
		Rare plants	British Bryo Soc (Atlas)					Partial coverage		Check if enough recorders
		Rare plants			NRW recordin g			Targeted survey.		Check if enough recorders

		Rare butterflies			UKBMS			Targeted survey.		
		Rare butterflies	GMEP					Stratified random hence misses rare occurrences.		
		Rare butterflies	BC (Atlas)					Complete coverage.		
		Rare birds			RSPB species surveys			Complete coverage?	Integration with national monitoring programs	Data access
		Rare birds	GMEP					Stratified random hence misses rare occurrences when not targeted specifically	Detection of management effects if targeted at rare birds.	Land access
		Rare birds		BirdTrack				Unstructured data with an effort proxy but likely extreme spatial biases	Development of analytical techniques, especially for rare species not recorded well by structured schemes	Spatial bias unavoidable and may change with time; inference will always be restricted relative to structured scheme data
		Rare birds	Webs					Censussed estuaries		
		Rare birds			Welsh Chough monitor-ing			Partial coverage	Integration across counties and with national monitoring programs	Data access
		Rare Bats	NBMP					Targeted recording at roosts and hibernacula		
	Other species	Mammals	Game bag					Stoats/Weasels only Other species recorded better elsewhere		
		Mammals	Deer initiative					National. Representativeness needs to be confirmed.		
		Mammals	Otter Survey					Volunteer based, national coverage. Has robustly demonstrated increases across Wales from 1978, '85, 91 to 2010.	Possible joint analysis with other dayasets to understand drivers of change.	

		Mammals	BBS mammal protocols					Undersampled because of day-surveys and suboptimal timing during the year.		Species coverage very limited and abundance may be confounded with breeding success
		Rare amphibians				Pond-Net		Used to assess Great Crested Newt. More info needed if useful for national level.		
		Bees, Wasps, Ants	BWARS					Annual recording usefully guided by priorities for particular groups across Britain. Network comprises many highly competent entomologists.	Wider use of data for research and monitoring and joint anlaysis with datasets recording other variables.	
		Invasive non native species		GB Non-Native Species Secretariat (NNSS)				UK-wide recording campaigns and alerts targeted at specific animals and plants. Individual records are sought and collated via iRecord and on-line forms.	Joint analysis with other datasets. Make taxa known to other schemes.	Records opportunistic because species are rare and not targeted in other surveys.
		Other taxa not covered by designed surveys .		NBN/LERC	NBN/ LERC			Covers a wide range of recorders and groups across many taxa. Quality and recorder effort will vary greatly.	Collation and analysis for assessment of Glastir impact.	Appropriate use of records requires working arrangement to be put on a firmer footing with Wales LERC.
	Habitats	Priority Habitats	GMEP					Stratified random hence misses rare occurrences.	Joint analysis with NRW datasets based on harmonised vegetation classification.	No secure funding. Misses rare PH. Quadrat data only records a subset of common bryophytes constraining NVC matching.

		Priority Habitats	Phase 1					Detailed census of Wales but priority habitats target-noted and sometimes not mapped. Carried out between 1979 and 1997 hence pre-dates BAP habitat classifications.	Integrated into the geo-informatics fused map of Wales.	Needs updating. A phased approach targeting rare habitats in areas most likely to have changed would seem logical but resources are unavailable. This is a potential application of fused map and Senitinel 1&2.
		Priority Habitats	Gwyllio					Composite EO (2003-'06 SPOT and IRS), aerial photo (Covi 2006) and phase 1 field survey map.	Selective updating using Sentinel but field survey critical for some habitat types.	Works well for some priority habitats and not others. Needs updating.
		Priority Habitats	Phase 2					Finely-resolved, very high quality quadrat-based NVC. Still ongoing but resources increasingly limited.	Joint co-analysis with GMEP/Citizen Science datasets to explore condition and change in condition.	Probably need to degrade the taxaonomic resolution and coverage of the data to match GMEP and then further still to match NPMS.
		Priority Habitats	Sentinel					Complete coverage. 10x10m pixel.	Many opportunities as the data become available for example updating Phase 1 and the fused map and deriving new models of field survey + reflectance relationships.	Sentinel still likely to be ambiguous for semi-natural grasslands, wet heath and bog for example.
		Broad Habitats	GMEP					Stratified random sample of 1km squares across Wales.	Potential for joint analysis with NRW datasets based on harmonised vegetation classification.	No secure funding. Quadrat data only records a subset of common bryophytes constraining NVC matching.

		Broad Habitats	LCM					Complete coverage. 25x25m pixel.	Many opportunities as the data become available for example updating Phase 1 and the fused map and deriving new models of field survey + reflectance relationships.	Sentinel still likely to be ambisguous for semi-natural grasslands, wet heath and bog for example.
		Broad Habitats	Phase 1					Detailed census of Wales but priority habitats target-noted and sometimes not mapped. Carried out between 1979 and 1997 hence pre-dates BAP habitat classifications.	Integrated into the geo-informatics fused map of Wales.	Needs updating. A phased approach targeting rare habitats in areas most likely to have changed would seem logical but resources are unavailable. This is a potential application of fused map and Senitinel 1&2.
		Broad Habitats	Gwyllio					Composite EO (2003-'06 SPOT and IRS), aerial photo (Covi 2006) and phase 1 field survey map.	Selective updating using Sentinel but field survey critical for some habitat types.	Works well for some broad habitats and not others. Needs updating.
		Broad Habitats	NFI					Complete coverage of conifer and broadleaf >0.5ha.	Joint analysis with GMEP/NRW/Citizen Science.	
		Broad Habitats	BBS habitat data					Stratified random.	Further development of analyses of field boundary, cropping and land-use data to record change at the Wales level; many features are not recorded elsewhere	Limited resolution of habitat quality measures

		Woodland	NFI					Range of metrics. Some differences to GMEP in metrics covered and definitions.		
		Ponds				Pond-Net		Range of metrics. More info needed as to coverage for national scale.		
	High nature value farmland		GMEP					New approach combines LCM and GMEP t provide single biodiversity indicator.	Concept and end-products are at an adavnced stage of development and acceptance by stakeholders.	Ultimately constrained by data availability hence established link with LERC biological records data is critical to increase local realism.
Soil	Carbon/ organic matter	--	GMEP					Stratified random.	Local pilot, joint analysis with NRW	No secure funding
	Nutrients and pH	--	GMEP					Stratified random.	Local pilot	No secure funding
	Biodiversity	--	GMEP					Stratified random.	Local pilot	No secure funding
	Contaminants	--			Local Authorities			Stratified random.		
	Contaminants	--	CS					Coverage unknown.		Some data for 1998 from CS at national scale
	Physical attributes (erosion, compaction, etc.)	--	GMEP					Stratified random.	Local pilot	No secure funding
	Area of sealed soil surface	--	Land Cover Map					Census map at 25x25 m pixel size that detects Urban and other artifical surfaces to thi sresolution.	Change mapping possible presuming current development of methods at CEH is successful.	

	Rare soils	--	GMEP					Stratified random.	Local pilot	No secure funding
	Carbon/organic matter	--	LUCAS					Stratified (Eunis) grid points	Joint analysis	Resolution?
	Nutrients and pH	--	LUCAS					Stratified (Eunis) grid points	Joint analysis	Resolution?
	Physical attributes	erosion, compaction, etc.	LUCAS					Stratified (Eunis) grid points	Joint analysis	Resolution?
	Physical attributes	erosion, compaction, etc.				mySOIL		Ad hoc, opportunistic	Possible augmentation of other datasets e.g. coverage of urban.	Biased/ad-hoc sampling
	Nutrients and pH	--				mySOIL		Ad hoc, opportunistic	Possible augmentation of other datasets e.g. coverage of urban.	Biased/ad-hoc sampling
	Carbon/ organic matter					mySOIL		Ad hoc, opportunistic	Possible augmentation of other datasets e.g. coverage of urban.	Biased/ad-hoc sampling
		Soil fertility	Farmers data via commer-cial companies					Better for pH, K, n and perhaps P. too few for Carbon and overall under-representation in Wales relative to England.		
Historics	SAMs and listed buildings		GMEP					Stratified random hence misses rare occurrences.	Data available for analysis. Provides unique national picture.	No secure funding. Will miss specifc/rare features.
	HEFS		GMEP					Stratified random hence misses rare occurrences.	Data available for analysis. Provides unique national picture.	No secure funding. Will miss specifc/rare features.
	Veteran trees		GMEP					Stratified random.	Data available for analysis. Provides unique national picture.	No secure funding. Will miss specifc/rare features.

	Tree preservation orders (TPOs)		tbc - CADW ?/Phase II							
	Historic landscapes & Parks and Gardens		GMEP					Stratified random hence misses rare occurrences.	Data available for analysis. Provides unique national picture.	No secure funding. Will miss specifc/rare features.
	Historic landscapes & Parks and Gardens		Historic Garden reporting ?							
	Ancient woodland inventory		GMEP					Stratified random.	Joint analysis with other targeted surveys e.g. NT/NRW.	Likely to miss the few very large ancient woods.
	Buildings at risk register		CADW					Phase II - tbc		
	Historic Environment Record/National Monuments Records		CADW					Phase II - tbc		
Landscape	Landscape character assessment		LANDMAP					Quality assured GIS layer for Wales started in 1997 and subject to a rolling program of field-verified updating.	The change detection and updating methodology may have wide-reaching relevance to the assessment of change and drivers of change across Wales.	
	Percieved visual landscape quality		GMEP Visual Quality Index					Stratified random.	Huge opportunities for public engagement and vidualisation of landscape change.	Will miss many specific locations of possible interest.

	Visitor numbers/appreciation of forest estate.			Footfall counts (FC)			tbc - phase II		
				Admissions money from Cadw?			tbc -phase II		
	Visitor numbers/ appreciation of HEFs and SAMs			Footfall counts (NT)			tbc -phase II		
	Field trees (preferred visual features)		Fused map and LAND-MAP - see above (Habitats)				Quality assured GIS layer for Wales started in 1997 and subject to a rolling program of field-verified updating.	The change detection and updating methodology may have wide-reaching relevance to the assessment of change and drivers of change across Wales.	
			GMEP				Stratified random hence misses rare occurrences.	Data available for analysis. Provides unique national picture.	No secure funding. Will miss specifc/rare features.
	Hedgerows (preferred visual features)		GMEP				Stratified random hence misses rare occurrences.	Data available for analysis. Provides unique national picture.	No secure funding. Will miss specifc/rare features.
			Fused map and LANDMAP - see above (Habitats)				Quality assured GIS layer for Wales started in 1997 and subject to a rolling program of field-verified updating.	The change detection and updating methodology may have wide-reaching relevance to the assessment of change and drivers	

									of change across Wales.	
Recreation	PROW condition		GMEP					Stratified random sample of 1km squares. Sample of PROW in each sqr following animal transect routes.		
	Path length/condition		GMEP					Stratified random sample of 1km squares. Sample of PROW in each sqr following animal transect routes.		
	Path length/condition		Stats Wales					Percentage of footpaths and other rights of way which are easy to use by local authority and year		
	Utilisation		tbc - phase II					tbc - phase II	Moreinformation needed	
	Tourism (contribution to GDP)		The United Kingdom Tourism Survey					The United Kingdom Tourism Survey is sponsored jointly by the National Tourist Boards for England, Northern Ireland, Scotland and Wales.		
	Tourism (contribution to GDP)		National Survey for Wales					Arts museums and historic places		
	Recreation (sport & outdoor activities)		Welsh Outdoor Recreation Survey					tbc - phase II	More info needed.	
	Recreation (sport & outdoor activities)		The Strategy for Older People in Wales: Financial year data					Percentage of people aged 50+ participating in any sport or activity during a four week period by local authority and time period		

	Landscape quality		GMEP					Stratified random.		
	Length of PROW per unit area		GMEP					Stratified random sample of 1km squares. Sample of PROW in each sqr following animal transect routes.		
	Accessibility/ affordability		GMEP					Stratified random.	Imopacts assessment of Glastir Access options.	Uptake probably low in GMEP sample.
			Phase II					tbc		
Green-house Gases	Agricultural Emissions	Field level	GMEP					limited but representative of improved and unimproved grasslands (N2O, CH4, CO2)		Can't measure everywhere – field data used to parameterise models
		National level	Annual Agri-cultural Inventory					High quality - but assumptions made that N2O EFs are appropriate for Welsh systems, e.g. extrapolation of N2O from grazing excretal returns in uplands are the same as those in the lowlwands		
	Soil and Biomass	tree biomass	National Forestry Inventory , GMEP						Difference in size of woodland and hedge captured between schemes	
		Soil carbon	GMEP					Topsoil 0-15cm only		
	Global footprint	Stockholm Institute Footprint	Phase II					tbc - phase II		Well being of Future Generations indicator?
		Farm data	Data from comer-cail hubs							Most farmers don't ask for Carbon. Lack of data for Wales relative to England

	C footprint for Agri	GMEP					representative farming typologies, also used to explore effects of GEGs in GMEP	Can be used to help scaling to the national level. Could be rolled out to undertake footprints of a larger number of typical farming typologies	Current tool is too complex / detailed for rolling out for mass footprinting.
Woodland area		GMEP, National Forestry Inventory							
Woodland carbon code		Phase II					tbc		
Woodland management		Phase II					tbc		
Farm Woodlands		GMEP					Phase II		
Farm biomass (hedges, corridors etc)		GMEP					Phase II		
Farm energy generation	GEGs farms	GMEP					Assessing potential for on-farm generation on the GEGs farms (N=18). Sample size could be increased.		
Energy efficiency		tbc - phase II				tbc - phase II			
Adaptation/ Resilience measures		tbc - phase II				tbc - phase II			
Anaerobic digestion		WRAP survey, AD Networks ?				tbc - phase II			
LULUCF	National level	Annual Inventory					High quality - if models are correct		

	Agricultural productivity	National level	CTS, milk process ors,				tbc - phase II	Data in many different places. UK GHG Inventory uses some national data to drive the model		
Provisioning and supporting services	Pollination		GMEP/CS					Stratified random.	Nature paper published which builds on CS2007 data for all GB showing potential to track trends building on CS/GMEP style survey.	Relevance and spatial variation in need for this service in Wales needs further quantification. GMEP does not measure fruit/seed set nor direct pollination deficit or performance.
			New National Pollinator Scheme					Likely mix of stratified random and record harvesting	Opportunity to assess volunteer uptake for a 'blind sample' scheme (DNA)	Uptake is unknown and may well be low in Wales - need to assess whether GMEP measures provide better opportunity.
	Agricultural Production		Defra agric stats					Farm census	Joint analysis with other datasets e.g. GMEP	Requires careful management of confidentiality and probably not referrable to individual fields.
	Diversity of Production		Defra agric stats					Farm census	Joint analysis with other datasets e.g. GMEP	Requires careful management of confidentiality and probably not referrable to individual fields.
	Timber Production		NFI and FC timber producti on					Established monitoring for strategic and commercial purposes.	Already used to estimate C stocks and alongside GMEP restimates of woodland extent. Many other opportunities for joint analysis exist.	Possible lack of detail on private forestry.
	Energy Production		Phase II					tbc - phase II		

Renewables		Phase II					tbc - phase II		
Nutrient cycling		CS					Stratified random		Potential nitrogen mineralisation and microbe efficiency assessed in 2007.
Primary production		GMEP					MODIS NDVI + Turf2Surf trait modelling approach in yr-2 GMEP report.	Greater resolution and higher frequency when Sentinel comes on stream.	Depends on cloud-free imagery to sample Spring window. Approach is novel and not yet published.
Food and drink action plans		Phase II					tbc - phase II		
Landscape services		GMEP					Stratified random.	Visual Quality Index developed from public perception studies at national scale.Could be added layer to Landmap. Relationship to other services t be expored using co-located data in GMEP.	
Soil formation and remediation		GMEP					Stratified random.	GMEP can explore impact of assocoiated Glastir options. Further work needed to define the service and identify shortfalls in available data.	Power depends on coincidence between uptake and GMEP squares.
Climate mediation (local)		GMEP					Stratified random.	GMEP can explore impact of assocoiated Glastir options. Further work needed to	Power depends on coincidence between uptake and GMEP squares.

									define the service and identify shortfalls in available data.	
	Flood risk mediation		Phase II					tbc - phase II		
	Cultural services		GMEP VQI and see Recreation , Health & Wellbeing					Stratified random.	Operational but probably needs further work to define the service and therefore identify shortfall in suplpy from VQI and other datasets.	Will miss many specific locations of possible interest.
Resilience	Diversity/ Functional Diversity		GMEP					Stratified random	Potential to co-analyse with other data sources	Requires linkage to data on functions
			BBS, UKBMS, NPMS					Range, but all have stratified random components		May need to be fully co-located to measure functional diversity, require linkage to functional types
	Structural diversity		NFI					Stratified random, only woodlands		Only woodlands are included
			GMEP					Stratified random		
	Connectivity		Land Cover Map					Complete coverage		Metrics need further development
			Phase 1					Complete coverage		Metrics need further development
			Gwyllio					Complete coverage		Metrics need further development
			Sentinel					Complete coverage		Metrics need further development
			UKBMS					Amalgam of stratified random and selected 1km squares.		Some experimental metrics, but needs much more work - this is amber / red

			GMEP					Stratified random	Field data can ground-truth ad update LCM	Metric needs further development
			GMEP LUCI model					Modelling approach	Uses landcover map	Reported for woodland only at present
	Extent/ landcover/ urbanisation	Semi-natural habitat extent		LCM/ GMEP				More in Phase II		Proposed as one of properties which confer resilience
	Condition or management		NRW protected site monitor-ing					Only covers protected sites	Combine with other data sources to get a fuller picture of protected site condition	No plans currently to use method outside protected sites
	Habitat condition/ FC Status		GMEP					Stratified random		
			NPMS					Weighted stratified random		
			NFI					Stratified random, woodlands only		
			Sentinel					Complete coverage, but EO proxies will not be suitable for use in all habitats		
		Trophic cascades (Duplicate: also Biodiversity)			ECN					These tend to be research scale assessments for single sites - not clear how to scale up
		Food webs (Duplicate: also Biodiversity)			ECN					These tend to be research scale assessments for single sites - not clear how to scale up
		Farm viability (economic)	Welsh Farm Business Survey							

		High nature value farmland (here and under Biodiversity)	GMEP					New approach combines LCM and GMEP t provide single biodiversity indicator.	Concept and end-products are at an adavnced stage of development and acceptance by stakeholders.	Ultimately constrained by data availability hence established link with LERC biological records data is critical to increase local realism.
		Data needed for models and mapping tools						Probably a duplicate of all the resilience attributes plus biodiversity attributes?		
		Response measure: data of activities likely to enhance			BARS			Coverage is patchy		Relies on interested parties entering data
		data on evidence of response/ vulnerability to an extreme						No surveys: will be hard to predict which survey is likely to show such a response. Research type activity.		
Natural hazards / disasters AND Manmade/ Industrial	Disease/ vector/ pathogen		NFI					Stratified random, woodlands only		
			Aerial photography					Complete coverage, woodlands	Potential to replace this with a cheaper Sentinel based system?	
			GMEP					Stratified random		
				APHA Inspections				Targeted surveys		
			Cattle Tracing System					Complete coverage, bovine animals		

Volcanoes						No surveys?			
Radionuclides			Predatory Bird Monitoring Scheme				Relies on people sending in carcasses		
		Radioactivity in Food and the Environment					Samples foods including locally-produced foods		
Pesticides			Predatory Bird Monitoring Scheme				Relies on people sending in carcasses		
			Wildlife Incident Investigation Scheme						
GMOs							No surveys currently		
Forest fires (risk)							Tool exists for risk assessment, relies on spatial analysis of range of factors		
Heather/grass fires (risk)						Uncertain			
Extreme weather		Met Office							
Coastal erosion		OS mapping							
		Sentinel							

	Acute air pollution		Air quality monitor-ing networks					Requires modelling to provide complete coverage		
	Landslides/ Earthquakes		Phase II					tbc - phase II		
	Drought							tbc - phase II		
	Flooding							tbc - phase II		
Health and well-Being	Physical and mental health		National Survey for Wales (adullts)					Well-being of Future generations Act(Wales) indicator for mean mental well being (29) and % of people who report taking part in any outdoor or indoor sporting activity (38)		
			Health Survey Wales							
	Social resilience		National Survey for Wales (adullts)					Well-being of Future generations Act(Wales) indicator for Percentage of people living in households in material deprivation. (19), Percentage of people agreeing that they belong to the area; that people from different background get on well together; and that people treat each other with respect (27), mean mental well being (29), Percentage of peoplewho are lonely (30)		

	Waste		Survey of Arisings and Use of Alternatives to Primary Aggregates in England); and SmithsGore / Faber Maunsell data for Wales.					Construciton and demolition waste reused and recycled by year. Well-being of Future generations Act(Wales) indicator Amount of waste generated that is not recycled, per person.(15)		
			Waste data flow					Municipal waste per person per annum by year. Well-being of Future generations Act(Wales) indicator Amount of waste		
			The Wales Public Sector Waste Production Survey					Disposal Of Public Sector Waste by Sector (Tonnes)		
			Waste data flow					Municipal, household, industrial and commercial waste recycled and sent to landfill by year		
	Noise		Wales Noise Mapping					Well-being of Future generations Act (Wales) indicator: Percentage of people satisfied with local area as a place to live. (26)		

Litter and fly tipping		National Survey for Wales					Well-being of Future generations Act(Wales) indicator: Percentage of people satisfied with local area as a place to live. (26)		
		Stats Wales					Fly tipping records. Monthly records for each LA		
Access to green space		National Survey for Wales				Spatial assessment	Well-being of Future generations Act(Wales) indicator: Percentage of people satisfied with local area as a place to live. (26)		
		Stats Wales					Accessible natural greenspace standards by local authority		
Contaminated land							tbc - phase II		
Deprivation (index of multiple deprivation indices)		National Survey for Wales					Well-being of Future generations Act(Wales) indicator: Percentage of people living in households in material deprivation. (19)		
Hiraeth (welsh word) (longing belonging sense of adventure)		National Survey for Wales					Well-being of Future generations Act(Wales) indicator: Percentage of people agreeing that they belong to the area; that people from different background get on well together; and		

							that people treat each other with respect (27)		
Clean air/pollution		UK-AIR: Air Information Resource, DEFRA				Requires modelling to provide complete coverage	Well-being of Future generations Act(Wales) indicator: Levels of nitrogen dioxide (NO2) pollution in the air.(4)		
		National Atmospheric Emission Inventory							
Poverty and environmental quality		House-holds Below Average Income (HABI) statistics					Well-being of Future generations Act(Wales) indicator: Percentage of people living in households in income poverty relative to the UK median, measured for children, working age and those of pension age.		
		National Survey for Wales					Well-being of Future generations Act(Wales) indicator: Percentage of people satisfied with local area as a place to live. (26)		
		National Survey for Wales					Measure of correlation between these?		
Access to clean soil							Well-being of Future generations Act(Wales) indicator: Concentration		

								of carbon and organic matter in soil (13).		
	Dark skies / Light pollution			Dark Sky Places				tbc Phase II - International Dark Sky Association?		The designation requires more than just data on how dark the sky is
	Crime (arson eg of heathland, damage to historics, wildlife eg poaching, off-roading)		Crime Survey for England and Wales (CSEW)					tbc - phase II		
	Access to water							tbc - phase II		

Draft working document – not all inputs will be represented in this table.
Amended since the production of the project report.

Appendix E
Technical/Topic Briefing Papers
Section Contents

A series of **technical briefing papers** were commissioned to provide up-to-date thinking of each of the technologies (or topics) thought relevant as inputs to this project's work. Each co-authored and extensively reviewed by a broad range of individuals from all of the key project stakeholders.

The first four papers listed here were reviewed and discussed in a **Stakeholder meeting 2** (23rd May 2016); comments, corrections and further review was undertaken following that meeting. The papers are intended to be working documents, edited and added to as needed – they act as guidance and input to the project team and steering group as he recommendations develop and further planning conducted.

The authoring and review teams included:

Alun Attwood	Dave Johnston	Helen Millband	Nick Moran
Andy Davey	David Allen	James Skates	Oliver Pescott
Andy Musgrove	David Chadwick	Jeremy Biggs	Paul Guest
Barnaby Letheren	David L. Jones	Kate Lewthwaite	Paul Robinson
Ben Wilson	David Noble	Kath Bollington	Peter Henrys
Cath Shellswell	David Robinson	Katie Metcalfe	Rachel Taylor
Catherine Duigan	Dawn Balmer	Kelvin Jones	Rob Griffiths
Chris Cheffings	Dylan Lloyd	Lawrence Way	Simon Creer
Chris Jones	Dylan Williams	Lindsay Maskell	Simon Smart
Claire Horton	France Gerard	Lisa Norton	Stuart Neil
Clare Rowland	Gavin Siriwardena	Liz Howe	Tara Froggatt
Colin Chapman	Havard Prosser	Martin Williams	Tristan Hatton-Ellis
Dave Allen	Hayley New		

From:

Bangor University	Freshwater Habitats Trust	Plantlife
BTO	Independent	Welsh Government
CEH	JNCC	Woodland Trust
DCWW	NRW	WRc plc
Environment Systems		

1. Briefing paper – Earth Observation
2. Briefing pager – Citizen Science
3. Briefing pager – Molecular/eDNA
4. Briefing pager – Freshwater Monitoring
5. Briefing pager – Emergency Response
6. Briefing pager – Data & Informatics

Appendix F
Briefing paper – Earth Observation

The Potential of Earth Observation Data for Environmental Monitoring in Wales

Three documents are presented here.

France Gerard (CEH)
Clare Rowland (CEH)

With inputs and assistance from Katie Metcalfe (Environment Systems), Lawrence Way, Paul Robinson, Chris Cheffings (JNCC), Lisa Norton, Claire Wood and Lindsay Maskell (CEH) and Claire Horton (Welsh Government).

July 2016

Earth Observation Briefing Paper – Preface

1. Earth Observation

Advantages and disadvantages

Main message: there are certain aspects that EO does very well. A simple approach or an approach focussed on one feature or variable is often very effective. Reliable monitoring can only be achieved when EO is combined with some form of field surveying. EO inherently has limitations which should always be kept in mind.

Advantages:

- EO provides a bird's eye view and allows the surveying and monitoring of dangerous, remote and restricted areas.
- Satellite EO can achieve a complete coverage of Wales in a very short period of time.
- EO data is spatially and temporally consistent, available at a range of spatial and temporal scales and delivered through a variety of means (e.g. satellite, aircraft, drone).
- A wide range of EO data is freely available and relatively easy to access.

- EO can detect that something has changed significantly, e.g.: change in land cover, and through time series of simple variables some more subtle changes or trends, e.g.: land subsidence, changes in management, changes in river corridor integrity.
- EO can accurately and easily map and detect changes between core land cover classes (for example, bare, artificial surfaces, non-woody vegetation, woody vegetation, water), many of the field crops, most broad habitats and many finer habitat classes.
- Other cover classes that are mapped relatively well are burnt areas, bare sand, wet versus dry land, flooded non-woody areas, bracken in non-woody areas, dead vegetation, Rhododendron when using hyperspectral data.
- EO can measure height and produce accurate digital surface and terrain models, which is particular effective for hedgerow, shrub encroachment, tree and woodland monitoring.
- EO can often detect vegetation affected by diseases or pests.
- EO can measure woody biomass (when the biomass is low).
- EO can detect land subsidence.
- When collected at high temporal frequencies it can measure dynamics within and across years, potentially providing useful ecological information about condition (e.g. grass productivity, coastal and large lake algal blooms).
- Once methods are established, and despite the large volumes of data, processing of EO to produce consistent measures can be highly automated

Disadvantages:

- EO always requires some form of field based calibration and validation.
- Cloud affects the availability of optical data and although a higher frequency of satellite acquisitions is improving the chances of cloud free observations, there will be areas in Wales which will still have a limited cloud free coverage.
- High data access costs often excludes extensive use of certain observation types for frequent (e.g. annual) and large area monitoring. These are either delivered through airborne campaigns (aerial photography, Lidar), or are very high spatial resolution (cm to m) multi-spectral optical satellite imagery (e.g. World view).
- Free satellite imagery is only available at 10 m resolution or above and so often cannot provide the very detailed spatial information required to map or monitor small patches of cover (e.g. field margins or habitat mosaics within a land parcel). A general rule is that the required spatial resolution of the data should be half the size of the smallest feature of interest.
- The spatial detail if the EO data has a direct impact on the resulting change statistics that can be obtained.
- Aiming for a high number of cover classes will invariably lead to lowering the mapping accuracy of these classes.
- Some cover classes require more effort to accurately map and monitor.
- There are some cover/habitat types and features that cannot be mapped using EO.
- Many useful physical surface and atmospheric characteristics (e.g. surface temperature, soil moisture, surface albedo, atmospheric CO_2, atmospheric Ozone) can currently only be derived at very coarse spatial resolutions (1km or above).
- A steep learning curve to utilise tools and technology, especially with radar.
- The volume of data is great and is expected to increase further

Implementation

To date, the most effective EO based approach to monitor for significant changes and update a land cover map is by searching for anomalies in the EO data (i.e. a hotspot of change map based on unexpected signals, typically derived from NDVI) followed by targeted more detailed investigation of these areas (whether through further EO based approaches or visual interpretation of aerial photography or in-situ surveying). Several operational examples exist (e.g. Forestry Commission to monitor forested land; Milton Keynes Council to monitor urban planning; Natural Resources Wales to update the Landmap).

We should expect the EO derived products that are currently available to be updated more frequently. We should aim for more integrated monitoring systems based on a combination of EO technology providing information at a range of spatial and temporal scales and underpinned by field surveys, networks of ground-based observations and possibly models.

Field observations are crucial to establish a robust link between the surface variable of interest (e.g. land cover class, condition measure) and the EO data. There is a strong case for using EO data in conjunction of environmental and biogeographical predictors such as aspect, elevation, soil type, and climate. Links can be established using existing historical field and EO data and continuously improved, incorporating newly collected field and EO data. Field observations are also required to validate the EO derived surface variables.

Sentinel-1 and-2 will be the main sources of EO-data for land cover mapping, including CORINE land cover.

The Sentinel-1,-2 and-3 satellite series are set to provide more frequent and spatially detailed data from 2015 onwards. For example, Sentinel-2 will revisit the same location every 3 to 5 days which is 4 times more frequent then Landsat (formerly the main source of data for land cover mapping) and provide imagery with pixels as small as 10m (compared with 28m for Landsat). A high revisit frequency increases the chances of cloud free data which will in turn improve the quality of the mapping and monitoring.

Also, the availability of free high frequency data at higher spatial resolutions opens up the opportunity to monitor in greater detail the land surface and vegetation as it changes on a weekly basis. This could be exploited in particular to determine and monitor grassland management practices, establishing grazing or cutting regimes, but requires testing.

The only solution to frequent cloud coverage is radar. Sentinel-1 will provide frequent and high spatial resolution radar data. Although radar ‘sees’ the landscape differently from optical, it is now being considered as a complimentary source of information in land cover mapping for areas where cloud cover is persistent. However further research and development funding will be required for radar based mapping to become fully operational.

The UK Land Cover Map is currently being updated for 2015 by CEH, this version and any other future versions will be pixel based. By keeping the land cover information in a pixel format it can easily be summarised to fit any custom defined spatial framework. Updating the UK LCM annually is operationally possible but requires external funding.

The Land Cover plus Crops is a newly developed annually updated layer (from 2015 onwards) which enhances the UK LCM with Crop information. This product is a joint venture between CEH and RSAC ltd. First validation results show that the level of accuracy that can be achieved is crop specific. The Crop layer is currently mainly based on sentinel-1 radar data, however there are plans to incorporate the interpretation of time-series of Sentinel-2 data to add information about crop health.

The provision of annually updated land cover (LCM) and use (LCM plus Crops) at the available spatial resolutions (10m to 30m) would greatly benefit current LULUCF estimates and related GHG accounting.

CORINE land cover: The first three UK CORINE products (1990, 2000 and 2006) were derived from the UK LCM through semi-automated generalisation and updating procedures. The latest version, CORINE 2012 was produced through identifying changes from CORINE 2006 using visual/manual interpretation of EO imagery following the standard procedure implemented by the majority of the European countries. Future updates are expected to continue with Sentinel-2 imagery as the main data source.

The production of 2015 very high resolution (~ 5m) layer products for Europe are being initiated by the European Environment Agency: Impervious layer; Forests; Grass and non-woody vegetation; Wetness and water; Small woody features. The accuracy and spatial consistency of the pilot products generated previously varied substantially, with the 'Impervious layer' (urban) being the most successful and the 'Grass' product requiring a total rethink of the implemented approach.

EO related costs:

Setup costs will be higher than running cost. The relative difference will depend on the complexity of the processing chain, the number of different types of EO data that the monitoring approach will require, the existing hardware and software, and the initial experience of the staff involved and amount of training required.

Running cost will be dependent on the type of EO date being used (free or commercial data), the degree of automation in the processing chain and the frequency of the monitoring. Further cost savings could be achieved by making the required field work (for validation and calibration) as effective as possible through well-developed sampling designs, targeted surveying or field data sharing.

The most affordable and effective EO based options will be the ones that

- are based on well-established or tested approaches (i.e. repeatable in space and time)
- require the least pre-processing or well-established automated pre-processing
- exploit existing field based monitoring
- are targeted to deliver a single measure (e.g. Forest cover; productivity; area of change; a basic set of cover classes)
- avoid duplication of effort (e.g. archives of pre-processed data and intermediate products)
- maximise the use of free data and open source software.

Interpretation

EO based applications rely on the conversion of the raw EO signal into useful information about the environment, land or water surface. Depending on the information required, the approaches, algorithms and models used for the conversion vary widely. These also tend to develop with time as both our understanding and technology evolves. For monitoring the key is to maintain consistency in the information that is retrieved from the EO data. Consistency is affected by the several factors: changes in sensor design between missions and sensor deterioration within the lifetime of a mission, changes in pre-processing steps (e.g. improved correction procedures), changes in the approach used to interpret the data (e.g. improved model). This can be managed through version control, detailed documentation of processing chains, product validation and the reprocessing of the

historical data with the updated procedures. When re-processing is not an option, the monitoring approach should include strategies for avoiding or managing these inconsistencies.

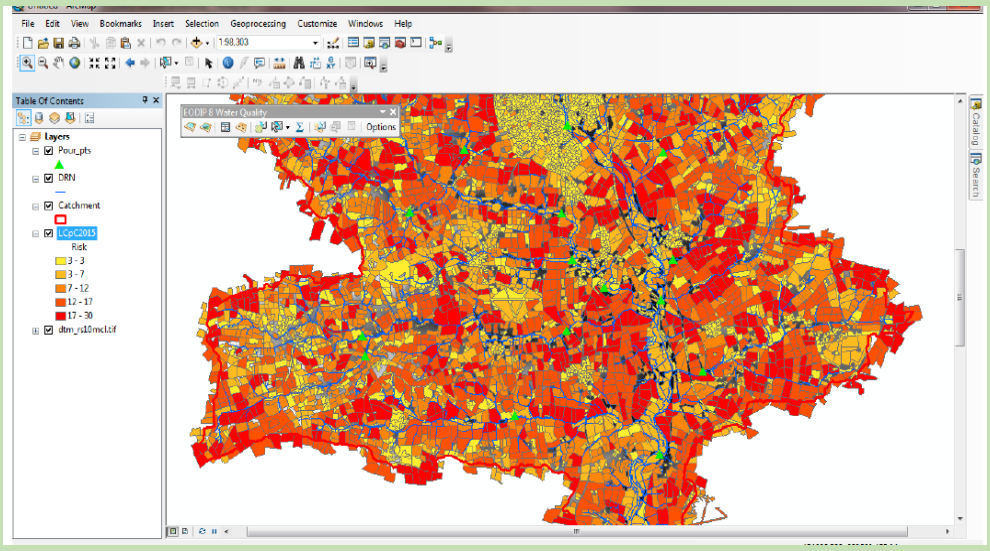
Certain EO image processing options are prone to delivering inconsistent outputs and should therefore be avoided. For example, segmentation an approach used by the NRW Habitat Map of Wales, UK LCM 2000 and the Living Maps to divide the landscape into parcels is sensitive to variations in spatial landscape patterns. Defining the segmentation input parameters which determine the resulting parcel size distributions is very subjective. Working at pixel level avoids this potential source of inconsistency.

For enforcement purposes the information provided from EO has to be accepted by Regulation and Policy as quantifiable evidence. In this context, validating the information derived from EO in a manner that satisfies Regulation and Policy is particularly important.

Experience to date

Case Study 1

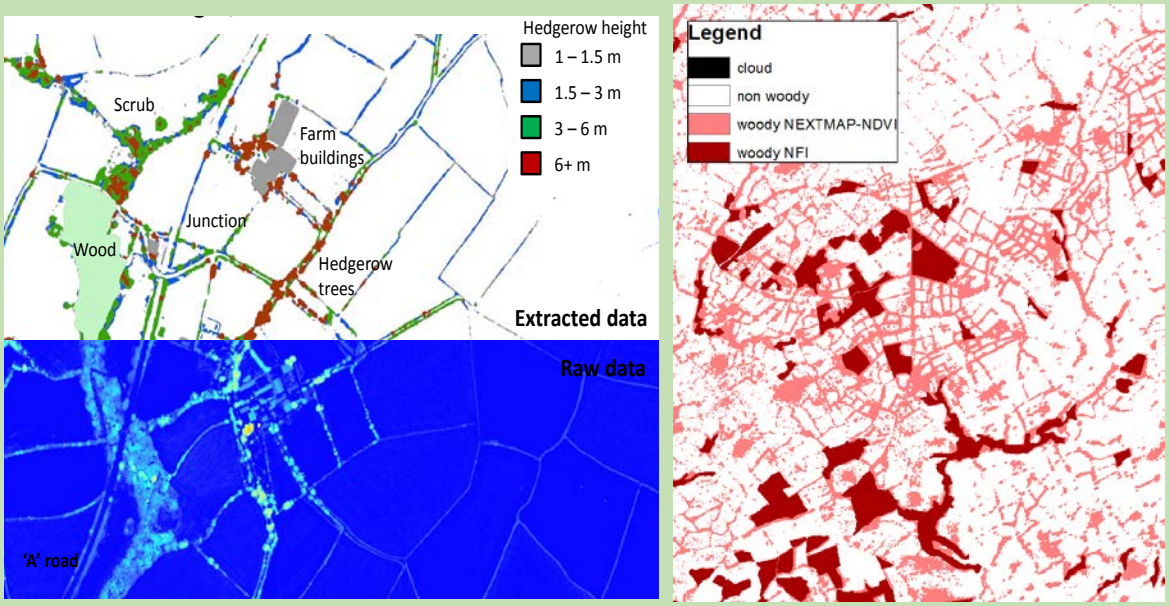
Currently in England water quality is determined through ~250,000 samples annually taken from 19,000 chemical and 6,900 ecological Water Framework Directive monitoring sites. Many sites show little change. Landcover Plus – Crop Map produced from Sentinel 1 radar data, combined with soils, slope, altitude, groundwater and rainfall data has enabled the development of a prototype system to support the targeting of monitoring effort to a smaller number of priority sites with the aim of enhancing the efficiency of EA's national water quality monitoring programme in England. Tools built to utilise these integrated data will also help with field investigations into the causes of water body failures.



The figure shows modelled weightings of risk factors to create a heat map for a catchment. *Image source: Defra Earth Observation Data Integration Pilot Project.*

Case Study 2

EO can accurately measure height using Lidar, radar or stereoscopic aerial photography. The degree of spatial detail and vertical precision that can be achieved is dependent of the spatial resolution of the data and the technology used, respectively. Height data, when combined with a greenness measure can deliver detailed maps of hedgerows, and woody vegetation (line of trees, shrubs, small woodland patches). The image below shows 2 examples of such a map.

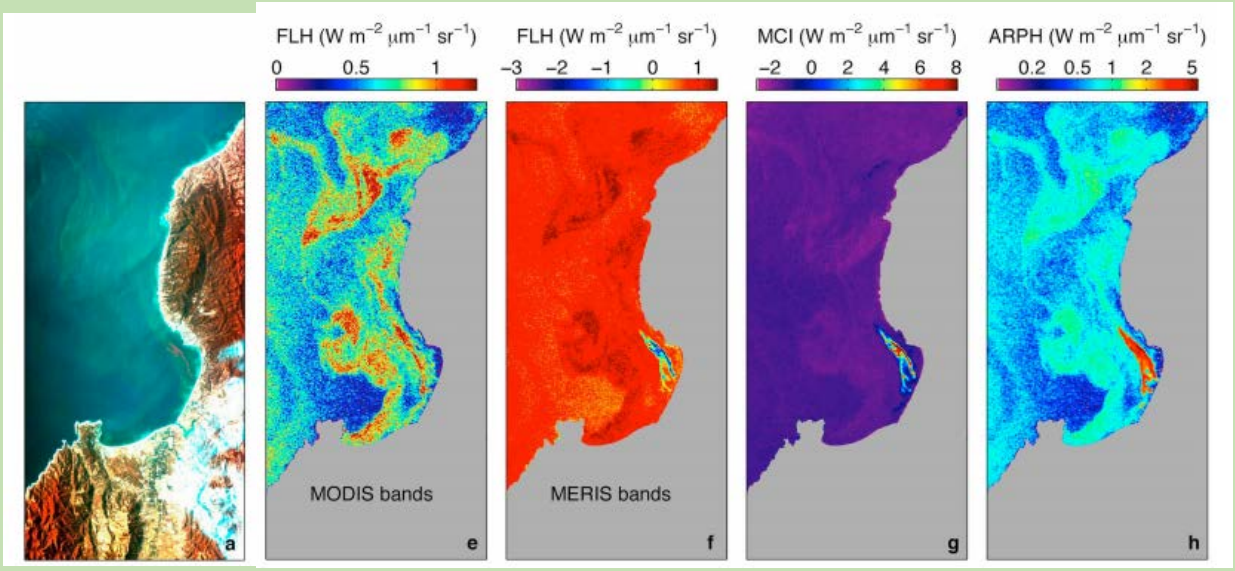


Left: a hedgerow and woodland map derived using height information from airborne Lidar, open-licence Ordnance Survey Vector Map data and the Forest Commission's National Forest Inventory dataset

Right: a map of woody vegetation derived using height information from aerial photography (NEXTMAP), greenness information from satellite NDVI and the Forest Commission's National Forest Inventory dataset.

Case Study 3

Operational algorithms exist to detect and monitor algal blooms and sediments in the surface waters along the coast or in large lakes. The methods require multi-spectral narrow bands observations which so far were only available at coarse spatial resolutions (1km and above). The Sentinel-3 satellite series (launch in 2016 and 2017) will soon enable operational algal bloom monitoring at



higher spatial resolutions (300 m). The image below is sourced from a publication (Ryan et al 2014) and compares a range of algorithms developed to detect algal blooms in Monterey Bay (USA).

Image Source: Ryan JP, et al. Application of the Hyperspectral Imager for the Coastal Ocean to phytoplankton ecology studies in Monterey Bay, CA, USA. Remote Sens 6:1007–1025 (2014); doi: 10.3390/rs6021007.

Case Study 4

Unmanned Airborne Vehicles or Drones are becoming increasingly more affordable. The most basic of data captured by a £1000 drone and camera setup (see image below) can quickly be converted into a spatially detailed digital surface model and RGB image allowing for a quick reconnaissance of an area in support of field surveying. More expensive setups ranging from £50K to £100K are being investigated for monitoring vegetation condition. The area coverage that can be achieved is typically small.

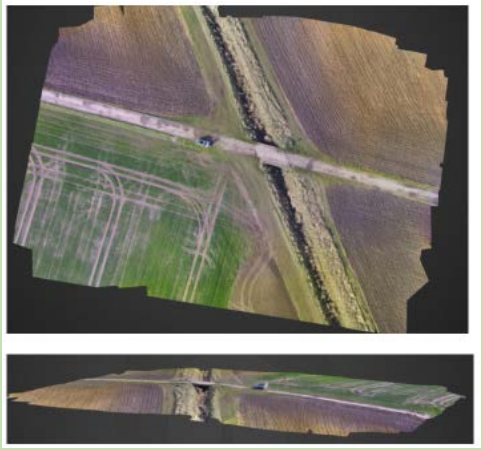


Image source: CEH

Case Study 5

A detailed new assessment of the extent and condition of the full Welsh peat soil resource was carried out based on an integrated analysis of BGS soil mapping data, CEH land-cover data and the use of aerial photographs to identify and map drainage ditches. This work has enabled the generation of spatially explicit emission factors for peat soils impacted by changing land use across Wales (see image below). Work is ongoing to generate a UK wide map of wetland soils and modification using a similar approach.

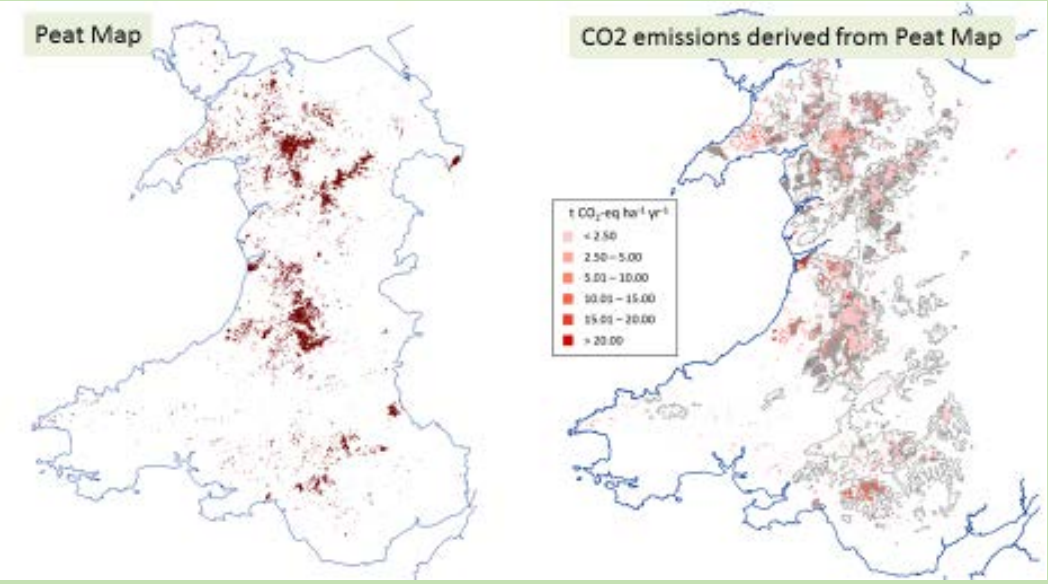
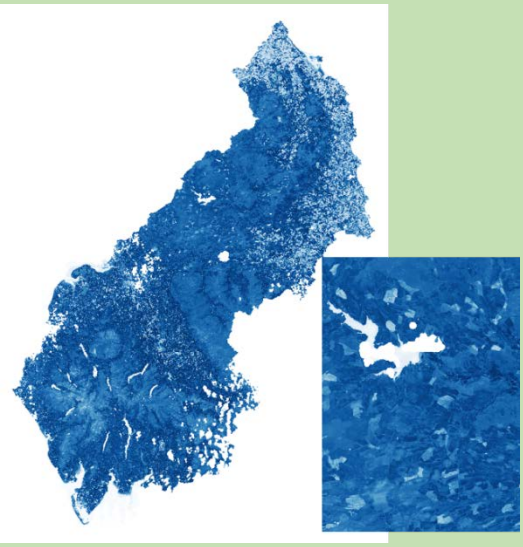


Image source: CEH

Case Study 6

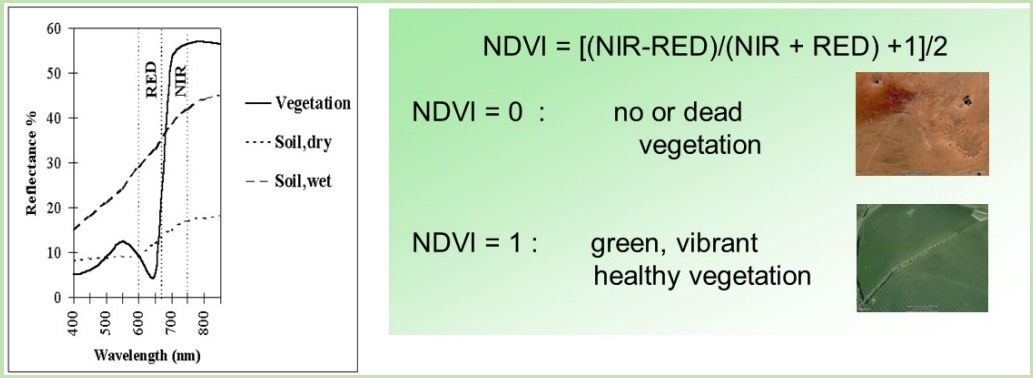


Normalised Difference Vegetation Index (NDVI) as an intermediate product. An EO Data Integration Pilot (EODIP) project on the generation of intermediate products clearly demonstrated how this can be achieved with a very high degree of automation using the available Landsat data. The next steps to progress this work will include establishing an automated process for Sentinel 2. Sentinel 2 can generate large volumes of data, but the maximum it could be for all of the UK, assuming that all images were cloud free and stored would be 82TB. This includes 2 indices being stored as well as the processed imagery. Although this is a large amount of data, the processing and storage is readily achievable at modest operating cost, based on other EODIP findings.

Example of standardised NDVI product based on Landsat data. Image source: Defra Earth Observation Data Integration Pilot Project.

Case Study 7

EO derived Vegetation Indices such as NDVI are very effective to monitor the greenness of vegetation over time. Figure below shows how NDVI was successfully linked to field based Above ground Net Primary Productivity (ANPP) which is used as an indicator of how improved a grassland is. The model used 296 plots collected from 82 x 1km^2 Countryside Survey samples. The model performs best for EO data acquired in spring (e.g. May)



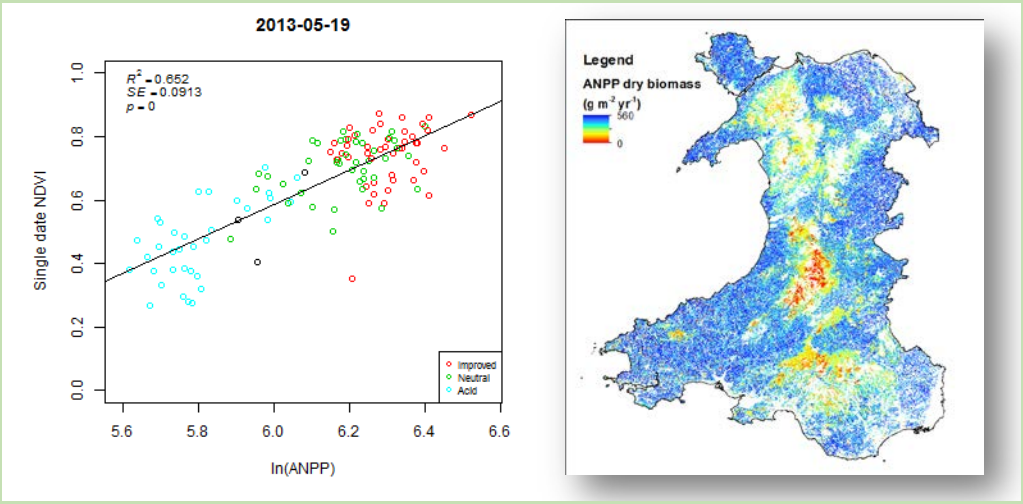


Image Source: CEH

Current assessment of technology

Could you try and fill in attached following traffic-light scheme:

	Local / investigative	National monitoring	2-5 years	➢ 5 years	Comments
Land cover		UK LCM; UK LCM + Crops; National Forest Inventory (with triennial loss/gain all woodland >0.5Ha). Updating Landmap of Wales through identifying hotspots of change. Derivation of landscape metrics from Land cover	Annual updates of UK LCM; and LCM + Crops; NFI; UK wide hotspot of change map linked to field or higher resolution data, provide drivers of change information as is already done in NFI and for Landmap of Wales. Coarse resolution monthly global night light products provide information on urbanisation and light pollution: http://commercedataservice.github.io/tutorial_viirs_part1/	Additional condition layers added to the UK LCM	EO is the only cost effective method for national land cover. Accuracy and consistency of maps is key for reliable monitoring.
Habitat area	Detailed maps produced using aerial and satellite data can be used to target field investigations (eg; south Glamorgan, map was starting point that updated unimproved grassland mapping) or change detection (as in Warwickshire).	National Scale mapping possible but requires high spatial resolution imagery, field validation and expert input (Wales Phase 1 update, Peatland); Resource intensive, so main contribution is to provide spatial framework for future change detection and condition monitoring	Opportunities to improve stock (area) and range of habitats features accurately detected, e.g: Wales Lidar coverage (as planned in England) would provide very accurate tree/hedge asset. Coastal airborne hyperspectral - Lidar (e.g. England) provides opportunity for very accurate coastal habitat mapping.	Convergence with Land cover mapping – more habitats can be detected as availability of higher resolution satellite data (higher frequency, lower cost) improves.	Detecting habitats at a finer classification than broad habitats in land cover is more resource intensive. Accuracy and temporal consistency needs to be proven. EO cannot identify all habitats, but the range of habitats that can be determined reliably will increase.
Habitat condition	Research is currently focussing on this topic. Variables with real scope: % bare ground, % dead material, % woody cover, forest density, 3D structure, productivity, wetness and surface temperature	Investigating hotspots of change within a spatial framework with targeted field effort or higher resolution data would characterise change in condition and give drivers of change.	Building up research and knowledge base to interpret seasonal and multi-year signals for variables that can be generated and analysed within the spatial framework of habitat or land cover maps. Linking to drivers of change (grazing, cutting, drainage etc). Some methods are already established eg: detection of moorland burn with radar.	Range of variables that can be reliably interpreted is likely to increase through the use of more sophisticated methods combining EO data and other data with physically based models.	Whilst variables can be efficiently calculated across Wales, understanding their significance will be habitat specific and monitoring effectiveness will vary with habitat.
	Algal Blooms in surface waters of large lakes and along the coastline.				Algal Bloom monitoring is limited to large water surfaces free of vegetation.
habitat diversity	Is based on using proxies which will rely on condition measures	Being used to assess habitat diversity for Wales already e.g. for GMEP			Will always be derived by proxy and may never be as effective as field surveying.

Soil & GHG		Peatland condition map in Wales	Improved peat mapping through a dedicated airborne campaign; Inclusion of annual LCM and Crops and soil moisture information into GHG accounting	Improved peat mapping through a dedicated airborne campaign; Inclusion of annual LCM and crops, soil moisture information into GHG accounting	Further research improving retrieval algorithms and models will make this possible.
Waters		EA Pilot used UK LCM + Crops to identify high risk area and target sampling	Hot spot of change map or LULUCF from annually updated LCM, combined with UK LCM + Crops rotational data helps identify high risk areas and target sampling.		
Animals	Density of life stock, through patterns recognition and counting of animals from very high spatial resolution imagery	Tracking greenness of woody vegetation in time is used to predict deer movement.			Examples exist, however a more feasible option could be analysing the animal movements dataset held by RPA/AHPA to establish stock densities spatially.
Health and disease	Still under development. EO could support the prediction of pollen densities, levels of Ozone, tick, midge or mosquito densities using spatially detailed land cover combined with other EO derived variables, models and ancillary data.				Research is being carried out. The degree of success will be determined by the suitability of the EO data and effectiveness of models.
Extreme weather events	Mapping of flooded areas locally is done operationally at national level.	Impact of weather extremes on cover/habitats; through combined use of models EO and networks of in situ observations (e.g. weather, soil moisture, phenology)			Research is being carried out to better establish the impact of weather extremes. The degree of success will be determined by the suitability of the EO data and effectiveness of models.
Archaeology	Local manual mapping of archaeological features using aerial photography or LIDAR data.	National mapping of archaeological features is possible through a rolling programme of manual interpretation.			Implementation is solely dependent on finance. Cost of manual interpretation by expert staff is high. Cost reduction is possible by combining with other EO surveys.

Data and informatics

EO data has to be acquired from the supplier, stored and distributed. Easy access of (archived) data to build up time-series is important. EO data also has to go through some form of pre-processing before it can be used. The pre-processing varies with data type. For example, optical data requires an atmospheric correction, a correction for topographic shading, conversion to reflectance and geo-registration, and in certain circumstances a correction for effects of a varying viewing and solar angle geometry is also required.

Certain intermediate products such as vegetation indices (e.g. NDVI for greeness, NDWI for wetness), cloud and cloud shadow masks or snow masks are used repeatedly for a variety of applications. The ability to build up and make available long term time-series of pre-processed data and intermediate products will enable future long term trend monitoring.

A centralised national hub that acquires, stores, pre-processes and distributes standardised and version controlled EO data and intermediate products relevant to national monitoring would avoid duplication of effort, cut cost and expedite the use of the EO data (e.g. NASA's tool: REVERB http://reverb.echo.nasa.gov/reverb/). Plans exist for UK focussed Sentinel data distribution points (e.g. http://sedas.satapps.org/) however these will not necessarily include intermediated products and other relevant EO data sources. One of the DEFRA EO strategy goals is to have by 2020 *"Secured access to data handling infrastructure and operators so that the rapidly growing sets of data and information products can be used efficiently to meet our policy and operational needs."*

Similarly, certain downstream products such as a generic UK land cover map, Wales character map, a digital terrain model, a hotspot map of change will assist a variety of users and so would benefit from a centralised data management approach.

Most applications use freely available EO data. However, some applications will remain dependent on expensive EO data such as airborne data (e.g. aerial photography, Lidar data) or very high spatial resolution (< 10 m) multi-spectral satellite imagery. These type of data are critical to identify and monitor small or narrow landscape features and land parcels. Procurement of country wide coverage for shared data access is the most cost-effective. For example, in 2010 a full coverage of Rapid eye imagery was acquired for the territory of France; The Netherlands have a rolling programme of Lidar surveys and procured near-daily DMC imagery (30m) for 2012-2016 period.

Next steps / immediate opportunities for development as a monitoring tool

Immediate

- Investigate feasibility and cost of securing Lidar coverage for Wales by adding Lidar acquisitions to the Welsh rolling 3 year aerial photography campaign (e.g. investigate combined aerial photography/Lidar Surveys in other European countries and the England plan for 1m Lidar coverage).
- Stimulate engagement and thinking across community (Wales and UK) to identify the types of change and drivers of change that EO is likely to help deliver through the derivation of simple reliable Wales-wide variables such as NDVI and the implementation of current operational or near-operational systems which are geared towards monitoring and change detection (e.g. UK LCM plus Crops, algal bloom monitoring, a hotspot map of change as one of the variables for risk based monitoring).

- Instigate an expectation that anything developed within Wales would be shared and developed as part of a wider community of practice.
- Review the projects underway through the EO Centre of Excellence to see which may have relevance for Wales.

Next steps:

- As overall priorities for information are clarified use a tiered approach to help find efficient solutions using EO's strengths combined with the strengths of other methods eg;
  - First the lowest cost/unit area: establish which parts of the requirements can be met Wales-wide through automated processing of freely available EO data (Sentinel-1 radar, Sentinel-2 optical, Sentinel-3 optical and thermal, other data) combined with relevant field sampling.
  - Secondly which parts of the requirement can be met by adding the three year aerial photography refresh (and Lidar if added) to determine and analyse change within existing data sets or spatial frameworks (e.g. LCMUK, habitat phase 1, Landmap, etc)
  - Thirdly which more subtle or detailed changes can be picked up with localised or targeted use of much higher spatial resolution data from satellites or drones, combined with field effort
- Following the Welsh Government's investment in developing a pre-processed Landsat Archive for Wales, develop a coordinated approach to the acquisition, pre-processing, production of intermediate products and distribution of EO data. Focus on data from Sentinel 1 and 2 in first instance but consider other relevant EO data sources. A UK level partnership may proof beneficial. The Defra EO strategy is working towards acquiring this capacity by 2020.
- Consider supporting research into monitoring using radar or combined radar, optical data: monitoring grassland management using time-series of radar and optical data.
- Evaluate the added value of expensive very high spatial resolution world view imagery to provide multi-spectral data with higher spatial resolution than Sentinel-2. Based on outcomes, consider the procurement of this data (consider a UK wide procurement).
- Evaluate the potential for using the very high spatial resolution EO-derived products planned by Europe.

Briefing note:

The potential of Earth Observation data for Environmental Monitoring in Wales

Brief description of technology

The terms Remote Sensing and Earth Observation cover not one technology, but a wide range of technologies that can be implemented for environmental monitoring in different ways. A full coverage of all available technologies is beyond the scope of this briefing note (see Appendix 1 for further info). The nature and capability of EO technologies vary depending primarily on the platform and the type of sensor. A wide variety of platforms are currently available, including satellite, aircraft, unmanned aerial vehicles (UAVs or drones), fixed ground instruments (often in networks) and mobile ground vehicles (e.g. unmanned robots or tractors).

A range of sensors are available, with the most common being optical sensors, radar, Lidar and thermal sensors (further detail is given in the Appendix). Optical sensors measure reflected light in wavelengths humans can see and cannot see. The radar signal responds to vegetation structure (i.e. tall, short or dense) and vegetation/soil moisture content, and in some circumstances can be processed to estimate height i.e. 3-d information. Lidar uses laser pulses to measure height and is typically used to produce very high resolution digital elevation models. Thermal sensors measure water or land surface temperature.

The constraints of the sensing technology and the limitations of the platform, along with a range of other variables including weather, military operations and other operating restrictions, affects the frequency (i.e. the time between repeat images of a site) of observations, the spatial scale of the observations, the spatial extent of the coverage and the cost. Satellite sensors offer panoramic and regular repeat views and so are better suited for wide-scale monitoring (i.e. national or greater). Airborne sensors generally have a much higher spatial resolution, but with narrower geographic and temporal scope so are limited to more targeted, or sample-based monitoring. Data acquired from airborne sensors are sometimes used for calibrating or validating satellite derived measurements. For monitoring change access to repeat observations that capture seasonal variations is key. Cost effective monitoring strategies will come from intelligent combinations of multi-scale EO data and field sampling. For example coarser spatial resolution satellite sensors can locate change that targets the use of higher cost very high spatial resolution data, or to optimise field samples to pick up what cannot be done remotely.

The type of EO dataset used affects the characteristics of the information that can be derived. Identifying appropriate methods and EO datasets for monitoring requires the feature(s) of interest and the expected update frequency to be clearly identified, but with flexibility in how these are measured, as EO may be able to measure proxies cheaply, allowing a more targeted approach to direct measurements. Ground based reference observations are essential for the interpretation and validation of EO data so the most effective monitoring strategy is one that integrates ground observations with EO.

For the purposes of operational monitoring, any EO derived data product should ideally meet the accuracy and precision level required for its purpose and have its uncertainty well documented and quantified. It should also be spatially and temporally consistent and repeatable.

The use of EO data for an application is determined by the cost of the data and the four main characteristics of the available data source:

- the type of sensor available (e.g. optical, Lidar, radar)
- the spatial detail (spatial resolution) of the observation
- the repeat frequency (temporal resolution) of the observation, this is particular important for optical data which are affected by cloud, or for applications that require a time-series of observations to capture within year dynamics.
- data continuity – for applications requiring a comparison with a long term baseline, comparable EO data (i.e. data from similar sensor-platform setups) need to be available from the past, present and future.

This review will focus on the type of data products that can be derived from EO data, rather than the underlying EO data.

Applications and current state of development

There is a strong principle of collaboration within the EO field in the UK creating opportunities to build on wider best practices and successes.

A range of products that use EO are already available for Wales including a range of complete coverage products (UK land cover map series; updated Phase 1 Habitat Map of Wales; NFI), some that focus on specific land cover types (CEH Land cover plus: crops 2015; GMEP woody cover); products that quantify one aspect of condition (GMEP ANPP; vegetation parameters; the Welsh Peat Map) and finally a network of fixed sensors (COSMOS-UK soil moisture and phenology cameras). EO is a rapidly developing area with other products under development through Copernicus or other organisations, such as EODiP MEOW.

UK Land Cover Map Series

Three UK-wide land cover maps have been produced for 1990, 2000 and 2007 at a spatial resolution of ~25m and a map for 2015 will be complete by the end of the year. This will provide Wales with a land cover map with 23 land cover classes, based on Broad Habitats, for 4 time points. Currently, there are issues with accurate, robust mapping of change over time, which is complicated by the spatial and thematic differences between the existing maps, however, methods are being developed by CEH that would resolve some of these issues.

Updated Phase 1 Habitat Map of Wales

The original field-surveyed Phase 1 Habitat Survey of Wales (surveyed 1979-1991) represented the primary spatial dataset of semi-natural habitats and the extent of agriculture across Wales for many years. Driven by a strong user requirement for up-to-date and accurate habitat data for Wales, an alternative approach to discriminating and mapping habitats was implemented by Environment Systems and Aberystwyth University using image segmentation and rule-based classifications

applied to SPOT-5 and other satellite sensors to generate a revised Phase 1 map of habitats in Wales for 2006.

CEH Land cover plus: crops 2015

The CEH 2007 land cover map has been enhanced with updated crop information for 2015. A time series of Sentinel-1 radar data have been used to produce the 2015 crop data, with more than 350 individual images of the UK being processed covering the whole crop growing season. The crop classes in 2015 are winter wheat, winter barley, spring barley, oilseed rape, field beans, potatoes, sugar beet, maize, other (vegetable crops, oats, rye, peas and early potatoes and maize) and improved grass. The map is currently being validated. The plan is to deliver an annually updated product.

National Forest Inventory

All woodland areas larger than 0.5 ha are available as a GI layer, with a tri-annual (soon to be annual) EO based update based on detecting wood loss and new planting. There is research underway managed by the Forestry Commission through the Defra EO Centre of Excellence that is looking at how to improve the range of canopy related information and size of woodland unit that can be detected using Sentinel 1 radar data.

GMEP EO work

The aim was to extrapolate information gathered from the 1km GMEP survey squares to a Wales-wide coverage and so enhance the monitoring and mapping of High Nature Value farmland. So far two products have been developed.

- ANPP – Aboveground Net Primary Productivity, based on a calibrated relationship between spring satellite imagery and GMEP x-plot field data. Due to the requirement for spring-imagery, a complete coverage of Wales may not be possible every year.
- Woody Cover – map of woody cover features such as copses and treed hedgerows that are not identified by the LCM or National Forest Inventory (i.e. <0.5ha), but play an important role in landscape connectivity.

Vegetation parameters

Research with CEH, more recently Environment Systems, and others has identified the potential to use Sentinel-1 and -2 derived parameters to help determine aspects of habitat condition (productivity [see above], scrub cover, bare ground and dead material). In combination with land cover mapping (eg: UK Land Cover Map, Updated Phase 1 Habitat Map of Wales) this provides the opportunity to monitor at site to national scales drawing on comparisons within season and between years. JNCC is developing a service to provide parameters to support condition monitoring covering the countries of the UK.

Welsh Peat Map

This is a detailed new assessment of the extent and condition of the full Welsh peat soil resource, based on an integrated analysis of soil mapping data, land-cover data and the use of aerial photographs to identify and map drainage ditches. This work has enabled the generation of spatially explicit emission factors for peat soils impacted by changing land use across Wales. Work is ongoing to generate a UK wide map of wetland soils and modification using a similar approach.

COSMOS-UK network

The COSMOS-UK network is a fixed sensor network established to represent the variety of soils, climates and land-uses across the UK. The network is primarily designed for measuring soil moisture, but also includes plant phenology observations from a camera, and a weather station. It is included here as an example of a different type of remote sensor, but one that is likely to play an increasing role in the future.

Other and related products

Other EO derived products are being developed as part of the SSGP (Space for Smarter Government Programme) programme and EODiP is currently identifying a set of intermediate EO derived products (e.g. NDVI) that are expected to cover multi-user needs. The production of 2015 very high resolution (~ 5m) layer products for Europe are being initiated by the European Environment Agency: Impervious layer; Forests; Grass and non-woody vegetation; Wetness and water; Small woody features. The accuracy and spatial consistency of the pilot products generated previously varied substantially, with the 'Impervious layer' (urban) being the most successful and the 'Grass' product requiring a total rethink of the implemented approach.

There are other spatial data sets, such as the OS open data layers and commercial products, such as the Blueskys' tree map. Welsh Government invests in aerial photography coverage of Wales which refreshes every 3-4 years. A variety of other data, such as soils data and topographic data (from a digital terrain model) provide useful ancillary information that supports and is essential to the interpretation of the EO data and the development of rule based classifications. LiDAR is now also freely available and accessible via the Welsh Government Lle GeoPortal. There are a range of biophysical data from both Welsh Government and Natural Resources Wales which provide invaluable supporting data and data from the Basic Payment Scheme (land ownership, management, livestock, crop etc.) are very useful for validation.

What are the advantages and disadvantages?

Advantages:

- EO provides a bird's eye view. This allows for the detection and monitoring of two and three dimensional patterns in the landscape, which are not easy to observe from the ground.
- Satellite EO can achieve a complete coverage of Wales in a very short period of time
- EO data is spatially consistent
- EO data is temporally consistent, and when it is collected at high temporal frequencies it can be exploited to measure the dynamics of several parameters within and across years, potentially providing useful ecological information about habitat condition.
- EO data is available at a range of spatial and temporal scales.
- A wide range of EO data is freely available and relatively easy to access.
- EO allows the surveying and monitoring of difficult, dangerous and remote areas or where access is limited. This is particularly relevant if very high spatial and/or temporal resolution data is needed.

Disadvantages:

- EO often indirectly observes the surface variable or landscape feature that needs to be monitored. Identification of suitable proxies relies on aligned field assessment.

- Cloud affects the availability of optical data and although a higher frequency of satellite acquisitions through sentinel-2 (providing optical data potentially every 3 to 5 days) is improving the chances of cloud free observations, there will be areas in Wales which will still have a limited cloud free coverage (see appendix).
- High data access costs often excludes extensive use of certain observation types for frequent (e.g. annual) and large area monitoring. These are either delivered through airborne campaigns (aerial photography, Lidar), or are very high spatial resolution (cm to m) multi-spectral optical satellite imagery (e.g. World view).
- The relative coarse resolution of free satellite imagery (10 m or above) means that it cannot provide the very detailed spatial information required to map or monitor small patches of habitats. A general rule is that the required spatial resolution of the data should be half the size of the smallest feature of interest. It is also important to remember that the level of spatial detail at which a feature is being mapped and monitored has a direct impact on the resulting change statistics that can be obtained. There are some habitat types and features that cannot be mapped using EO.
- A steep learning curve to utilise tools and technology, especially with radar.
- The volume of data is great and is expected to increase further.

What could the technology deliver in 1-5 years time?

As the European Copernicus program matures, the next years will see an increase in the frequency of multi-spectral, radar and thermal satellite observations for the UK. Sentinel-1 (radar, high resolution every 6 days), Sentinel-2 (optical, high resolution, every 5 days) and sentinel-3 (optical and thermal coarse resolution, daily) are the most relevant for Wales. The trend is for more temporally and spatially detailed data with improved signal quality which will enhance the reliability of the information that can be derived from EO. The availability of high frequency data at higher spatial resolutions opens up the opportunity to monitor in detail the land surface and vegetation (within coarse categories) as it changes on a weekly basis, although for optical data frequent cloud cover is likely to substantially limit what can be achieved. As a result we should expect an extensive increase in research and development focusing on the use of radar.

There will be applications which will remain dependent on the more expensive airborne data (e.g. Lidar data for detailed elevation models) or the very high spatial resolution multi-spectral satellite imagery. Without government intervention to ensure regular and affordable coverage of this type of data, these applications will remain underdeveloped. In Wales, inclusion of Lidar acquisitions as part of the Welsh national aerial photography campaigns would transform the monitoring of small three-dimensional landscape features such as hedgerows, ditches, shrubs, tree lines and archaeological features and enable forest density monitoring.

The use of unmanned drones has expanded dramatically in the past 5 years and is expected to continue to expand. Their use has become increasingly easy and the range of EO instruments available for use on drones is expanding. Unmanned drones show great potential for use in support of the field surveying at local scales (see appendix), but more work is required to realise their potential for ongoing landscape monitoring (see appendix) [1]. Also current aviation laws could limit their use in on-going landscape monitoring. This could potentially be circumvented through the use of autonomous high altitude drones. Similarly the technology supporting network of sensors has matured substantially and could in the future contribute to country wide monitoring.

[1] See MEOW 3 report, work carried out by CEH to look at UAV data for CS squares

The hardware and software to handle large volumes of data automatically is continuously progressing and data download services for Copernicus and other free EO data sources are proliferating. Accessing EO data should become easier. The challenge will be to match this with operational data processing chains to support efficient EO based monitoring. The EO archive for Wales project (currently focussing on pre-processed imagery) is a good starting point.

The recently developed Welsh Space Strategy (http://space.aerospacewalesforum.com/strategy), which was jointly launched by industry, Welsh Government and Satellite Applications Catapult, is providing a mechanism for progressing and building the EO capacity in Wales and has the potential to speed up the developments described above.

In terms of derived data products we would expect the products currently available to be updated more frequently and for more integrated monitoring systems to be developed. More integrated monitoring systems would be based on a combination of EO technology at a combination of scales and underpinned by networks of ground-based observations and field surveys. Such a system could operate at a combination of scales (Figure 1) and would become increasingly integrated with meteorological data and models to enable accurate detection and attribution of change (e.g. an earlier spring vs a change in vegetation condition due to drought, a change in management, a change in cover). The different levels of observations could include:

Coarse scale EO (>250m pixel size) – such data would provide monitoring at landscape scale, detecting gradual changes in vegetation condition (e.g. a gradual shift over many years towards more improved grasslands), and sudden anomalous behaviour against a baseline from previous years (e.g. a sudden change in cover or a drought event). It would provide the background for the finer resolution data. This method is already being used by the Forestry Commission to detect hotspots of forest cover change and so indicate where the detailed manual interpretation of aerial photographs is required.

Soil moisture and surface temperature are particular examples of satellite derived products that for now will only be available at coarser scales (1km), but with the potential of highlighting landscape areas showing sudden changes or gradual trends.

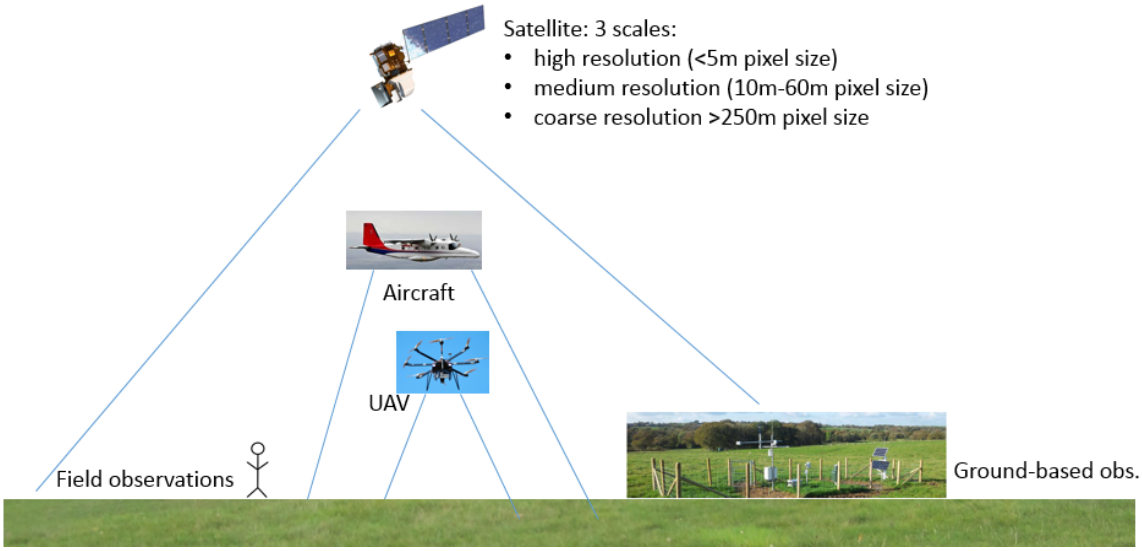


Figure 1: Range of observations scales in a fully integrated monitoring system based on EO.

Medium resolution (10m-30m pixel size) – a range of products could be produced, such as:

- A land cover map (based on a mix of optical and radar), which is updated every year or possibly less frequent but incorporating an annually updated crop map.
- An impervious surface map, e.g. from Copernicus high resolution layers (repeat every 3-5 years)
- Grassland productivity, condition and management (annual, but based on time-series of optical and radar observations)
- A woody cover map (repeat every 3-5 years)

High resolution (<5m pixel size) – including aerial photos, airborne Lidar and high resolution multi-spectral satellite data could be used for more detailed investigation of areas highlighted as potential hotspots of change but may increasingly be used to produce countrywide derived data sets as part of a rolling medium term monitoring programme. The types of derived data are likely to be similar to the medium resolution data sets, but with higher spatial resolution and additionally will include more targeted measures for key habitats or areas, such as cities or floodplains, where there are specific data requirements.

One alternative to complete-coverage or targeted mapping, is to use a random sample-based approach within a statistical framework that is linked up with the field surveying.

Field observations – field observations will be key to validating and calibrating the EO data and will require observations distributed widely and systematically across Wales. EO is also very effective in targeting where detailed field surveying could be required.

Networks of ground-based observations – advances in telecommunications and low cost technology (e.g. Raspberry PI) mean that remote sites can be used for real-time measurements, so fixed sensor networks are likely to become increasingly important in future monitoring strategies as the diversity of sensors increases.

Costs

Setup costs will be higher than running cost. The relative difference will depend on the complexity of the processing chain, the number of different types of EO data that the monitoring approach will require, the existing hardware and software, and the initial experience of the staff involved and amount of training required.

Running cost will be dependent on the type of EO date being used (free or commercial data), the degree of automation in the processing chain and the frequency of the monitoring. Further cost savings could be achieved by making the required field work (for validation and calibration) as effective as possible through well-developed sampling designs, targeted surveying or field data sharing.

The most affordable and effective EO based options will be the ones that

- are based on well-established or tested approaches (i.e. repeatable in space and time)
- require the least pre-processing or well-established automated pre-processing
- exploit existing field based monitoring
- are targeted to deliver a single measure (e.g. Forest cover; productivity; area of change; a basic set of cover classes)
- avoid duplication of effort (e.g. archives of pre-processed data and intermediate products)

- pre-processing, creation of intermediate products)
- maximise the use of free data and open source software.

EO - FURTHER READING

More background on the technology

The term Earth observation (EO) is used to cover a variety of activities that represent 'the gathering of information about planet Earth'. In this briefing note EO refers to activities that involve the use of remote sensing technologies that collect electromagnetic signals reflected, scattered or emitted by the Earth's surface (Figure 1). Typically the range of electromagnetic waves used in EO covers (listed from short to long waves or high energy to low energy) the visible, the near- and shortwave- infrared, the thermal infrared and finally the micro waves (i.e. high frequency radio waves). Other parts of the spectrum worth mentioning are the gamma rays (high energy) and cosmic rays (very high energy).

Different technology is used to observe different parts of the spectrum (Figure 2):

1. Analogue photography and digital cameras observe the reflected sunlight in the visible and near-infrared,
2. Lidar systems record the reflected intensity and timing of near infrared light beamed onto the Earth's surface,
3. Multispectral and hyperspectral scanners view the reflected sunlight in the visible, near- and shortwave- infrared,
4. Thermal infrared cameras or scanners observe emitted thermal infrared signals,
5. Radar systems receive the backscatter and phase of microwaves transmitted onto the Earth's surface, and
6. Radiometers observe emitted microwaves.
7. Cosmic ray probes or gamma ray spectrometers are specialist instruments designed to capture cosmic or gamma rays radiated from the Earth's surface.

Except for the cosmic ray probes which are used in-situ and gamma ray spectrometers which are used on board aircraft, currently the technology exist to have any of the sensors listed above on board aircraft and satellites. Through recent advances in miniaturization, digital cameras (multispectral, hyperspectral and thermal) and lidars can now be carried by lightweight unmanned drones. Digital cameras, multispectral sensors and cosmic ray probes are also used operationally in-situ as part of regional, national or international networks (e.g. http://phenocam.sr.unh.edu/webcam/gallery/ ; http://cosmos.ceh.ac.uk/). Most EO observations acquired from satellite and in-situ networks are frequent and consistent for medium to long term periods. Observations acquired from aircraft are dependent on good weather conditions and so tend to be opportunistic or part of a low frequency rolling program. Unmanned drones, also dependent on good weather, are mainly used for local one-off or short term repeat observations.

Our ability to remotely sense the Earth using different parts of the spectrum is limited by the following key constraints:

A first main constraint is the atmosphere which interferes with the electromagnetic signal. Clouds and smoke will block all signals from the visible to the thermal spectrum (i.e. affecting signals received from cameras, lidars and spectral and thermal scanners), leaving the microwave range (i.e. radars and microwave radiometers) unaffected.

The second constraint is the magnitude of the desired signal relative to the background noise, also referred to as the signal-to-noise ratio. Signal-to-noise ratio becomes smaller with increasing wavelength which results in a direct link between the spatial detail that can be achieved and the length of the wave observed. For example, on board satellites, digital cameras can achieve cm to m detail colour imaging. In contrast, surface temperature derived from infrared radiometers is delivered at a 1km resolution and soil moisture derived from microwave radiometers at 36km. For radar systems, which actively send a signal to the surface to collect the backscatter of that signal, the signal-to-noise ratio is determined by the power that can be generated on board the satellite (i.e. the size of the solar panel) and the maximum size of the antenna that can be achieved. So in the case of radar, the signal-to-noise ratio and spatial detail that can be achieved is linked to the size of the satellite.

A third constraint is the volume of data that can be stored and transferred between locations and manipulated at any one time. This constraint is prevalent throughout the processing chain, from the moment of data capture (on board the satellite or airplane) all through to the delivery of an application. A general rule is that every increase in spatial detail and in repeat visits represents an exponential increase in data volume. For example, although the Sentinel-1 satellite has the potential to provide a near daily global coverage of 20m radar observations, the current European infrastructure is not capable of handling the large volumes of data this would generate. As a consequence, for now, high frequency data collection is limited to Europe (Figure 3).

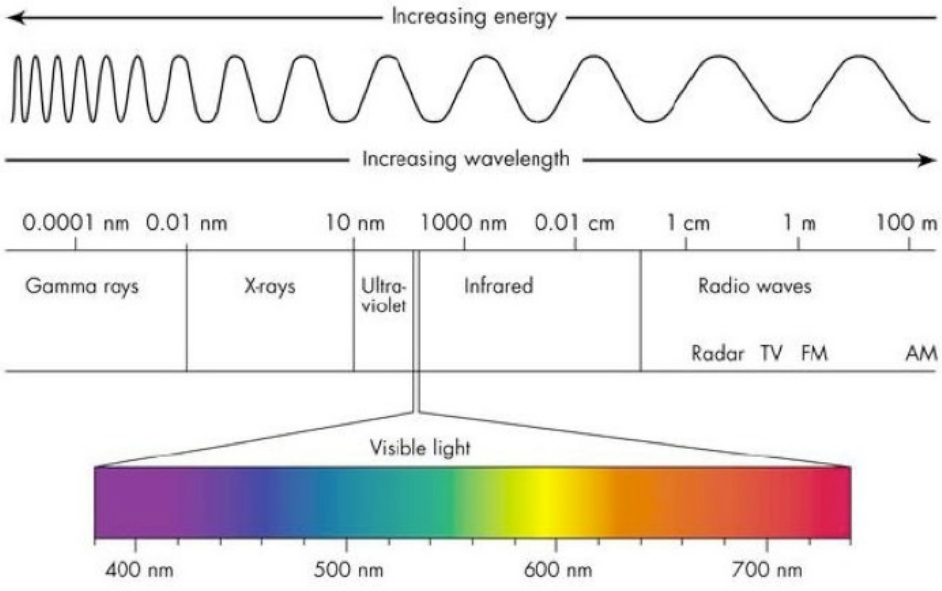


Figure 1: *Schematic showing the electromagnetic spectrum.*

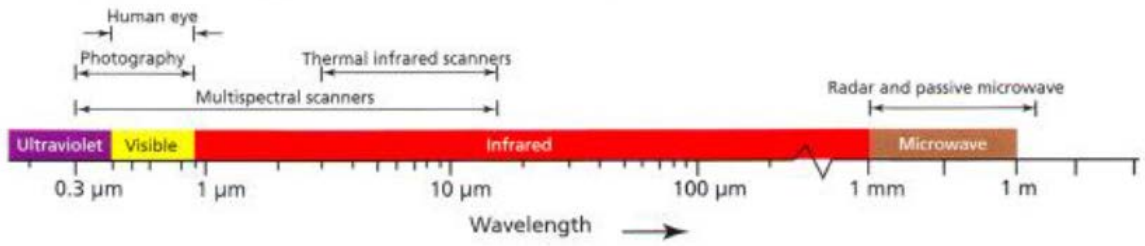


Figure 2: *Schematic showing the type of technology used to observe parts of the electromagnetic spectrum*

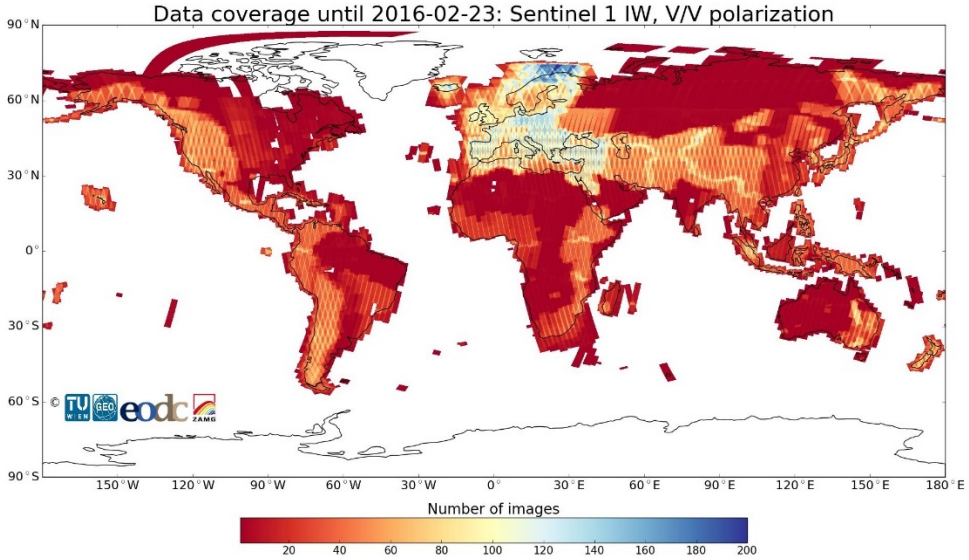


Figure 3: *Data coverage for Sentinel-1 SAR-C radar imagery since the time of the satellite launch in 2014 until 23 Feb 2016*

The manner in which a surface reflects, scatters or emits electromagnetic radiation in different part of the spectrum provides information about the physical and chemical properties of that surface. Some EO based applications rely on the direct conversion of the electromagnetic signal into measures of these physical and chemical surface properties (e.g. temperature, colour, moisture content, height). However often the information is inferred or modelled indirectly from the properties that influence the signal (e.g. biomass, land cover type, habitat type, area where change occurred) (Figure 4). The information could be quantitative (e.g. height, biomass) or qualitative (e.g. colour, land cover type).

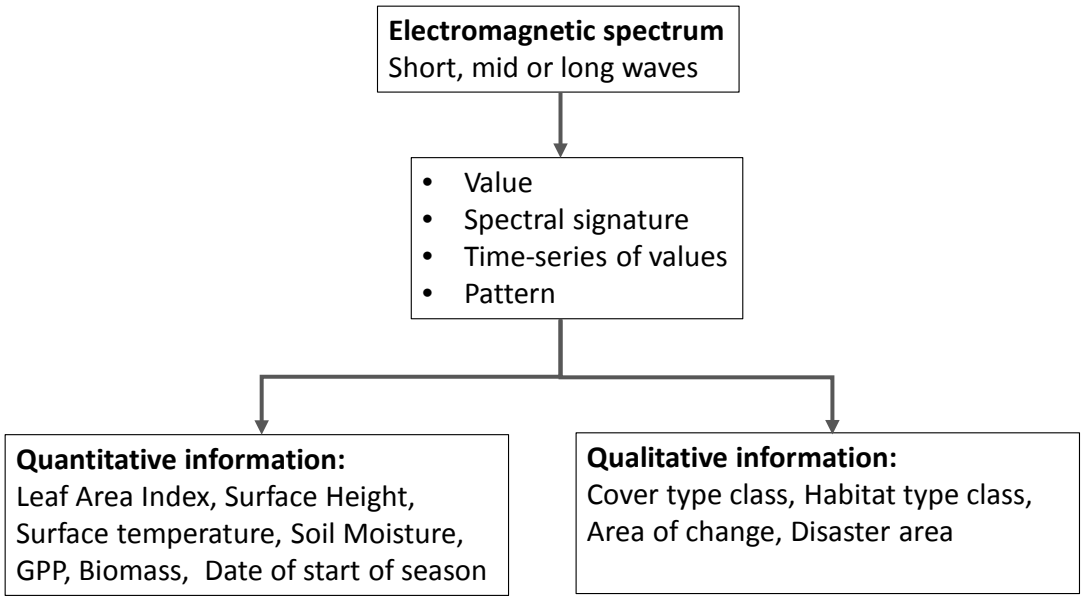


Figure 4: *Schematic illustrating the conversion flow of EO data into relevant information.*

The Crick Framework (see tables below) provides a way to categorise how well Earth Observation (EO) techniques can be used to identify particular habitat and features on the ground (e.g. many features of grassland habitats can be identified with EO and clarified with field survey, but sub-tidal habitats are very poorly characterised by current EO techniques). EO data and techniques differentiate vegetation types and habitats by identifying specific features that are shown up by different spectral bands or combinations of bands. In the same way that some plants are easy to identify because of the colour and shape of their leaves in field survey, some plants can similarly be easily identified from imagery. Where these plants comprise some of the main cover species of a habitat then this habitat can be picked out with relative certainty. Where two habitats are more difficult to distinguish – they have similar spectral features, or cover small areas of ground, etc – the habitats may be distinguishable using both spectral data and ancillary datasets. This wide range of interacting factors has been considered along with ecological knowledge, to develop a generic classification system that proposes categories (tiers) of habitat groups.

This set of Tiers is the first and most accessible component of the Crick Framework, providing a categorisation for habitats, based on existing ability to map and monitor them using EO, with or without ancillary data sets. The framework has been designed to consider Biodiversity Action Plan (BAP) Priority habitats and Habitats Directive Annex I habitats, which are necessary for EU reporting targets. For example, habitats such as heathland dominated by ling heather and bilberry are a solid 3a habitat which from the MEOW projects' experiences have always been easy to identify.

Table a: The Crick Framework

Tier 1	**Likely to be identified solely using EO**				
Tier 2	**Likely to be identified using EO and ancillary data**				
	Tier 2a – Likely to be identified using EO together with ancillary data	Tier 2b – Likely to be identified using VHR[1] EO together with ancillary data	Tier 2c – Likely to be identified using EO (in some cases VHR) but ID dependent on good geological data	Tier 2d – Likely to be identified using EO methods such as fuzzy membership values	Tier 2e – Likely to be identified using EO including LIDAR to give detailed information about vegetation structure
Tier 3	Likely to be identified using EO and ancillary data but also dependent on availability of time series of imagery				
	Tier 3a – Likely to be identified using EO together with ancillary data	Tier 3b – Likely to be identified using VHR EO together with ancillary data	Tier 3c – Likely to be identified using EO (in some cases VHR) but ID dependent on good geological data		
Tier 4	Currently unlikely to be determined using EO				
	Tier 4a - Habitats distinguished by low frequency or small features	Tier 4b – Habitat hidden from above for most of the year			
Tier 5	Cannot be identified using EO				

[1] *VHR: Very High spatial Resolution*

Table b: Number of habitats expected to be detectable using a specific EO approach

		UK BAP Priority Habitats	EC Habitats Directive Annex I habitats
Tier 1		0	0
Tier 2	2a	6	6
	2b	7	2
	2c	2	5
	2d	1	1
	2e	1	1
Tier 3	3a	6	5
	3b	9	11
	3c	4	6
Tier 4	4a	3	26
	4b	12	9
Tier 5		0	3

Applications at the current state of development

Below are details of an example list of missions that are available for land monitoring in the UK

1. Aerial photos: on demand (Visible and Near Infrared, <1m) – pan government
2. Multi-Spectral:
    - WorldView-3 [2]: on demand (VIS,NIR, SWIR, 1.24m to 3.7m) - expensive
    - SPOT [1]: on demand (VIS, NIR, SWIR, 5m to 20m) - expensive
    - Landsat [1]: every 16 days; (E)TM [3], OLI [2] (VIS, NIR, SWIR, Thermal 25m) - free
    - Sentinel-2 [1]: every 5 to 10 days; MSI [2] (VIS, NIR, SWIR, 10m to 60m) - free
    - Sentinel-3 [1]: daily; OLCI [2] (VIS, NIR, SWIR, 300m); SLSTR [2] (Thermal, 1km) - free
    - Terra and Aqua [1]: daily; MODIS [2] (VIS, NIR, SWIR, Thermal; 250m, 500m, 1km) – free
3. Airborne LiDAR: on demand (1m to 3m) – pan government
4. Radar:
    - Sentinel-1 [1]: every 6 to 12 days; SAR C-band [2] (resampled to 20m standard; interferometric wide swath mode, IWS - VV and IWS - VH) - free

[2] Name of Satellite Mission
[3] Name of sensor on board the satellite

- Terra-SAR X [1] and COSMO sky med [1]: on demand; SAR X-band [2] (25cm, 3m & 6m resolution; Multiple polarisation available) - expensive

Spatial and temporal resolution

The spatial resolution of EO data can vary from < m to 25 km. A general rule is that the required spatial resolution of the data should be half the size of the smallest feature of interest. It is also important to remember that the level of spatial at which feature is being mapped and monitored has a direct impact on the resulting change statistics that can be obtained. Also if the spatial discrepancy between the EO derived observations and the field-based observations is too great, the task of reconciling or consolidating change statistics from both sources may become insurmountable.

The temporal resolution or the frequency at which an observation is repeated automatically can vary from hourly (in situ sensor or geostationary satellite), every 16 days, every ~5 years (rolling programme of airborne campaigns) to a one-off (e.g. on demand acquisitions). Except for the commercial mission offering very high spatial resolution imagery (e.g. WorldView) most satellite missions collect data automatically and regularly. Except for radar observations, in areas with frequent cloud cover, the chances of a cloud free image will increase with increasing temporal resolution. As most of the monitoring involves observing temporarily dynamic vegetation or soils, matching the timing of the EO data with periods of the year that are the most suitable for monitoring is crucial.

Applications in function of the types of observation available:

The visible and near infrared part of the spectrum, captured by cameras or multi-spectral scanners, is typically used to map land cover or landscape features, detect changes in the land cover and monitor the condition of vegetation (Figure 7), including crops. Some have used this data to monitor large populations of animals (e.g. birds) in the landscape. The approaches used rely on covers showing differences in reflectance values in space and time, but also differences in textures or shapes when data is available at very high spatial resolutions. When the imagery is available at high spatial resolution (cm) and as a stereoscopic pair it is used to derive digital terrain and digital surface models.

Lidar systems use the near-infrared spectrum to measure the height of surfaces. The most prolific use of this technology is for the production of digital terrain models, digital surface models, vegetation and building height, mapping of hedgerows and boundary walls (Figure 8), and the identification and mapping of archeological features. Another possible product is a solar irradiation map.

When the visible and near-infrared spectrum is observed in combination with the shortwave-infrared the land cover mapping can be more detailed in terms of number of classes and better mapping accuracies are achieved. The shortwave-infrared, particularly sensitive to vegetation water content, is also used for vegetation condition. In addition, when the visible to shortwave spectral range is observed using a hyperspectral sensor at high spatial resolutions (m) it is possibility to estimate plant canopy traits such as % water content, dry matter content, N and P).

The thermal spectrum so far has been mainly used at global and continental level to routinely produce daily observations of the sea and land surface temperatures and map temperature anomalies linked to fires which are typically delivered at 1km spatial resolutions. The potential exist to use thermal imaging to infer soil moisture or plant stress.

Radar systems exploit the microwave part of the spectrum and have the main advantage of not being affected by cloud. Radar is used for flood mapping and the production of digital terrain and digital surface models. Radar has also been relatively successful in measuring forest biomass. In the UK radar has been used operationally to monitor crops growth and more recently to differentiate different crop types (i.e. Land Cover map Plus Crops). Combining radar with multi-spectral to further enhance land cover maps, especially for areas with frequent cloud cover, is the obvious next step. Microwave signals are also used to derive soil moisture where the woody vegetation cover is sparse and the topography is relatively flat; an example 1km soil moisture product will produced for the UK by September 2016.

Cosmic ray probes are used operationally as part of networks to measure in-situ soil moisture across an area with a radius of about 300 m. These sensors are particular attractive as they match more closely the spatial resolution of satellite observed soil moisture (1km), making them ideal for validating the satellite derived measures. In the UK these are combined with an in-situ camera and a weather station which in the long term will enable the monitoring of vegetation condition and identifying the possible causes of observed changes (Figure 9).

Gamma ray spectrometer data, collected as 300m x 300m samples on a regular grid from low flying aircraft, have been converted into maps showing soil organic matter content and soil moisture saturation levels (Figure 10).

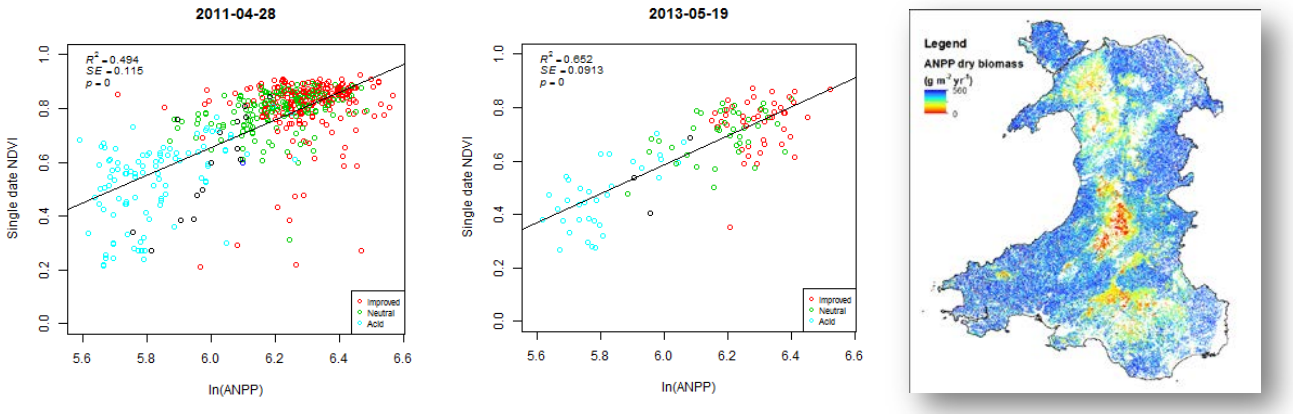


Figure 7: *Grassland above ground productivity (ANPP) estimated for Wales using an empirical model linking EO data from the visible and near-infrared spectrum (NDVI) with field based sample observation of grassland productivity. The model used 296 plots collected from 82 1km² Countryside Survey samples. This example also illustrates how the timing of the EO observation impacts on the model performance.*

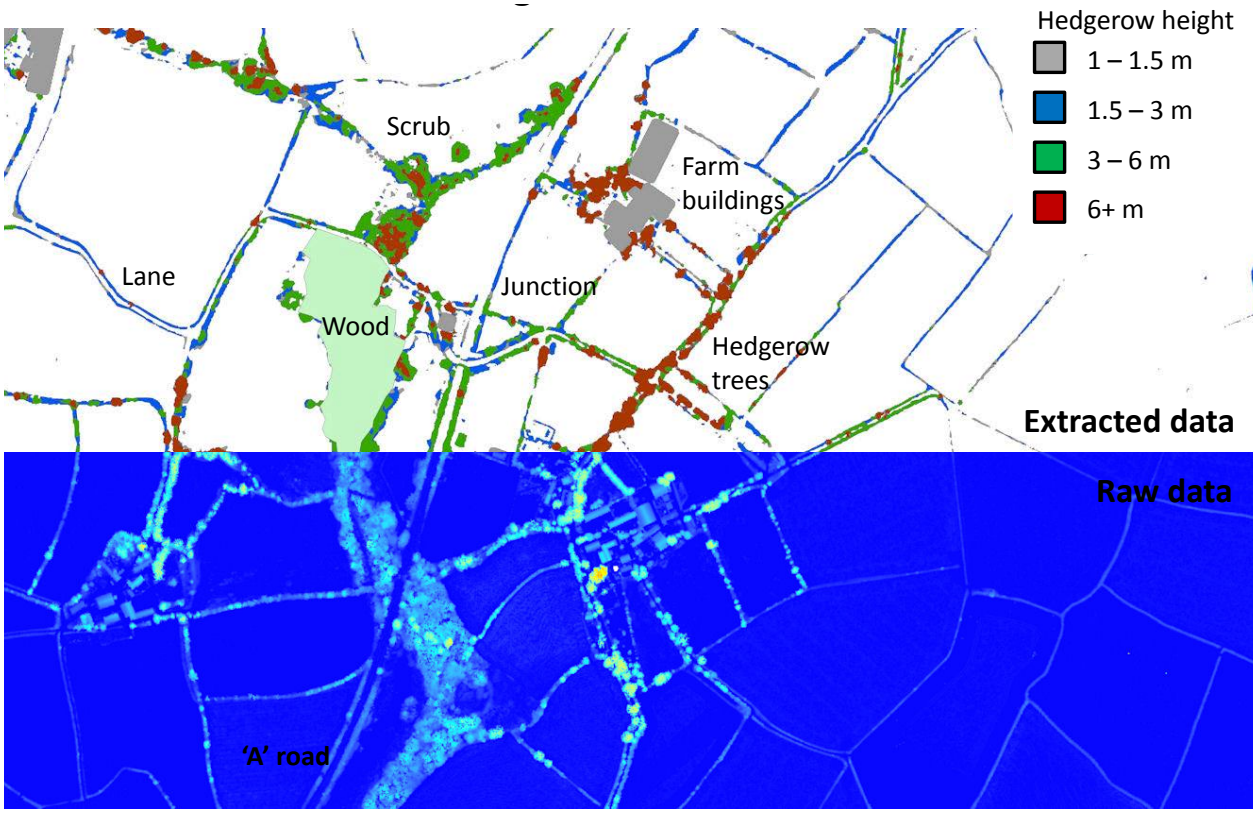


Figure 8: *Example of a woodland, roadside hedge (or wall), and farmland trees map using the digital terrain and surface models derived from free 1m lidar data captured for Cornwall and Devon during a 2014 airborne campaign. The lidar data was combined with freely available and open-licence Ordnance Survey VectorMap data to help identify buildings, temporary outbuildings and parked cars in driveways; and the free Forest Commission's National Forest Inventory dataset to identify woodland blocks greater than 0.5 ha (Source CEH, TELLUS-HOW project).*

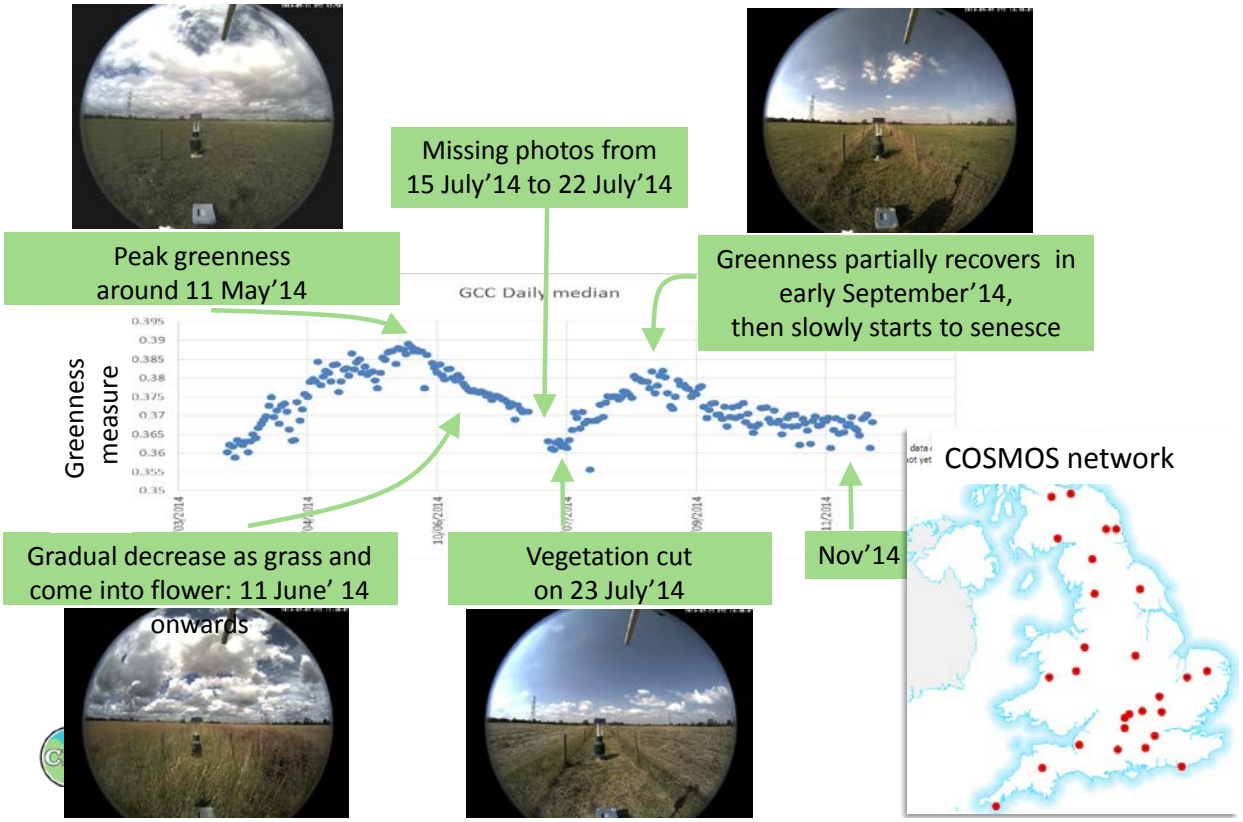
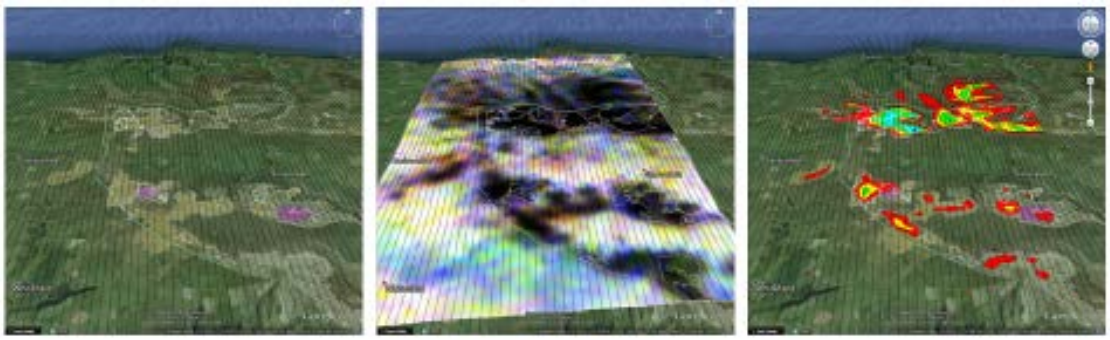


***Figure 9**: Example of a digital camera (phenocam), which forms part of the COSMOS-UK soil moisture network, capturing daily records of vegetation greenness (Source CEH, COSMOS-UK network).*



Existing mapping of peat on part of Exmoor

Ternary radiometric image, black areas show where total count is attenuated

Soil Saturation indicated by total radiometric count

TELLUS South West

***Figure 10:** Example of how Gamma ray radiometry acquired for Cornwall and Devon during a 2014 airborne campaign could be used to map peat soils and determine levels of soil saturation (source BGS, TELLUS-SW project).*

Advantages and disadvantages – cloud cover

The availability of useful EO data from the visible, near- and shortwave-infrared spectrum is heavily reduced in areas where there is a high occurrence of cloud, haze or smoke. Figure 5 shows the impact of cloud on satellite MODIS NDVI data on a seasonal basis. This MODIS product is provided at 250m resolution as an 8 day time-series which is a composite of cloud free data selected from daily observations within an 8 day window. Figure 6 shows cloud free data availability for daily satellite MERIS imagery (300m resolution) on an annual basis.

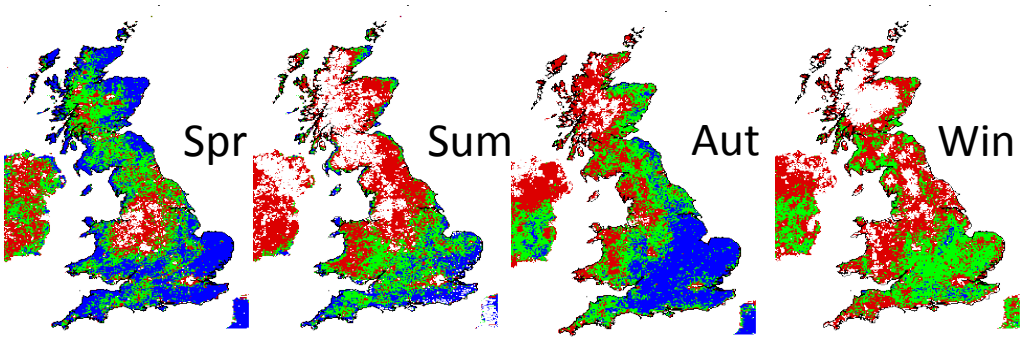


***Figure 11**: Cloud cover: MODIS NDVI 250m example for 2002-2012 period. In each year there are 46 8-day periods, however due to cloudiness, haze or snow, an observation may not be available for a particular 8-day period in the 10-year record. Figure 5 shows for each 250m pixel, the number of 8 day periods within a season for which there are 6 or more years of good quality data (red = 1 – 3, green = 4 – 6, blue = 7-10(max)).*

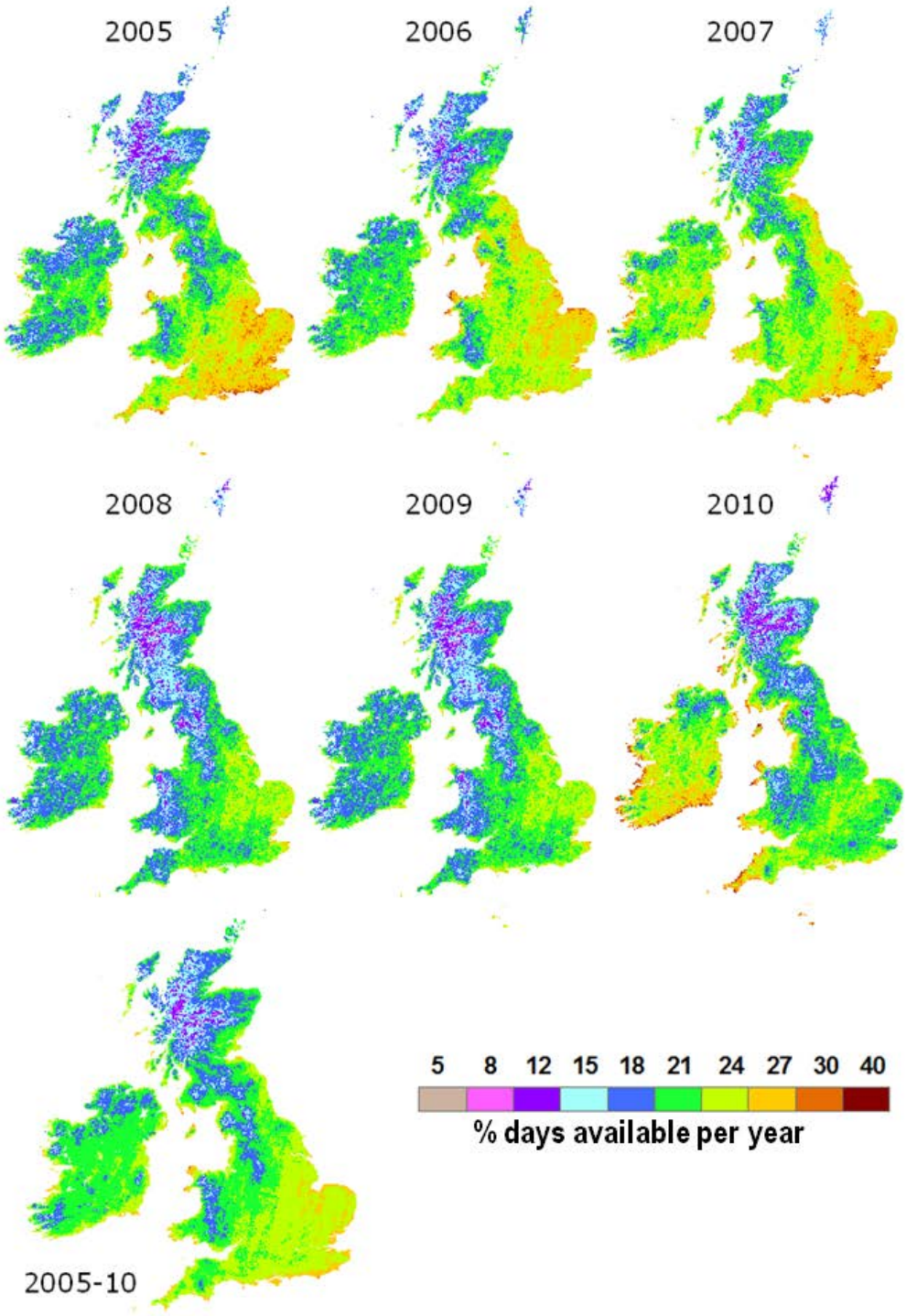


Figure 12: *Cloud free data availability for daily MERIS imagery as a percentage of the total number of days for each year from 2005 to 2010 (above) together with a 6 year mean availability for the total period (right). Source: Final PHAVEOS report to STB – project No 130517 by Astrium GEO-Information Services.*

What could the technology deliver in 1-5 years time? – unmanned drones (UAVs)

CEH carried out a comparison between field and UAV-based observations. The key finding were:

- From UAV imagery it was possible to identify between 30-50% of the polygons recorded in field survey
- Field survey recorded 50% more habitat types than could be interpreted from UAV imagery
- Variance between the extents of habitat recorded in the field and interpreted from UAV imagery were between <1 and 19.6%
- 1.4 detailed vegetation/management codes were mapped against each polygon recorded from the UAV data compared to 3 for field survey data
- Length of linear features interpreted from the UAV imagery were 46% of those recorded in the field.
- Lines/belts of trees were under-predicted by 50% and managed hedges were over-predicted by 78%. Around 60% of the linear features interpreted from UAV imagery were co-incident with a field surveyed feature.
- It was possible to predict that a hedge would be of mixed species from UAV imagery but no other detail (as collected in the field) was possible.
- 54% of point features located in the field survey were interpreted from the UAV imagery. Only 30% of these features were recorded accurately (i.e. as the same feature as recorded in the field). As for linear features, additional attribute data (beyond identification of point type) could not be interpreted from the UAV imagery.
- Mapping from the UAV image took within 5 minutes of 2 hrs for each of the squares (flight times not included). Mapping in the field took approximately 1.5 field days for each of the squares.

Appendix G

Briefing Paper - Citizen Science

The Potential of Citizen Science Data for Monitoring in Wales

Gavin Siriwardena (BTO)
Simon Smart (CEH)
Chris Cheffings (JNCC)

With input and assistance from David Robinson (CEH Bangor), Dylan Lloyd, Dave Allen, Liz Howe (Natural Resources Wales), Jeremy Biggs (Freshwater Habitats Trust), Katie Metcalfe (Environment Systems), Colin Chapman (Welsh Government), Kate Lewthwaite (Woodland Trust), Andrew Davey (WCr plc), Steve Lucas (Bat Conservation Trust).

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July 2016

Definition/purpose

- Here, we define citizen science as biodiversity and soils recording conducted by volunteer or unpaid observers.
- We recognize five relevant types: (i) structured national surveys designed to collect particular evidence (e.g. for biodiversity, schemes such as the BTO/JNCC/RSPB Breeding Bird Survey), (ii) the collation of records collected independently of any survey structure (e.g. the harvesting of biological records for monitoring), (iii) local monitoring projects conceived and conducted by amateur naturalists, (iv) recording activity designed primarily to encourage public engagement, (v) "blind" sample collection (recordings or physical samples) for professional analysis. These types are most developed for the biodiversity evidence category, but are applicable more widely.
- (i), (ii), (iv) and (v) are typically managed professionally and therefore incur costs for administration, database and project management as well as analytical and reporting effort.
- In Wales, Local Environmental Record Centres often function as a clearing house for the professional storage and dissemination of data from all four categories of activity, although some societies and local schemes work directly with the Biological Records Centre.
- The Wales Biodiversity Partnership (http://www.biodiversitywales.org.uk/Citizen-Science) also acts as a delivery mechanism, publicising and facilitating use of citizen science in Wales, recognising its importance in public engagement and contributions to official statistics.

- We do not consider (iv) any further because data collection may lack rigour or be prone to spatial and temporal biases, but the databases produced can be used as data of type (ii). Examples include OPAL surveys, BioBlitzes, the New Year Plant Hunt, the RSPB Big Garden Birdwatch, RSPB Starling Survey and GWCT Farm Bird Count. Note that type (iv) is increasingly considered to cover all "citizen science" in parts of the global conservation movement, e.g. Kobori et al. (2016): " we define citizen science as engaging the public in a scientific project, a definition that is gaining general acceptance among citizen science researchers and practitioners".
- It should be noted that the process of synthesising disparate datasets and the diverse components of different schemes, including type (iv) onto useable databases and then dealing analytically with variation in quality and quantity can incur substantial downstream costs.
- Table 1 below allows quick comparison of different types of citizen science survey data.

Advantages/Disadvantages of citizen science approaches to monitoring

Advantages:

- Cheap with regard to survey effort (including identification training) compared to professional survey.
- Tapping into an otherwise unused skill set among the general public, although the potential for increasing both skills of individuals and the numbers of skilled people is limited.
- Potentially education of the public (although this should be secondary because learning on the job conflicts with quality control), including supporting longer term policy outcomes, increasing awareness of environmental issues, and influencing behaviours that contribute to mitigating or adapting to environmental change.
- Can increasingly be tied to remote-sensed data to provide habitat context and thus to reduce the need for complex sampling protocols; can also potentially validate or ground-truth remote-sensed data.
- Quantity of information collected compensates for lack of quality control for individual records.
- New technologies increasingly allow more sophisticated data collection by untrained observers; together with automated verification, this may help to attract new cohorts of observers.
- Highly committed surveyors may fund their own survey/sampling equipment, although there will be limits, of course.
- Fully structured surveys, especially those with randomized site selection, provide data equivalent to those from professional monitoring when protocols are well-designed (although survey intensity is unlikely to be as high).
- Local survey intensity restrictions mean that citizen science data are typically most valuable for inference at large geographical scales (regional or national), although this value increases with sampling structure and geographical biases can be a problem.
- Coverage of greener locations within easy reach of people tends to be good, meaning that data can be representative of lowland farmland and suburban areas, but uplands and city centres are more challenging. However small schemes and societies can help to drive delivery of *ad hoc* data for many specialised taxa.
- Current WG policy restricts professional survey data collection to areas for which express access permissions have been obtained, but volunteer observers are free to survey from all rights-of-way, so can potentially cover locations that professionals could not.
- Type (iii) surveys are entirely volunteer-driven, so require no *necessary* central funding or control, but collation, storage and dissemination of data, e.g. via NBN or LERC, incurs costs.

Disadvantages:

- Considerable investment in recruitment, reporting-back and engagement activities for surveyors, including continual replacement of older observers (although overall the costs are always likely to be far lower than those associated with purely professional surveys of the same size).
- Data collected still need to be input, checked, processed and analysed professionally, or by volunteer organizers, such as LERCs (although online and automated systems are increasingly performing some of these functions). Resources for these activities need to be provided for any scheme.
- Not all taxa or monitoring activities can be assumed to be equally attractive to volunteers, even maximizing uptake. Taxa well covered by volunteer schemes are strongly aligned to taxonomic groups of higher public interest; capacity to increase coverage of others will always be low and more structured surveys are likely to interest fewer people. Type (v) surveys require a different approach to make them attractive if they are to be conducted by volunteers.
- Sampling from precise locations (and repeat visits) cannot be guaranteed, so targeting specifically for local data applications may not be possible.
- Repeat monitoring in the absence of change may cause observer fatigue, limiting long-term consistency, although this should be minimized by sophisticated sampling designs, as well as well-chosen survey frequency and a balance between spreading effort spatially and temporally.
- Data that can be collected are restricted, in particular the collection of contextual data is often resisted by surveyors with a strong interest in a particular group, for example.
- Complicated protocols both turn off some observers and may not be followed closely by those who do take part, although sophisticated designs can be successful and there are examples of approaches with high uptake and high data quality among BTO surveys, for example.
- Restrictions on recording effort (available spare time limits survey duration/sampling effort) limit protocols to less complex or low intensity designs.
- Avoidance of unpopular locations, even with randomized site selection (e.g. avoiding inner cities, remote places or areas of low biodiversity interest, or the need to secure land owner's permission or to follow biosecurity protocols to gain access), can cause geographical bias and volunteer drop-out, and limits representativeness at large scales. Unpopular locations are also likely to include habitats perceived as boring, such as arable fields, conifer plantations and improved grasslands, despite the fact that such areas are often a focus for agri-environment scheme funding. These biases can be measured, but not necessarily corrected for.
- Responsive recording may cause bias (e.g. collection of samples only when problems are perceived or submission of records of common species only when rare species are also present).
- Quality control is limited (record verification and training or certification of volunteers may be impossible or costly, although this is highly variable between taxa); it may also be impossible to control how closely observers follow protocols. The required level of quality may, however, differ with the purpose of the scheme.
- Particularly with respect to type (ii) and (iii) data, ownership of the raw data often lies with multiple individual recorders and societies, which complicates how permissions for uses of the data are obtained and managed, and may create logistical difficulties with reporting.
- Particularly considering type (ii) data, people sufficiently interested to put effort into sampling may be intrinsically biased, e.g. self-reporting of environmental impacts by farmers or conservationists highlighting policy priorities, although some such problems may involve perception and credibility, rather than being real.
- Wider cultural change could mean that current interest in monitoring is not reflected in future generations, although it is also possible that interest will rise and education could play a role.
- Individual observers survey fewer locations than professionals, introducing more observer variation per unit sample size, and potentially requiring greater investment in equipment.

- Type (iii) surveys lack central direction and, potentially, rigour, while data supply to central monitoring processes cannot be guaranteed, may not be free and may leave significant processing work to be done professionally.

I. Applications and current state of development

Long-running volunteer surveys (type (i)) in the UK underpin much of the monitoring of biodiversity in the UK, particularly with respect to birds and butterflies. Historically, the norm was for structured, detailed surveys of user-selected locations (e.g. the Butterfly Monitoring Scheme, Common Birds Census and Rothamsted moth recording), but there has been an increasing drive to replace or to augment these schemes with surveys based on random site selection, to avoid geographical or habitat biases and to produce results representative of national populations. Thus, the Breeding Bird Survey has reported on bird (and some mammal) populations since 1994. Newer schemes are now aiming to do the same for butterflies (Wider Countryside Butterfly Survey http://butterfly-conservation.org/113/wider-countryside-butterfly-survey.html) and plants (National Plant Monitoring Scheme http://www.npms.org.uk/). The National Bat Monitoring Programme (NBMP) has annual structured transects as well as targeted recording of roost sites and hibernacula, while new technologies are also facilitating the development of new, standardized and structured approaches. A further new scheme is also likely to be launched in the near future for pollinators. All of these surveys are particularly strong in revealing large-scale variation in abundance of widespread species; they are less useful for rarer species, because their habitats are unlikely to be covered by random sampling. Statistical approaches to make the most of these data have been in development for more than 20 years and established procedures now exist for index production, separation of long-term trend from inter-annual fluctuation, dealing with spatial and temporal autocorrelation, spatial generalization ("gap-filling"), estimation of precision and the investigation of causes of change. New, more refined approaches continue to be developed, however, as this is a live field of research. An important area of research is in determining how many plots and locations is enough. This requires first specifying the monitoring question requiring evidence and then determining, often using simulation methods, whether a particular number of records with particular spatial coverage is sufficient for answering the question. Questions differ with policy-driven needs for evidence. Monitoring of simple temporal change requires fewer data points than analysis to diagnose causes of change. Notwithstanding the analytical power of newer techniques such as Bayesian modelling, more records surveyed with minimum spatial and temporal bias are likely to give more reliable answers.

In recent years, there has been a new focus on extracting information from unstructured biodiversity recording, especially for taxa and regions where sufficient amateur survey effort to support structured surveys has traditionally been difficult to find. There have also been various drives to increase the collection of such data, often using online and smartphone/tablet technology to provide user-friendly interfaces for data collection and basic verification, with the added value (from the user's perspective) of central data collation and storage. Unstructured data from record-harvesting notably have the potential to provide critical information about scarce taxa that are not surveyed efficiently by randomly located sample sites. New developments to enhance the value of unstructured information have taken two principal directions, first, to encourage the recording of spatial and temporal recording effort and, second, developing new analytical approaches. Each approach attempts to overcome the effects of biases in recording effort and thus to allow the extraction of reliable information on (especially) temporal change. This is also a live research area, but there will always be a hard limit to data quality for target taxa and areas where recording effort is negligible. It is in these areas where there may be no choice but to deploy fully funded professional surveyors.

All of the above monitoring effort considers populations or distributions of different taxa, but other properties of key populations, such as timing (phenology) and wildlife health, are also covered with citizen science approaches, generally via collated type (ii) data. F or example, the long-running Nature's Calendar run by the Woodland Trust (WT), which involves volunteers across Britain recording the timing of natural events such as date of first Ash leaf or Swallow arrival in the vicinity of their home. The trends captured by these data have been used in earnest by academic researchers investigating the advance of the growing season in recent years, for example (see Box ? for other citizen science schemes run by WT).

Natural resource monitoring outside the broad biodiversity area has had little citizen science involvement until recently, but growing numbers of approaches now exist. One general technique, which is being applied to cryptic biodiversity and to other targets, such as soils, is the solicitation of "blind" sample collection by citizens for image or chemical analysis centrally, generally in professional laboratories. Sample collection can be entirely unstructured/opportunistic, or via soliciting records from specific locations. Such methods are in use for soils (mySoil, http://www.bgs.ac.uk/mySoil), amphibians (using eDNA to identify the presence of newts in ponds, http://freshwaterhabitats.org.uk/projects/pondnet/survey-options/edna-for-great-crested-newts/), bats (static detectors recording ultrasonics for sound spectrogram analysis centrally, http://www.batsurvey.org) and the Predatory Bird Monitoring Scheme for surveillance for pesticide effects from analyses of livers and eggs (via corpses submitted to a central laboratory, http://pbms.ceh.ac.uk/). In addition, proven relationships between groupings of organisms, identifiable by non-expert volunteers, and environmental conditions mean that records can be used as proxy indicators of pollution (http://www.apis.ac.uk/nitrogen-lichen-field-manual).

Policy-relevant questions about biodiversity change that have been answered effectively using citizen science datasets include the following:
What has changed over time? A domain of interest is specified such as the UK or Wales and the answer is provided by an analysis of trends in a species or a group of species. Examples include the C4, C5, C6 and C8 UK Biodiversity indicators published by JNCC (http://jncc.defra.gov.uk/page-4233).
What has caused the observed change? This question requires that changes in the biota of interest can be either divided into impacted versus unimpacted groups or arranged along gradients with respect to likely driving variables. Structured survey designs with relatively even yet randomised coverage of the areas in which drivers have operated make it much easier to address this question. Spatial and temporal biases either associated with unstructured data or with variable uptake of structured schemes increase the chances that gradients of various drivers will be unevenly sampled leading to unreliable hypothesis tests about the causes of change.

In Wales, survey coverage has historically been sparser than in England, chiefly reflecting the low density of human observers in the upland areas that make up much of the country. For example, BBS coverage has been lower than ideal and volunteer recruitment drives and mentoring have been undertaken in recent years with the aim of sustainably increasing long-term coverage. This has been very successful with the number of BBS squares in Wales increasing from 245 in 2010 to 330 in 2015. Similarly, the new National Plant Monitoring Scheme (NPMS) began volunteer recruitment and recording in earnest in 2015. Uptake in Wales was low, however, but 2015 was considered a pilot year and a major push has been organised by Plantlife to promote greater engagement, hopefully resulting in more vegetation plots per habitat in subsequent years (see Appendix 1).

Current national reporting and evidence gathering for Wales relies on a wide range of available structured survey data (see Appendix 1), showing the value that NRW place on current and past citizen science data in Wales. There may be additional value in the harvesting of unstructured records to contribute to future recording in Wales, both by increasing biological recording effort and

carrying out more central collation and processing. Unstructured survey data should be exploited to its fullest potential because full deployment of structured survey effort may be hampered by low uptake. For example, this may limit the potential of the new National Plant Monitoring Scheme in Wales. Exploiting unstructured survey data requires that the quantity and quality of records are maximised. This means working in partnership with Wales LERC, whose data holdings may often exceed the numbers available via the NBN, and with centres of analytical expertise such as CEH and BTO who can help deal with spatial and temporal variation in recording effort.

Citizen science approaches are well-suited, within limits and with careful use, to a range of surveillance, monitoring and evaluation applications with respect to natural resources (including monitoring towards national or regional environmental targets), but they are not suitable for local-scale regulatory applications (e.g. compliance of farms to statutory regulations). Variation in the ability of differing citizen schemes to provide robust long-term, large-scale evidence for monitoring can be understood in terms of a tension between policy-focused end-users of data and those more focussed on the benefits to scheme participants.[4]

a. Costs

All monitoring schemes are different, so costs are variable. For planned schemes, requirements for data inputting, sample processing and data analysis are variable as well. While online data capture saves costs, the systems required can also be expensive to develop, and have ongoing hosting, updating, user web support and maintenance costs. Simple field survey costs are far lower than those of monitoring programmes using professional observers, but volunteer management (site allocation, dealing with queries, data checking and reporting back) and system development costs are likely to negate much of any savings for the first few years. Record harvesting approaches are less costly, especially if they can make use of pre-existing systems for data recording (which may exist primarily for the personal interest of the recorders), although analyses will certainly be more complex and this may introduce higher associated costs.

b. Key Issues for Implementation (including costs)

- Citizen science schemes of types (i), (ii), (iv) and (v) require professional infrastructure for design, administration, data storage, analysis and reporting, both nationally and to volunteers. This incurs significant costs, but field cost per unit effort is far lower than that of professional surveys.
- Costs vary between monitoring schemes. For structured schemes, requirements for data inputting, sample processing and data analysis also vary. Online data capture systems can also be expensive to develop, and have ongoing hosting, updating, user web support and maintenance costs. Record harvesting approaches are less costly, especially if they use pre-existing systems for data recording, although analyses will be more complex and this may increase associated costs.
- Skills required of contributors are highly variable, from following detailed protocols and specialist identification of difficult groups to simple deployment/collection of sampling equipment, with no skills required at all.
- Citizen science is critically linked to volunteer motivations; what works for a one-off survey might not work for long-term monitoring. Schemes may also compete with one another for a limited pool of volunteer effort.
- The design of schemes has to take motivation into account and with the growing range of schemes and information portals, participant expectations are rising, for example regarding ease of use of the website, timeliness of feedback, etc.. This has implications for costs.

[4] *Pocock, MJO et al (2015). Developing and enhancing biodiversity monitoring programmes: a collaborative assessment of priorities. J.Appl.Ecol. 52, 686-695.*

- In Wales, Local Environmental Record Centres often function as a clearing house for the professional storage and dissemination of data from all types of citizen science, although some societies and local schemes work independently or with the Biological Records Centre.
- Certain NGOs already organize structured schemes or calls for unstructured data, typically supported by government or agency funding.
- Citizen science field effort and scheme organization do not have national monitoring for Wales as their primary driver, so any implementation of systems to extract monitoring evidence needs to take account of, and may be subservient to, potentially competing priorities at the scheme level.
- New analytical initiatives, e.g. using scheme data to measure management effects, as in Box 1, require funding support, and potentially extra funds for methodological development.
- New monitoring schemes need long-term support for design, pilot projects and infrastructure.
- The UK Environmental Observation Framework (UKEOF) has produced valuable reports on the practicalities of extracting evidence from citizen science projects, considering motivational factors and their interactions with successful project design, and introducing a new tool for evaluating the costs and benefits of new schemes. Aligning scheme design with (potential) participant motivations is critical, as is buy-in to effective evaluation from stakeholders. The cost tool is freely downloadable, in MS Excel format, and aims to take account of monetized and non-monetized factors via cost-benefit, cost-effectiveness and return-on-investment analyses.

c. Current and potential future contributions of Citizen Science biodiversity recording to NRW evidence needs

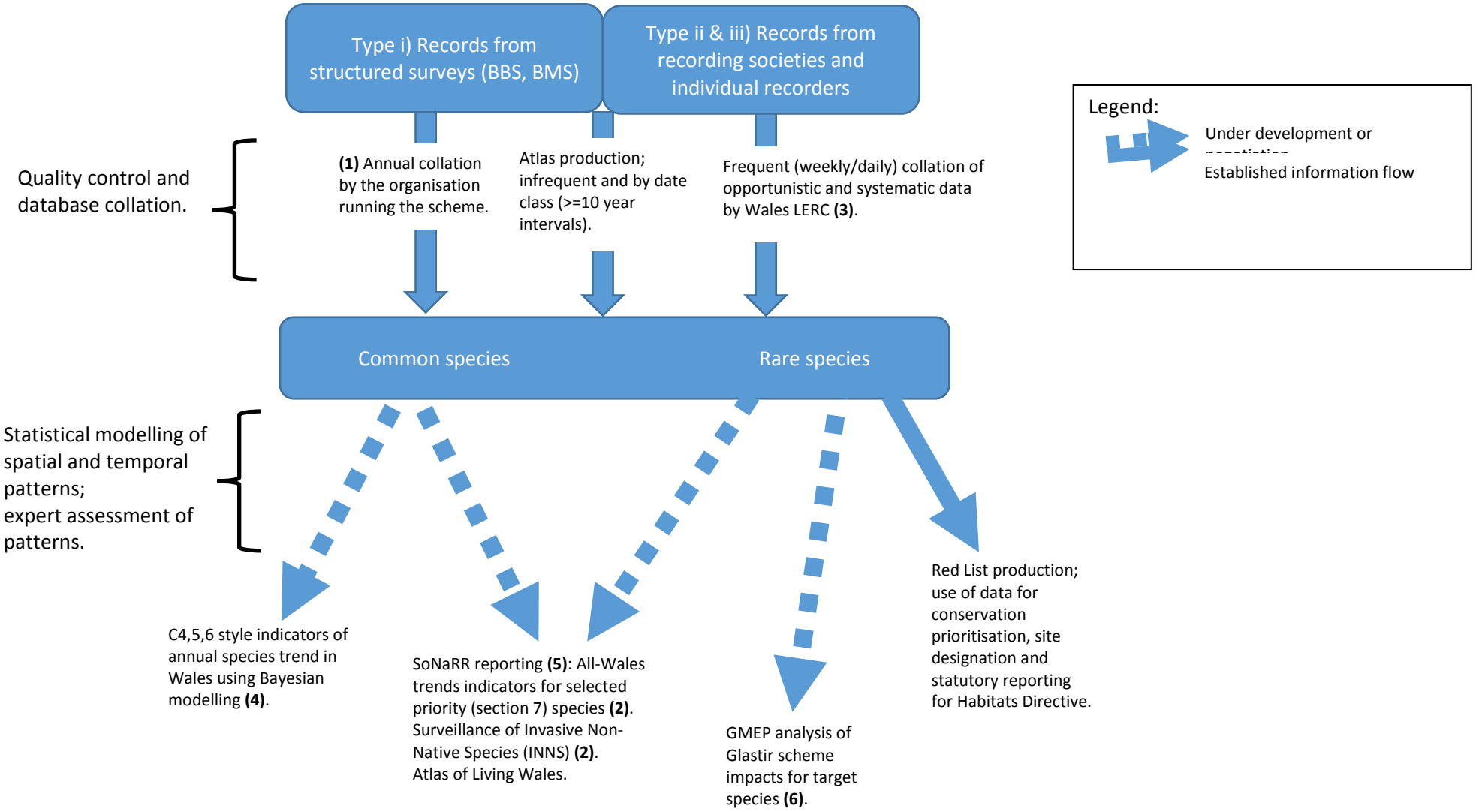
A wide range of citizen science species-recording schemes are relied upon for evidence by NRW (see Appendix 1). Figure 1 summarises the current and potentially future flows of information from citizen science schemes devoted to species observations, from recording through to their use as evidence either internally for operational decision-making or to fulfil reporting obligations for example for SoNaRR and Habitats Directive. Records are included from designed surveys (type i), record collations (type ii) and local voluntary recording projects (type iii). Type iv and v records are also utilised in national evidence when collated into a spatial database and so become referable to type ii.

The collation and analysis of records accumulated by designed survey schemes such as BBS and BMS represents a model for established, state-of-the-art translation of records into evidence in the form of GB spatial maps and temporal trends **(1)**. However variable recording effort in Wales, especially with regard to rare species, raises ongoing issues regarding the acquisition, identity and possible level of aggregation of species records into useful evidence of status and trend. Maximising the numbers of records available for the range of section 7 species and INNS is an obvious priority **(2)**. The Wales Local Environmental Record Centres therefore have a central role as a hub for collating and disseminating up-to-date records and thereby removing from the end-user the sometimes complex task of establishing trust and good working relationships with a diverse range of recorders and societies **(3)**. Moderation of the records by species' experts prior to acceptance for analysis is an additional process handled in-house by the structured national schemes yet also needed for a range of other species particularly section 7 taxa.

Translating species records into reliable spatial maps and temporal trends depends fundamentally on the numbers of records available and the biases in their distribution. Modern statistical modelling methods can help adjust for differences in recorder effort. Applying these techniques and carrying out the research needed to explore how they perform under varying levels of bias and noise, is currently performed at an analytical hub such as the Biological Records Centre at CEH **(4).**
A number of information flows are currently the subject of ongoing development and discussion and will be supported by the Future Options consultation process. This includes the role of citizen

science sources in providing possibly new evidence required to discharge the duty to prepare and publish SoNaRR in the new Environment Act (2016) **(5)**. Work is also ongoing to determine the scope of a priority species trend indicator for Wales **(4)**. In addition, ongoing discussion seeks to make available the highest quantity and quality of records for taxa explicitly targeted in Glastir option bundles. These data are essential for testing the hypothesis that species abundance has benefited from Glastir uptake **(6)**.

Figure 1. Citizen science species-recording schemes and NRW evidence requirements



d. Key Issues for Interpretation

- Designed schemes have data collection designed to lead to monitoring outputs and indicators, and so a natural and clear link between data and evidence; this also facilitates their use for other analytical purposes, such as evaluating environmental impacts.
- Unstructured data sources may need considerable scoping work to determine the level of reliable inference supported, and then sophisticated analyses to extract real evidence from the raw data.
- Citizen science sources feature inevitable geographical reporting bias, less with structured data but not zero, because there is bias in the uptake of randomly allocated sites for surveys in practice away from those that are harder to access. This leads to situations like a "black hole" in coverage in mid-Wales. However, given *some* coverage of difficult regions, sampling biases can be corrected, especially within structured surveys.
- New analytical approaches using Bayesian models may increase the utility of unstructured data, for example incorporating prior knowledge of the extent of species' distributions or their trends in England to inform the production of trends for Wales. Recent CEH research (Isaac et al. 2014, Methods. Ecol. Evol.) has compared a range of approaches to developing temporal trends from these data and made recommendations, but tests of approaches for use in the assessment of environmental impacts have yet to be conducted.
- The principal benefit from citizen science data is that large quantities of information can be collected or collated at a low cost, such that possible problems with the quality of individual records are swamped by a more reliable majority.
- Citizen science is best suited to low-intensity, low-effort surveys that require only limited skills (or skills that are common in the population). Hence, the data produced are best for large-scale surveillance intended to detect widespread changes and are less useful for local-scale, short-term impacts of management or environmental change. However, sampling biases can have significant effects on the representativeness of the results.
- There is a very wide range of forms of data, from randomized, structured surveys indistinguishable from professionally-collected data sets to entirely opportunistic and biased sets of records. The options for interpretation of these datasets are similarly broad. *They cannot be considered as a single form of information.* If structured surveys are feasible, they are preferred, but harvesting unstructured records may be the only option. In either case, the extent to which the desired, reliable inference can be gleaned from the best citizen science approach available needs to be assessed objectively before a final decision on survey approaches is taken.

e. Experience to date

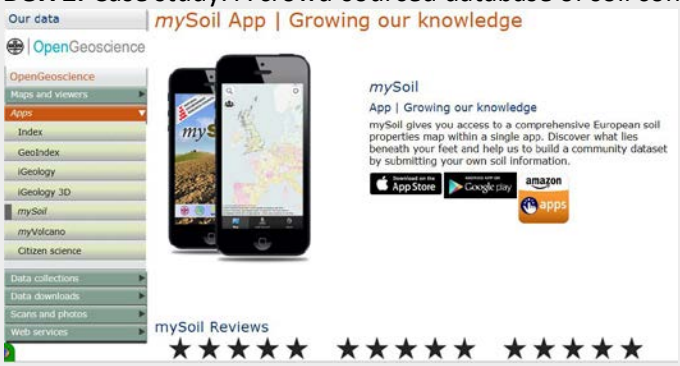
- Almost all citizen science data collection and use in monitoring to date has involved biodiversity, and the majority of that has involved more charismatic, diurnal animal groups (although particular amateur experts have contributed hugely in respect of specific other groups). Thus, evidence of the value of such data is heavily biased towards population trends and, to some extent, evaluation of environmental impacts, on birds and butterflies. The use of these data for national reporting is well-established.
- NRW place a high value on current and past citizen science data in Wales and use the information in national reporting and evidence gathering, including monitoring trends in biodiversity via the C4, C5, C6 and C8 UK Biodiversity indicators published by JNCC (http://jncc.defra.gov.uk/page-

4233). The same data are then of critical value for analyses determining the causes of change, for which changes in the biota of interest can be either divided into impacted versus unimpacted groups or arranged along gradients with respect to likely driving variables. This is much easier with structured survey designs, as applied to investigations of impacts of historical agri-environment impacts on birds in Wales (see Box 1).

- The Woodland Trust runs successful citizen science projects with trained (upskilled) volunteers collecting valuable, if unstructured and, therefore, probably geographically biased, data on tree health, phenology and the locations of ancient trees (which inform planning issues) (Appendix Y).
- The mySoil smartphone app provides novel capacity for reporting soil condition, but only via the solicitation of unstructured data. Hence, biases in the representativeness of the data are possible and similar data for the UK Soil Observatory from Wales collected by a self-selected sample of farmers show opposite trends to a well-structured, professional survey, because samples have been collected disproportionately when problems with soils were perceived. See Box 2.
- Another new initiative is the use of volunteer effort to ground-truth Earth observation data, which is being scoped by JNCC, with a view to monitoring of environmental change. A pilot project led by Environment Systems has trialled such an approach in Warwickshire (see Box 3).
- In Wales, survey coverage has historically been sparser than in England, chiefly reflecting the low density of human observers in the upland areas that make up much of the country. This is important to note in assessments of the potential of citizen science approaches based on experience elsewhere.
- Low-intensity survey data are valuable when used to assess large-scale effects/trends, but less useful at small scales, where more intensive monitoring, and, probably, professional surveyors, are required.

BOX 1. Case study: application of Breeding Bird Survey data to evaluating Tir Gofal
The BTO/JNCC/RSPB Breeding Bird Survey (BBS) is a volunteer survey conducted annually in a random sample of 1km squares across Wales using standardized methods. As part of GMEP, species' counts over time were analysed (following Baker et al. 2012, J. Appl. Ecol.) to measure effects of Tir Gofal (TG) management on bird population changes. Options providing Grassland habitat, Arable winter seed, Arable invertebrates, Woodland creation & stock exclusion, Heathland, Scrub management and hedgerow management were considered. The citizen science and management data were combined with Land Cover Map background habitat information (from Earth observation) to remove habitat biases from the analyses. Positive associations with TG options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management. The evidence suggests, therefore, that this management under TG has had positive net effects on Welsh bird populations, but that the other option types have not been so effective.
Weaknesses with this study include the inability to assess rarer species and options because of small sample sizes, so the results may not reflect high conservation priorities. The balance of effects across species for several option types suggests that TG has been broadly beneficial; for other options, either small sample size effects (e.g. heathland) or failure to address limiting factors (e.g. arable invertebrate options) probably underlie the limited effects.

BOX 2. Case study: A crowd-sourced database of soil condition data.



Soils data in the form of unstructured records, are collected through both the mySoil iphone and android apps (http://www.bgs.ac.uk/mySoil/#ad-image-ad-image-0) and also through the UK Soil Observatory Online (www.UKSO.org). The digital apps and portal are able to collect any written and photographic data; guides are provided for basic texture, pH and photos. The existing soil data tools were designed to raise awareness of soils but have great potential for added value data collection. The next upgrade of mySoil will include Welsh language support, whilst the next version of the UKSO will include crowd-sourcing and verification of landcover map data.

A survey of users shows, 40% are gardeners, 30% are farmers and 30% are in research. The team are currently trying to understand how users apply these tools. Respondents say that mySoil increases knowledge about soils and increases the quality of work they do. The following comment about mySoil shows the utility of these platforms for small business, “I find this really useful in my role as an agricultural crops advisor, it gives me a good idea of the predominant soil type in any particular location”.

BOX 3. Combining citizen science and Earth Observation: opportunistic ground-truthing of habitat maps in England.

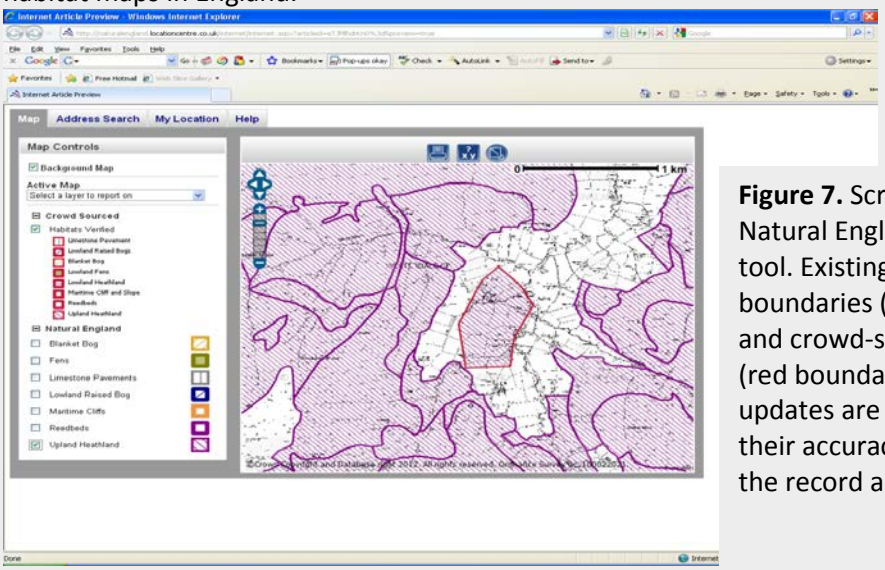


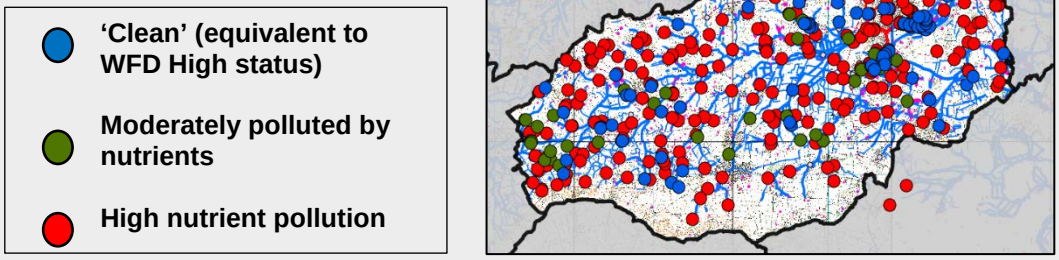
Figure 7. Screenshots from the Natural England pilot interactive tool. Existing Priority Habitat boundaries (a) (purple boundary) and crowd-sourced updates (a) (red boundary). Submitted updates are then moderated for their accuracy and plausibility and the record accepted or rejected.

Maps showing the extent of Priority Habitats are available from the NBN and MAGIC portals. These provide access to finely resolved data but the resulting coverage is based on compilations of survey datasets of varying age and reliability. Natural England have piloted an on-line tool to allow updating of the habitat map by professionals or volunteers.

A similar project has been carried out by Environment Systems and Warwickshire County Council where a remotely sensed habitat map of the county can be updated by volunteers on the ground (Medcalf et al 2015).

BOX 4 : A Citizen Science campaign to measure water quality in Oxfordshire.

Figure 1. Water quality in the River Ock, Oxfordshire catchment. Undertaken using citizen science methods, this is the first survey of all waterbody types across a whole river catchment.



In April 2016, Freshwater Habitats Trust organised a citizen-based survey of nitrate and phosphate levels on 570 sites (ponds, lakes, streams, rivers, ditches, fens) in the catchment of the R. Ock, Oxfordshire as part of the Clean Water for Wildlife project. This was slightly more than 1 waterbody / km^2 in this 470 km^2 catchment. Most sites are not currently monitored.

Rapid water test kits were successfully able to separate 'clean' water (i.e. those at 'High' status under WFD) from more polluted waters.

Nearly a third of sites were 'clean', predominantly ponds and lakes, with some streams and ditches. Most running waters experienced substantial nitrate or phosphate pollution.

The data are now contributing to a range of practical projects.

*Table 1. **Current assessment of technology.** Cell colours denote the current state of citizen science for monitoring in Wales with respect to the examples listed: Green – happening, possible, doable, achievable; Amber – likely, probable, achievable after a bit more progress; Red – not likely, hard to achieve, challenging; Grey – unknown/unknowable. These categories have been used to be consistent with the other "technologies" considered in this report. For citizen science and biodiversity monitoring, there are several constraints on how information can effectively be fitted into the categories available. First, there are many data owners and the authors have not been able, in the time available, to consult with them all over plans and data quality so as to be able to make reliable, supportable judgements about possible inference now and into the future. Second, an important issue in assessing quality or possible inference is what the monitoring target actually is. For many of these datasets (and from the point of view of the data owners), "success" might be the collection of data, nationally representative sampling, the capacity to detect national trends or the capacity to detect effects of environmental/management change. Moreover, rather different forms of data are required to answer questions involving variation in abundance or presence (distribution). ? And what data are needed – presence or abundance? Third, unstructured biodiversity recording may be useful for selected locations (reserves, gardens, villages, farms, parishes or whatever), but poor/unrepresentative at larger scales, so the definition of the exact scale involved for "local" monitoring could be critical. Fourth, the use of "investigative" implies a study structure with controls as well (usually) as application at the local scale, so it creates rather a narrow category and it has been disregarded in populating the "local" column. Finally, the definition for amber is rather positive and overlaps with that for green. For the data sources considered here, a category for "uncertain, may work with further development of volunteer networks or statistical processing but further trialling is required" would have been useful.*

Example	Local (site or grid square)	National surveillance (Wales)	2-5 years	>5 years	Comments
Plants	NPMS	NPMS			Some local inference may be supportable for limited/biased locations; national representativeness will depend upon uptake and taxonomic resolution.
Plants	BSBI recording (TPP)	BSBI recording (Atlases and Local Change)			Recording is underway for Atlas 2020. The Threatened Plants Project (TPP) and Local Change (LC) surveys could be repeated and extended in Wales.
Birds	Schemes designed for national inference	BBS used for national population reporting and tests of management effects; BirdTrack can be	As current – significant increases in volunteer effort are unlikely	As current – significant increases in volunteer effort are unlikely	Some local inference may be supportable for limited/biased locations

		developed further for rarer species			
Butterflies	WCBS designed for national inference, BMS suitable locally for target habitats	WCBS and BMS are used to produce national indices	As current – significant increases in volunteer effort are unlikely	As current – significant increases in volunteer effort are unlikely	Some local inference may be supportable for limited/biased locations
Bees, Wasps & Aculeates		BWARS			Annual or longer term trends probably achievable for more common taxa using modern occupancy modelling with recorder effort correction but representativeness depends upon taxonomic coverage, rarity and the influence of spatial and temporal biases.
Other invertebrates	Unstructured NBN data only – may be suitable for selected locations	Unstructured NBN data only – some national monitoring may be possible using new statistical approaches	As current		
Bats	Schemes designed for national or regional inference, but maternity roost and hibernation site surveys inform at the site level where they are conducted	National Bat Monitoring Programme was designed for the UK, but the data support statistically reliable trends for Wales for the species monitored	Scope for further development and standardization of monitoring methods and to tap into a new volunteer base	As 2-5 years	Extent of additional potential volunteer effort unknown
Other mammals	Possibly some useful records for certain species in NBN	Some species covered by BBS; extent of additional potential			

		volunteer effort unknown			
Aquatic vertebrates	Only presence/ absence tractable, limited value at local scales	New FHT volunteer surveys in development, with species-level eDNA. Power and sample biases uncertain.	As current; scope for structured sampling being investigated. Volunteer interest uncertain.		
Water quality	New FHT volunteer surveys in development. Power and sample biases uncertain.	New FHT volunteer surveys in development. Power and sample biases uncertain.	As current; scope for structured sampling being investigated. Volunteer interest uncertain.		
Habitat mapping	e.g. Case study from Warwickshire when combined with EO	Ground-truthing of CEH Landcover has just been added to mySoil/UKSO, uptake unknown; JNCC are scoping broader potential	Ground-truthing of EO habitat data is being trialled and may be effective but scope and biases unknown		
Soil	Being trialled in mySoil and other apps e.g. the Crap- app. NRM have published their data but bias identified so would need work and only does farmers (so no forests or coast etc)	Could explore possibility for sending in samples from selected squares but untested to date	Unknown	Unknown	
Health and disease: animal pesticide effects	Predatory bird scheme and collection of otter carcasses for rodenticides, etc. provides unstructured	Predatory bird scheme records are probably biased with respect to human population	As current	As current	

	data with unreliable local record density	density but are believed to be reliable			
Pollution recording	EA solicits reactive data on incidents; CEH, in collaboration with a range of partners, have produced an on-line app linking lichen morphotypes to nitrogen deposition levels[5]	Various apps on pollution e.g CEH have various. Not sure if anyone has tried to make a map out of it or interpreted results?			

[5] http://www.apis.ac.uk/nitrogen-lichen-field-manual

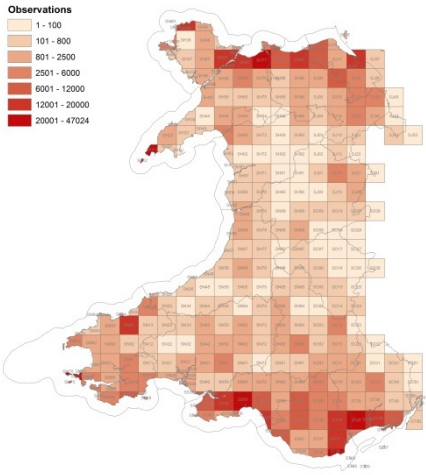
f. Data Informatics

- Important ongoing surveys in Wales can be tapped into to inform about changes and impacts/management effects on natural resources. There may be significant added value to be gained from applying Bayesian models to unstructured data, but this requires further development.
- Citizen science data are best-suited to large-scale applications in which local-scale site turnover is not important and detailed local inference is not required, subject to survey uptake being suitably representative (see Figure 1 for an illustration of current citizen science coverage in Wales). Professional surveys are required otherwise. Structured volunteer surveys are the best citizen science option, where practical, followed by unstructured data collation with as much secondary recording of recording effort as possible.

Figure 1. *Distribution citizen science survey effort in Wales: (a) randomly selected 1km BBS squares taken up by volunteers, with the depth of grey colour indicating the number of years of survey coverage to date (up to 21); (b) numbers of unstructured BirdTrack observations, across all species, submitted up to 2016, summarized by 10km square.*

(a)

(b)



- Data harvesting and the solicitation of unstructured records clearly enable the collation of large quantities of data. While these data could generate valuable monitoring evidence, this is not necessarily the case, because geographical and other biases are likely to limit reliable inference significantly. Data analysis can account for some issues here, but is not a panacea. Intrinsic data quality, typically involving the degree of structure underlying data collection, will be central in determining the evidence value of available data and should be evaluated in critically in determining the extent to which a given data source meets evidence needs.
- Further engagement-focused initiatives are likely to arise because soliciting data is an effective way of increasing interest and educating the public. However, the value of the data collected from these processes for monitoring and delivering evidence is limited and it is important that this is recognized at policy level.
- Exploiting unstructured records requires that the quantity and quality of data are maximised. This means working in partnership with Wales LERC, whose data holdings may often exceed the numbers available via the NBN, and with centres of analytical expertise such as CEH and BTO who can help deal with spatial and temporal variation in recording effort.
- Data ownership is a sensitive issue with citizen science data. First, more structured schemes require investment to support design, volunteer management and data analysis, leading to

organizations having significant intellectual property. Second, many individual volunteers commit great time and effort to data collection and, sometimes, monitoring design. In both cases, the (part-)ownership of these data by the organizations or people concerned needs to be respected, recognized and rewarded adequately to maintain effort and data quality in the long term. How to manage this in the long term and across all ultimate uses of data collected via citizen science schemes is a significant challenge.

II. Unique Selling Point

The application of volunteer/amateur recording effort to monitoring priorities can be a cost-effective alternative to large-scale professional surveys, potentially with added value in community engagement.

III. Future potential

Public interest underlies citizen science effort and is secure as a resource in the long term. Funding support for many structured schemes is also probably fairly secure because the data products are valued at policy level. Although this is subject to the maintenance of government and agency support, the ongoing importance of citizen science to UK-wide environmental surveillance is recognized and promoted by the UK Environmental Observation Framework[6]. Increasingly sophisticated remote-sensed data are likely to add value to citizen science by providing more and better habitat context information, while online recording platforms provide increasingly sophisticated data capture and checking facilities. While public interest and regional biases in activity are always likely to limit monitoring in practice, more sophisticated statistical models are likely to improve the utility of unstructured data.
Threats to continued volunteer effort include loss of skills as older naturalists are not replaced because younger generations may lack the level of engagement required to conduct surveys for some taxa. However this may be more of a threat to trying to increase coverage rather than to maintenance of existing levels and may be offset by increasing numbers of retirees joining volunteer surveyor communities, although it is possible that over-reliance on demographic change and recruitment does not constitute a sustainable strategy for citizen science. Rising transport costs are likely to be a growing problem for volunteers to contribute high levels of survey effort.
A cost-effective approach to more representative or complete coverage than volunteer effort allows may be to augment existing volunteer effort with professional effort, for example in remote areas. However, effective survey designs for volunteers typically require low field effort per survey so as to be more tractable in people's spare time. Such protocols, without modification, are unlikely to deliver cost-effective use of professional surveyors' time. Paying travel expenses for surveyors may be a further route to increase coverage, assuming that costs are limiting for them, but this could cause organizational problems within surveys. There may also be potential to develop novel data collection systems making use of volunteer effort, supported by new technologies, from online

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[6] The UKEOF aims to develop a holistic picture of the observation needs of the UK, to share knowledge and information, to understand the use of observation data and tools for knowledge transfer, to enable funding mechanisms for long-term observations and to build a strong community to share data and expertise.
The Citizen Science working group provides a forum for member organisations to share good practice and discuss future needs and plans, helping partners make best use of different monitoring approaches.
Resources: http://www.ukeof.org.uk/resources/citizen-science-resources .

Two project reports have also recently been published on "Understanding Motivations for Participating in CS"; and on "CS and Environmental Monitoring: Opportunities, Costs and Benefits". These can be found on the main page of the EOF web site.

systems to laboratory DNA analyses, for example in the freshwater environment. However, levels of volunteer interest are always likely to be limiting and cannot be taken for granted. Costs of developing new schemes may also be significant. All developments of new monitoring should be piloted to ensure that the data collected can provide appropriate evidence and revised or abandoned if this is not the case.

A general issue with citizen science is clarity of aims and objectives. There is broad scope to develop new data collection protocols and creative approaches for interaction with and encouragement of the public. Schemes can be focused on monitoring, engagement and/or education, so there is potential to achieve multiple objectives at once. However, the optimal scheme designs for these objectives may be very different, varying in factors such as observer skills required, duration, replication, minimum sample size and geographical locations. Particularly from the perspective of national monitoring requirements, it is critical that new scheme designs and the exploitation of existing data match data quality to potential inference appropriately, such that evidence needs can be met reliably.

a. Next steps for development as a monitoring tool

- Citizen science approaches are well-suited, within limits and with careful use, to a range of surveillance, monitoring and evaluation applications with respect to natural resources (including monitoring towards national or regional environmental targets), but they are not suitable for local-scale regulatory applications (e.g. compliance of farms to statutory regulations). Structured surveys such as BBS, NBMP, WCBS and NPMS are valuable for future monitoring and can contribute to the evaluation of management impacts at large scales. With further methodological development, the same may be true for some unstructured datasets. However, if detection of management effects means making existing simple methods more complex and difficult to implement this will probably result in reduced engagement from volunteers.
- Future development of citizen science for monitoring can take four directions: new surveys, exploitation of further unstructured sources, more analyses of existing data and integration of citizen science and professional effort.
- It is possible that additional structured surveys could succeed, but observer interest will be a strong restriction. The fate of new pollinator, plant and Earth Observation ground-truthing survey initiatives will be instructive.
- Freshwaters represent a significant monitoring gap, in Wales as elsewhere. The Freshwater Habitats Trust has identified significant potential for developing semi-structured monitoring of freshwaters in Wales. These involve ongoing development of the PondNet and Clean Water for Wildlife programmes so that citizen surveys, especially for large scale water pollution monitoring and biodiversity monitoring using eDNA, can now provide data which are not available with other approaches. In particular, citizen science approaches are seen as a valuable, cost-effective approach to covering the large numbers of small water bodies and low-order streams that have high environmental importance. Future work will focus on developing the sample-collection-and-testing approach further for water quality and biodiversity applications, considering the key methodological, statistical and practical application questions. As with other data sources lacking a formal sampling structure, work is needed to reveal the evidence value of the data likely to be collected, i.e. the representativeness of the sampling and the sensitivity to reveal (a) changes over time and (b) effects of management or environmental change. See Appendix Y to the Main Report for further details.
- There may be additional value in the harvesting of unstructured records to contribute to future recording in Wales, both by actively soliciting increased biological recording effort and by carrying out more central collation and processing. Unstructured data should be exploited to its fullest potential where structured surveys would not be feasible due to low uptake, such as may limit the potential of the new National Plant Monitoring Scheme in Wales.

- The most cost-effective approach to future monitoring with representative or complete coverage may be to combine volunteer recording with professional effort, for example in remote areas.
- Effective survey designs for volunteers typically require low field effort per survey so as to be more tractable in people's spare time. Such protocols, without modification, are unlikely to maximize the data collected during professional surveyors' time, so the latter should certainly only be applied to structured surveys. More sophisticated combinations of effort are likely to be more cost-effective, for example using tiered sampling approaches, with volunteer data informing about gross patterns and professional supplementation providing complementary detail, as used in the combination of BBS and professional bird surveys in GMEP.
- Paying travel expenses for surveyors may be a further route to increase coverage, assuming that costs are limiting for them, but this could cause organizational problems within surveys.

***Table 1**: Types of citizen science scheme and their attributes, with relevance to Wales[7].*

Forms of scheme/data collection	**(Stratified) random surveys (type i)**		**Surveys with observer selected locations (type i)**	**Atlases (type i)**	**Biological records (type ii)**	**List data (type ii)**	**Volunteer run projects (type iii)**	**Samp (type**
Example data sets	BBS, WCBS, NPMS		BMS, CBC, ObservaTree	Bird Atlas 2007-11, Butterfly Atlas	NBN, Ancient Tree Inventory, Nature's Calendar, Earthworm Watch	BirdTrack, WildWalks	Welsh Chough monitoring	mySo eDNA PBMS Surve
Primary purpose	Tracking temporal change		Tracking temporal change	Mapping (change in) distributions	Personal interest of recorders; some with more direction	Personal interest of recorders	Personal interest of recorders, tracking temporal change	Most and s for gr
Species/other target coverage in practice	Widespread species		Widespread species and some habitat specialists	All species	Rarer or specific species (and phenology)	All species (and phenology)	Specific rare species	Speci samp
Primary spatial unit	Standard survey areas (often 1km squares)		Patches of target habitats	Grid squares (size taxon-dependent)	Simple locations of records	Locations of records	Locations of records or patches of habitats	Speci sites locati recor
Representativeness/bias	Representative of habitats in sampling design		Typically broadly representative of target habitats	Complete coverage (at large scales, at least as an aim)	Biased according to recording effort	Biased according to recording effort	Typically complete for restricted target areas	Proba accor recor but v
Value at national scale	High		Moderate to high, depending on coverage	High	Can be high if coverage is high or unbiased with respect to distributions	Moderate	Typically low unless whole populations are measured in a single local area	Can b cover unbia
Value at local scale	Low		Low to high, depending on field method	Low	Can be high if there is local standardization in recording	Low	High	Low t depe meth
Stability of funding support	High (subject to government and agency support)		High (subject to government and agency support)	Moderate	High	Moderate	Low	Mode start- only;
Effort control	Strong		Strong	Strong (large scales) to moderate	Weak	Moderate	Moderate	Stron

[7] *See also http://ecsa.citizen-science.net/community/map for Citizen Science capacity-building across Europe.*

Forms of scheme/data collection	**(Stratified) random surveys (type i)**		**Surveys with observer selected locations (type i)**	**Atlases (type i)**	**Biological records (type ii)**	**List data (type ii)**	**Volunteer run projects (type iii)**	**Samp (type**
Quality control/verification	On data entry, automated (moderate)		On data entry, automated (moderate)	Strong	Weak to strong, depending on taxon and location	On data entry, automated (moderate)	Strong	Strong
Counterfactual/zero records	Included automatically		Included within target habitats	Included automatically	Not considered	Included but may be biased	Not included but reliably inferred	Includ autom
Sensitivity to change: value for measuring changes over space and time	High		High	Low (long periods between repeat surveys)	Low to moderate (mostly presence data with variation not controlled)	Low (more often presence data than counts, variation not controlled)	High	Variab (many yet to evalua
Suitability for measuring management or environmental effects	High (for long-term, widespread effects subject to uptake and dispersion)		Moderate (depends upon coincidence of target habitat and drivers of interest)	Low (only via space for time substitution)	Low (high uncontrolled variation and difficult to associate with spatial data)	Low (high uncontrolled variation and difficult to associate with spatial data)	Moderate (limited spatial extent)	Variab (many yet to evalua
Spatial coverage (extent)	Wales (but with habitat biases due to uptake).		Wales (in target habitats)	Wales	Wales (with habitat biases)	Wales (with habitat biases)	Restricted areas	Restri but gr
Standardization of spatial sampling unit	Fully standardized		Loose only	Fully standardized	None	None	Loose or none	Loose stand
Sampling design	Randomized (but with observer-selected details)		Observer selected with restrictions	Complete	None	None	Observer selected with restrictions	None select restri
Standardization of sampling method	Fully standardized		Fully standardized	Partly standardized	None or full (in more directed schemes)	Some (effort recording)	Partly standardized	Fully s
Frequency	Annual		Annual	Periodic (less than decadal)	Flexible dependent upon summarization (including sub-annual)	Flexible dependent upon summarization (including sub-annual)	Annual	Variab annua
Examples of use for evidence	AES evaluation in England and Wales		Identification of farmland bird decline due to agricultural change	Identification of bird range expansion due to climate change	Records summarized for some State of Nature recording and UK Biodiversity indicators.	Identification of phenological change in bird migration		Identi ponds Creste inform devel

The potential of citizen science data for monitoring in Wales

FURTHER READING

1. Key datasets derived from volunteer-based schemes that currently contribute to the evidence needs of Natural Resources Wales (courtesy Dr Liz Howe, Head of Species Team, NRW Bangor).

- **Bird data**- all BTO datasets and trends analyses plus red listing and birds of conservation concern.
- **Bat data**- Bat Conservation Trust and all rare bats recording projects.
- **Mammal data**- mammal society datasets.
- **Dormouse**- National Dormouse Monitoring Program run by the PTES (Peoples Trust for Endangered Species) http://surveydata.ptes.org/dormousemonitoring/.
- **Otter**- UK otter survey (https://naturalresources.wales/media/4590/osw-5-english-24-06-2015.pdf)
- **Herpetofauna** – National Amphibian and Reptile Recording Scheme (http://www.narrs.org.uk/) and the rare reptile and amphibian database held by ARC.
- **Butterflies**- the UKBMS and in Wales the Butterfly Conservation, Marsh Fritillary and other rare species surveys.
- **Moths**- National Moth Recording Scheme also run by Butterfly Conservation (http://www.mothscount.org/text/27/national_moth_recording_scheme.html).
- **Other animals** – also rely on evidence and data from a range of other recording schemes and societies.
- **Inverts** – The Wales invertebrate recorder database has over 0.5 million records and will be going onto the NBN soon.
- **Plants** – BSBI and Plantlife recording schemes.
- **Non-vascular plants** - various recording schemes (primarily the British Bryological Society and the British Lichen Society) and the red lists that go with them.

2. Examples of newer citizen science schemes and derived indicators relevant to Wales

Soils data and the mySoil app

Soils data in the form of unstructured records, are collected through both the mySoil iphone and android apps (http://www.bgs.ac.uk/mySoil/#ad-image-ad-image-0) and also through the UK Soil Observatory online (www.UKSO.org); all platforms provide information, with more than 50,000 users and 4000 records crowdsourced from across the globe. The digital apps and portal are able to collect any written and photographic data; guides are provided for basic texture, pH and photos. The existing soil data tools were designed to raise awareness of soils but have great potential for added value data collection. For instance, farmer soil analysis records could be collected, peat depth mappers could record across Wales and games could be developed around data collection; there is no reason to prevent the tools being used in professional survey. The tools would need some upgrading for these applications, for example mySoil has no offline capability to record information, and this could be added and is important for Wales. The next upgrade of mySoil will include Welsh

language support, whilst the next version of the UKSO will include crowd-sourcing and verification of landcover map data.

Atlas of Living Wales

This project is ongoing and involves harnessing the functionality of the recently completed Atlas of Living Australia. The Atlas of Living Wales will be built using an open source biodiversity data infrastructure and is intended to deliver on the fourth Strategic aim of the NBN Strategy, The Atlas of Living Wales will offer the ability to create a Welsh view, bringing together species and habitat data. To quote from the NBN website "*The Atlas of Living Wales will offer the ability to create a Welsh view, bringing together species and habitat data and offering functionality including the ability to view and upload photographs, search for biological data by predefined areas, by postcode or by polygon search tools, find organisations working in a particular area (geographic or taxonomic) and create alerts for species records. Additionally, the Atlas of Living Wales will provide bilingual functionality, offering users the option to switch between Welsh and English language pages – functionality which has not previously been available via the NBN Gateway.*
This project is part of a work programme to build Atlas infrastructure for England, Wales, Scotland and Northern Ireland and use the same scalable platform to create an Atlas of Living UK. Each of these five atlases would have the same functionality and same basic design and be supported by a single database but offers users a more focussed, local view of the national data holdings."
New functionality is also likely to include alerts to expert recorders allowing them to moderate newly uploaded records. This should favour an increasing quantity of useable records but not at the expense of quality. It is also worth noting that this facility already exists through iRecord (supported by national recording schemes and societies and available at http://www.brc.ac.uk/irecord/) and BirdTrack (http://www.bto.org/volunteer-surveys/birdtrack/taking-part/birdtrack-apps).

UKBMS indicator for Wales

BRC with Butterfly Conservation are due to produce an indicator for Wales that is consistent with the UK JNCC C6 indicator of butterfly trends (http://jncc.defra.gov.uk/page-4236) but based on improved Bayesian occupancy modelling. This will be updated annually under the current UKBMS contract which runs for another year till end of financial year 16/17.
Most of the work on the indicator has been done, but the information (sample sizes for species, trends, indicator plots) needs consolidating into a form agreed by NRW. Once finalised the indicator will be placed in the public domain.

Plantlife section 42 species monitoring activities

Plantlife have devoted considerable effort toward accumulating high resolution records for section 42 higher plants, grassland fungi and lichens in Wales. However they do not currently run structured monitoring of these taxa but may be able to fund future activities pending the outcome of funding bids (Cath Shellswell pers.comm.).

Developments in bird monitoring in Wales

Multiple structured and semi-structured volunteer schemes led by the BTO contribute to annual or periodic bird abundance monitoring in Wales, and some then provide data for Wales-specific indicators (Appendix 1). In addition, professional monitoring and periodic, targeted volunteer surveys record various rare and priority species under the SCARABBS programme (e.g. raptors and twite), or led by volunteers (e.g. chough); the SCARABBS surveys are led by NGOs. Various schemes also monitor bird demography, but these are not strictly relevant here. The BTO/JNCC/RSPB

Breeding Bird Survey (BBS) is the principal annual scheme for monitoring terrestrial breeding birds, and a recent drive to increase survey engagement via peer-to-peer mentoring has seen a 35% increase in coverage. The Waterways Breeding Bird Survey (WBBS) is a sister scheme for linear waterways that has specific relevance for Wales because of the importance of the rivers for specialists such as dipper and grey wagtail; it is currently supported by BTO and reported along with the main BBS. Wintering waterbirds are covered annually on estuaries and a sample of freshwaters by the BTO/RSPB/JNCC Wetland Bird Survey (WeBS); complete coverage is achieved of coastal sites, whereas it is more patchy inland and increased uptake would be valuable. Non-Estuarine Waterbird Surveys are conducted approximately every nine years to record wintering birds away from estuarine sites and are particularly important for the rocky shoreline in Wales. Bird Atlas 2007-11 was the latest in a series of periodic (c. 20-yearly) Britain and Ireland projects measuring distribution and relative abundance of all species in winter and summer, which included complete coverage of Wales at the 10km square level. In addition to these general schemes, the BTO organizes specific, periodic monitoring of particular target groups, with notable examples for Wales including the Wales Chat Survey from 2012 (for whinchat, stonechat and wheatear) and the Peregrine Survey from 2014. Finally, the BirdTrack system (partners include the Welsh Ornithological Society) is an online recording portal to capture casual bird records, including recording of complete lists, which provide a measure of effort and thus an element of structure to the data. Methods for the analysis of these data are still in development, but they have the potential to fill information gaps for scarce and localized species all year round, as well as providing information about the timing of migration.

National Plant Monitoring Scheme

For more widespread plants and CSM indicators linked to semi-natural habitats the nascent NPMS scheme may have a prominent role to play in future monitoring. The great advantage of the scheme is its low cost. It is managed by Plantlife, BSBI and CEH and among volunteer-based schemes uniquely addresses the challenge of annually monitoring common plants within fixed vegetation quadrats that can be explicitly grouped by habitat type. The scheme has been running for one year across the UK. Uptake in terms of number of quadrats recorded in 2015 in Wales is indicated in Table A1 alongside quadrat numbers for the two professionally funded vegetation monitoring schemes that have covered Wales; GMEP and Countryside Survey.

The NPMS scheme clearly has the potential to be an important contributor to future monitoring. Currently uptake is however relatively low in Wales and Plantlife are involved in ongoing attempts to increase participation.

A number of issues pertain to the use of NPMS in addressing possible questions about monitoring change in vegetation and common species and identifying the drivers of those changes in the future.

Issues:

1. Differences in plot sizes between schemes (NPMS versus CS and GMEP versus NRW datasets). The requirement here is to measure diversity and other variables of interest in such a way that they are corrected for differences in area censused. This only applies if there is a real need to amalgamate datasets but in some cases this may be the case.

2. How many plots are actually required? Could it be that despite low current uptake of NPMS it may in fact provide enough quadrats to answer relevant questions? This depends on the question; attribution of changes over time to multiple driver gradients requires adequate randomised, replicated and crossed samples along each hypothesised gradient. Modern Bayesian modelling methods can readily deal with missing data but the critical point is that Bayesian imputation does

not guarantee lack of bias in inference. It therefore does not correct for biased sampling across the domain of interest. In essence there is a limit on the extent to which sampling variation can be compensated by sophisticated modelling. If the question is about identifying trends over time then it is still the case that biased sampling will produce a trend estimate representative of some areas but not of others.

3. Roughly a third of the NPMS plots in 2015 are recorded at wildflower level and another third at CSM indicator level. Joint analysis of NPMS and other quadrat datasets could be carried out by reducing the taxonomic coverage of all datasets to an equivalent level; for example only selecting wildflowers or CSM vascular plants from CS, GMEP and NRW quadrats. Work is underway to determine the cost versus benefit of this approach with respect to the use of NPMS plots in England as a counterfactual for the current HLS re-survey.

4. It may be important that bryophyte (moss & liverwort) cover is not recorded in NPMS plots. Total bryophyte could presumably be easily added to the guidance for NPMS in Wales. In the western oceanic seaboard of Britain and in upland habitats, bryophytes provide important ecosystem functions including moderating run-off, N fixation, substrate protection, C storage and habitat for other species of animals plants. They are therefore likely to contribute to ecosystem resilience.

5. It would be useful to explore the effect of any bias in NPMS locations toward freely accessible land for which land-owner permission did not need to be sought. Again, information as to whether volunteers sought permission or not could presumably be recorded in future years and retrospectively gathered for 2015 plots.

6. By design the NPMS preferentially targets 1km squares rich in semi-natural habitats. This is because its purpose is to measure change in the abundance of species typical of these more threatened habitats across the UK. Square selection was achieved using an objective weighting of all UK 1km squares by land-cover diversity. Therefore since all 1km squares in Wales have a weighting the coverage of NPMS plus GMEP and the extent to which they are severally and jointly representative of Wales could be readily quantified.

7. NPMS targets semi-natural habitats. Improved land and conifer plantation are therefore deliberately avoided by NPMS yet these habitats attract a range of Glastir interventions and so NPMS may not be optimal in these habitats. Conversely NPMS plots ought to help detection of impacts in semi-natural habitats. Further consultation is required to determine how far NPMS could be adapted to help with detecting Glastir impacts. At a recent workshop discussing future monitoring of HLS and Countryside Stewardship options in England it was thought that asking NPMS volunteers to additionally stratify by in or out of option land would foist prohibitively complex protocols on them and risk drop-out.

8. Options for further exploring the contribution of NPMS to monitoring in Wales could include adoption of existing GMEP squares, or at least some of the GMEP quadrats within squares, by NPMS volunteers. The emphasis would presumably be on ‘interesting’ and ‘accessible’ squares near to volunteers’ homes.

9. Analysis of NPMS plots and GMEP plots in accidentally coincident squares could also shed light on differences in species and habitat coverage by the two methods.

Table A1. *Total numbers of fixed vegetation quadrats in Wales currently available for analysis from three monitoring programs, the volunteer-based National Plant Monitoring Scheme, which went live in 2015, and the professionally funded Glastir Monitoring and Evaluation Program and Countryside Survey of Great Britain. Note that neither of these two latter schemes have secure funding for any future re-recording. Quadrats are grouped by the habitat or feature they sample. Note that finer divisions of plots to section 42 habitat is possible. NPMS quadrats include those from all three levels of recorder effort; wildflower, indicator and inventory (see http://www.npms.org.uk for more information). Numbers of NPMS plots were correct at 18th March 2016 (courtesy Oli Pescott, CEH Wallingford).*

Quadrat types and broad habitats from CS/GMEP	**NPMS habitat types**	**NPMS**	**GMEP**			**CS**		
		2015	**2013**	**2014**	**2015**	**1990**	**1998**	**2007**
A plots on cultivated field margins	Arable margins	2	7	14	8	0	11	17
Bog	Bog and wet heath	9	104	90	63	9	41	58
Broadleaved woodland + linear H and D plots	Broadleaved woodland, hedges and scrub	58	106+ 388	143+ 515	83+ 362	50+ 52	74+ 300	159+ 608
All coastal broad habitats	Coast	21	17	11	16	18	43	44
Streamside plots	Freshwater	12	183	226	174	209	257	458
Heath	Heathland	13	54	54	66	18	56	101
Neutral grassland	Lowland grassland	55	125	135	107	53	88	152
Fen, Marsh & Swamp	Marsh and fen	14	93	121	64	41	74	96
Inland rock	Rock outcrops, cliffs and scree	8	5	5	5	1	9	17
Acid grassland	Upland grassland	20	86	128	136	60	138	209

Woodland Trust led or partnered citizen science projects.

Project	Background	What does the project do?	How is the data used?	Partners	Who are the key WT contacts?
Nature's Calendar www.naturescalendar.org.uk	The longest running citizen science project at WT, started 2000	Thousands of untasked volunteers across the UK collect information about the timing of natural events where they live eg date of first swallow of spring, first tinting leaf of autumn. A sister project called Track a Tree is run by our PhD student based at University of Edinburgh	The project has a huge database (modern and historic records) and is used by academics and government to show how natural timings are changing as a result of climate change.	WT is lead partner. Supported by Centre for Ecology & Hydrology.	**Kate Lewthwaite** is project manager. **Judith Garforth** is project administrator
Ancient Tree Inventory http://www.ancient-tree-hunt.org.uk/	Began as a five year, WT-led, HLF funded project in 2006 as the 'Ancient Tree Hunt'. Name changed to reflect the value of the data now held.	Untasked volunteers seek and record ancient , veteran and notable trees; an estimated half of all these trees in the UK are now on the project database. Tasked volunteer verifiers visit and check each tree eg that species correctly identified	Data used strategically to aid in conservation decisions such as the designation of Sites of Special Scientific Interest and in deciding planning applications.	Project partners of ATI include specialist charities the Tree Register of the British Isles (TROBI) and the Ancient Tree Forum.	**Jill Butler** is project manager**. David Alderman** and **Kylie Knight** provide additional support.
Observatree	4 year project, began in 2013, funded by	Recruited and trained a network of 200 tasked volunteers to add capacity	Data used to help track the impact of pests and diseases	Forest Research is lead partner. Other partners	**Kate Lewthwaite** leads WT activity. **Helen Jones** is

www.observatree.org.uk	European funder LIFE+ WT leads on volunteer management and project communications	to tree health scientists by helping to sift pest and disease records and carry out site visits. Promotes the use of FC online tool 'Tree Alert' to encourage reporting of pests and diseases of concern.	in the UK and to support more general scientific research	are National Trust and FERA. DEFRA, Natural Resources Wales and APHA are supporting partners.	volunteer officer, **Anna O'Connor** is comms officer. **Judith Garforth** provides additional support.
UK National Tree Seed Project www.kew.org/ukntsp (NB This is not a monitoring project)	Five year project launched by Millennium Seed Bank Kew in 2013	WT recruits, trains and manages skilled tasked volunteers called "seed collection champions". The collected tree seed is stored deep frozen by Kew where possible, species that cannot survive this (eg oak) are grown on straight away by Kew or FC.	The project aims to gather a genetically comprehensive collection of important UK tree seeds to aid research and conservation efforts.	Kew is the lead partner. Other partners include Forestry Commission and National Trust.	**Kay Haw** and Kylie Knight lead WT activity.

Some definitions

Tasked volunteers- Specific number of people recruited via application to the WT volunteer team. People have a task outline (a bit like a job description), training for the role and a named WT task manager. They record their volunteering hours and receive out of pocket expenses.

Untasked volunteers – A more typical model for citizen science where people volunteer as and when they wish, no limit to the number of people that can help or the time spent. No formal training, volunteer manager or task outline. Do not claim expenses since carry out tasks as part of their normal day to day living.

Future citizen science development in freshwaters: Comments from Freshwater Habitats Trust

Jeremy Biggs, 3 June 2016

We provide some brief comments and suggestions on the main themes discussed at the monitoring workshop as they relate to freshwater ecosystems.

Summary

1. Citizen science: A citizen science approach to freshwaters offers several opportunities in Wales to complement, and extend cost-effectively, current freshwater monitoring work. Much of the infrastructure has been established thorough current and on-going FHT work developing the PondNet and Clean Water for Wildlife programmes so that citizen surveys, especially for large scale water pollution monitoring and biodiversity monitoring using eDNA, can now provide data which are not available with other approaches.

2. Freshwater monitoring: A key requirement of freshwater monitoring in Wales, as elsewhere, is the effective incorporation of small waterbodies (headwater streams, ponds, small lakes, ditches) into monitoring programmes. Although increasingly recognised as important, small waters generally remain outside of current regulatory monitoring programmes. A major hurdle to effective monitoring of small waters is cost, and citizen science programmes can provide a way round this substantial problem.

3. Possible ways forward for citizen-science based freshwater monitoring programmes: Work during 2016 has provided a proof of concept of the value of rapid water quality test kits for large scale evaluation of water quality across whole catchments (including both large and small waters). Similarly, Great Crested Newt eDNA work has also clearly demonstrated the value of this technique for volunteer monitoring of protected freshwater species.

We suggest that in 2017, using the freshwater citizen science monitoring network established in Wales by Freshwater Habitats Trust with HLF support, there is a good opportunity to explore further the potential of this approach for monitoring freshwater biodiversity and pollution problems. We recommend a larger practical trial to address key methodological, statistical and practical application questions, in three or four key catchments, as part of work to assess the potential for a longer term national citizen based freshwater monitoring network in Wales.

Background

Freshwaters in Wales include ponds, lakes, streams, rivers and ditches. As in most parts of the world, it is likely that in terms of numbers and length, small waters (ponds and small lakes; zero to second order streams; ditches) greatly outnumber the larger waters (lakes, rivers), although larger waters of course occupy a larger area.

At present, most formal monitoring of freshwaters, in terms of hydrological, chemical and ecological quality, is focussed on larger waters. Although Wales is notable for having taken a lead in work on ponds and small lakes, worldwide there is generally little monitoring of smaller waters, whether still or flowing, despite increasing recognition that small waters are important both in their own right, and through their critical influence on larger waters.

Freshwater Habitats Trust's monitoring interests

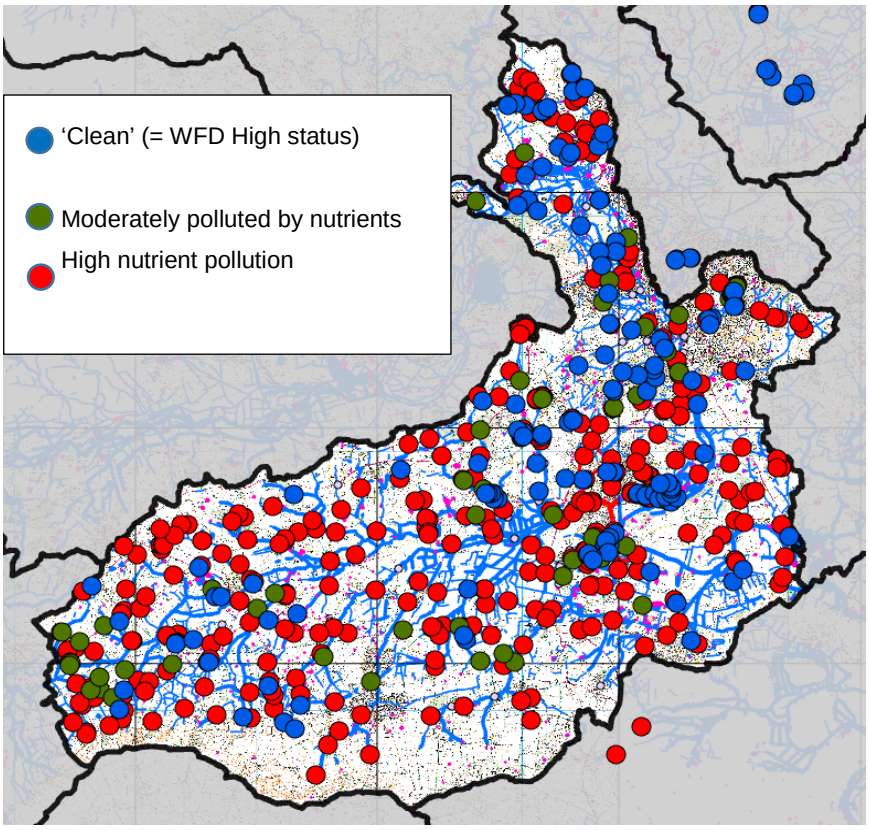
Freshwater Habitats Trust's primary interest in monitoring is to encourage, and undertake, effective monitoring of freshwater biodiversity. This also includes aspects of ecosystem service delivery, particularly water quality.

There are three areas of monitoring work in which Freshwater Habitats Trust is currently involved which could contribute to understanding of the water environment in Wales:

1. The new national, volunteer-based, pond monitoring network, PondNet, which has been established with the support of Defra, Natural England and the Heritage Lottery Fund and is currently being rolled-out to cover all of Wales and England. The programme is based around a nationally stratified sample of 1 km squares and is initially focused on assessing the quality of all ponds nationally, of Priority Ponds (a subset of all ponds) and of

c.30 freshwater priority plants and animals, including the Great Crested Newt. This programme has a national database capable of managing both species and habitat data (including water quality) called WaterNet which, as well as dealing with ponds and small lakes, is designed to be extended to manage datasets from all types of freshwater, still and flowing. The investment in this programme to date is about £500,000, and has created an infrastructure that can be used by both professional and non-professional workers. A new bespoke website for WaterNet will be launched later in June.

Figure 1. Water quality in the River Ock, Oxfordshire catchment. Undertaken using citizen science methods, this is the first survey of all waterbody types across a whole river catchment.



2. A detailed technical manual for the use of rapid test kits will be published at the end of June. The use of a new generation of rapid nutrient test kits for nitrate and phosphate which can quickly and cost effectively provide an over-view of diffuse pollution at catchment and landscape scale. This could provide datasets which have not previously been available for an integrated form of water management planning covering all types of freshwaters and wetlands. The kits are usable by both professionals and volunteers (and programmes in which both groups work together are probably going to prove most effective). An example dataset from a catchment (the River Ock, which includes Oxford), hosted as part of the Defra Catchment-based Approach by FHT, is shown in Figure 1. In April 2016, Freshwater Habitats Trust organised a citizen-based survey of nitrate and phosphate levels on 570 sites (ponds, lakes, streams, rivers, ditches, fens) in the catchment of the R. Ock, Oxfordshire as part of the Clean Water for Wildlife project. This was slightly more than 1 waterbody / km2 in this 470 km2 catchment. Most sites are not currently monitored. Rapid test kits were successfully able to separate 'clean' water (i.e. those at 'High' status under WFD) from more polluted waters. Nearly 1/3rd of sites were 'clean', predominantly ponds and lakes, with some streams and ditches. Most running waters experienced substantial nitrate or phosphate pollution. The data are now contributing to a range of practical projects. We believe this is the first example of a whole catchment, all waterbody type, analysis of water quality.

3. The exploitation of new eDNA techniques to collect datasets describing the status of waterbodies or species that are not covered by traditional monitoring programmes (e.g. most small waters, many freshwater species of conservation concern). Although there is currently considerable interest in using eDNA to replicate 'traditional' approaches (e.g. invertebrate surveys for WFD), there is also considerable potential to do things with eDNA which currently cannot be done practically by traditional methods e.g. fish surveys in lakes, large scale Great Crested Newt presence/absence surveys, large-scale surveys of fish in headwater systems. As well as having developed the Great Crested Newt eDNA programme, FHT is exploring opportunities for further single and multi-species work for monitoring freshwater biota.

Next steps

We believe that a citizen-based national or regional monitoring programme in Wales to assess the status of a representative sample of all waterbodies, focusing particularly on smaller, largely unmonitored, waters is technically and practically feasible. Such a monitoring programme could help provide a better understanding of the status of (a) water quality, particularly nutrient pollution, in a much wider cross section of freshwaters than is currently possible, (b) selected species, using eDNA techniques, cost-effectively filling gaps in existing monitoring approaches.

Examples of the kinds of practical issues such an approach could help tackle are:

1. Providing water quality data from sites of importance for freshwaters biodiversity, particularly small waters. Such work could include screening of headwater streams to identify High status sites which should be subject to 'No deterioration' objectives; monitoring lakes which are not in the existing SSSIs/SAC programme; monitoring Priority Ponds and monitoring SSSI ditch networks which are currently more or less unmonitored. As eDNA techniques develop it is likely that, in addition to water quality data, further single or multi species tests could be used by non-specialists to monitor individual freshwater species of conservation concern for which there is currently little regular monitoring. We believe there may also be benefits in assessing the potential of eDNA to detect water plants (e.g. charophytes, which are taxonomically challenging for most freshwater botanists), with the first studies of eDNA detection of water plants suggesting this may be possible.

2. Evaluating the success of measures to improve water quality such as agri-environment schemes to reduce local point source pollutions or diffuse pollution. The test kits would again be used to focus on smaller systems, rapidly screening large numbers of sites which may currently have only limited, or no, monitoring, with follow-up using standard regulatory approaches where kits provide the first evidence of impacts (either positive or negative). This also opens up the possibility of landowners being able to see for themselves the extent of pollution, and the effects of agri-environment schemes, which has the potential to both empower land managers and encourage co-operation. Although test kits are not as accurate as laboratory analysis, they can distinguish between clean and polluted habitats, and can be used at large numbers of sites to provide a scale of survey which it is hard to fund using laboratory analysis.

3. Find clean water locations, encouraging stakeholders to more highly value these sites and ensure that small point and diffuse sources potentially affecting these areas are prioritised for remediation. At present, much of the focus of monitoring is on improving the bad rather than protecting the good. We believe that there is much to be gained by helping people focus on, and celebrating, what is already good, looking after that well, and trying to build out from it. There is also a wealth of biological evidence that shows that this is more likely to work, at least for biodiversity, and will be an essential part of improving the degraded. Thus it is clear that in many cases recovery of freshwater biodiversity depends to a large extent on recolonisation from 'good' locations.

We currently hope to continue, and extend, the freshwater monitoring programme involving citizen science in Wales which has been established in the People, Pond and Water project. Practically, our main requirement is to support FHTs Wales Officer who is co-ordinating citizen monitoring at present. We would also recommend further exploration of the pilot work undertaken with rapid test kits and eDNA during 2016 and 2017, to evaluate optimum designs for rapid test kits surveys. For example, although we have run a quite detailed programme of testing comparing the kits with lab data we still have a range of questions about the variability of the kits and their statistical power to detect change. With eDNA we would like to test the single species approach further in its ability to detect individual protected species, given the success of the great crested newt approach. Similarly, can citizen scientists collect fish or amphibian multi-species eDNA samples? We would also like to explore whether other rapid water quality test kits are useful

(e.g. heavy metals, aluminium) and to further develop links between citizen survey data and practical actions to improve the environment.

Specific comments on freshwater monitoring options

1. WG could specify a vision for how freshwater monitoring activities might support a Natural Resource Management Programme including the assessment of ecosystem resilience and ecosystem service delivery, and articulate the economic, social and environmental benefits of basing management decisions on sound evidence. Through consultation, this vision could be translated into an agenda for collective action involving all stakeholders.
We suggest that through involving a citizen science element it would be possible to incorporate a wider range of both small and large waterbodies into the monitoring network, providing an excellent but practicable representation of the freshwaters of Wales.

2. NRW in partnership with Phase 2 of Future Options should undertake a comprehensive review of all freshwater monitoring activities in Wales with the goal of identifying opportunities for greater co-operation and co-ordination. Building on earlier work by the UK Environmental Observation Framework (UKEOF), the review could seek to identify information gaps, areas of duplication and overlap, and opportunities to harmonise methods and standards. Meta-data for each monitoring programme could be consolidated and made publically available to facilitate future co-ordination.
We agree with this and would include in this analysis the strengths and limitations of citizen generated datasets.

3. NRW in partnership with Phase 2 of Future Options could explore the core NRW freshwater monitoring networks to see how they can be supplemented and complemented by data and information from other sources. Working with other stakeholders, consideration could be given to the pros and cons of using models to integrate disparate data sources, and how separate lines of evidence could be combined to build a coherent, unified assessment of the state of natural resources.
We agree with this recommendation and would comment only that it should ensure effective incorporation of the wide range of new knowledge on the importance of small waters.

4. Proposed reductions to NRW's statutory monitoring networks could be subject to an impact assessment to understand the associated increase in risk. The implications could be communicated to interested parties so that they can adapt their own data gathering and reporting activities accordingly. A series of statistical and modelling approaches could be used to develop the most efficient and cost-effective approaches including a cost-benefit analysis.
The potential to use citizen networks as a 'backstop' where statutory networks must be curtailed should be assessed. It is important not to oversell the value of citizen data, but there may be situations where, as well as providing something that cannot be generated using 'traditional' statutory networks, citizen datasets may help maintain a watching brief, with less sensitive techniques, on waterbodies which would otherwise go completely unmonitored.

5. NRW in partnership with Future Options could explore the possible benefits to Wales of pooling data with environmental regulators in England, Scotland and Wales and co-operating on the development of future tools and models, including the advantages and disadvantages of modelled data. Lessons learned and new technologies being exploited by other countries could also be explored.
Freshwater Habitats Trust is happy to pool/share/exchange data. We have a policy of openly sharing all datasets.

6. WG could explore options for supporting the exchange of monitoring data between organisations in a way that encourages multifunctional data use. This could take the form of a consolidated data

hub/warehouse or a de-centralised data sharing portal that allows organisations to retain ownership and control of their data.

Freshwater Habitats Trust is happy to encourage the use of our data platforms (especially WaterNet – which is intended for multi-user collaboration) to share datasets.

3. Notes (specific analytical approaches, considerations of evidence quality)

- From an analytical perspective, most structured, designed scheme citizen science survey data are fundamentally just survey data: all standard analytical approaches can be used and it is irrelevant that observers are volunteers. However, scheme-by-scheme assessment of survey site uptake and of the distribution of surveyor ability may indicate that additional controls or post-hoc weighting are required to reduce bias in estimated parameters.
- Required sample sizes and their spatial arrangement will vary with the question being asked. The challenge is to estimate the point below which the number of records and their locations lead to a) unrepresentative answers, because of bias, and b) uninformative answers because of too much uncertainty. There is also likely to be another upper threshold beyond which extra numbers of records start to add less and less statistical power. In a voluntary scheme these extra records may not incur significant extra cost whereas in a professionally funded field campaign such an excess represents an inefficiency. These issues highlight the value of the low cost per record of citizen science schemes and of the need for careful design of professionally funded schemes where these are necessary because of low observed or expected uptake of voluntary recording.
- Summarization of data from local/point locations can improve standardization/representativeness at larger scales
- Bayesian approaches can consider bias in unstructured data, but in no way represent a panacea because information may still be lacking for some areas or periods. Bayesian imputation allows models to be constructed but does not make up for missing data. If it did then we would not need data!
- Proofs of concept and potential from larger scales or other geographical areas (e.g. UK versus Wales) may not be reliable at the Wales scale because data availability and biases are different for this subset of the full dataset concerned.
- Survey uptake per head of population in Wales for the BBS, for example, is the highest in the UK, which illustrates that simple observer density may be the limit to recruitment of volunteer effort in Wales, as opposed to levels of interest. Recruitment may also be negatively affected in some Welsh communities by a perception that survey organization is “English”.

Appendix H
Briefing pager – Molecular/eDNA

The Potential for Molecular Genetic Identification of Biodiversity across the Welsh Biosphere

S. Creer (College of Natural Sciences, Bangor University)
R. Griffiths (CEH)
T.W. Hatton-Ellis (NRW)
D.L. Jones (College of Natural Sciences, Bangor University)

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Introduction

In order to monitor and evaluate the biological condition of our nation's natural resources and determine how they are affected by environmental and management change, there is a pressing need to assess the composition and diversity of organisms across the breadth of life in both space and time (e.g. bacteria, fungi, invertebrates, fish etc). Traditionally, this national-scale monitoring has been operationally limited by the difficulties in identifying and counting different taxa, both of which incur significant resource constraints (i.e. manpower, cost). For many taxonomic groups, the skills base to effectively and consistently monitor a diverse range of organisms may be inadequate or even completely lacking. Advances in molecular biology now provide alternative new approaches that can revolutionise how biodiversity is monitored in a comprehensive way across the whole of the Welsh landscape.

The molecular genetic toolbox

For many years, out of necessity, researchers in the field of microbiology have been using molecular approaches to assess the biodiversity of communities using genetic approaches. However, the relatively high cost of such work has tended to restrict its use to the research community or to more specialist applications. Recent developments in sequencing technologies have greatly increased the accessibility and hence attractiveness of this technology, including its use in assessing the biodiversity of larger taxa.

By focusing on a range of genetic source material (e.g. community-level or environmental DNA [eDNA]), habitats, and spatial scales, we can now characterise entire communities more easily and cheaply across a wide range of taxonomic groups. The purpose of this paper therefore is to provide a succinct summary of the different molecular approaches suitable for the assessment of biodiversity and showcase the ecological research opportunities afforded by contemporary DNA sequencing. The text is derived primarily from Creer et al. 2016. An ecologist's guide to sequence based identification of biodiversity available Online Open from http://onlinelibrary.wiley.com/doi/10.1111/2041-210X.12574/abstract and augmented with relevant case studies throughout.

Genomic, community, or environmental DNA?

For the field ecologist, we can define many forms of DNA. Genomic DNA is extracted from a single individual (or from a collection of individuals belonging to the same species). Community DNA consists of genomic fragments from many individuals representing a mix of different species. Community DNA is isolated from organisms in bulk samples, but separated from their habitat (e.g. soil, sediment, river benthos). Community DNA extracts have important potential in ecological studies, especially for biomonitoring purposes, since the focus is on the extant community. Environmental DNA (eDNA) (Figure 1) is isolated directly from an environmental sample without first isolating any type of organism (e.g. soil, sediment, faeces, water, air, etc.). One of the most powerful aspects of eDNA analysis is the ability to sample biodiversity that is not easily sampled by other means or requires complicated procedures to extract organisms of interest (e.g Tullgren funnel extraction of soil fauna, or filtering organisms from aqueous material). The combination of genomic, community and environmental DNA therefore provide a variety of sources of biodiversity information that can be analysed using the approaches here on.

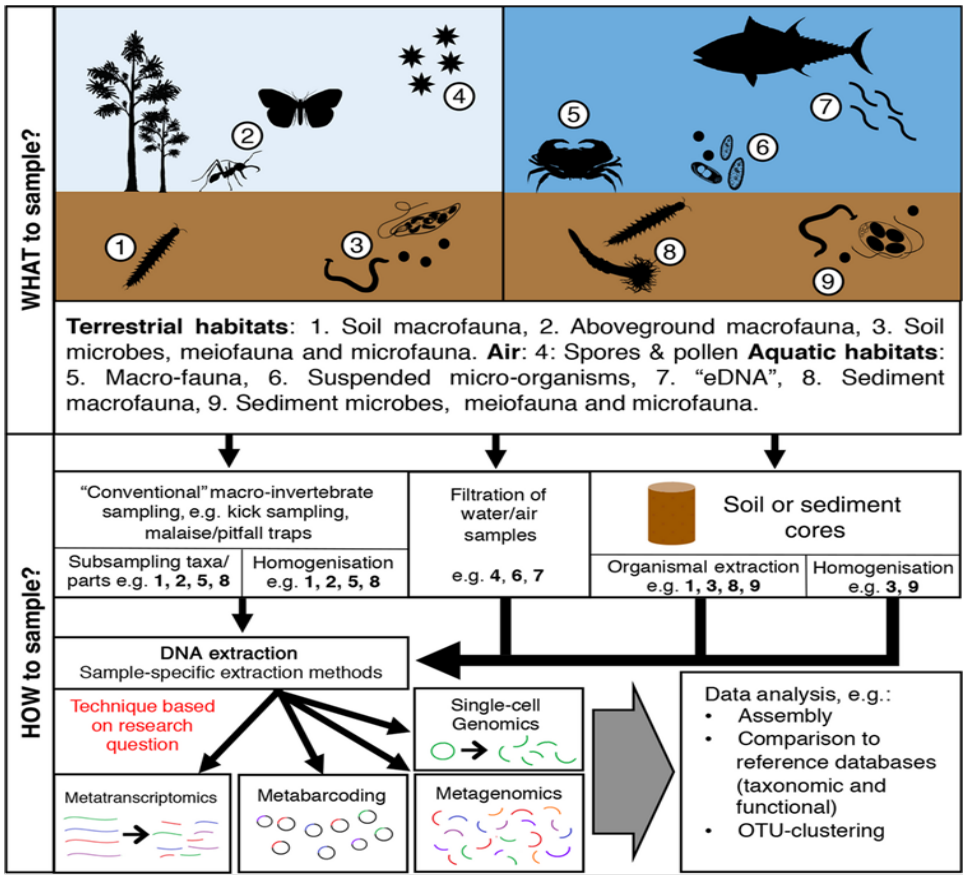

Figure 1. Schematic showing the decisions involved in a molecular ecology/biodiversity workflow. Samples can be collected from a variety of different environments. DNA/RNA is then prepared and used to answer a variety of ecological questions: metabarcoding is used to answer questions about 'who' is present, while the function of communities or individuals can be established using a metagenomics, single-cell genomics or metatranscriptomics.

Current and potential applications

Researchers have used eDNA methods for fundamental research into the diversity of life and its function in a variety of habitats as well as to answer ecological questions relating to environmental or management change. More recently, the methodologies have been used in larger scale survey and monitoring to establish broader drivers of microbial diversity (e.g GB Countryside Survey 2007, see ukso.org; Glastir Monitoring and Evaluation Programme - GMEP). For larger organisms, contemporary eDNA analyses have already been extensively implemented for detecting invasive

species in aquatic environments using species-specific markers and more recently for reliable detection of fish and/or amphibian communities. In rivers, eDNA can even represent information that is integrated over large spatial areas due to the transport of DNA downstream and is an area (in addition to marine ecosystems) currently benefiting from investment from NERC Highlight Topic Funding (http://mefgl.bangor.ac.uk/news/can-we-use-edna-as-an-environmental-magnifying-glass-24870). Marine sediments have provided eDNA and community DNA for analysing the pollution impact on biodiversity. It is also possible to collect plant eDNA from the air, from faeces, or from pollinators (e.g. honey bees). Ancient DNA from locations such as lake beds or permafrost offers a window into past communities.

One important advantage of eDNA approaches, is that DNA can be stored in small volumes and archived for future use. For instance, at CEH a DNA archive is available for over 1000 soil samples collected across Britain in 2007 and a further 750 samples collected across Wales in 2012-2016. Whilst this was initially used for a microbial survey, the development of new markers means that the samples can now be probed for a variety of other taxa. Coupled with long term and large scale monitoring, these technologies potentially allow for investigations into the spread of invasive or pathogenic taxa over time (e.g. insect vectors of disease; livestock pathogens; microbial human and plant pathogens; non-native plants etc., see Case Study 1).

Case study 1: Soil biomonitoring

Soils are one of the most biodiverse habitats, and traditional methods for reliable sampling and taxonomic characterisation are under-representative. Most studies to date have focussed on microbial communities since they represent the bulk of the soil diversity and biomass, as well as playing key roles in important processes such as carbon storage, nutrient cycling and regulating greenhouse gas emissions. Much of this diversity cannot be assessed using traditional culturing and so prior to the implementation of molecular methods our knowledge of the true of extent of soil diversity was limited; and our understanding of biodiversity distribution and ecological drivers of spatial patterns was almost non-existent.

The application of molecular approaches to large-scale soil surveys, has revealed much new information on the broad drivers of bacterial biodiversity. For instance, as part of the GB scale "Countryside Survey" CEH provided a molecular assessment of the bacterial communities across England, Wales and Scotland and revealed strong relationships with the same geological and climatic features that determine the distributions of plant communities. Importantly, this revealed that at the broad level, we can make certain predictions as to the type of bacterial communities found in different climatic and geological settings; and also infer likely effects of land management based on direct effects on soil edaphic conditions. Subsequent research further confirmed this by producing detailed predictive maps of bacterial distributions (see the UK soils portal: ukso.org), utilising the modelled relationships between bacterial biodiversity and habitat type obtained from the remote sensed UK Land Cover Map and existing geological maps.

A key challenge is how to implement soil eDNA approaches for a wider variety of taxa and to use the information to inform on ecosystem services. For instance, using the same DNA resources from the Countryside Survey researchers have used a specific qPCR assay to report on the distribution of *Mycobacterium avium ssp. Paratuberculosis*, a soil borne animal pathogen.

Cont/.

Such quantitative assays could be developed for other taxa such as other human or plant pathogens, and then applied to DNA resources from large-scale surveys. Equally, the use of high throughput sequencing assessing the diversity of broad specificity marker genes (as now implemented e.g in GMEP) may also provide relative abundances on specific taxa of interest. There is currently much research on the use HTS approaches to quantify the diversity of soil mesofauna, particular members of which are considered soil "ecosystem engineers"; and wider taxa also play a large role in soil decomposition processes. Traditional methods for the enumeration of soil mesofauna involve complex and biased specimen extraction, as well as labour intensive taxonomic characterisation and so there is considerable hope that eDNA methods may overcome these issues. Potential barriers to implementation include: choice of marker gene to provide reliable taxonomic ID for a wide range of mesofauna; poor molecular records of known species in nucleotide databases; and sampling issues with respect to adequate representative coverage (DNA is often extracted from <0.5g of soil in large scale surveys, meaning potential "catch" may be limited). Nevertheless, these issues are likely to be overcome in the near future, given the considerable speed of progress and research effort in this area.

What are the advantages and disadvantages of molecular genetic approaches for national scale monitoring in Wales?

Most monitoring essentially boils down to five general questions:

What species is / are present?
Where are they?
When were they recorded?
How much / many of them were there?
What does this tell us about environmental quality?

The first three questions are more or less essential for monitoring to have any real usefulness. The fourth question is useful in most circumstances though it can be challenging to collect in many circumstances, resulting only in presence / absence data. The last question is the most important of all as it connects the data to environmental management and policy questions. In many cases specific monitoring tools exist that integrate all five questions (see Case Study 3). In this section we compare molecular methods in general terms with current methods against the criteria above.

What species are present?
Although most biological recording is carried out at the species level, a significant amount of recording also takes place at higher taxonomic levels such as the genus or even family. As discussed, molecular methods are generally predicted to be more effective at species detection than conventional methods. They are capable of correctly detecting species at lower abundances than is normally possible; detecting a wider range of taxa than conventional methods from a single sample, and have the potential to identify taxa that cannot be identified at all using existing methods (e.g. different life history stages and difficult to identify species). There are also limitations in the genetic databases used to identify environmentally retrieved sequences, since the majority of global species have yet to be sequenced. As a result, not all molecular sequences can as yet be assigned a taxon name, but will instead be assigned a taxonomy according to the most closely related taxon in the reference database. Assigning identities to sequences derived from community/ eDNA is implicit, and therefore, a unified stance on building specific DNA reference data bases is of utmost

importance. Augmenting the existing databases with the necessary records can be achieved at low cost per species (e.g. £10-£15 per species). A significant advance in Wales has been the collation of plant barcodes for the majority of Welsh and UK flowering plants, covering 1,479 UK native flowering plant species http://www.gardenofwales.org.uk/science/barcode-wales/ – an invaluable resource for the future of botanical, pollinator and allergenic health research in Wales, that is already drawing in substantial RCUK funding (http://mefgl.bangor.ac.uk/news/new-1-2m-nerc-grant-aims-to-revolutionise-pollen-forecasting-24704).

The greater detection power of molecular methods (especially eDNA) has significant potential for species monitoring, especially at low abundances or in environments that are difficult to observe / sample cost-effectively using other methods. Species detection records generated through the analysis of eDNA can then be used to target other forms of survey and management actions (see Case Study 2). Examples of relevant policy applications include:

Detection of rare and priority biodiversity (e.g. Section 42 species) in order to focus management action, planning decisions or further survey;

Detection of invasive species in order to facilitate eradication at an early stage, before the species becomes established (of interest to a range of stakeholders and Dŵr Cymru, Welsh Water;
Broad scale monitoring of biodiversity patterns in poorly sampled environments such as soils and marine ecosystems

Understanding the relationship between environmental stressors and biodiversity indicator species

Case Study 2: eDNA as a tool for detecting Great Crested Newt

Great Crested Newt is a globally threatened species that is strictly protected by UK and European Law, but is locally quite common in parts of England and Wales. Adult newts enter the water in spring to breed and remain until early summer when they return to land. The larvae may be present in the pond at any time of year but are difficult to detect using conventional surveys. Traditional surveys use a combination of trapping and searching by torchlight when the newts are active, but this is a relatively labour-intensive process and can only be carried out at certain times of year. In addition, a relatively high rate of false negatives means that several surveys are required before newts can be declared to be absent.
These constraints are a problem for developers in areas where Great Crested Newts are present, because they can cause substantial delays and additional costs to projects. By collecting water samples and testing them for great crested newt eDNA, an approach developed by the Freshwater Habitats Trust can now be used to correctly identify ponds where newts are present or absent with a much higher success rate than previously. This provides decision makers with the information they need much more quickly, thus reducing costs to developers and facilitating conservation of this threatened amphibian. Natural England and Defra have now adopted this eDNA test as part of the formal process for consenting developments where Great Crested Newts are likely to be present.

Where are they?

Since molecular methods frequently sample remains or traces of organisms, there is an additional complication in linking a molecular record to an actual occurrence of a living organism. In more

stable, static environments (e.g. soils, ponds and lakes) this is unlikely to be an issue, but in more mobile environments such as rivers or the sea the potential for eDNA transport is more significant. Current research programmes are studying the transport of eDNA in rivers and the marine environment to better understand the effects of this.

Most current monitoring records the presence of living or dead organisms to at least a 6 figure grid reference (i.e. $10m^2$), though data may be analysed at lower resolutions such as $10km^2$ for simplicity. From a regulatory perspective, it is not usual to analyse biological data at a coarser grain than this and so ongoing research will illustrate the different scales over which eDNA/conventional analyses integrate biodiversity information in relation to existing approaches. However, potential monitoring issues related to the spatial scale over which eDNA analyses may reflect broader biodiversity could be overcome by adjusting the sampling technique (for example collecting community DNA instead of free eDNA). Conversely, the scale at which eDNA analyses may reflect biodiversity could offer additional insights in relation to our understanding of broader, catchment scale level biodiversity in relation to environmental pressures/land-use. Nevertheless, such insights currently fall outside the remit of standard monitoring approaches.

When were they recorded?

Existing methods generally record sightings on a daily basis, though this has become lost by some datasets (e.g. Atlas data). As with spatial resolution, since molecular methods may be sampling traces of organisms rather than the organisms themselves, there can be additional uncertainty. DNA can persist in the environment for some time depending upon the habitat and conditions, and therefore it is possible that organisms recorded in a sample were actually present weeks, months or even (in some cases, such as ancient sediments) decades, or centuries ago. As with transport, this is an area that requires further study and will be highly substrate dependent. It is well documented that small and fragmented DNA can become bound to sediments and persist for substantial periods of time. Nevertheless, initial work suggests that DNA samples correspond reasonably well with seasonal variation as measured by conventional methods. In general the detection of older DNA requires more specialised techniques and therefore its effect on regular sampling is likely to be small. Consequently, it is likely that DNA records are likely to reflect timescales that are ecologically relevant for the vast majority of applications. However, where very fine resolution is required (i.e. less than two weeks), molecular techniques are likely to lose resolution.

How much / many?

Although not essential for all applications, estimations of abundance greatly increase the value of most biological data. Molecular data is not truly quantitative and will likely never give exact estimates of abundance in terms of biomass of any given species. It is also important to acknowledge the confounding issue of the occurrence of different life history stages, eggs, larvae and adult phases, contributing to the molecular genetic signal. Given the importance of this issue, especially in relation to biomonitoring (e.g. EU Water Framework Directive), estimates of habitat quality and understanding ecological interactions, there are very few studies that provide adequate data contrasting molecular data with abundance estimated using conventional methods. However, in most cases conventional methods of estimating abundance are also relatively imprecise, hence the frequent use of broad abundance classes rather than absolute numbers. For different reasons, abundance estimates of different species may also be biased using either conventional or molecular methods.

With appropriate molecular genetic sampling design and / or lab analysis it is often possible to gain insights into the relative abundance of communities that correlates well with measurements using conventional methods, suggesting that molecular methods are capable of estimating abundance at

least in general terms. Further work is needed in this area, but initial results suggest that in many cases, molecular methods have the potential to estimate abundance to a comparable level of accuracy and precision to conventional methods. However, where estimates of habitat structure (e.g. zonation, cover / extent, mapping) are required, molecular methods will in general be unsuitable or more expensive than conventional methods.

Environmental Quality

Initially, molecular methods are being used to transpose existing biomonitoring tools in order to provide more cost-effective ways to measure pressures (Case Study 3). However, it is already apparent that molecular methods are detecting a much wider range of taxa than was previously possible. Once suitable research datasets across a range of different habitats and pressure gradients are available, it should be possible to construct more reliable pressure indices and also to objectively measure pressures and trends that were not previously quantifiable. This more applied use of molecular methods is of particular importance, and should be a key research goal.

Despite the massive potential of eDNA approaches for rapid and cost-effective widespread monitoring of biodiversity; there are limitations to the current approaches. A number of these are outlined in Figure 2. First and foremost, this is a recent but rapidly developing technology and particularly for larger organisms there is currently no consensus on which marker gene is most appropriate to reliably discriminate between recognised taxa. Whilst this is a highly active current area of research, it is likely that there may never be a single marker gene which gives reliable species level discrimination across the variety of life. The extent to which this is a problem depends upon the purpose of data collection but may to some extent restrict the opportunity for integrating different molecular datasets if a standardised marker system has not been established. Similar problems already exist for some conventional datasets. Further advancements in sequencing technologies may overcome these limitations to a certain extent, when it is possible to sequence larger proportions of the genomes present in eDNA.

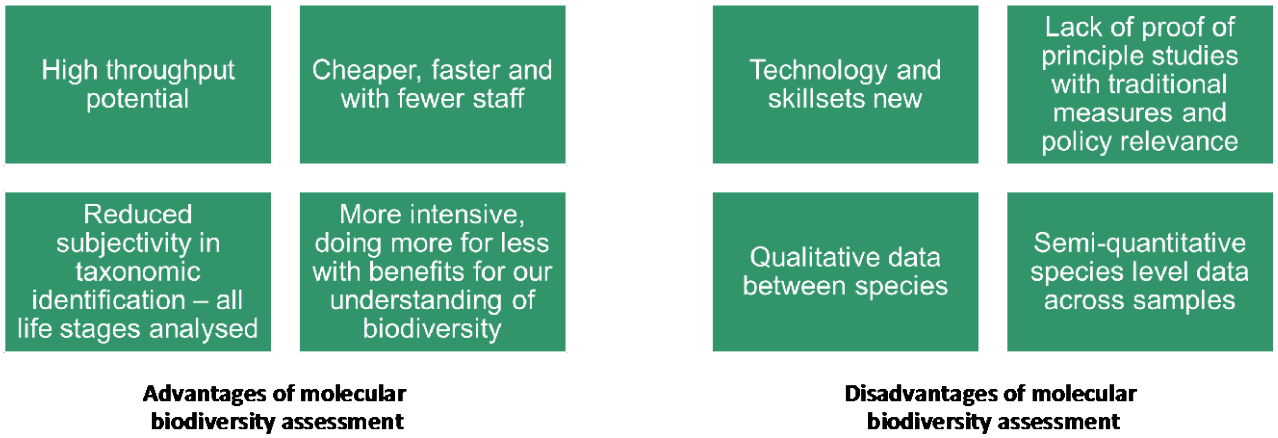

Figure 2. The advantages of molecular biodiversity assessment are primarily related to resource efficiency in implementation and a reduced level of uncertainty. Such power leverages the ability to analyse more biodiversity from more samples, with associated benefits for assessing the relationship between biodiversity and ecosystem health, and/or doing the same job with less resource. Conversely, critics often focus on the quantitative nature of the data, potential biases and technical artefacts and how relevant the different approaches are to traditional approaches associated with policy relevance.

Molecular methods deal with minute quantities of DNA and the risk of contamination is therefore a significant one. In many cases it is not easy to identify the source of any contamination. Scrupulous

quality control mechanisms would be needed to ensure that correct conclusions are reached, especially if the outcome of the test affects livelihoods.

Case Study 3: Molecular Approaches for Water Framework Directive Monitoring

The Water Framework Directive (WFD) requires member states to develop and use monitoring tools to assess the ecological quality of their freshwater and inshore marine waters. These tools cover a range of taxon groups and should respond to environmental pressures such as nutrients. The Directive includes quite a detailed framework on the nature and structure of these tools including the taxon groups to be monitored, general parameters to be assessed (e.g. diversity and abundance) and procedures for ensuring comparability among member states. Tools exist for a wide range of taxon groups including macroinvertebrates, aquatic plants, diatoms, phytoplankton and fish. WFD monitoring occurs in a network of thousands of sample points throughout the UK in and therefore is very costly.

The UK group tasked with managing the technical development of the freshwater ecological tools is currently investigating and assessing the options for using eDNA in WFD monitoring in partnership with the scientific community. The ecological tools vary substantially in their suitability for eDNA conversion and cross-calibration is required to ensure that comparable results are obtained to the existing method. One, the rivers diatom tool, is likely to be operationally ready within the next year; others such as the lakes diatom tool and one of the lakes invertebrate tools show promise. eDNA is also allowing the development of a cost-effective and non-damaging lake fish tool; existing methods require the use of gill nets which kill large numbers of fish and are very ineffective at detecting many species.

Initial estimates suggest that, where suitable, eDNA methods are around 30-40% cheaper than existing WFD methods, though this is highly scale-dependant. In future it may be possible to identify sensitive taxa from groups that cannot be identified using traditional methods and therefore improve the power of our biomonitoring tools.

Although the operating cost of molecular methods is low, the setup cost is high. Purpose built laboratories with highly trained personnel are required. This initial investment can be recouped by economies of scale, but due to the large size of the investment, the adoption of eDNA techniques is likely to be most effective if undertaken collaboratively at a UK level.

Finally, there is a general concern that eDNA could discourage appreciation of nature and ecosystems by taking a very technocratic but less aesthetic view of nature that minimises time spent in the field, over time produces a more deskilled workforce and produces a disconnect between ecologists and the environments they study. Certainly molecular methods place a much greater emphasis on laboratory work than many other methods, although conventional approaches such as sorting invertebrates or counting diatoms using a microscope is also heavily laboratory based. However, the existing taxonomic skills base for many groups is already inadequate or non-existent, resulting in very poor national coverage. In essence, this means that conservation of them is weak or non-existent and national experts become overburdened with identifying individual specimens rather than studying their taxonomy or ecology. Used correctly, molecular methods have the potential to break these logjams and facilitate new insights into ecosystems and the biodiversity

they support. In turn, this creates the potential to create new and better tools for measuring the status of our environment.

What could the technology deliver within a five-year timescale?

Via the GMEP program, we have already implemented proof of principle studies to assess terrestrial microbial (in particular, bacteria and fungi) biodiversity across the Welsh landscape and this could be enhanced to include quantitative measures where appropriate. For example, the DNA archive could be used at any time to assess the distribution of specific organisms (e.g. the causative agent for bovine TB, *Mycobacterium bovis* in soil). Dŵr Cymru, Welsh Water also have requirements to develop pathogen (e.g. *E.coli* and *Cryptosporidium*) and odour imparting organism (e.g. *Geosmin and Methylisoborneol*) detection assays.

Molecular methods have also been used extensively in freshwaters, where they are beginning to contribute directly to statutory processes. As well as their use for detecting great crested newts, work in France demonstrates that they can be used to monitor whole amphibian and fish communities in ponds and rivers. Since most amphibian species receive some form of protection in the UK, such a test is highly relevant. Moreover, in the UK, some WFD methods are also being transposed to eDNA and are likely to become operational within the foreseeable future. Were funds to be made available, single species or whole community tests for rare species or even entire communities would be a reasonable aspiration within a relatively short timescale.

The potential for molecular approaches for assessment of biomonitoring of larger taxa, with concomitant benefits for efficiency and resource use is particularly high. The current Welsh Government/DEFRA annual spend on evidence is in the region of £200 million, with approximately 35% of this attributed to statutory reporting. With the appropriate level of resource and collaboration with existing stakeholder bodies and/or research organisations, we would be in a position to identify how molecular genetic approaches for biodiversity assessment could enhance existing approaches employed in the freshwater (lentic and lotic), marine and terrestrial biomes. Moreover, we would also be able to employ a cost benefit analysis (including socio economic considerations), what level of information can be obtained from the different approaches and how molecular approaches could be incorporated into statutory reporting. Many of these goals are being replicated across Europe by distributed networks of researchers seeking to enhance the way that we assess the relationship between biodiversity and ecosystem health (http://www.cost.eu/COST_Actions/ca/CA15219?management).

Costs

As per traditional analyses, samples still need to be collected from the field and so if downstream analyses are necessary, the costs for the field component are roughly similar whichever approach is used. Typically, the costs of extracting DNA from a sample is £6, while commercial suppliers offer custom biodiversity sequencing at £40-80 per sample assay. The establishment of a bespoke facility would require careful costing but it is highly likely that the cost-benefit incurred for an original start-up would be favourable for larger scale operations, with diminishing returns for smaller-scale operations/assessments. For the latter, using existing facilities or commercial providers could be economically preferential alternatives.

Summary

In conclusion, molecular approaches provide new ways to assess biodiversity at a variety of spatial scales. In some cases, they are unlikely to replace existing and well-established survey approaches (e.g. for birds and butterflies). However, in many cases they can generate results that are comparable to, or better than existing methods at a lower cost, or over a longer survey season. For many taxon groups and environments (e.g. microbes, soils, lake fish), they provide fresh and transformative insights into Welsh biodiversity, replacing existing methods that were ineffective and costly.

The cost of analysis and manpower involved in these molecular approaches is often reduced in comparison to existing approaches. In addition, DNA samples of less than 1ml can be preserved indefinitely in an archive allowing targeting of specific questions as and when the policy need arises (e.g. to evaluate the presence of a pathogenic bacteria or insect disease vector). As an exemplar, GMEP has pioneered the use of molecular biodiversity assessment to assess the impact of land management on soil organisms in Wales and similar opportunities exist in the marine and freshwater biomes spanning the full spectrum of organismal diversity. Carefully designed strategic molecular sampling networks that take account of the minimum spatial, temporal and taxonomic requirements in the terrestrial, freshwater and marine environments could be used to provide Wales level biodiversity datasets for a range of operational, management and policy purposes, augmenting and in some cases replacing other data collection approaches. In addition, more specific eDNA tools and tests could be developed for specific policy drivers, as is already taking place for the Water Framework Directive.

The above notwithstanding, it is important to stress that molecular approaches remain one tool among many. In our view, they are a highly efficient, powerful and effective tool for many biodiversity related applications and we expect that they will become cheaper, more widely used, accessible and accurate with time. However, they are not a panacea: there will remain applications, environments and species where other approaches are more informative and/or cost-effective.

Further Reading

What key methods feature in using molecular approaches for biodiversity discovery?

Quantitative (qPCR) or real time PCR (rtPCR)

It is widely acknowledged that real-time or quantitative PCR (qPCR) represents the gold standard in both the qualitative and quantitative assessment of cells/biomass. Enhanced by recent recommendations for minimum quality, qPCR is widely employed at the diagnostic level and has been used extensively in the development of single species approaches to detect rare and endangered species via the analysis of aqueous eDNA. Of particular note is that eDNA evidence is now accepted at the statutory level to assess the presence of the endangered great crested newt for DEFRA. Nevertheless, qPCR is only useful for targeting specific taxa (either a "species" or broader taxonomic group), reducing its efficacy and raising costs when assessing the composition of diverse communities.

Marker Gene Assessment - Metabarcoding

Marker gene studies have become the most prevalent approach, typically relying on broad coverage PCR primers to amplify marker genes from environmental samples. Whilst not as directly quantitative as qPCR approaches, the main advantage is the rapid assessment of the change in relative abundances of a broader range of taxa. Currently implemented marker genes include the ribosomal rRNA marker for bacteria and some eukaryotes (though the validity as a species specific taxonomic marker is acknowledged as weak for the latter); the ribosomal RNA Internal Transcribed Spacer region (ITS) mainly for fungi but also wider eukaryotes; and the Cytochrome oxidase subunit 1 (COI) gene which is being touted as a universally informative marker for larger eukaryotes (see http://boldsystems.org/). Marker gene assessments are more generally known as 'amplicon', 'metagenetic', 'metasystematic'and metabarcoding sequencing among many others. The recent advancement which has facilitated the rise of these approaches is the development of high throughput sequencing technologies. These approaches allow the simultaneous analyses of several hundred PCR amplified DNA samples in a single assay; utilising complex but now well established bioinformatic approaches to essentially generate quality filtered tables of taxon abundances across many samples.

Metagenomics – environmental shotgun sequencing

Prokaryotic Communities

True 'metagenomic' approaches utilize random sequencing of genomic fragments isolated from environmental samples to elucidate both the taxonomic and functional genomic capability of a community. Shotgun sequencing can provide a complementary, independent method for assessing community diversity, additionally allowing for the capture of information from groups that are otherwise difficult to survey. Metagenomic data are typically used in two ways. The taxonomic component of shotgun sequencing can be used to identify organisms present in a sample, followed by ecologically informative analyses. Metagenomes can also be used to characterize the functional potential of microbial communities through investigation of their full genomic repertoire.

Microscopic and macroscopic eukaryotic communities

Environmental shotgun sequencing could resolve some of the biases prevalent in metabarcoding studies, particularly if it is used in conjunction with targeted genome sequencing. Accordingly, the sequencing of DNA from organelles is developing as an alternative: mitochondrial genomes for animals and chloroplast genomes for plants. Clearly, sequencing the genomes of mixed communities, compared to specific genetic loci, requires a huge increase in sequencing power and consequently a reduction in sample throughput. An alternative relies on using DNA capture array technology to target specific organelles. Here, arrays are designed from existing genomic organelle information which are used to hybridize and extract specific

regions from genomic DNA, thereby reducing the size of the genomic target and increasing throughput. It is likely that different studies will utilize different approaches depending on budget, sample number, community composition and questions.
Future molecular approaches that are in development and may represent the future of the field include metatranscriptomics and targeted genome sequencing, but are not covered here, since they will less likely to become operational within the near to mid future.

Future potential for directly assessing functionality?

Given the vast amount of functions performed by biodiversity, and particularly microbial biodiversity, it is hard to directly infer that a change in abundance of a particular taxa will result in a change in functionality. Such questions are better addressed by directly addressing change in specific gene pathways, such as the genes responsible for the degradation of a carbon source, nitrification, or pathogenicity etc.. Molecular approaches based on sequencing the whole soil DNA pool (whole genome metagenomics) or total transcribed RNA (metatranscriptomics), and then counting reads annotated to functional categories offers a potentially more useful approach to directly addressing change in functionality. Despite advances in sequencing technology the costs required to conduct such analyses often restrict the analysis of 100s-1000s of samples, although it is likely that in the future sequencing costs will come down and such approaches will become more routine.

RNA or DNA?

It has long been acknowledged that DNA may be highly resistant to degradation and may persist in the environment for long periods. Therefore there have been numerous concerns that the detection of genes/organisms through DNA based approaches may not derive from functionally active organisms. For this reason, several studies have explored the sequencing of either the ribosomal RNA marker directly for taxonomic investigations; or transcribed RNA for functional studies (metatranscriptomics). Particularly for soil systems, there have been few studies which have reported major changes in the communities assessed by either the RNA and DNA approaches for taxonomic investigations. This is possibly because active organisms may also be numerically abundant; or alternatively because ribosomal RNA is also long lived in soil. Given this and also the greater degree of labour required for working with RNA due to the lack of high throughput approaches for extraction, it is unlikely in the near future that RNA methods will become routine for large scale monitoring. With respect to metagenomic approaches for functionality; DNA based methods are considered to give information on functional potential, but again it is thought that targeting RNA directly (metatranscriptomics) will better reflect the genes which are functionally expressed at a given time. Unfortunately at present these methods are very much in their infancy; and so there are few studies which have directly compared the results from both methods. Undoubtedly direct sequencing of the total RNA pool should provide more information on both taxonomic identity (no use of specific rRNA primers) and functional genes; and so could be a good solution to addressing both taxonomy and function in the future once sequencing costs decrease.

Definitions at a glance

Amplicon sequencing. Targeted sequencing of an amplified marker gene.

Community DNA. Defined here as the DNA derived from many individuals representing several species.

Degenerate primers. A mixture of similar, but not identical oligonucleotide sequences used for amplicon sequencing where the targeted gene(s) is typically similar, but not identical.

Environmental DNA (eDNA). DNA isolated directly from an environmental sample (e.g. air, faeces, sediment, soil, water).

Genomic DNA. Defined here as the DNA derived from a single individual or from a collection of individuals of the same species.

Locus. The specific location of a gene or DNA sequence on a chromosome.

Marker gene. A gene or DNA sequence targeted in amplicon sequencing to screen for a specific organism group or functional gene.

Metabarcoding. Uses gene-specific PCR primers to amplify DNA from a collection of organisms or from environmental DNA. Another term for amplicon sequencing.

Metagenomics. The random sequencing of gene fragments isolated from environmental samples, allowing sequencing of uncultivable organisms.

Metatranscriptomics. Shotgun sequencing of total RNA from environmental samples. Techniques such as poly-A amplification or rRNA depletion are often used to target messenger (mRNA) transcripts to assess gene expression patterns in complex communities.

Polymerase chain reaction (PCR). Used to amplify a targeted piece of DNA, generating many copies of that particular DNA sequence.

Shotgun sequencing. DNA is fragmented into small segments which are individually sequenced and then reassembled into longer, continuous sequences using sequence assembly software.

Appendix I
Briefing pager – Freshwater Monitoring

FUTURE OPTIONS FOR MONITORING NATURAL RESOURCES

FUTURE OPTIONS FOR FRESHWATER MONITORING IN WALES
Final Report

Dr Andrew Davey, Senior Consultant – Catchment Management, WRc

Andrew Davey

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Executive Summary

The aim of this Briefing Paper is to suggest possible options that Welsh Government, in collaboration with other stakeholders, could explore for re-configuring freshwater monitoring activities in Wales to make more effective and efficient use of resources, which best deliver alignment and optimisation of monitoring activity for delivery across WG Departments and NRW.

Building on NRW's ongoing Monitoring Review and informed by discussions with monitoring experts from NRW and Dŵr Cymru Welsh Water, it envisages a future in which:

- all monitoring activities will be subject to a much more rigorous cost-benefit and affordability assessment;
- data collection will become increasingly multi-functional;
- monitoring activities will be better co-ordinated across the public, private and third sectors;
- freshwater monitoring will be more closely integrated with terrestrial and marine monitoring; and
- data will be shared more openly, facilitating the use of data for multiple purposes.

Seven areas are highlighted as possible options that WG, in collaboration with other stakeholders, may wish to consider in Phase 2 of the Future Options project.

1. define evidence needs to support natural resource management;

2. identify opportunities for greater co-operation and co-ordination between organisations;
3. optimise existing monitoring networks using a risk-based approach;
4. support closer integration of datasets and models;
5. consult on potential for wider collaboration;
6. promote and facilitate greater data sharing; and
7. assess opportunities presented by citizen science monitoring.

Case studies are provided to illustrate the successful application of some of these approaches.

1. Introduction

Aim and Objectives

Welsh Government (WG) and Natural Resources Wales (NRW) have established a Task and Finish Steering Group to identify future options for developing and adapting the Glastir Monitoring and Evaluation Programme (GMEP) into a new Natural Resources Monitoring Programme, phase 1 of which will be launched in 2017.

The focus of this "Future Options" project is on terrestrial monitoring but, as a precursor to a more in-depth review, WG has commissioned CEH and WRc to scope out possible options for re-configuring freshwater monitoring activities to yield cost savings and/or additional insight into the state and trend of natural resources in Wales.

The aim of this Briefing Paper is to suggest approaches that WG could explore in the second phase of the Future Options project. Specifically, it looks at:

- optimising existing monitoring networks and identifying efficiency savings (Section 0);
- making greater use of existing datasets through integrated monitoring and modelling (Section 0); and
- facilitating co-ordination and data sharing among organisations (Section 0).

Finally, Section 0 proposes for discussion some specific options that could be taken forward in future work packages.

Scope and Approach

The focus of this paper is on the monitoring of chemical, biological and microbiological quality of freshwaters (i.e. rivers, lakes, streams, ponds and groundwaters). Monitoring of fisheries, water quantity and alien species are not considered explicitly although the approaches outlined are equally applicable to these parameters, as well as to terrestrial, estuarine and marine monitoring programmes.

This paper builds on NRW's ongoing Monitoring Review and has been informed by discussions with monitoring experts from NRW and Dŵr Cymru Welsh Water (DCWW). It looks beyond NRW's own monitoring programmes to explore the broader challenges and opportunities facing freshwater monitoring in Wales and sets out options by which scarce monitoring resources could be used more effectively and efficiently. Case studies are included to illustrate how other organisations have applied some of the approaches presented in this paper to help improve their data gathering activities and minimise monitoring costs.

The use of earth observation, molecular genetics and citizen science techniques for freshwater monitoring are discussed briefly, but interested readers are referred to a set of parallel papers produced as part the Future Options project, which covers these issues in greater detail.

This paper does not consider how existing monitoring programmes might ultimately be amalgamated into a fully integrated natural resources monitoring programme to support implementation of the Environment (Wales) Act 2016.

2. Optimising existing monitoring programmes

Balancing cost vs risk

Data is collected not for its own sake, but rather to provide information to support management decisions. With the exception of prescriptive, statutory requirements, decisions about monitoring should be informed by a cost-benefit analysis to determine whether the benefits accruing from the information that is generated outweigh the costs of gathering, transmitting, storing, managing, processing, and interpreting the data. Further Reading/Section A elaborates on the value of taking an objective, risk-based approach to designing monitoring programmes.

All else being equal, more data:

- allows parameters to be estimated more precisely;
- improves confidence (reduces uncertainty) in reported results;
- increases the power of the monitoring programme to detect non-compliance and measure change;
- leads to improved decision making; and
- reduces the risk of adverse environmental, social or economic impacts arising as a result of inadequate information.

The rule of diminishing returns applies, however, so a trade-off has to be made between cost (i.e. sampling effort) and risk.

This trade-off is complicated by the fact that sampling effort can be allocated in many different ways. In designing a monitoring network, one has to simultaneously consider: how many sites should be sampled, where these sites should be located, and at what frequency samples or measurements should be taken. Fortunately, statistical techniques such as ***stratification*** and ***optimal allocation*** can be used to make the most cost-effective use of limited resources. In this way it is possible to either minimise the level of sampling effort required to reduce risk to an acceptable level or, to maximise the level of risk reduction for a fixed monitoring budget.

Case studies 1 and 2 in Further Reading/Section B illustrate how these techniques have been used successfully to optimise monitoring programmes in similar settings.

State of the art in Wales

NRW has already undertaken a review of some of its core monitoring programmes, notably its Water Framework Directive operational monitoring network for rivers and microbiological sampling at Bathing Waters. The review has delivered cost savings by reducing monitoring effort (i.e. numbers of sites and frequency of sampling) closer to the statutory minimum amount permitted by relevant national Regulations and EU Directives. In some cases, these changes have been informed by a statistical assessment of the increased chance of mis-judging compliance or mis-classifying status class.

NRW intends to extend the review to other monitoring programmes. Two areas where there may be some significant flexibility to adjust the amount and allocation of sampling effort are:

1. freshwater Special Areas of Conservation (SACs) – the UK legal requirements for monitoring under the Habitats Directive are less prescriptive than for the Water Framework Directive;
2. the WFD surveillance monitoring network – was originally designed as an England and Wales-wide network and existing sites may not necessarily be fully representative of water bodies in Wales. The power of the network to quantify national and regional-level trends in status can now be tested using data from the first (2009-2015) river basin planning cycle, which will help reveal how cost savings may be delivered with minimum loss of information.

3. Making greater use of existing datasets

Integration of land and water monitoring

NRW's routine freshwater monitoring programmes currently focus on assessing the status of water bodies, and additional investigations are often necessary to understand the reasons for failure and quantify the relative contribution of different pollution sources. It is recognised, however, that monitoring needs to "go beyond water quality" by considering the impact of multiple stressors including hydrological and morphological modification. This will require NRW to integrate more closely its water quality, hydrometric and river habitat survey networks of sites.

Co-location of monitoring sites is an attractive concept because it facilitates the linking together of multiple datasets. However NRW's chemistry, biology and fisheries sampling points are already co-located as far as possible with river habitat survey sites and flow gauging stations, and there are practical and logistical constraints on where sites are located. For example: water chemistry samples can be taken quickly and cheaply from bridges, whereas biological surveys require bankside access to suitable stretches of river. Also, some parameters, notably river flow, can be predicted very accurately using hydrological models, vastly reducing the number of locations at which measurements need to be taken.

Earth observation (EO) techniques appear to be under-utilised at present in understanding how changes in land use and land management impact upon the freshwater environment. NRW's SAGIS-SIMCAT water quality model combines land cover information with export coefficients to undertake chemical source apportionment, but the spatial information has poor granularity. DCWW believes that remote sensing can assist greatly in mapping risks to water quality and reviewing the effectiveness of catchment solutions, at a landscape or local scale, and is currently exploring the potential of using aerial surveys to map cropping patterns at a field scale and identify high risk source areas. The potential applications of EO are being actively explored by NRW through the Defra funded and EA led Earth Observation Data Integration Pilot (EODIP) initiative.

Combining monitoring and modelling

Monitoring and modelling go hand in hand.

Models can be used to predict where pressures on the natural resources might be most severe and to help target monitoring activity as part of a risk-based approach.

Models can also be used to complement monitored data. For example, available resources allow only a small proportion of river water bodies to be monitored for water quality; unmonitored water bodies are classified using expert judgement or simple grouping rules. However, the unidirectional flow of water

through dendritic river networks allows downstream changes in water quality to be modelled using tools such as SIMCAT and SIMPOL-ICM. At present, the ability of these, and other models, to predict water quality at unmonitored locations and reveal local anomalies is not fully utilised. There may be benefit, therefore, in integrating local data with information on catchment land use and upstream water quality to yield more accurate estimates of water body status.

But of course, models cannot completely substitute for monitoring. Sampling data is vital for calibrating and validating models, which must be grounded in reality to be accepted and useful. But there is a balance to be struck between having too few monitoring points, which make model calibration difficult and lead to large prediction errors, and having too many monitoring points, which leads to data redundancy. If models are to play a more prominent role in the future, then it is imperative to understand the impact that reductions in monitoring will have on model performance.

Making more effective use of existing and new modelling tools will require consideration of NRW's capability in this area.

Moving to a weight of evidence approach

Against a general trend of cut-backs in publicly-funded monitoring programmes, there is a growing need to make use of all available sources of information when assessing the state of natural resources. These supplementary sources of evidence may include: monitoring undertaken by private companies, NGOs or citizen scientists, earth observation data, predictive models, field observations, and expert judgment.

A wide variety of qualitative (e.g. logic tables) and quantitative (e.g. Bayesian MCMC models) techniques are available for combining disparate lines of evidence. Most of these techniques involve weighting individual lines of evidence to reflect differences in their importance or credibility, and then weighing the overall body of evidence to gauge how strongly it supports one or more hypotheses.

Advocates argue that a weight of evidence approach:

- is consistent with natural cognitive processes and considered to be good scientific practices;
- provides a consistent and transparent means of interpreting myriad types of data and information; and
- makes false conclusions less likely and allows decision makers to make better informed decisions.

On the downside, combining evidence can involve difficult qualitative judgments and require additional time, resources and expertise.

Case study 3 in Further Reading/Section B illustrates how the Environment Agency is making increasing use of weight of evidence techniques for assessing the impact of abstractions on aquatic ecology.

4. Multi-agency co-ordination

Co-ordination within Wales

Multiple organisations play a role in monitoring freshwaters in Wales. These include:

- government agencies – e.g. NRW;
- water companies – e.g. DCWW, Severn Trent Water, Dee Valley Water, United Utilities;
- research institutes – e.g. Centre for Ecology & Hydrology, British Geological Survey;
- NGOs – e.g. Rivers Trusts, Freshwater Habitats Trust (formerly Pond Conservation), Riverfly Partnership;

- local authorities – e.g. private water supplies; and
- universities (i.e. academic research projects).

At present, the monitoring activities carried out by these organisations are fragmented and unco-ordinated. There has been no systematic review of who is doing what and so it is not currently possible to comment on the nature and extent of any gaps and overlaps. It is recognised, however, that these organisations are responding to a multitude of drivers and that their activities differ with respect to:

- the geographic coverage;
- the parameters measured;
- the number of sites;
- the frequency of sampling;
- the methods used;
- the analytical limit of detection; and
- the degree of quality assurance.

For example, NRW and water companies have distinct drivers, with NRW having a very diverse and spatially extensive monitoring network and water companies collecting much more specific types of data from a smaller network of sites in critical areas (
Table 1). The sensitivity of the analytical methods used depends on the water quality standards; for example, drinking water standards for pesticides are lower than the corresponding environmental quality standards. Other organisations may hold very specialised, high quality datasets for specific locations as a result of project-based or investigative monitoring, which complement broader, national datasets.

Table 1 Comparison of freshwater monitoring undertaken by NRW and water companies

Aspect	NRW	Water companies
Reasons for monitoring	To gather evidence to support the implementation of the Water Framework, Urban Waste Water Treatment, Nitrates and Habitats Directives.	To manage the impact of the business on the environment, measure the compliance performance of wastewater assets, and to support compliance with the Drinking Water Directive.
Parameters	A wide variety of chemical, biological and micro-biological parameters.	Restricted set of chemical and microbiological parameters for which there are drinking water or effluent quality standards.
Locations	Rivers, lakes and groundwaters across the country.	Predominantly rivers and reservoirs at the point of abstraction/discharge, with limited upstream and sub-catchment investigations. Mostly surface water, with some groundwater sampling.

Co-ordination with other UK nations

Natural resources management in Wales is now a full devolved responsibility, but that should not preclude NRW and other organisations from seeking opportunities to work collaboratively with their counterparts in England, Scotland and Northern Ireland. Several examples of successful partnership working already exist including: the WFD UK technical Advisory Group (UKTAG); the UK Environmental Observation Framework

(UKEOF) and the less formal information sharing network among water companies serving western and upland parts of the UK (DCWW, Northern Ireland Water, Scottish Water and United Utilities).

Aside from the benefits for managing cross-border river catchments, the ability to draw on a larger body of environmental monitoring data and expertise from across the UK could:

- improve the precision and confidence of UK and nationally reported indicators;
- support the development of more sophisticated and more accurate predictive models; and
- share the costs of producing derived datasets and reported statistics.

Data sharing

From a natural resources management point of view, there would appear to be benefits to all stakeholders of greater data sharing, for example in:

- supporting the designation of Nitrate Vulnerable Zones to control nitrate pollution of drinking water sources;
- understanding sources of pollution in Drinking Water Protected Areas upstream of abstraction points; and
- analysing long-term trends in water quality to identify emerging issues and plan future management strategies.

At present there is some, limited sharing of freshwater monitoring data between organisations in Wales. Water companies submit their catchment and effluent monitoring data to NRW's WIMS database and NRW's own monitoring data is made available to stakeholders on request. NRW is currently in the process of making its data openly available via the Lle data platform (http://lle.wales.gov.uk/home). The Freshwater Habitats Trust has also established a national database, WaterNet, which is capable of holding both species and habitat data (including water quality) and designed to be accessible to both professional and non-professional workers.

Citizen science monitoring

A citizen science approach to freshwaters offers potential opportunities to complement, and extend cost-effectively, current freshwater monitoring work. For example, the Freshwater Habitats Trust, taking advantage of advances in eDNA technology and rapid test kits for nitrate and phosphate, has pioneered the wide-scale use of citizen science for monitoring headwater streams, ponds, small lakes and ditches (as illustrated by Case study 4 in Further Reading/Section B). Notably, a new national, volunteer-based, pond monitoring network, PondNet, has been established with the support of Defra, Natural England and the Heritage Lottery Fund and is currently being rolled-out to cover all of Wales and England. Potential benefits of citizen science include: the empowerment, engagement and education of landowners and the public; substantially greater coverage than existing monitoring programmes; cost-effective sampling of numerous, smaller water bodies; rapid screening for emerging issues. However, there are limitations (e.g. the sensitivity of the sampling methods used) and challenges (e.g. deriving a statistically valid and representative sample) that need to be explored and overcome.

5. Conclusions

Freshwater monitoring activities in Wales need to evolve to meet future challenges. Food security, population growth, climate change, invasive species are placing growing pressures on the aquatic environment that need to be understood and managed. Domestic legislation is placing new obligations on

NRW to undertake an integrated assessment of the state of natural of natural resources. At the same time, funding for freshwater monitoring is shrinking.

This paper provides a starting point for stakeholders to discuss what the future of freshwater monitoring might look like and how the transition to a more integrated and cost-effective system of monitoring can be achieved. The following seven areas are highlighted as possible options that WG, in collaboration with other stakeholders, may wish to consider in Phase 2 of the Future Options project.

Define evidence needs to support natural resource management

WG could set out a vision for how freshwater monitoring activities might support a Natural Resource Management Monitoring Programme, including the assessment of ecosystem resilience and ecosystem service delivery, and articulate the economic, social and environmental benefits of basing management decisions on sound evidence. Through consultation, this vision could be translated into an agenda for collective action involving all stakeholders. In terms of ongoing governance, consideration could be given to establishing an expert Standing Panel on Environmental Change, which could (i) provide a consensus summary of the significance and causes of contemporary environmental trends, (ii) identify evidence gaps and future threats, and (iii) make recommendations to WG on priorities for monitoring and any need for tactical redeployment of monitoring or modelling effort.

Identify opportunities for greater co-operation and co-ordination between organisations

NRW, in partnership with Phase 2 of Future Options, could undertake a comprehensive review of all freshwater monitoring activities in Wales with the goal of identifying opportunities for greater co-operation and co-ordination. Building on earlier work by the UK Environmental Observation Framework (UKEOF), the review could seek to identify information gaps, areas of duplication and overlap, and opportunities to harmonise methods and standards. Meta-data for each monitoring programme could be consolidated and made publically available to facilitate future co-ordination.

Optimise existing monitoring networks using a risk-based approach

Proposed reductions to NRW's statutory monitoring networks could be subject to an impact assessment to understand the associated increase in risk. The implications could be communicated to interested parties so that they can adapt their own data gathering and reporting activities accordingly. A series of statistical and modelling approaches could be used to develop the most efficient and cost-effective approaches including a cost-benefit analysis.

Support closer integration of datasets and models

NRW, in partnership with Phase 2 of Future Options, could explore how core NRW freshwater monitoring networks might be supplemented by data and information from other sources. Working with other stakeholders, consideration could be given to the pros and cons of using models to integrate disparate data sources, and how separate lines of evidence could be combined to build a coherent, unified assessment of the state of natural resources.

Consult on potential for wider collaboration

NRW, in partnership with Phase 2 of Future Options, could explore the possible benefits to Wales of pooling data with environmental regulators in England, Scotland and Northern Ireland and co-operating on the development of future tools and models, including the advantages and disadvantages of modelled data. Lessons learned and new technologies being exploited by other countries could also be explored.

Promote and facilitate greater data sharing

WG could explore options for supporting the exchange of monitoring data between organisations in a way that encourages multifunctional data use. This could take the form of a consolidated data hub/warehouse or a de-centralised data sharing portal that allows organisations to retain ownership and control of their

data. Existing data platforms such as WaterNet and the Lle Geo-Portal should be reviewed to identify how their use can be promoted and expanded.

Assess opportunities presented by citizen science monitoring

NRW, in partnership with Phase 2 of Future Options and relevant stakeholders such as the Freshwater Habitats Trust and Rivers Trusts, could investigate the potential for citizen science to complement and augment other established monitoring programmes. Taking into account the strengths and weaknesses of citizen-generated datasets and available sampling technologies (e.g. eDNA and water quality test kits), the review could identify opportunities to, for example, undertake large-scale biological surveys, monitor small water bodies and identify emerging issues.

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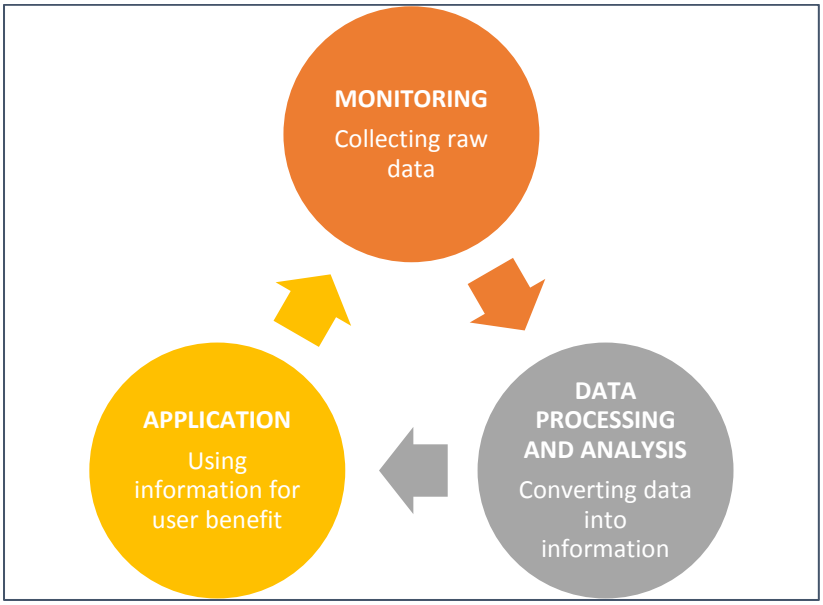
FURTHER READING

SectionA: A strategic approach to monitoring

Justifying investment in monitoring

Data is collected not for its own sake, but rather to provide information to support management decisions. The collection of data should not be divorced from its subsequent application and data collection activities should be driven by the needs of end users, not the other way round. In practice, this should be a cyclical process, whereby the user reacts to information provided by the monitoring programme, and the monitoring programme evolves in response changing user needs (Figure 1).

Figure 1 The evidence cycle



Ultimately, decisions about monitoring strategy should be informed by a cost-benefit analysis to determine whether the benefits accruing from the information that is generated outweigh the costs of gathering, transmitting, storing, managing, processing, and interpreting the data. When viewed in this way, the central question shifts from “Can I afford to monitor?” to “Can I afford not to monitor?”.

In most cases, the costs of implementing a specified programme of monitoring can be calculated or reliably estimated; the main challenge is, therefore, to quantify and monetise the benefits of monitoring. These benefits can usefully be thought of in terms of reducing the risk of undesirable and costly outcomes.

Using monitoring to manage risk

Risk – the potential to lose something of value – is commonly thought of in terms of the ***likelihood*** that something might happen multiplied by the ***consequence*** of that event happening.

Monitoring is one way of gathering evidence that allows individuals, communities and organisations to devise and implement measures that reduce the likelihood or consequence of undesirable outcomes. In the context of natural resource management, monitoring is used to help prevent or reverse negative

human impacts on the environment, so yielding economic and social (health and wellbeing) benefits. Monitoring can also yield financial benefits by helping to ensure that investments in natural resource management are effective and efficient. Table 2 provides some examples of the benefits that can accrue from monitoring activities.

Table 2 Benefits accruing from environmental monitoring

Reason for monitoring	Consequence of not monitoring	Benefit of monitoring
Monitoring is a statutory requirement	Imposition of penalty (fine, infraction) or other regulatory sanction if monitoring is not undertaken	Avoided penalty/sanction
To provide public information (e.g. bathing water sampling)	Bathers cannot take informed decision about where to swim, leading to human health impact	Reduced incidence of illness
To judge whether water quality or environmental status is compliant with relevant standards (e.g. WFD EQSs)	No knowledge of where environmental degradation is occurring so unable to implement a targeted management response (i.e. unnecessary investment in same areas; absence of investment in others)	Natural resources are protected only where necessary; efficient use of limited resources
To know whether or not natural resources are deteriorating (e.g. climate change warming of rivers)	Inability to implement timely management intervention; natural resources are degraded; more expensive interventions are needed later on	Natural resources are protected through timely and cost-effective mitigation measures
To evaluate the impact of management interventions (e.g. Glastir)	Risk of persisting with a policy/initiative that is failing to deliver the required level of improvement, or of failing to invest further in an effective policy/initiative	Effective and efficient use of limited resources

The recognition that monitoring can contribute to the management and reduction of risk leads naturally to to a ***risk-based approach***, whereby greater investment in monitoring is justified in situations where the risks, and therefore benefits/ or avoided costs, are highest.

Quantifying the performance of a monitoring programme

Data gathered from a monitoring programme is typically used to estimate a parameter, or calculate the value of an indicator or other derived metric. But because we cannot sample everywhere all of the time, and because people and equipment are less than perfect, there will almost always be some sampling error and measurement error. These errors mean that our calculated value is only an ***estimate*** of the true value; how close we are likely to be can be quantified by constructing a ***confidence interval*** around the estimate. The wider the confidence interval, the less ***precise*** (more uncertain) is the result.

Often, these statistics are subsequently used to, for example, assess compliance against a standard, make comparisons between sites, or to test whether there has been an improvement or deterioration over time. All these applications all involve some form of ***hypothesis testing***, in which the available data is used to decide which of two mutually exclusive (null and alternative) hypotheses is true. In the case of compliance assessment, for instance, the available data are used to determine whether or not the system being

monitored is complying with the required standard. Attempting to discern the truth with imperfect information leads to two possible types of error:

- a ***Type I error*** of wrongly rejecting the null hypothesis – that is, thinking we've found something interesting when it is actually just due to chance (e.g. a false alarm); and

- a ***Type II error*** of failing to reject the null hypothesis when we ought to have done – that is, concluding that an apparent effect could just be due to chance when actually it was genuine (e.g.. failing to detect non-compliance).

These contrasting errors are illustrated in Figure 2. The ability, or ***power***, of a monitoring programme to detect a genuine effect (e.g. a change, difference, or non-compliance) is the inverse of the Type II error rate and it depends, amongst other things, on the level of confidence required and the amount of monitoring data available for analysis.

Figure 2 *Type I and Type II errors associated with scientific hypothesis testing*

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">True situation in population</td></tr>
<tr><td>Null hypothesis is true</td><td>Null hypothesis is false</td></tr>
<tr><td rowspan="2">Conclusion reached on basis of monitoring data</td><td>Accept null hypothesis</td><td>✓</td><td>Type II error (β)</td></tr>
<tr><td>Reject null hypothesis</td><td>Type I error (α)</td><td>✓</td></tr>
</table>

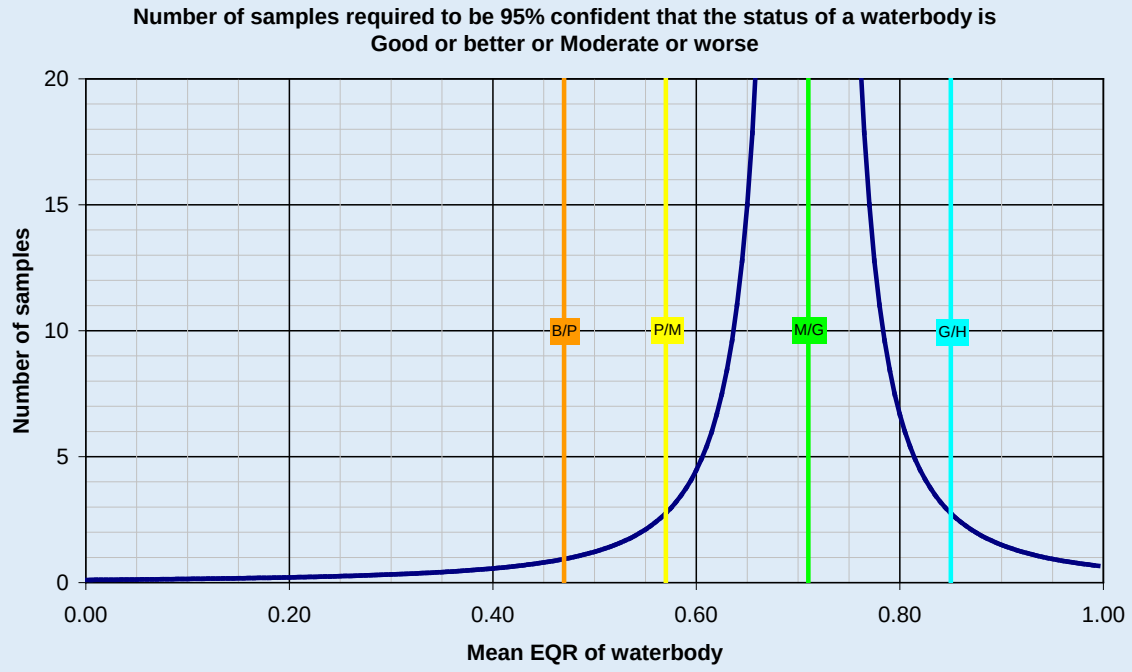
Developing a monitoring strategy therefore requires decisions to be taken about that level of risk is acceptable, and trade-offs need to be made between risk and cost.

FURTHER READING

Section B: Case studies

Case Study 1: Optimising the Water Framework Directive operational monitoring programme in England

The Environment Agency's operational monitoring network is used to assess biological and physico-chemical status of rivers under the Water Framework Directive. Data from the network was analysed by WRc to quantify the typical level of temporal and spatial (between-site) variation and, in turn, to calculate the minimum number of sites / samples required to limit to 5% the risk of mis-classifying a water body as Good or better, or Moderate or worse status. Statistical rules were then developed as part of a decision support system to identify opportunities to reduce the level of monitoring effort without compromising the evidence base for implementing programmes of measures.

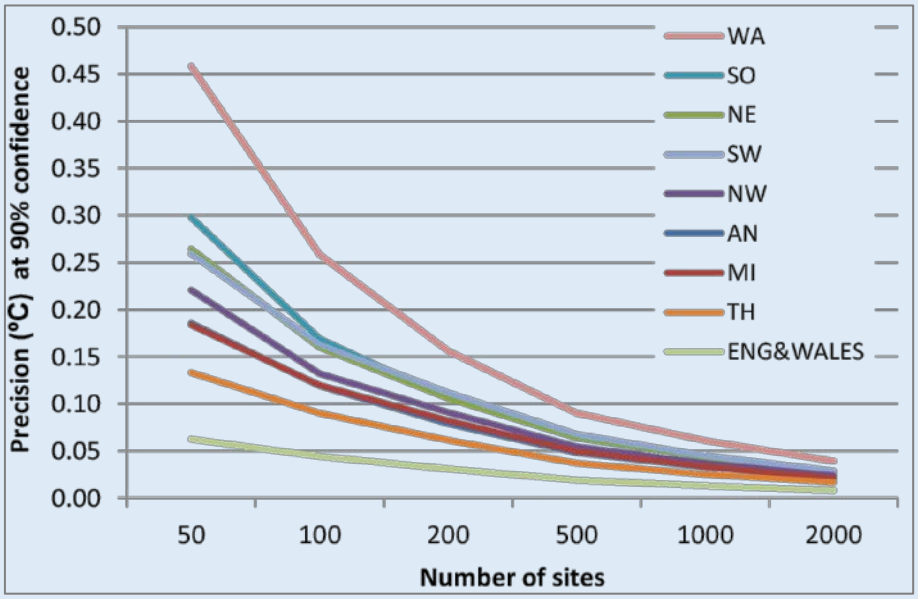


Case Study 2: Designing a dedicated river water temperature monitoring network for England and Wales

Climate change is predicted to lead to warmer air and river temperatures which, in turn, will influence stream chemistry and the health of freshwater plants and animals. Historically, the Environment Agency (EA) has monitored river water temperature in an *ad hoc* fashion, primarily as a by-product of routine water quality monitoring, but this approach is not adequate for reliably measuring the impact of climate change. A study was therefore undertaken by WRc to design a dedicated water temperature monitoring network to provide a national indicator of change in river water temperature.

Statistical analysis of archived time series data revealed that:

- At individual monitoring sites, spot sampling can be expected to reliably detect only major changes in mean temperature over long time (30+ years) periods; continuous (daily) monitoring is therefore necessary to quantify the magnitude of temperature change with a reasonable level of precision and confidence.
- Over a 10 year period, the national average rate of temperature change can be estimated to within ±0.03 ºC/decade with 95% confidence using a stratified sample of 200 monthly spot sampling sites or 110 continuous monitoring sites.



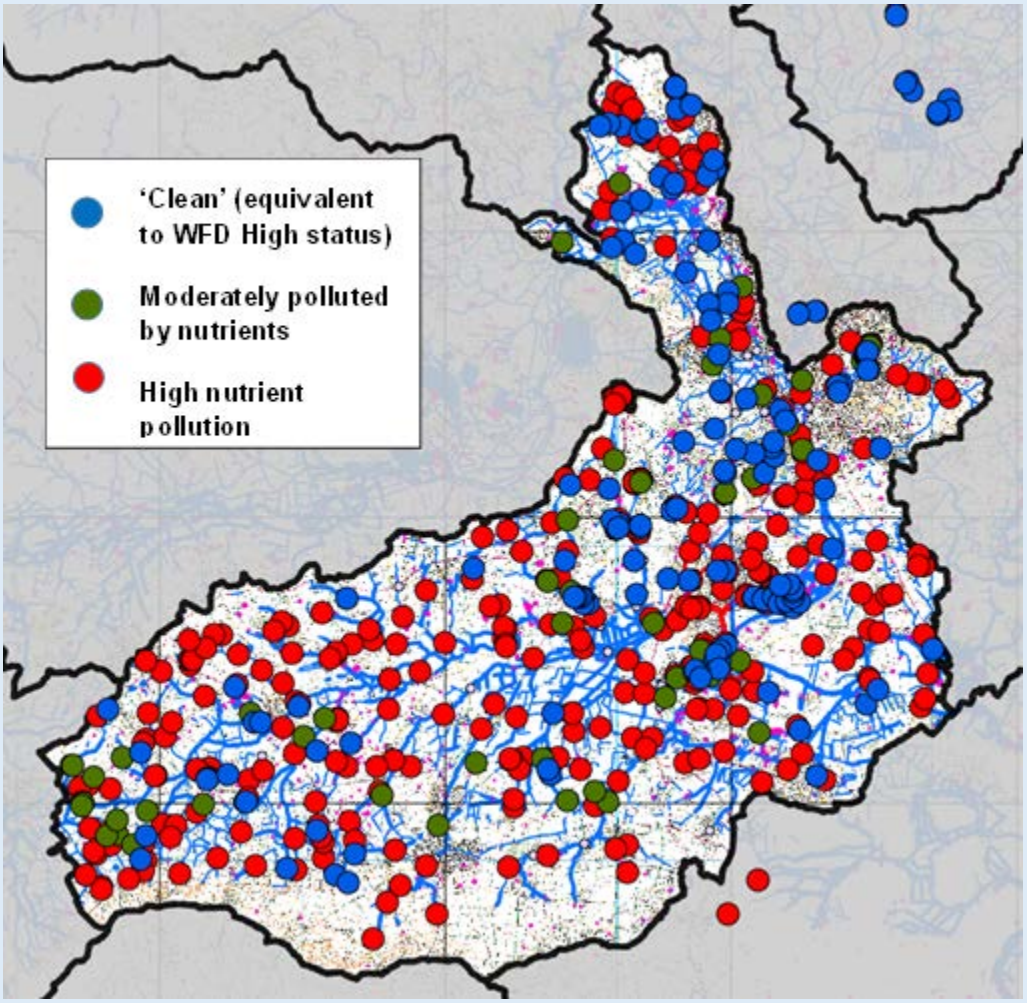
Case study 3: Integrating hydrological and ecological data to assess the impact of abstraction

The Environment Agency uses a range of methods to assess the impact of abstractions on aquatic ecology, but the complex interplay between multiple pressures combined with limited information makes it difficult to regulate licenced abstractions in a fair and consistent manner. In 2015, the EA undertook to formalise the process of combining hydrological data, ecological data, expert knowledge and other available data into a coherent method that would allow clear, consistent and justified decisions to be made when reviewing existing abstraction licences. WRc and APEM reviewed a variety of weight of evidence methods to assess their ability to support risk-based decision making using diverse and variable information, and established a framework for assessing the weight of evidence on a case by case basis.

Case study 4: River Ock citizen-based water quality survey

In April 2016, Freshwater Habitats Trust organised a citizen-based survey of nitrate and phosphate levels on 570 sites (ponds, lakes, streams, rivers, ditches, fens) in the catchment of the River Ock, Oxfordshire, as part of the Clean Water for Wildlife project. This was slightly more than 1 waterbody per km^2 in this 470 km^2 catchment. Most sites are not currently monitored.

The kits were successfully able to separate 'clean' water (i.e. those at 'High' status under WFD) from more polluted waters. Nearly a third of sites were 'clean', predominantly ponds and lakes, with some streams and ditches. Most running waters experienced substantial nitrate or phosphate pollution.
The data are now contributing to a range of practical projects. A detailed technical manual for the use of rapid test kits will be published at the end of June.



Appendix J
Briefing pager – Emergency Response

Requirements and opportunities for Emergency Response in an integrated national monitoring programme

Havard Prosser

With contributions from Kate Bollington (NRW), Martin Williams (WG), Chris Jones (NRW), and Catherine Duigan (NRW)

July 2016

Rationale

The Civil Contingencies Act 2004 defines an emergency as a situation or series of events that threatens or causes serious damage to human welfare, the environment, or security. In most cases the response to emergencies will be conducted at a local level by local responders, usually the emergency services, local authorities, health bodies and government agencies. These are termed Category 1 responders. The Police Service usually has the lead role in managing the immediate emergency response, although other agencies can take the lead, depending on the type of emergency. In the recovery phase the lead responsibility is normally formally transferred to the agency with the most significant role.

Category One responders such as NRW have four main duties under the Act:

- risk assessment;
- emergency planning;
- business continuity management;
- maintaining public awareness and arrangements to warn, inform and advise the public.

During the recovery phase, NRW's role is to advise and support the multi-agency effort, and to perform our regulatory duties.

These arrangements operate for local incidents, but for the most severe emergencies a co-ordinated combined government response may be essential. The Pan-Wales Response Plan[8] sets out arrangements for the way that this response is implemented. The Wales Civil Contingency Group decides on whether the Plan is initiated.

[8] *Pan-Wales Response Plan. Wales Resilience Forum, September 2014*

The primary source of scientific and technical advice for is provided by the government agencies working within the response team. The STAC (Scientific Technical Advisory Cell) advises on the monitoring requirements - both immediate and long term. An Air Quality Cell is a pre-established STAC specifically for responding to air quality emergencies. At the UK level via COBR, the Scientific Advisory Group for Emergencies (SAGE) is responsible for coordinating scientific and technical advice.

Objectives of Environmental Monitoring

Environmental monitoring is an integral part of emergency response to incidents involving releases of materials, chemicals or radioactivity to the environment. Environmental monitoring is essential to assess the impacts of an incident and needs to cover the main media – air, water, soil, vegetation and the food chain The monitoring data aids the implementation of counter-measures, and post-incident recovery plans.

Monitoring has four main objectives

1. The most urgent need is for assessment of the impacts of an incident – whether man-made or natural – on public health. The public health focus is on assessing contaminant levels, and the resulting intake of these contaminants to humans. This needs to consider both short-term exposure and chronic longer-term exposure. The human population is not homogenous, so exposure must be considered for groups characterised by age, diet types, and lifestyle. For example radiological protection is based on the EU Basic Safety Standards Directive, which requires assessment of the doses to members of the most highly exposed population groups ('critical' groups) from all relevant potential sources of anthropogenic radioactivity and all relevant potential exposure pathways to such radioactivity.
2. Environmental monitoring helps to inform risk reduction plans, which may include removing target groups of people and animals to areas where they are less exposed, or introducing protection measures to reduce exposure. For example iodate tablets can be issued to people most directly exposed to radioactivity.
3. Monitoring is necessary to assess the impacts on the natural environment. For example, an oil pollution incident often has most impact on birds, fish and shellfish. Studies are important if the emergency affects a nature designated area e.g. SAC
4. Following the immediate assessment of impacts of an incident, monitoring has an essential role in tracking the recovery of systems to the baseline levels of contamination, state of health and population. This requires environmental monitoring information on baseline levels.

Key Components of National Monitoring for Emergency Response.

For a national monitoring programme to maximize its value for emergency response, the main requirements are

1. Modeling expertise using meteorological data and dispersion models to assess direction of pollutant plume and likely pathway of dispersion/deposition. Fate of pollutants also need to be considered. This informs immediate counter-measures to protect the public, either by moving them, or installing protection measures.
2. Modelling also facilitates planning of the monitoring network to target the most exposed areas, and to provide preliminary assessment of sensitive receptors. The assessment helps to decide on immediate ways to protect sensitive receptors,

3. Based on the monitoring plan, provision of adequate trained resources to sample the environment – if possible before the incident reaches the environment, and subsequently. Sampling should be to agreed standards/protocols, with effective health and safety protection.
4. Deployment of continuous monitoring equipment for analysis of contaminant levels – particularly important for air and water. Analysis is to agreed protocols.
5. Accredited laboratory facilities for sample preparation and analysis of collected samples
6. Data analysis including validation of predicted model behaviour of the releases based on baseline monitoring data
7. Public health expertise to assess exposure of the population and sensitive sub-groups most likely to be exposed, in relation to standards for concentrations and exposure levels. This aids planning of counter measures

Current Environmental Monitoring Facilities for Immediate Response

After an incident, the monitoring priorities are to assess human exposure from pollutants via the following pathways:

- By inhalation from the air directly or from deposited materials which are resuspended
- By consumption of drinking water
- By consumption of freshly collected vegetables exposed to the atmosphere
- By consumption of milk from grazing animals
- By consumption of eggs from free-range poultry
- By consumption of fish and shellfish

Facilities that are available for monitoring and modelling these pathways are the following.

<u>Air</u>
UK RIMNET gamma monitors for radioactivity
UK Automatic Urban and Rural Monitoring Network
UK PAH and Toxic Organic Micro Pollutants Network
UK Eutrophying and Acidifying Pollutants Network (allows samples to be collected for a range of deposited materials)
UK heavy metals network
Wales local authority and NRW monitoring equipment. Continuous monitoring sites mainly in urban authorities. Results available from Wales Air Quality Forum.
EA/NRW Mobile Monitoring Facility for NO_2, SO_2, PM_{10}, $PM_{2.5}$ & CO
Mobile monitoring equipment from consultants
EA/NRW and consultants for air quality modelling

<u>Drinking Water</u>
Water companies are responsible for monitoring the quality of public water supplies, under the regulation of the Drinking Water Inspectorate. Private water supplies are common in rural areas and local authorities have a risk-based sample monitoring programme. In the case of an incident, the monitoring programme would need to be intensified. Provision of adequate resources for sampling and analytical facilities is a potential gap. At the time of the Foot and Mouth epidemic, a private contractor was used to monitor private water supplies around Epynt.

<u>Vegetables, Milk, Eggs, Fish and Shellfish</u>

Food Standards Agency (FSA) has responsibility for monitoring foods. In practice, WG field officers help in sample collection. Analysis is carried out by accredited laboratories contracted by FSA. At the time of the Foot and Mouth disease outbreak in 2011, FSA analysed dioxin and PCB contents of a range of foods because of concerns about contamination from animal pyres.

FSA carries out a routine monitoring programme around UK nuclear sites. Monitoring is done by FSA and NRW in Wales. Reports on Radioactivity in Food and the Environment are published annually by FSA and the environment agencies.

Current Environmental Monitoring Facilities for Monitoring Natural Environment and Recovery Phase

Monitoring of the recovery phase is needed mainly to assess effectiveness of recovery interventions to the baseline state. This work focuses on monitoring herbage, soils, fresh waters, marine waters, and biota most likely to be affected by dispersion and deposition. Sampling requires adequate expertise provided by NRMF partners to comply with protocols.

The UK Soil and Herbage Pollutant Survey[9] completed in 2007 by EA provides the most comprehensive baseline survey. Samples of soil and herbage taken from 122 rural, 28 urban and 50 industrial locations were analysed for metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and dioxins. Analysis was done by FERA. The Survey published sampling and analytical protocols for reference.

Freshwaters and marine waters are monitored by NRW to assess compliance with the Water Framework Directive. In the case of an emergency, sampling and analytical facilities would need to be diverted from routine monitoring programmes.

Monitoring of impacts on biota is monitored by NRW where incidents affect sites designated under the Habitats and Birds Directives. Impacts on SSSIs also need assessment. Analysis of aquatic species helps to understand the impacts on food-webs for fish and birds. Marine areas are particularly sensitive to oil pollution.

Opportunities

The NRMF has a potential role for coordinating sampling and analysis, and data interpretation in support of the Category 1 responders to an emergency. The Framework could support the role of NRW as a Category 1 responder, and aid Welsh Government is overseeing the recovery phase of an emergency. The role of the NRMF in the Science and Technical Advice would need further consideration.

[9] *UK Soil and Herbage Pollutants Survey SC000027, Environment Agency 2007*

Appendix K
Briefing pager – Data & Informatics

Requirements and Opportunities for Data and Informatics in an Integrated National Monitoring Programme

Peter Henrys (CEH), Colin Chapman (WG), Stuart Neil (WG), Paul Guest (WG), Barnaby Letheren (NRW), David Chadwick (Bangor University), Gavin Siriwardena (BTO)
July 2016

For any future monitoring programme it is important to have a clear and comprehensive strategy to steer the collection, management, use and dissemination of its data, information and evidence.

Rationale
The Welsh Government recognises the value of the data and information collected and used within environmental monitoring programmes. Increasing the accessibility of data and evidence and encouraging its re-use can lead to improvements in efficiency, promote transparency and dialogue and raise the level of quality of a shared environmental evidence base. This can also lead to novel uses and give individuals and organisations the ability to access the data and combine it with other data sources in new ways. The Welsh Government's Open Data Plan sets out its commitment to publish data, where it is appropriate to do so, under the Open Government Licence (OGL) and make it accessible to as wide an audience as possible without restriction. In addition to this, it is acknowledged that to fully understand and report on key aspects of the environment, there is a growing need for integrated data analysis. These key issues of openness of data and data integration highlight the need for a formalised approach to data and informatics within any future natural resources monitoring programme.

The complexity and high data requirement of a Natural Resource Management monitoring programme requires a clear strategy sensitive to the diverse nature of the content, quality and ownership of datasets in order to maximise appropriate usage and exploit the possibilities of data sharing and integration. A number of key themes must be considered when developing an appropriate strategy. These include:

1. Data strategy and governance
2. Appropriate consideration and management of data accessibility
3. Utilise and promote existing Data standards
4. Preserve and expose auditability and provenance of evidence
5. Make use of data capture technologies

1. Data strategy and governance

Before any monitoring takes place it is important to define the strategy and governance arrangements for capturing, storing, managing, quality controlling, disseminating and using

the data. This will include considerations such as data flow, ownership, access permissions, roles and responsibilities, policies and procedures, retention etc. Fundamental to this is clearly defining the purpose of the monitoring and the expected use of the data and information gathered. In other words, being clear about the question that the monitoring is designed to answer.

2. Data Accessibility

Wherever it is practicable and appropriate, a future national monitoring programme would aim to make datasets and data products available for re-use in an appropriate format. However there are a range of situations where data may not be publishable without restriction. For example, there are many data sets that have usage restrictions that legally must be adhered to due to regulation, confidentiality, licensing or compliance and they often have very different constraints that impact their use. It is therefore important to consider these separately and for each case to be assessed in its own right. For some, usage restriction limits the ability to disseminate derived outputs, whereas for others restrictions can be such that the raw data itself is concealed and is only available for analysis in an aggregated form. Such data sets, however, can often be central to analyses that underpin the evidence base one wishes to present. It is therefore important that, whilst usage restrictions are maintained, the potential of the data is maximised and that evidence is not compromised. As an example, it may be necessary for a particular data set to be hosted by a particular institution and copies cannot be shared. The data, however, is needed for integrated analyses and provides key evidence in its own right, as such it is important that any natural resources report utilises this data. In such cases consideration will be needed to make metadata available so that the data can be identified and information about how to access the data and the appropriate restrictions are clear.

3. Data standards

To maximise the reuse of data and to understand the potential of integrating data together, certain standards should be adhered to. Standards are created so that attributes and associated meta-data of data sets are exposed and an understanding of the underlying data structure is made as simple as possible and common across different sources. An example of such data standards is the EU INSPIRE Directive, which Welsh Government is committed to implement by 2019. This directive aims to enhance the sharing of environmental spatial information and better facilitate public access to spatial information. Data standards are also used to ensure consistency across data, which can be crucial for integrated analyses or presentation of evidence across multiple data layers. Both geographic and temporal consistencies, as well as consistency of terminology, measurements and data tags via the use of controlled ontologies and thesauruses can be particularly important. There are existing examples of good use of data standards within environmental science, thesauruses established and ontologies published (e.g. Darwin Core) that should be used wherever possible. When designing any new monitoring activity or data collection task, the data collection should consider how the data will be archived and what associated meta-data is required. This can lead to efficiencies in post processing. Sorting primary data and metadata into the correct formats for archiving can take a huge amount of time post collection, so careful planning is needed to avoid this.

The challenge of controlling data standards is intensified with third party data sets that are used in integrated analyses or to supplement the evidence base. For these “independent” data sets it may be ok to insist on minimum data quality limits, but to insist on or to

encourage changes in practices by external organizations would require funding and could be expensive. Ultimately, good communication across data providers is key to understanding where compromise is needed and where strict codes of practice are needed.

4. Auditability and Provenance

When assessing the suitability of data for a particular use or presenting evidence, it is important that the quality of the evidence can be assessed in a systematic fashion. A key element of evidence quality is having a clear audit trail such that it can be traced back to the point of data collection. This requires exposing the workflow and data sets that contributed to the evidence. If this is clearly described in associated meta-data, then the user has an increased confidence in the evidence presented. In this sense, the provenance of data or evidence links back to data standards. Further, if derived output and evidence is tested and challenged by comparison against existing models, expert knowledge, controlled studies or published research, then confidence in the product is increased and robustness satisfied. Based on these principles, sufficient resource should be allocated to support conversion of data into robust evidence products.

It is also important that a publishing workflow is established and potentially presented with any dataset. For example what checks were made on the data to ensure it was appropriate for publication before being signed off for public dissemination. These checks would typically include quality assessment, and environmental or legal sensitivity. Critical to this is the transparent recording of data characteristics, which allow appropriate controls and caveats to be applied to the raw data. In such circumstances, it is better to provide sound outputs in which such caveats have already been taken into account with the link back to the raw data made clear.

5. Data Capture

Over the last 10-20 years there have been huge gains made in the field of informatics relating to data capture. A driving principle behind much of the development has been to find increased efficiencies via a reduction in any post-processing and improved data quality. This has led to an increasing move towards electronic data capture, whereby surveyors themselves input the data either out in the field via computer software or post-hoc via web-based forms. There are many examples of such systems in place in environmental recording each with varying degrees of success. One particular example of this move to electronic data capture was the 2007 Countryside Survey, where a GIS oriented solution was adopted utilising both a strong database design and capture software facility. It was estimated that the move to electronic data capture saved the survey in excess of £700,000. The Breeding Bird Survey also successfully utilises a system of web forms to allow the participants to fill in their own records online. This has helped improve data standards and reduce post-processing of paper-based data entry.

An important issue to consider is how further development of data capture technology can be used to provide additional efficiencies and improve data quality. One consideration may be the use of open source software for field data collection that can be shared across providers and modified accordingly. An existing example of which is the COBWEB project that provides a facility to easily generate mobile apps for environmental citizen science. Another consideration for increased efficiencies may be to align the data collection initiatives directly with the database formats. An additional consideration may be whether the same software application could be used across professional surveyors, volunteers and across different environmental domains. Using existing data and/or reference data to

suggest confidence is also an area of great potential. Ultimately, the pros and cons of each system should be considered specific to the monitoring activity in question. As an example, one may consider the pros and cons of using open source GIS software such as QGIS or proprietary software such as ESRI ArcGIS for spatial mapping of habitats. In this instance, whilst the free open source QGIS solution offers much the same user functionality as the paid-for ESRI product and provides an easier basis on which to develop bespoke software extensions, the back-end database solution provided by ESRI offers significant advantages in terms of data storage, structure and accessibility. Further, one can expect maintenance and stability in paid-for software as well as a managed program of updates from one version to another, which can be of critical importance for sensitive environmental data. Hence it is important to fully consider the pros and cons of any data capture system prior to deployment and to take advantage of any previous investment.

In many cases base maps and spatial reference aids such as GPS are used to aid data collection and have provided a significant improvement in data capture over recent years. In some situations open base mapping datasets (such as Open Street Map or Welsh Government's Digital Aerial Imagery) or the use of location enabled data recording devices (e.g. via GPS) can be used to reduce reliance on heavily restricted base mapping products such as Ordnance Survey Mastermap which can hinder wider publication and data sharing. Care must be taken though to ensure that use of different reference datasets does not impede data integration.

Current Initiatives

There are many examples of current applications that present evidence or provide a window to available data. Data catalogues such as lle.gov.wales, catalogue.ceh.ac.uk and data.gov.uk and evidence portals such as the NBN gateway, GMEP reporting portal, UKSO, StatsWales and the future Atlas of Living Wales all provide clear examples that should be utilised wherever possible rather than re-inventing the wheel. Ongoing national and international activities should be exploited where possible and lessons learnt from past experiences. Though the operational functionality of data storage, archiving and tagging of data and the dissemination of key results and summaries are very different, it is important that they are not viewed in isolation.

Relationship with new technologies considered as part of the future monitoring programme

The use of emerging technologies within a monitoring context provide additional opportunities and challenges from a data and informatics perspective. Most notably, many new initiatives collect vast volumes of data and often require a considerable amount of processing prior to analysis. In addition to this, coordination of data capture and adherence to strict data collection protocols and consistency across observations must be maintained.

The use of citizen science to aid data collection introduces a particular set of considerations with regard to data capture and protocols. To save post-processing time and to ensure consistency across the volunteers it is important that some central coordination effort is in place and that data collection exercises are suitable for non-professional surveyors in order to minimise errors and increase efficiencies. Using electronic data capture technologies can help with this. There are current examples already in place such as the iRecord suite of mobile applications used by many biological recording societies and the web-form system used by the BTO for the Breeding Bird Survey. There are also additional open source smart phone apps that could be easily configured to record environmental information, for example COBWEB, Fieldtrip GB and EpiCollect+.

The use of eDNA approaches in environmental monitoring produce a large amount of data that are processed and condensed into environmental indicators of interest. The raw data itself is then of little use except for re-analysis. The issues then centre around how and where the vast quantity of raw data are held. It is important to ensure these new data resources are kept and managed accordingly for data citation, retention period etc.

Finally, the use of EO data requires a considerable amount of processing and storage which can be a challenge to computing infrastructures. For example the 2007 Land Cover Map classified over 8.6 million land parcels. There are, however, EO strategies and commitments in place across the political and administrative spectrum where such considerations are already being addressed (eg Defra CoE). The underlying principle of developing EO as a new technology for Government, including related informatics activity, is therefore through collaboration.

Future Potential

The complexities involved in developing an effective informatics strategy, as listed above, are such that a collaborative approach will be necessary to ensure that all data issues are fully captured. As such, any future monitoring programme should have a data and informatics coordination board to oversee this strategy and to increase the sharing of data and evidence.

In the short term, the emphasis should be focussed on understanding current developments in this area across Welsh Government (and potentially wider) to avoid duplication of effort and to consolidate existing activity. Efforts could concentrate on existing data catalogues such as Lle and data.gov.uk to understand how these could be exploited further and contribute to a future natural resources gateway. As an example, any current environmental data sets that are available via data.gov.uk that could be utilised in a future monitoring programme should be exposed. Utilising existing catalogues ensures that data already conform to certain data standards and hence achieving consistency. Ensuring robustness and consistency across data and evidence should be a clear priority in the short term. The consistency may be in the way that data is stored (eg same file formats), the way that data is collected, the way that data is described (eg species nomenclature) or the way that data is analysed. The robustness of data and evidence may relate to the auditability of the product or whether any conclusions have been challenged via, for example, multiple modelling approaches or expert opinion, to validate inference potentially used in decision making. The goal should be to provide a clear benchmark and guidance for all data providers and analysts for sharing of data and evidence. The key will then be to establish where the data should reside and be disseminated in the long term, for example should biodiversity data go to the NBN.

In the longer term the aim should be to have a single gateway for all Welsh environmental data and evidence. This may cover certain elements of raw data, summary data or the presentation of robust evidence products. This “hub” should provide a window to data products and evidence without necessarily being the one place where all data is stored. Evidence and data may, and in many cases should, exist on other platforms that make the most of existing infrastructures. Some data may be directly accessible, whereas for other data all that is available is a meta-data record and link to a third party site. Similarly for evidence, whilst all available evidence should be clearly presented it may be that this is drawn from 3rd party sites via the use of web services such as WMS for displaying national maps. In reality, this gateway may represent a simple landing page from which other archives and infrastructures can be accessed – building on these existing initiatives will bring the biggest efficiency savings. This would enable clear distinction between raw data and summary results, but provide a single port of call for environmental information across Wales.

Aside from these future priorities, it is perhaps important to recognise that whilst such development can provide efficiency savings a significant amount of resource is required to maintain and develop the infrastructure required. Currently there is precious little infrastructure or skill to manage, analyse and synthesise domain specific data. A significant proportion of resource available should be ring fenced for data and informatics to underpin data coordination and sharing activities, analysis and interpretation both to the end user community and across organisations. It is therefore important to acknowledge the possibility of sharing the available funding resources for this management activity between organizations that may contribute external data sets. An alternative consideration could be that the raw data management and access is outsourced, but consideration would have to be made as to whether this was sustainable or desirable.

Ultimately, it is well recognised now that a well thought out and well-resourced approach to data and informatics can lead to significant efficiencies, increased use of and recycling of data and better engagement with policy makers and public via dissemination mechanisms.

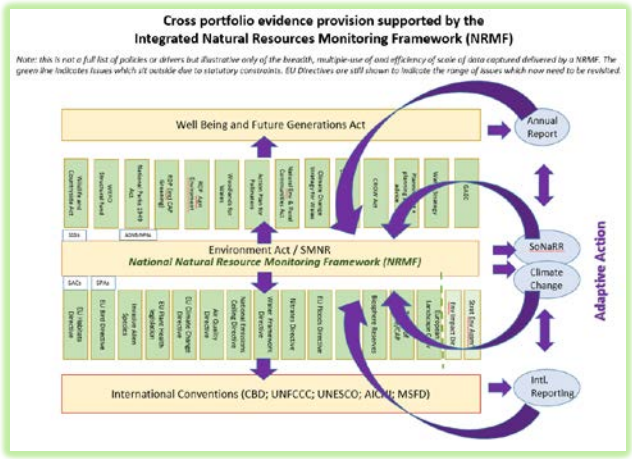
Appendix L1
Stakeholder Workshop 3 Summary

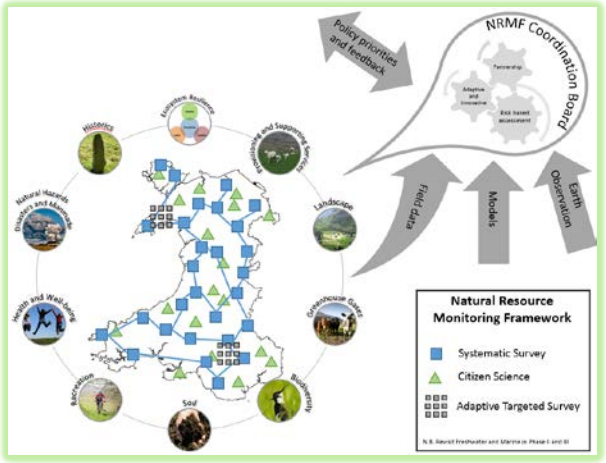
"In a Nutshell" – Comments on the Draft Recommendations (High-Level)
(from the Future Options Stakeholder Workshop #3, 22 June 2016, Llandinam, Powys)

- ✓ Broad agreement. "Devil is in the detail" but this is an ambitious but worthwhile vision that, done right, will be good for Wales.

- ✓ Changes made to diagrams to show feedbacks in policy interrelationships and influence of policy priorities to inform actions in an adaptive approach. Change in bubbles to reflect the 10 evidence categories agreed in Workshop 1 (with the addition of marine and freshwater to capture Phase II and III).

  Revised *(policy diagram also amended in light of EU referendum result):*





- ✓ Write in plain language. The order of recommendations to be changed. There might be a 'vision statement' or something similar. There hasn't been enough time - but progress has been impressive.

- ✓ Ensure customers are recognised as being both inside Wales and outside (UK and International).

- ✓ Change 'risk-based' to 'adaptive' to reflect wording in legislation

- ✓ 'Standard methods' needs to have some flexibility to capture different purposes.

- ✓ Limited resources – have to do more with less (or at least, the same with less). NRMF will build capacity across broad range of needs.

- ✓ We need to be innovative about funding, seek co-funding and develop novel products/solutions working with industry.

- ✓ Use the word ‘rebalance’ rather than ‘adequate’ with respect to resources.
- ✓ Not just WG & NRW – many other partners, many needs. Broad church.
- ✓ Be clear about timescales and the ambition of these recommendations. Plan clear, practical, step-by-step advances.
- ✓ NRMF cannot do everything but will have an international view (best practices/common needs/common data) and be cognisant, but not prescriptive, of local needs (monitoring, procedure, resources, data-management, etc.).
- ✓ Data access/sharing will have to be limited in some cases due to legal restrictions. But when not restricted, open data principles will be followed. Acknowledgement that meta-data will be very important. Risks of inappropriate use in rush for cost-saving.
- ✓ Specific support for Recommendation which stated that data and informatics is important enough for a separate subgroup of the Coordination Board (data management, meta-data, accuracy, right-data, right-time, right-place, use of technologies, data access, pros and cons of freeware/software explored etc).
- ✓ Need a recommendation about engagement. **Fixed**: Recommendation #11 (number will change): *“Encourage activities to increase awareness and appreciation of the fundamental importance of Wales’ natural resources to its green economy and well-being of future generations. This could include some citizen science activities which are primarily aimed towards this outcome rather than the delivery of robust evidence products”*
- ✓ Need some detail about the process under which board should operate. This will follow when broad recommendations are agreed and advance further. Needs serious thought. Certainly the Coordination Board will need to respond to a variety of policy, reporting, user, legal, community and economic demands. They will also need to identify metrics to identify progress and ensure an ongoing improvement plan.

Appendix L2
Stakeholder Workshop 3 – Benefit Realisation and Risk Summary

Facilitated breakout-groups were conducted during the third stakeholder workshop event (22nd June2016). The objective being to gather the comments, suggestions and thoughts of the stakeholder community on the risks and benefits of each of the recommendations as presented.

The groups were specifically asked to consider benefits in two parts – the 'what' and the 'who'. And in an effort (even at this early stage) to work toward practical and achievable implementations, the groups were asked to list possible *measureable characteristics* (metrics) that could be used to assess the success of each recommendation.

A summary of the outputs of this working session is presented below.

Note that since the wording and ordering of the recommendations have evolved since the date of this meeting both the current and original wording of the recommendations are shown for context. Although the texts have developed, we believe the core observations of the stakeholder group to each of the recommendations remains valid and valuable and has provided an input to the thoughts further presented in the main report on implementation, options, benefits and risks.

Recommendation 1: Develop a co-owned and co-funded Natural Resources Monitoring Framework (NRMF) to integrate evidence at the landscape scale. This should adopt an adaptive approach which is responsive to policy priorities and emerging risks and pressures whilst maintaining a systematic evidence base of change in stock and condition in the wider countryside. This will increase cost-benefits

The text as reviewed in Workshop 3: "1. Cost-benefits should be realised through the development of a co-owned and co-funded Natural Resources Monitoring Framework (NRMF) informed by a risk-based approach."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				• Set up costs could be higher but with operating costs less. Cost benefit improved, not just costs • Benefits of delivery, not just costs. Cost savings from cofounding approach. Benefits in terms of filling current resources gap for monitoring. Benefits in data analysis eg trend analysis • In short terms, costs could be higher. But not in longer term. Prototyping is important to reduce start-up costs. There are also costs of getting it wrong. Benefits can come from

				avoiding mistakes of not having a framework. New methods may also incur costs • Much depends on Coordination Board taking hard decisions on what to stop or re-target. Timing important to achieve cost reductions. Opportunities exist to enhance benefits • Cost reduction is the important benefit. May need resources to start with but in medium- to long term – costs should reduce. May need pilot to start it off. Opens doors to getting additional funds from other organisations
More efficient and integrated reporting				•
Policy (development and evidence)				• A wider base • Yes, it would help build confidence by sharing data interpretation, where an evidence vacuum often exists • Provides a focus for questioning on policy options, and should help policy lead to focus. Should help to provide evidence of how policies are working and where changes are required
Robustness				• If approaches are consistent • since conclusions are based on wider range of evidence and interpretation • need to ensure a better platform for challenge. Transparency could increase too, Could lose robustness because of compromises on standards • risk based approach should help
Adaptability / Responsiveness				• Care required that a larger project does not reduce agility with too standardised an approach • Could be more or less depending on how effective is the Coordination Board • It may be harder to be flexible, governance must be good
Collaborative working				• Yes, much depends on how well the Coordination Group works
Reputation and presentation				• Reputation can be increased by a systematic, coherent approach • A big plus, since reputation of the data and interpretation should be enhanced • if every participant supports it and there is transparency or operation
Well-being				• It will support WBFG Act • Should provide a richer narrative at a local level. Important for Public Service Boards
Capacity building				• Growing skills in Wales • Depending on buy-in by participating organisations

Data sharing / collect once use often				• If done right
increasing innovation				• Particularly with access to external funds or collaborative projects with other UK/EU partners

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes
WG				
NRW				
3rd Sector				• Yes it would help the sector to get funding if seen that proposals have Govt support, sector has lot of experience to contribute in return, but risks in achieving delivery
Community as a whole				•
Funders				• Maybe but depends on aligning with funder priorities
Future generations				• Supports WBFG Act • should provide a richer narrative at a local level. Important for Public Service Boards
Private Sector				• might use the data e.g for EIA for development projects • Utilities via partnership for catchment management schemes. Private sector needs to be charged for data, and this might be a source of funds – not sure how this fits with WG open data policy
UK and international organisations				• Could Wales approach become a world leader? • who may collaborate on data, and also on development projects
Cross border agencies				• Linking in to get UK/EU assessments
Academia				• access to data and identifying research needs
Public service boards in Wales				•
NPAs and LAs				•

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• And the no. of reporting pathways • data downloads • Citations
Partners involved				• a measure of co-ownership ??
Technologies exploited				•
Cost				• And increase of external funders

				• increased external funding
Outcomes				• need to be defined
How it helped evidence needs				• Consistency of indicators and measures across WG strategies
NRN metric?				•
Greater utility				•
Measures of co-ownership				• *e.g. evidence of collaboration* • *Use by WG depts.* • *Contributing to other WG Dept policies*
Avoiding failures in reporting				• *e.g to EU, or other statutory reporting*
Evidence of monitoring framework that works				•
Consistency of other metrics				• *Consistency of indicators and measures across WG strategies*

Risks

- Risk of not doing things properly – governance important
- Lack of political will and leadership
- Lack of buy-in by participating organisations
- Reporting methods vary, and yet monitoring methods become too standardised
- NGOs might not change their methods
- Risk of reduced capacity - since some data collection could be stopped in interests of rationalisation

Recommendation 2: NRMF should service the needs of a wide customer base for natural resources evidence across WG departments, NRW and partners in recognition of the social and economic benefits arising from a healthy and resilient stock of natural resources.

The text as reviewed in Workshop 3: "3. A wider customer base across WG departments, NRW and other partners and stakeholder for environmental data to be served by the NRMF to increase cost-benefit realisation."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				
More efficient and integrated reporting				•
Policy (development and evidence)				•
Robustness				•
Adaptability / Responsiveness				• depends on the framework manager and Coordination Board
Collaborative working				
Reputation and presentation				•
Well-being				
Capacity building				•
Data sharing / collect once use often				•

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes
WG				
NRW				
3rd Sector				•
Community as a whole				•
Funders				•
Future generations				•
Private Sector				•

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• Number of functional units in WG and NRW using the data from the monitoring framework
Partners involved				•
Technologies exploited				•
Cost				•

Risks

None noted.

Recommendation 3: The community should take advantage of the NRMF domestically and internationally to build capacity, increase co-funding and investment into Wales, and develop novel solutions and products with industry exploiting the full economic potential of the NRMF for developing the green economy.

The text as reviewed in Workshop 3: "4. The full economic potential of an innovative integrative world-class framework to be exploited domestically and used to inform and support international initiatives with skills and technologies exported."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				• drive economic growth • maximising investments that have already been funded • money saved through informed decision making • exploiting new markets
More efficient and integrated reporting				• exploiting technologies
Policy (development and evidence)				•
Robustness				• exploiting technologies • transparency
Adaptability / Responsiveness				• new markets • have an established 'go to' network • better informed
Collaborative working				• upskilling • new markets • have an established 'go to' network • transparency, experts and facilities available for teaching • better informed
Reputation and presentation				• branding/marketing • upskilling • experts and facilities available for teaching •
Well-being				
Capacity building				•
Data sharing / collect once use often				•

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes

WG				
NRW				
3rd Sector				•
Community as a whole				•
Funders				•
Future generations				•
Private Sector				• *Wales PLC* • Industry • commercial sector

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• Number of citations • IPR registrations
Partners involved				• Numbers of different programmes funded • Expanding range of funding programmes • Increase customer base, plus number of return customers • Number of partnerships
Technologies exploited				• Use of commercial data by NRMF
Cost				• amount of funding/co-funding
Outcomes				• Number of training schemes • Courses tailored to demand • Number of PhD's • Jobs created

Risks

- External funders may have different agendas
- Concentrating on International market?
- Too much emphasis on economy
- Qualitative benefit might not be captured
- Where does it fit into the economy as a whole?
- This recommendation maybe a bonus once the framework had been established and so timescale for realisation is inherently longer.

Recommendation 4: The NRMF should integrate monitoring methods and technologies and in so doing deliver innovation, new opportunities and cost-savings. This should include a robust and systematic assessment of new technologies prior to their potential adoption. This approach will improve strategic deployment of resources ensuring an ongoing improvement programme and immediate to short-term cost benefits whilst countering unintended risk

The text as reviewed in Workshop 3: "10. The new programme needs to strategically combine existing technologies and adopt new technologies to improve strategic deployment of resources ensuring an ongoing improvement programme and immediate to short-term cost benefits."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				• Possibly very high short-term costs? • Costs of the three approaches (EO, CS & eDNA) are very different • New methods have the potential to reduce costs, but this will not necessarily happen •
More efficient and integrated reporting				• Mixed views
Policy (development and evidence)				• Increased spatial coverage from these technologies and combining them is a specific benefit
Robustness				•
Adaptability / Responsiveness				•
Collaborative working				
Reputation and presentation				•
Well-being				
Capacity building				
Data sharing / collect once use often				•

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes
WG				
NRW				
3rd Sector				• Mixed opinions
Community as a whole				• Citizen science monitoring can increase public engagement as a side benefit
Funders				•

Future generations				•
Academia				•
NPAs and LAs				•
Other comments				• The range of beneficiaries is limited because many will not have the ability to interpret the data. This means that we need accessible reporting products

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• Accessibility of data sources (not sure what exact metric might be)
Partners involved				• Numbers of collaborations across technologies
Technologies exploited				• Impact metrics as applied by Research Councils
Cost				• Complex area: need to differentiate between short-term and longer-term cost benefits

Risks

- Different new approaches my not be used in a complementary way because different organizations are responsible for running them
- eDNA may lead to a loss of volunteer and public engagement as monitoring does not involve people actively
- Loss of citizen science engagement and associated funding
- Novel approaches have more uncertainty and may not work
- Data from new approaches/partners may not shared as desired
- Trials of new approaches may show then not living up to their early promise, so they may have to be dropped
- Rather than making reporting easier, this will make it more complex
- Are people excited by new ideas rather than ensuring that the right tools are used for the right jobs?
- Benchmarking of goals and standards will be essential in the introduction of new methods
- eDNA has lots of potential applications but will be quite expensive and the viability of a long-term, large-scale scheme has yet to be demonstrated.
- Archaeological issues are generally under-represented in this process, but there are a lot of potential co-benefits with other targets from applying new technologies

Recommendation 5:

The new NRMF should provide the primary data source for SoNaRR, a range of International reporting requirements and the primary natural resource data requirements of Well Being of Future Generations Act reporting. This follows the principal of collect once – re-use often.

The text as reviewed in Workshop 3: "5. The new NRMF will provide the primary data source for SoNaRR and International requirements and the natural resource evidence requirements of WBFG following the principal of collect once – re-use often thereby increasing cost efficiencies."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				
More efficient and integrated reporting				•
Policy (development and evidence)				• decisions based on data • data accessibility • power of information increased • access to datasets which have never been available in the past.
Robustness				•
Adaptability / Responsiveness				•
Collaborative working				
Reputation and presentation				•
Well-being				
Capacity building				•
Data sharing / collect once use often				•

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes
WG				
NRW				
3rd Sector				•
Community as a whole				•
Funders				•
Future generations				•
Academia				• academia, research, teaching

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• report on reporting indicators • Amount of data used by PSB in area statements • Dataset might only be used once, however it might be critical for X,Y,Z, number of policies that use the data for reporting, how different SoNaRR reporting will be in 5 years.
Partners involved				•
Technologies exploited				•
Cost				•

Risks

- Smaller groups might feel they are being 'dictated' to
- Data being used for non-compliance
- Mis-use or misinterpretation of data. Must ensure collecting right data at the outset. Important to recognize the data we don't need
- Funding for other organisations etc might be put at risk.
- Too much emphasis on policy requirements
- Other data providers might get forgotten
- Limitation to data sets
- Scope creep
- Technology has advanced and we haven't got the vision for use (risk)
- Important to bring citizen science along without 'forcing'. Might have more engagement but not as much reporting.

Recommendation 6:

A Coordination Board should be established which is representative of the natural resources monitoring community and its extended customer base. This Board should be tasked with optimising and targeting the collective survey and monitoring, analytical and interpretation resources in Wales. This will deliver an adaptive approach to monitoring, increase efficiencies, improve partnership working and help guide future management decisions to improve the resilience of our ecosystems and increase benefits.

The text as reviewed in Workshop 3: "6. Establish a Coordination Board to optimise and target available survey and monitoring, analytical and interpretation resources including a response to emergencies thereby exploiting the greater partnership working and infrastructure of the NRMF."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				
More efficient and integrated reporting				
Policy (development and evidence)				
Robustness				• Not discussed
Adaptability / Responsiveness				
Collaborative working				• Not discussed
Reputation and presentation				• Not discussed
Well-being				
Capacity building				• Not discussed
Data sharing / collect once use often				

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes
WG				
NRW				
3rd Sector				
Community as a whole				
Funders				
Future generations				

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• No specifics
Partners involved				• No specifics
Technologies exploited				• No specifics
Cost				• No specifics
Consistency of other metrics				• No specifics
				• **In general**: Clear Milestones for delivery of the new board and its functions will be needed

Risks

- A single co-ordination board could be an inappropriate structure. For example it has to have the power and resources to convene sub-groups dealing with more specific aspects with resources and a clear remit to feed findings into the co-ordination board.

- Risk then is that it becomes an additional complex layer of bureaucratic machinery that gets weighed down with administration lack of clear leadership and purpose and has little traction, exposure and identity with WG or the public and so support for its existence withers from within and without.

- Risk of the group monitoring its own milestones “marking own homework”. Needs external oversight e.g. external consultant like NAO to periodically review but this depends on what it does.

- Without authoritative and respectable leadership/governance/chairing it could lose credibility.

Recommendation 7: To reduce duplication and increase efficiencies, NRMF should embrace the collect once - use multiple times principle by adopting a clear approach to increase the sharing of data and conversion of data into robust evidence products. A Coordination Board sub-group on data and informatics should be established to help deliver a rebalancing of resources away from data collection to data coordination, sharing, analysis and interpretation. This should exploit new computer technologies which allows for networking of data, information and analytical tools.

The text as reviewed in Workshop 3: "7. Increased sharing of: technologies; data; expertise and analysis but recognising statutory reporting may require some internal walls."
"8. Adequate resource needs to be allocated to underpin provision of data coordination activities including managing and sharing of data which builds on past experience and ongoing national and international activities."
"9. Ensure sufficient resource allocation is available to support conversion of data into robust evidence products and making these derived evidence products available to the wider community thus supporting policy and legislative reporting evidence needs and multiple re-use by partners and stakeholders."

These recommendations generated the most discussion and we find it difficult to summarise common views across all the workshop groups and combine the comments for the three originally worded recommendations. It was generally agreed that data sharing offered **significant benefits** and yet came with the **greatest risks.**
Many specific comments were noted.

Risks & Comments

Data management is a big undertaking and resource rich to establish but there are long term efficiencies. should compare costs to 'do-nothing'
Risks- needs sufficient resource but needs to be considered against funding landscape
Could spend a lot of resource with no successful outcome.
There are many difficulties in data sharing, licensing (time needed for realisation), IP, sensitivities.
Need to enable and allow time.
Risk that data could be driven by commercial need rather than societal.
Risk that recording of long-term data could stop
Risk to data gatherers as better use of data means less collection
Risk is that there are insufficient linkages between information hubs which could create silos
There are examples of where data has been commercialised e.g. metoffice, OS, that contradict high level data sharing,
Need time to allow 'what fits Wales' to evolve.
Currently paying for the same data to be re-packaged, could be cost savings
Investment will derive benefit in the future, quality, longevity of data, data curation and legacy.
Appropriate resource not in place
Could policy hold things back
How to translate National capability- upskilling
Will other things suffer from a shift in resources?
Negative cost-benefits
Gathering more data than you can analyse
Data quality

Mistakes in analysis distributed
Bad interpretation of data could get promulgated
Will the co-ordination group slow responsiveness
Not simple immediate solutions
IP or other reasons for holding back/limiting use of data products…but data sub-group of the co-ordination board should be able to help reduce this risk
Recognition that duplication of effort occurs may not actually deliver savings in practice because other factors drive activity
Data protection constraints on sharing - could produce a loss of capacity relative to unshared data
Compromises to intellectual property of data collectors or scheme designers
Disproportionate costs could be incurred from data standardization
Alienation of data owners/collectors if policies and communications do not take account of their interests adequately.
Compromises necessitated to provide integration may weaken data or analytical quality and fail to deliver the inference required given cost limits
Quality assurance and metadata ma not be transferred when data are shared (especially between third parties), hence affecting interpretation
Negative political issues between potentially sharing partners
Data sources not agreed upon for sharing (content or level of summarization?)
Loss of NGO or agency staff after redundant operations are identified
Integration and sharing mean multiple stakeholders and potentially a need for steering groups and committees, which may bring reduced speed of response and organizational inertia working against adaptability.
We need some measurement or evaluation of the effectiveness of sharing (i.e. monitoring success)
Different issues may apply to different things being shared (data, expertise, etc), so it is difficult to focus on all issues at once in this recommendation
Sharing is a concept; it does not necessarily mean use by all parties involved
Benefit to well-being is very indirect and may also be negatives for some groups if their efforts are identified as being redundant
Well-being benefits depend on capacity increases from sharing data being acted upon appropriately
"Sharing" could mean "making available to purchase" (this is contrary to the spirit of sharing that likely to be understood by stakeholders)
Does data sharing need to involve raw data or processed information?
Capacity building and cost benefits of efficiency may be in conflict: given more efficiency, we could either do more or do the same for less.

Recommendation 8:

The NRMF should establish a modelling capacity as a core component of the analytical and iterative framework. This to be used to underpin data interpretation and develop a predictive capacity for natural resource management. This will aid the development of robust policies which optimise the social and economic benefits derived from our natural resources.

Not assessed in workshop 3

Recommendation 9:

To realise the significant benefits of this integrated framework a phased approach over 5 years is required to convert the ambition into a practical programme and align with ongoing activities and initiatives: Phase I being this initial exploration period; Phase II putting into practice opportunities identified in Phase I; and Phase III realising a fully integrated monitoring framework spanning the terrestrial, freshwater and marine sectors.

The text as reviewed in Workshop 3: "2. A phased approach is required to develop this new monitoring framework between WG and NRW given the significant ramifications for the structures for WG, NRW and partners – 5 years is required to realise the full benefits."

What is the benefit?

Benefit	Not supported	Yes or mostly	Very much or unanimous	Notes
Costs				
More efficient and integrated reporting				•
Policy (development and evidence)				•
Robustness				•
Adaptability / Responsiveness				•
Collaborative working				
Reputation and presentation				•
Well-being				
Capacity building				• Gets the right people and resources in place. We need a "cross-sectoral building of the community".
Data sharing / collect once use often				•

Who Benefits?

Body	Not supported	Yes or mostly	Very much or unanimous	Notes
WG				

NRW				
3rd Sector				•
Community as a whole				•
Funders				•
Future generations				•
Private Sector				•
UK and international organisations				• *Not discussed*
Cross border agencies				• *Not discussed*
Academia				•
Public service boards in Wales				• *Forestry*
NPAs and LAs				•
Ag sector				•

Metrics

Metric	Not supported	Yes or mostly	Very much or unanimous	Notes
Data use and re-use				• Increasing number of reporting pathways
Partners involved				•
Technologies exploited				•
Cost				•
Increased investment				•

Risks

- Lack of political will so that the idea withers on the vine. Realised by being starved of resources.
- Only tackle the easy wins and so does not represent a step change in integration of effort and expertise across sectors and evidence needs.
- Worry that the phased approach to implementing terrestrial then freshwater then marine could compartmentalise effort and lose focus on ways of deriving evidence that went across these sectors.

- Suggestion that marine and freshwater needed clear timelines agreed sooner than later.
- Also that terrestrial would get lion's share of resource with less left as you move forward and that perspectives developed for terrestrial would be inappropriately propagated through to subsequent phases.
- New technologies could end up being applied badly.
- Great ambition but is this REALLY going to be achieved with declining budgets and resources?
- Concern that SSSI monitoring will get left behind.
- Concern as to how this initiative will deliver evidence for Habitats Directive reporting in 2018.
- Risk that it will not be possible to secure a 5-year commitment for the budget needed hence unable to deliver all recommendations.

Recommendation 10: The final function of the NRMF is to increase engagement across cabinet, the Welsh Government, business and the public in communicating the fundamental importance of Wales' natural resources to its green economy and the well-being of future generations.

Not assessed in workshop 3

Appendix M1
Partnership Working - Pilot Survey Report

Introduction

An exploration into partnership working to exploit the systematic integrated ecosystem survey approach developed by the Glastir Monitoring and Evaluation Programme (GMEP), both to increase efficiency and to enable comparison of performance with the national baseline. Some of the benefits of adopting such an approach are the application of common monitoring methodologies, sampling structures and indicators to provide a common framework for reporting. Within the current GMEP programme 8362ha of National Parks, 3675ha of Natura 2000 sites, 4656ha of SSSI's, and 479ha of National Nature Reserves are already monitored. This approach exploits investment the Welsh Government has already made in developing a partnership approach to deliver a national monitoring programme of natural resources through GMEP, which can be built upon to detect trends at a local level.

A pilot project to test this concept was developed whereby staff from the Brecon Beacons and Snowdonia National Park Authorities, National Trust, Natural Resources Wales and Local Authorities attended a three day classroom and field demonstration of the GMEP field survey monitoring methodologies. This gave potential partners hands on experience to evaluate the methods, sampling strategies, skills and support required for operating a systematic national survey plus opportunity to assess how the national programme can be integrated with monitoring at the local scale.

Pilot delivery

11 representatives from the Brecon Beacons and Snowdonia National Park Authorities, National Trust, Natural Resources Wales and Local Authorities attended a 1 day classroom session and a 2 day field demonstration. GMEP monitors land use, plants, birds, pollinators, top soil condition, headwaters and ponds, landscape and historic features all within 300 1 km survey squares. All elements of the survey were demonstrated and the benefits and cost efficiencies of co-locating all ecosystem surveys was demonstrated. The future natural resources monitoring programme was also discussed and considered. Representatives were asked to provide feedback.

Feedback Summary

1. All organisations acknowledged GMEP delivers an excellent monitoring programme with high levels of training and Quality Assurance.
2. 80-100% expressed they want to receive trend data for annual national, regional and their organisations land holdings.
3. None of the organisations felt they would adopt the GMEP monitoring framework in its entirety. However, all organisations were interested in potentially adopting one or more individual elements of the framework. See *Table 1*.

Survey element	% of respondents
Habitat mapping	100%
Vegetation	100%
Soil	80%
Pollinators	80%
Headwaters streams	60%
Ponds	60%
Birds	60%
Historic Environment Features	60%
Modelling	40%
Landscape photography	20%
Greenhouse gas measurements	20%

***Table 1**: GMEP survey elements the respondents* are interested in adopting into future monitoring.*
**respondents included staff from Brecon Beacons and Snowdonia National Park Authorities, National Trust, Natural Resources Wales and Local Authorities*

4. 100% of respondents confirmed the survey would need to be adapted to meet their organisational needs. Some of the suggested examples are listed below:

- *Integration with existing monitoring:*
  The aspiration of the partners is to strengthen their existing surveillance and integrate with other national recording schemes such as National Plant Monitoring Scheme (NPMS), BeeWalk, Wider Countryside Butterfly Survey (WCBS) and other surveys such as Statutory Conservation Agencies & RSPB Annual Breeding Birds Scheme (SCARABBS), lesser horseshoe bat maternity roost and hibernation counts. Concerns were expressed over integrating Common Standards Monitoring (CSM) methodologies with GMEP, which needs to be explored further, however other national monitoring schemes clearly have potential to contribute to future monitoring.

- *Inclusion of volunteers / local recorders / citizen science:*
  With limited resources, the partners would make use of volunteers to monitor certain elements of the survey. As such, it would be necessary to simplify the methodologies of some survey elements in order to reduce complexity and time. See the case study below which is an example of how GMEP style methods have been adapted to meet the requirements of partners at a local scale cost effectively. However, in this case citizen science was not considered to be a viable option and recruitment of professionals to understand the evidence was not considered prohibitive. Brecon Beacons National Park Authority suggested a trainee programme for ecological surveyors could be developed on the back of the monitoring programme. However, the demand for ecological surveyors must be assessed. Perhaps the requirement for statistical and data analytical skills is greater. See *Table 2* below.

Case Study: College Valley Vegetation Monitoring
(http://www.college-valley.co.uk/index.htm)

The College Valley Estate (6500ha) lies within the Northumberland National Park. The mainstay of the estate's income is upland sheep and beef farming, forestry, holiday lettings and shooting. In 2011, there was a change in an agricultural tenancy and 1600 ha of moorland were taken back in-hand. The Scottish black faced ewes were removed from the Cheviot Massif which is a Site of Special Scientific interest. CEH were approached to devise a long-term vegetation monitoring programme across the whole Estate to provide baseline status of vegetation; monitor change within habitats; inform long term management decisions; and to monitor the effectiveness of agri-environment schemes. GMEP style methods were adapted and using base-line information from data supplied by Natural England and Northumberland National Park, survey points were randomly stratified. A rolling 5 year programme took place where each point was visited and vegetation sampling carried out and repeated over the following 5 years. MAVIS (https://www.ceh.ac.uk/services/modular-analysis-vegetation-information-system-mavis), a programme for analysing vegetation data was used to predict Countryside Vegetation System (CVS).

In this case, the need for high quality consistently recorded data across the whole valley over four years of planned summer campaigns meant that citizen science was not a viable option. It would be impossible to guarantee personnel availability, skill level and ability to visit and record in remote, difficult and relatively dull habitats to ensure data was high quality and consistently recorded over the survey period (4 years). Even if volunteers had helped record in the field, there is a requirement for knowledge of the Estates current and past management and an understanding of its ecology to perform data collation, analysis, interpretation and reporting. This would have to be completed by a professional and it was considered to be more efficient and robust, in terms of turning data into evidence, to fund a small team of locally based, experienced consultants to do the whole package.

- *Open source software:*
  The GMEP survey currently uses a field-based data capture and data analysis system using Esri UK's ArcGIS platform running on ruggedized field computers. Surveyors collect information in the field, on tablets and the data is transferred digitally directly into a central ArcGIS geo-database. This system reduces the time to undertake surveys, publish results and there is no requirement for data to be digitised. However, partner organisations have expressed concern over using non-open sources software and have requested that they are considered during the requirements capture of the future programme.

5. All partner organisations would require support if they were to undertake monitoring. The table below shows the support/advice the respondents would require.

Support/Advice	% of respondents
Statistical advice	100%
Data analysis	100%
Training	80%
Laboratory analysis	80%
Quality Assurance	60%
Interpretation	60%

Table 2: *Support and advice the respondents would require if they were to undertake a structured survey similar to GMEP*

The future Natural Resources Monitoring Framework (NRMF) needs to build capacity within Wales in terms of skills, expertise and technology e.g. through apprenticeship programmes, postgraduate studies, and partnership work with industry. Software and hardware design, statistical and data analysis skills should be considered.

Other considerations

- *Funding:*
  Partners currently have insufficient resources for specialist skills training, laboratory analysis, survey equipment, data analysis and interpretation.
- *Data ownership accessibility and confidentiality:*
  The information GMEP collects is the property of the Welsh Government and individual land owner's names and land holdings cannot be identified in reporting. Data collected from the survey is presented in summary form only. GMEP surveyors are not permitted to disclose any sightings of priority species or instances of non-compliance against the requirements of the single farm payment scheme for example. This has been critical in securing permission to survey (only 4% refusal), however this code will have to be explored if data is to be used for other future reporting requirements. One organisation would like to use the data to engage with the land owners and provide targeted management advice. GMEP data is currently stored in an ArcGIS geodatabase with access restricted to the GMEP consortium partners under licence. Dialogue with the Local Environmental Records Centres (LERC) will be critical as they play a significant role on managing biological record data.
- *Priority Species:*
  Concerns were raised over the 'broad scale' monitoring of natural resources undertaken by GMEP. Current monitoring commitments of partner organisations are targeted to Priority Habitats (Habitats Directive Annex 1) and Species (Environment Act (Wales) Section 7 (which replaces section 42 of the NERC Act 2006)), or surveys are reactive in response to planning applications or community needs for example. It is important to understand the stock and condition of both priority and common species and habitats. The future NRMF will include a systematic surveillance element which tracks ongoing change in the stock and condition of natural resources in combination with an adaptive risk-based assessment approach providing evidence of rapid change and citizen science for priority or localised survey.

Appendix M2

Pilot Survey Feedback Summary

Q no.	Question	Gwynedd LA	SNPA	BBNPA	NT	NRW	TOTAL	Summary
1	Do you feel you understand the basic concepts of the GMEP field survey design?	yes	yes	yes	yes	yes	5	100%
2	Would your organisation like to be alerted to the annual national trend data from the GMEP survey on the GMEP portal?	yes	yes	yes	yes	yes	5	100%
3	Would your organisation like to receive regional annual trend data from the GMEP survey and how it compares to ongoing National trends? (N.B. this is dependent on there being sufficient data)	yes	yes	yes	no	yes	4	80%
4	Would your organisation like to receive annual trend data from GMEP squares within the boundaries of your organisations land holdings/designated sites and how it to compares to ongoing National trends? (N.B. this is dependent on there being sufficient data)	yes	yes	yes	yes	yes	5	100%
5	Would your organisation adopt the GMEP framework for monitoring land holding /sites in its entirety?	no	maybe	maybe	no	no	0	0%
6	Would your organisation adopt the GMEP framework for monitoring land holding /sites in part?	maybe	maybe	yes	yes	yes	3	60%
6.1	Habitat mapping	yes	yes	yes	yes	yes	5	100%
6.2	Vegetation	yes	yes	yes	yes	yes	5	100%
6.3	Soil	yes	yes	yes	yes	no	4	80%
6.4	Streams	yes	yes	no	yes	no	3	60%
6.5	Ponds	yes	yes	no	yes	no	3	60%
6.6	Pollinators	yes	yes	yes	yes	no	4	80%
6.7	Birds	yes	yes	yes	no	no	3	60%
6.8	HEFs	yes	no	yes	yes	no	3	60%
6.9	Landscape photography	yes	no	no	no	no	1	20%
6.1	Modelling	yes	yes	no	no	no	2	40%
6.11	Climate change - GHG measurements	yes	no	no	no	no	1	20%
7	Would the survey need to be adapted for your organisation	yes	yes	yes	yes	yes	5	100%

Q no.	7.1
Question	Expand on required adaptions
Gwynedd LA	Yes, for Local Authority use it would require adaption and simplification and parts of the survey would have to be omitted. The survey needs to be undertaken by trained specialists. Local authorities do not currently have funding to carry out surveys like this, which are intensive. Local Authorities work often tends to be reactive e.g. responding to planning applications or community needs. We have no facilities to undertake lab work for soil analysis, water analysis and we currently have no funds to contract out analysis work or surveying work.
SNPA	SNPA only own about 0.5% of the Snowdonia National Park area, the biggest land-holding being Llyn Tegid, most of which wouldn't be suitable for GMEP techniques. At the moment, given limited resources, SNPA staff are involved with and undertake a limited amount of national and local biodiversity monitoring e.g. Wider Countryside Butterfly Survey, Lesser horseshoe bat maternity roost and hibernation counts, black grouse lek counts, PTES Migneint water vole transects, Bird Atlas squares, occasional SCARABBS surveys e.g. hen harriers as time allows, twite colour-ringing project work etc. These provide information at a local level for a number of priority species, but also contribute to a wider national picture, with some of the data being used for e.g. Article 17 SAC feature reporting, production of national Bird Atlas. Occasionally SNPA contribute to professional surveys by specialist contractors e.g. rare bryophytes, Myxas glutinosa (Llyn Tegid Ramsar site feature) etc. Sufficient long-term resources would need to be secured for on-going GMEP type monitoring commitments.
BBNPA	---
NT	As a charity we have a very limited resource, so are interested in what would fit best with our existing approach to biological survey – with additional work being undertaken by volunteers. For example, habitat mapping could be an approach that works for us in the uplands/ or is combined with initial plans for volunteer condition mapping. Vegetation could be incorporated into specific biological site survey to give us plots in which to monitor change. Soils, streams, and ponds would need to be incorporated into either existing biosurvey or gathered by volunteers and we'd most likely want the simplest measures for analysis as costs would otherwise be prohibitive. Pollinators would need to be capable of being done by volunteers.
NRW	Ability to map habitats listed under Annex I of the Habitats and Species Directive. Information on condition of SSSI features and Annex I features outside protected sites. Information of state of factors of key significance to SSSI/Annex I features (please note – these are all items which NRW could contribute through a co-production model).

8	**Would your organisation require support from GMEP for**	**Gwynedd LA**	**SNPA**	**BBNPA**	**NT**	**NRW**	**TOTAL**	**Summary**
8.1	Statistical Advice	yes	yes	yes	yes	yes	5	100%
8.2	Training	yes	yes	yes	yes	no	4	80%
8.3	QA	yes	yes	yes	no	no	3	60%
8.4	Lab analysis	yes	yes	yes	yes	no	4	80%
8.5	Data analysis	yes	yes	yes	yes	yes	5	100%
8.6	Interpretation	yes	yes	yes	no	no	3	60%

Q no.	**9**
Question	**Further Comments**
Gwynedd LA	Gwynedd Council like most Local Authorities does not have the resources or the equipment or specialists to undertake a survey based on GEMP, e.g. Councils don't have laboratories for soil analysis and most Local Authorities do not have specialists in statistics, most LA have ecologists, some have archaeologists, geologists, landscape specialists. LAs are currently working on flood alleviation schemes that could benefit from GEMP data. Survey and monitoring using GEMP provides data on a range of environmental features: habitats, species, soils, water, landscape, archaeology. This data could be used to inform or report on targets for Local Development Plans, Local Biodiversity Action Plans, Wales biodiversity ecosystem groups and biodiversity

	duties under the Environment Act 2016 and the Future Generations Act 2016. The data obtained from GEMP is perfect for reporting on the state of the Natural Resources of Wales.
SNPA	With current very limited resources, SNPA would probably look to continue to concentrate Phase 2 vegetation mapping and monitoring on High Nature Value Sites e.g. Section 7 Environment Bill (Wales) 2016 habitats and species rather than potentially sampling a lot of habitats of less interest e.g. agriculturally improved grasslands. For example, NVC surveying and mapping has been completed for the ≈67ha farm (Yr Ysgwrn) that the SNPA acquired in 2013, and is used to inform management decisions. The biodiversity monitoring we are committed to at the moment is generally targeted to species of conservation importance e.g. Annex II species, Environment (Wales) Act 2016 Section 7 species. Natural resource monitoring of the type undertaken by GMEP is quite broad scale and appears to be potentially quite demanding in terms of resources, although SNPA are currently unaware of the breakdown of costs of such monitoring. SNPA understand the value of the broad natural resource monitoring undertaken by GMEP. It is understood that NRW's State of Natural Resources Report (SoNaRR) and area statements, and Welsh Government's National Natural Resources Policy (NNRP) are due to be published in the near future. It is envisaged that these documents will provide vital evidence for public bodies (such as SNPA) on the priorities, risks and opportunities in relation to our natural resources and can help to inform future decisions. Currently the SNPA publish a 'State of the Park Report' every 5 years – see www.eryri-npa.gov.uk/looking-after/state-of-the-park. This Report will be added to periodically before the next formal report is published in 2021, and it is envisaged will include some SoNaRR and GMEP information relevant to the Snowdonia National Park.
BBNPA	---
NT	We'd be looking for an approach that we could apply across England & Northern Ireland as well as Wales and so I think we'd only consider elements that we could greatly simplify and adapt for inclusion in our own survey /develop as a programme for volunteers. How information we gathered could be compared with national trends would be an area of interest. I have ticked areas where, if we went down this route, we might need support to implement however with the exception of training, we'd need much more information about the nature of any partnership relationship.
NRW	We were very impressed with the survey protocols and standard of training and QA

Appendix N1

Steering Group Members and Engagement

Member	Job Role	Organisation	TOR ? (see key)	Meeting 1 23/2/16	Meeting 2 18/4/16	Meeting 3 2/6/16	Meeting 4 14/7/16
Alun Attwood	Evidence, Monitoring and Reporting	NRW	Other				✓
Andy Davey	Consultant	WRc plc	Team		✓		
Bethan Webber	Secretariat	WG	Team	✓	✓		✓
Betsan John	Glastir Policy Officer	WG	ToR	✓	✓	Rep.	✓
Bob Vaughan	Land Management	NRW	ToR	✓			✓
Bridget Emmett	Project Lead	CEH	Team	✓	✓	✓	✓
Bron Williams	Project Team	CEH	Team		✓		
Catherine Duigan	**Chair**	NRW	ToR	✓	✓	✓	✓
Catherine Lawton	RDP Monitoring & Evaluation	WG	ToR				Rep.
Chris Bell	Project Manager	CEH	Team			✓	✓
Chris Cheffing	Project Team	JNCC	Team		✓		
Claire Horton	Data Management	WG	ToR		✓		
Chris Lea		WG	Other				✓
Clive Walmsley	Climate Change	NRW	ToR	✓	✓		✓
Colin Chapman	Data Management	WG	ToR	✓	✓		✓
Dai Harris	Biodiversity Policy (also covering J Hartley)	WG	ToR		✓		✓
Dave Chadwick	Project Team	Bangor U	Team		✓	✓	✓
Dave Jones	RDP Statistical Analyst	WG	Other		✓		Rep.
David Allen	Monitoring Strategy	NRW	ToR		✓	✓	✓
Dewi Jones	Agriculture & Climate Change Policy (also cover HMS)	WG	ToR	✓	✓	✓	✓
Emily Finney	Natural Resource Management Policy	WG	ToR		✓		
Emma Waters	Project Team	CEH	Team			✓	
Fiona McFarlane	Forestry & Policy	WG	Other		✓		✓
Gavin Siriwadena	Project Team	BTO	Team		✓	✓	
Havard Prosser	Project Team	Ind.	Team		✓	✓	✓
Helen Minnice-Smith	Agriculture and Climate Change Policy	WG	ToR	✓			

Howard Davies	Covering Bethan John and Catherine Lawton	WG	Cover		✓		
James Skates	Senior Responsible Officer	WG	ToR	✓	✓		✓
Jenni Hartley	Biodiversity Policy	WG	ToR	✓	✓	Reposted	Reposted
Jim Latham	Woodland	NRW	Other		✓		
Joanne Amesbury	Social Sciences	WG	ToR	Rep.	✓	✓	✓
Julian Bray	Marine Biodiversity Policy	WG	ToR				
Kathleen Mulready	Covering Jo Amesbury	WG	Cover	✓			
Kevin Austin	Head of Sustainable Land Management	WG	ToR				
Laurence Jones	Guest	CEH	Other		✓		
Peter Henrys	Project Team	CEH	Team		✓	✓	✓
Peter Jones	Habitats	NRW	ToR	✓			
Simon Smart	Project Team	CEH	Team		✓		✓
Steve Spode	Natural Resource Management Policy	WG	ToR			✓	✓
Stuart Neil	Agricultural Statistics (also covering D Jones)	WG	Other	✓	✓	✓	✓
Susan Williams	Social Sciences	NRW	ToR			✓	
Victoria Seddon	RDP Monitoring & Evaluation	WG	ToR		✓	✓	

Keys:

ToR – named in the Terms of Reference document as a Steering Group member
Cover – covering for a ToR
Team – a member of the Project Team
Other – invited attendee
Rep. - represented (by a cover)

Appendix N2
Steering Group Minutes

Steering Group Meeting 1

Future Monitoring Options Task and Finish Steering Group Meeting 1
Gateway Centre, Shrewsbury – Tuesday 23 February 2016

Attendees:

David Allen NRW
Bridget Emmett CEH
Dewi Jones WG
Stuart Neil WG
Clive Walmsley NRW
Bronwen Williams CEH
Colin Chapman WG
Jenni Hartley WG
Peter Jones NRW
James Skates WG
Emma Waters CEH
Catherine Duigan NRW – Chair
Betsan John WG
Helen Minnice-Smith WG
Robert Vaughan NRW
Bethan Webber WG

Overview

GMEP was commissioned in 2012 to capture evidence of Glastir impact and to take stock and condition of our natural resources.

The change over 7 year period is limited, eg carbon. We are now taking into account wider programmes for reporting. GMEP is coming to the end of its 4-year cycle, we need to identify programmes for future options for monitoring, eg directives and carbon budgets.

Must be co-produced product and sustainable long-term and more integrated in terms of organisations.

Our Deputy Director, Chris Lea, is keen to establish a singular terrestrial and marine monitoring mechanism.

How will it look like and how will it be achieved? It will need to be a phased approach- We need Phase I opportunity identified by end of Summer 2016. (which will itself consist of 3 phases)

Q: Is a single programme a solution?
JS: We have been asked to identify options to build a monitoring programme for the future. There are regulatory requirements by 2017. We need to look at an integrated approach.

GMEP – An Introduction ppt: Bronwen Williams, CEH

Q: Is there a chance of re-prioritising?
JS: The Commission are looking at value of investment to recipient.

The word 'Glastir' may disappear for this project - its causing confusion. The future monitoring and evaluation programme is relevant across many ministerial portfolios.

Q: How can we make data more accessible?
JS: Referring to data protection, we will not jeopardise relationship with landowners, we cannot retrospectively allow access to data which was collected as confidential, will have to re-evaluate for any new programme.

Observation: NVZ areas could pose a risk.
Observation: If GMEP is undertaking research, will land-owners ask for a report?

Biosecurity – WG protocols adhered to. More clarity and signed acceptance could be incorporated into access permissions letter.

Should Rural Inspectorate Wales and NRW staff do more?

Exploration Activity and Peer Review ppt – James Skates WG

Designated areas to be in Phase I – **NRW Agreed**.

NRW to contribute to Workshops on Future Options – **NRW Agreed**

CEH plea for data from NRW please!

We need to define Phase I, II and III – Timing important

JS keen for Bernard Llewelyn to deliver a talk at one of the workshops from a land owner perspective.

What will Workshops I, II and III look like? – see separate document

CEH to develop proforma to present to Steering Group – **ACTION**

Steering Group Meeting 2

Future Monitoring Options Task and Finish
Extraordinary Steering Group Meeting 2
Welsh Government, Ladywell House, Newtown – Monday 18 April 2016.

Attendees:

David Allen DA - NRW
Andy Davey AD – WRc
Emily Finney EF – WG
Peter Henrys PH – CEH
Dave Jones DJ – WG
Fiona McFarlane FMcF – WG
Victoria Seddon VS – WG
Simon Smart SS – CEH
Dave Chadwick DC - Bangor Uni
Catherine Duigan CD - NRW – Chair
Dai Harris DH – WG
Betsan John BJ – WG
Laurence Jones LJ – CEH
Stuart Neil SN - WG
Gavin Siriwardena GS – BTO
Clive Walmsley CW - NRW
Chris Cheffings CC - JNCC
Bridget Emmett BE – CEH
Jenni Hartley JH - WG
Dewi Jones DJ – WG
Jim Latham JL – NRW
Havard Prosser HP – Ind Consultant
James Skates JS – WG – SRO
Bethan Webber BW – WG Secretariat
Bronwen Williams BWms – CEH

By telecon: Joanne Amesbury JA – WG Claire Horton CH – WG Colin Chapman CC – WG

Apologies:

Kevin Austin KA – WG
Catherine Lawton CL – WG
Steve Spode SS – WG
Susan Williams SW – NRW
Julian Bray JB – WG
Helen Minnice-Smith HM-S – WG
Robert Vaughan RV – NRW
Peter Jones PJ - NRW
Kathleen Mulready KM – WG
Emma Waters EW - CEH

ACTION NO	ACTION DETAIL	WHO	DEADLINE
1	Circulate presentation and accompanying word doc to steering group	BW	
2	To comment on policy pathway A3 Spreadsheet	SG	9 am 25/4/16
3	To comment on evidence topics to draw boundaries	SG	9 am 25/4/16
4	To comment on monitoring activity identification.	SG	9 am 25/4/16
5	To cross check spreadsheets with UKEOF database		
6	To add in funding support to spreadsheet	BWms	20/4/2016
7	To arrange bilateral meeting with various topic groups identified	BWms	asap

1 Croeso/Welcome Catherine Duigan - Chair

- CD welcomed attendees and presented objectives of the meeting. An extraordinary Steering Group meeting to include GMEP Future Options Project Team – round table introductions.

2 Introduction to Future Options project – JS

- James explained that the expectations of the Future Options project have grown and the remit has shifted.
- The remit does not include the requirement to define indicators
- The purpose of the meeting was for the steering group to agree next steps, to update the team on recent bilateral meetings and collect evidence for reporting purposes.

3 Overview of SoNaRR – EF

- Emily Finney presented an overview of part 1 of the Environment Act – Sustainable Management of Natural Resources.
- **ACTION** BW: Circulate presentation and accompanying word doc to steering group
- Where are the boundaries for statutory requirements? – BE. All current legislation still apply – Environment Act being the primary legislation.
- We are currently working in silos which is non-efficient, the requirement now is to integrate eg: must connect health and environment – JS

- How much step-change is everyone willing to do? – BE
  Our role is to provide an adaptable, flexible programme which provides evidence quickly for policy requirements. A phased approach will be taken:
  Phase I – not a step-change – better alignment of programme activities.
  Phase II – Resource implications, where there may be a requirement to re-balance the monitoring portfolio and assess the associated risks. Need support from incoming minister - this is where step-change will happen
  Phase III – will include marine
  Group discussion on connecting GMEP and SoNaRR; and the Wellbeing and Future Generations Act (WFGA)
- Need a robust programme in place
- Pilot Scheme at the National Parks
- Important to include peri urban areas
- Need to look beyond immediate beneficiaries to be able to report on resilience.

4 Update on bilateral meetings

- DA and BE provided a brief overview of the monitoring reviews being conducted at both NRW and CEH. It is important that we are efficient, identify gaps and ensure work isn't repeated in both organisations.
- Urban environment important
- DC and DJ provided an overview of the Agriculture and Climate change Industry Stakeholders meeting.
- Agriculture to 'de-carbonise'
- Ruminants in dry matter intake. Improving efficiency and production.
- SS and DA gave an overview of a meeting with NRW and CEH staff where options for future data analysis using both GMEP and NRW data where discussed. E.g.blanket bogs. GMEP to contribute to article 17 reporting.
- Re: Section 7 – nothing set in stone. WG are working with LRC's for NRW – DH
- BE updated the team on a recent biological indicators meeting organised by JNCC. This programme will identify reporting pathways and existing indicators. A combined approach is required to data collection and modelling. I.e. structured, unstructured and modelled.

- BWms reported that additional field survey squares will be included in a pilot study to explore partnership working with the National Parks, Local Authorities and NRW. BE added that the Conwy catchment will also be included which is currently part of defra SIP.

5 Plan for Stakeholder Workshop 1

- Need space for 45 participants, 3 x rooms booked at Newtown office
- **ACTION: SG** to comment on policy pathway A3 Spreadsheet
- **ACTION: SG** to comment on evidence topics to draw boundaries
- Could GMEP data be used to respond to potential disasters e.g. foot and mouth, nuclear, volcano erruption? This could add value to the project. Could a scoping paper be included as an output of this work?
- There is such a project going on in agriculture at the moment – VS
- **ACTION: SG** to comment on monitoring activity identification. What kind of data? When is evidence, evidence? What's missing on the list, eg: National Forest Inventory (NFI)

ACTION: Steering Group Members to provide comments on above before 9:00 am Monday 25 April 2016 please.

6 Feedback session

Synthesis of Policies and Monitoring Activities – to identify gaps (spreadsheet on screen) – BE

- In Workshop 1, we will have 5 x break out groups working on evidence gaps and needs with a facilitator on each group. One hour each, max. Spreadsheet will be split by topics for Workshop 1.
- Scalability. GMEP captures 1½% of Wales. What model can you use to cover pan Wales? – GS
- Columns: Sampling Scale, Spatial Extent, Sampling Design and Protocol.
- Bear in mind that 'current' data could be from e.g. 2013 – DA
- Have we made use of the UK Environment Observation Framework (UKEOF) activity catalogue? This would be a good cross-check exercise – DA
- **ACTION**: To cross check spreadsheets with UKEOF database
- ACTION: **BWms** to add in funding support to spreadsheet

7 AOB

Bilateral meetings: Agreed Biodiversity, Water, Data Management and EO, Woodland , RDP?
ACTIONS: BWms to arrange bilateral meeting with various topic groups identified

End of meeting – Date of next SG meeting 19 May 2016.

Steering Group Meeting 3

Development of a Future Natural Resources Monitoring Programme for Wales: Future Options

Steering Group Meeting 3 – Meeting Minutes
2nd June 2016, Teleconference

Present: Catherine Duigan – Chair (NRW), Bridget Emmett (CEH), Chris Bell (CEH), David Allen (NRW), Victoria Seddon (WG), Sue Williams (NRW), Pete Henrys (CEH), Dewi Jones (WG), Havard Prosser, Steve Spode (WG), Joanne Amesbury (WG), Stuart Neil (WG), Gavin Siriwardena (BTO), Dave Chadwick (BU), Emma Waters - Secretary (CEH)

1. Update of progress to date (Bridget Emmett)

a. Stakeholder Workshop 1

The report from workshop one (WS1) is in progress. 29 attendees from 13 organisations including government, NRW, industry and NGOs. Three activities completed and a set of evidence categories were broadly agreed along with a list of evidence providers.
ACTION: Chris Bell to send list of policy/strategy drivers output from WS1 to NRW [Done]

Bridget Emmett is working on a schematic to show reporting pathways for domestic legislation and EU legislation, showing how they can come together and support other policies and strategies also. It was noted that there were some fundamental differences in requirements for level of detail required for EU vs domestic reporting and there will be gaps between the two.

ACTION: Sue Williams offered input on social and economic policy as she had not been able to attend the workshop. Follow-up.

Bridget Emmett asked whether there had been any outputs from the NRW review of monitoring in Wales which could inform this work/prevent duplication
ACTION David Allen to investigate any outputs from NRW review of national monitoring [Done] (After meeting update: David Allen confirmed there is no collated list of monitoring activity across Wales that had been produced as part of the work on SoNaRR).

It was noted that UK EOF was intended to build on this work, tagging activities in the countries in which they were occurring.
ACTION Bridget Emmett to cross check UK EOF against evidence lists from workshop 1 [Done]

It was recognised that each organisation would have different priorities and issues and this will be clearly recognised.

b. Stakeholder Workshop 2

There were 4 papers and associated presentations, 3 on technologies which could be useful going forward (earth observation, citizen science and eDNA techniques). After

feedback to writers of the papers they are being restructured. Authors have been asked to fill in a colour coded matrix to show what is ready to go locally and nationally and what might be ready in short and longer term. Big thanks to all the hard work from the paper writers and others who input.
ACTION: Ensure C. Horton (WG) invited to input to EO & T. Hatton-Ellis (NRW) to eDNA [Done]
ACTION: All: if you have other people who should be involved in the final editing rounds please contact Chris Bell

There was also a document on freshwater which was framing what kinds of activities could inform phase 2 of Future Options; there has already been a lot of input from NRW into the paper.

A fifth paper has been commissioned on data and informatics,
ACTION: Helen Wilkinson from NRW to be invited to input to this paper. [Done]

Catherine Duigan noted that Natural England/EA having similar discussions about eDNA
ACTION: any information about outputs from this to be forwarded to Chris Bell

Final versions of all the workshop 2 papers will be available as background for workshop 3. We will be coming with recommendations for discussion which will inform final set of recommendations which will be brought to steering group

c. Bilateral meetings
Meetings have taken place looking at: biodiversity reporting, Landmap, RDP, water, agricultural and climate change action, NRW habitats and species, NRN, data and informatics, National Forest Inventory. Still to come are Cadw, marine, and plant health. A template is filled out after each meeting with what was discussed, actions and implications for national monitoring. These will be background papers available for everyone before stakeholder workshop 3.

d. Pilot-surveying update - Snowdonia National Park (SNP)/Brecon Beacons national parks(BBNP)
As part of one action identifying how scalable the GMEP approach may be for more local level reporting and monitoring needs, 2 pilot studies are taking place in BBNP and SNP. These were made up of a one day classroom overview and 2 days in the field and a feedback session with a template to capture how useful the participants think this approach would be for their organisations. Participants came from National Park authorities, National Trust, NRW and local authorities. Feedback will be available for stakeholder workshop 3. The Chair reported positive feedback informally from NRW.

The National Trust have approached us to discuss how they might be able to exploit the GMEP approach across the UK as a whole.

2. **Working towards Workshop 3 (22 June)**
Documents that will feed into Workshop 3 will be the reports from previous workshops, notes from bilaterals and feedback from pilots along with a short overarching document all aligned against original objectives as outlined by WG commissioning document. This will be setting the scene and giving some high level recommendations for steering group as to how we progress this going forward, along with what should be involved in phase 2 of the Future Options Programme – how long should it be and what should it involve. This should include freshwater,

although we recognise that activities are already going on in NRW perhaps some of the methods outlined by Andy Davey in his paper for workshop 2 could be further explored.

14 July will be the final steering group meeting to consider recommendations after hearing all the feedback from workshops and project team. These will go to James Skates as WG project lead and will then be passed to core evidence group and on to the Minister.

3. **Date for additional steering group meeting in mid-June (?)**
   Agreed not to go ahead with an extra meeting due to time pressures.

4. **AOB**
   None

5. **Minutes of last meeting**
   Agreed

Next Stakeholder Workshop 22 June 2016. Next Steering Group meeting 14 July 2016.

Steering Group Meeting 4

Future Monitoring Options Task and Finish
Steering Group Meeting 3
Trawscoed Room, Welsh Government, Aberystwyth

Thursday 14 July 2016

1	Dave Allen	DA	NRW
2	Jo Amesbury	JA	WG
3	Alun Attwood	AA	NRW
4	Chris Bell	CB	CEH
5	Dave Chadwick	DC	Bangor University
6	Colin Chapman	CC	WG
7	Catherine Duigan (Chair)	CD	NRW
8	Bridgette Emmett	BE	CEH
9	Dai Harris	DH	WG
10	Peter Henry	PH	CEH
11	Betsan John	BJ	WG
12	Dewi Jones	DJ	WG
13	Chris Lea	CL	WG
14	Fiona McFarlane	FM	WG
15	Stuart Neil	SN	WG
16	HavardProsser	HP	Independent
17	James Skates	JS	WG
18	Simon Smart	SSm	CEH
19	Steve Spode	SSp	WG
20	Bob Vaughan	BV	NRW
21	Clive Walmsley	CW	NRW
22	Bethan Webber (Secretariat)	BWe	WG

By telecom: none
Apologies:

ACTION NO	ACTION DETAIL	WHO	DEADLINE
1	Minutes from Workshop 3 to be circulated to SG	CB	Monday 18 July or soonest
2	Re-draught final Executive Summary and Recommendations for comment to JS and CD for sign-off	BE	By Friday July 2016

Item No

1 Welcome CD (Chair)

- CD welcomed attendees. It has been quite an achievement in short space of time. Group to think about next steps. Minutes of last meeting agreed.

2 Various short items

- JS thanked everyone for contribution so far. Significant challenges overcome and progress made, objective of the day final review of draft recommendations and steering group sign off

- BE informed the group that the 10 recommendations on the 'Executive Summary and Recommendations' paper (circulated to the group) had been agreed by the project team and hopefully reflected wider community feedback. BE thanked everyone for their input and attendance at all meetings.
- JS reminded everyone that there will be a list of outstanding actions in the final report, ie meeting with OCVO
- BE advised that briefing documents had been completed but final report has not yet been comlpeted. Following Workshop 3, outputs are being simplified. Risks and benefits captured.

ACTION - Document from workshop 3 to be circulated to SG

ACTION - BE to draught final report for comment to JS and CD by Friday 22 July 2016,JS and CD to sign off on behalf of SG.

<u>Executive Summary and Recommendations paper observations and discussion.</u>

- Document needs to be kept at high level - BE
- Devil is in the detail, will it be agreed by Steering Group or wider groups? - DA
- Keep with high level recommendations, discuss detail later on - CD
- Details can be reviewed in Phase II - BE
- Need to agree on activities as a community - JS
- Need to be 'clean' on recommendations, a sales document, to establish principle of support - HP
- 'Lower cost for higher benefit' in outstanding actions for Phase II
- Need to get into some of the detail to establish Phase II for 'sales document' - JS
- Need to sign up organisations for next steps. 'Principles' and 'Next Steps' in parallel at Sales document stage - CW
- This will need a phased approach - HP
- Do we need indication of this before September? - CD
- Need to focus on resource for initial support. Additional resource may be difficult to secure and will require sensitive negotiation. JS
- Significant resource required for processing and monitoring - CW
- Need to re-balance. Need to filter through the information we already have - BE
- Easier to sell to the community if endorsed by the Minister and is regarded as a 'sales document' - BJ

<u>Update from Chris Lea, Deputy Director Land Nature and Forestry Division, Welsh Government</u>

- Fantastic opportunity at time of Brexit
- Fit for future, not just for Cabinet
- Celebrate and build on Wales' Natural Resources, link to WFG Act and Environment Act. Valuable link to mental health and wellbeing, green growth, education, engage children early on for social change.
- GMEP has already been celebrated in Europe. Ambition to get an international reporting system.

- Valuable to the voluntary sector.
- Interest from other Ministers and Deputy Secretary.
- Opportunity to deliver. One evidence base for terrestrial and marine.
- Born in Wales, Made in Wales Scheme
- Earth Observation (EO) moving forward backed up by ground truthing.
- Paramount for moving forward, working with Natural Resources Wales.

Executive Summary and Recommendations paper observations and discussion.

- Objective is to build a resilient fit for purpose Future Monitoring Programme. - JS,
- Must use NRW data collectively: eg Forestry, Marine, plant health - CL
- Mindful of what is happening outside of Wales - JS
- Defra and academia tested data impartiality. An opportunity for Wales - CL
- Referring to meeting with CEH, JNCC, NRW, Natural England: Defra has stopped funding in some areas. What are the challenges post-Brexit? Wales used a joined-up approach. Keep links on methodology. No individual areas. USP is a combination of data integration and making best use of - BE
- SoNaRR and Environment Act can give us the tools to deliver - CL
- This needs to be a tool across Cabinet. Risk = Cost. An evidence-based, strong document upfront - SN
- This is reflected in the first sentence of Executive Summary. In economic terms, this could be the catalyst for business development and could be sold worldwide. Health and Wellbeing - difficult to get matrix. Important to get James Price (Deputy Permanent Secretary for Wales) on board. - HP
- Link to environment and economy with benefit to tourism - CL
- Evidence and links important for use across Cabinet - JS
- Climate Change adaption and mitigation - HP
- Need to make sure that evidence from NRW underpins other areas - SS

3 - 6 Review of Recommendations 1 - 5

Key words and observations:

- 'Cabinet'
- Social economic and environmental resilience
- Cost and benefits
- Well-being of Future Generations (Wales) Act 2015 and Environment (Wales) Act 2016
- Natural Resources Policy
- Live document and keeps evolving
- Not green economy, just economy
- Customer representation across the board, eg health
- Use Industry or Business
- Make better use of resources to deliver increased benefits.
- Concerns over the word 'framework'
- Original item number 6 on the paper to move to top 5.
- Co-ordination and integration.

It was agreed that BE would re-vamp 1 - 5 over lunch and SG to review.

Items 1 - 10 on Executive Summary were reviewed.

Document summary to reflect the underlined items from sections 1 - 10 - Green box to be re-visited by BE

At the end of the review session, to note that the group agreed to 5-year review - JS

7 Next Steps

- Group happy with recommendations - Agreed
- Report to be issued by Friday 22 July to JS and CD to comment and sign-off on behalf of SG.
- High-level recommendation to core evidence group for recommendation
- CL and JS to meet Cabinet Secretary next week.
- Directors meeting due later in Summer.
- End Autumn - move to Phase II - any ideas are welcomed.

JS thanked everyone for their contribution.
CD thanked everyone on behalf of NRW.

End of meeting.

Appendix O
Stakeholder Meetings Project Team Notes (Drafts)

WORKSHOP 1

Future Monitoring Options Task and Finish
Workshop 1
Welsh Government, Ladywell House, Newtown – Tuesday 3 May 2016.

Attendees:

1	Jo Amesbury	JA	WG
2	Alun Attwood	AA	NRW
3	Jill Bullen	JB	NRW
4	Dave Chadwick	DC	Bangor University
5	Chris Cheffings	CC	JNCC
6	Catherine Duigan (Chair)	CD	NRW
7	Chloe Elding	CE	Wildlife Trusts
8	Bridget Emmett	BE	CEH
9	Ian Halfpenney	IH	CADW
10	Dai Harris	DH	WG
11	Peter Henry	PH	CEH
12	Liz Howe	LH	NRW
13	Peter Jones	PJ	NRW
14	Rachel Lewis-Davies	RLD	NFU Cymru
15	Bernard Llewellyn	BL	NFU Cymru
16	Fiona McFarlane	FM	WG
17	Stuart Neil	SN	WG
18	Charlotte Priddy	CP	FUW
19	Havard Prosser (Facilitator)	HP	Independent
20	Paul Sinnadurai	PS	Brecon Beacons National Park Authority
21	Gavin Siriwardena	GS	BTO
22	James Skates	JS	WG
23	Simon Smart	SSm	CEH
24	Steve Spode	SSp	WG
25	Roy Tapping	RT	Cofnod
26	Clive Walmsley	CW	NRW
27	Emma Waters	EW	CEH
28	Bethan Webber (Secretariat)	BWe	WG
29	Dylan Williams	DW	NRW

By telecon: none

Apologies:

Clare Burrows	CB	NRW
Keith Davies	KD	NRW

Bronwen Williams BWi CEH

ACTION NO	ACTION DETAIL	WHO	DEADLINE
1	Access to data proving difficult on Farm Biomass – any suggestions?	ALL – email Bron Williams, CEH please	Asap
2	'Air quality in England and Wales: policy priorities, best practice and industry engagement' meeting	Dewi Jones to report back	By Friday 20 May 2016
3	How much milk are we producing? Welsh Farming Survey coming up	Dewi Jones to map out and report back	asap
4	Organise Bilateral meeting with CADW – Ian Halfpenny	Bethan Webber	Arrange over next week or so
5	Recreation: household based survey – who owns it?	Project Team	
	Landmap/tranquillity. Exploration required. Some of it significant. Potential recommendation merger	Project Team	
	Circulate Workshop Dates	Bethan Webber	By Friday 6 May 2016

1 Croeso/Welcome Catherine Duigan - Chair

- CD welcomed attendees and presented objectives of the meeting. This is Workshop 1 to include, GMEP Future Options Stakeholders, Steering Group and Project Team – round table introductions.

2 Background to the Glastir Monitoring and Evaluation Programme (GMEP) - BE

- https://gmep.wales/

- GMEP covers:
  - Combating climate change
  - Improving water quality and managing water resources
  - Improving soil quality and management
  - Halting biodiversity loss
  - Managing landscapes and historic environment and improving public access to the countryside
  - Woodland creation and management

- To provide constant feedback on progression of the scheme and evidence for programme.
- Working with Citizen Science and modelling systems using latest technology/Earth Observation
- 300 x 1km² being used for programme, covering 1% of Wales on a rolling 4-year programme with the change point at year 5.
- Click on above link for in-depth and latest GMEP information

3 Introduction to the scoping study for Future Options for Natural Resources Monitoring Programme for Wales - JS

- explore and identify options for a single framework focusing on a wider remit for delivery

- identify overlaps to reduce costs
- opportunity for working collaboratively for evidence base
- will feed into State of Natural Resources Report (SoNaRR) – evidence reporting
- Wellbeing and Future Generations Act and Environment Act take account of drivers
- Short, medium and long-term approach
    - Phase I A better alignment of terrestrial programme activities – working together better
    - Phase II Re-balance the monitoring portfolio – on-going improvement
    - Phase III Develop marine

- What is the timeframe for phases? – AA
  No defined date for Phases– group to discuss and identify options - JS

- Quality and detail stand out on GMEP – BL
- Build on GMEP's strengths. There are new opportunities to use latest Earth Observation (EO) data, important to share data – JS
- Chair was in agreement with this statement – good to strengthen – CD

4 Introduction to breakout sessions - HP

- BE explained details of the spreadsheets put up on the wall for each session
- No more money available so we must use data Wales currently holds - BE
- Report must present findings and gaps by mid-July - BE
- Developing a Natural Resource Monitoring programme – boundaries are not defined. If there is any absent subjects, please add – JS
- Add and/or break down topics if necessary – GS
- Important to challenge, support and contribute - JS
- Environment Act – brigade into headings. Provision of ecosystem services and resilience links in the Wellbeing and Future Generations Act. Must have links to Section 7 biodiversity list and current Section 42. Link to Environment Impact Assessments (EIA) – SS
- Important to identify gaps not resources – JB
- identify where we could deploy resources but does it present a risk? JS
- Gaps may not link to policies, eg: natural disasters. Important to feedback – BE
- Scale – Think spatially, think quality. How good or bad is current data? What about data outside Wales? How often do we need to monitor biodiversity? Is every 4 years enough? We need to recognise monitoring times to activities - HP

- Workshop session split into 3, as follows:

Group 1	**Group 2**	**Group 3**
Alun Attwood	Chris Cheffing	Jo Amesbury
Dave Chadwick (lead)	Catherine Duigan	Jill Bullen
Peter Henrys	Chloe Elding	Bridget Emmett (lead)
Liz Howe	Dai Harris	Ian Halfpenney
Dewi Jones	Peter Jones	Bernard Llewellyn
Rachael Lewis-Davies	Gavin Siriwardena (lead)	Charlotte Priddy
Fiona McFarlane	James Skates	Simon Smart
Stuart Neil	Steve Spode	Roy Tapping
Havard Prosser	Dylan Williams	Clive Walmsley
Paul Sinnadurai		

5a Breakout sessions

Biodiversity

Group 1 – Reporter Peter Henry

- How far do we go with some policies, eg: Highways Act?
- Connect ecosystem approach to biodiversity/water framework directive WFD.
- Happy with topics under biodiversity
- Section 42 – red list species, addition of statutory and non-statutory sites – but group generally happy
- Data – additions that could contribute to change. Phase 1 NBC(?) Surveys, SSSI monitoring.
- Create extra column for using volunteers
- Possible data sources: planning applications, SAF data, Red tractor auditing, trees in towns and green space.
- Data quality provenance and transparency important.

Group 2 – Reporter Gavin Siriwardena

- Focused on how the policies link together.
- (some deleted, not evidence) Added: CBD, floods/WFD directive, evasive aliens, plant health, heather and grass burning, NVZ
- 'Declining' priority species to be taken out
- Habitats = Broad Habitats
- HNV = ecosystem resilience
- BRC and national recording scheme to be split

Group 3 – Reporter Simon Smart

Welsh Government Natural Resources Policy Statement to include SoNaRR Reporting:
http://gov.wales/about/cabinet/decisions/2015/jul-sep/environment/cs0793/?lang=en

- Need to know more about SoNaRR to identify gaps to fit into this programme (see above link)
- AONB/National Parks have a statutory 10-year plan – do they have datasets?
- Engage in partnerships LRC's eg: dormouse
- I-tree scheme Urban trees – do we include the 'green areas'?
- Who holds the data from planning applications/site assessments? FoI regulations and Access? Could have valuable biodiversity data?
- What matrix do we need for carbon budgets and trading – second part of the Environment Act
- One or two suppliers for Soil data available
- Inventories are agreements not the truth, eg tree diseases

- Need to develop urban information for Future Options. Specific programmes derived from carbon trading. What is the sufficient requirements to feed the policy developments? JS
- **ACTION:** Access to data proving difficult on Farm Biomass – please email Bron Williams, CEH - BE
- NRW have peri-urban and urban data – PS
- GMEP has up to 75% urban, NOT peri-urban – BE

Comments from breakout session

- Policies have been approached in a different way - BE

- Reporting on operations is also important. WFG Act, biodiversity, water quality, farming. Must put the WFG Act first – SS

Soil and Greenhouse Gases

Group 1 – Reporter Peter Henry

- Key meeting: 'Air quality in England and Wales: policy priorities, best practice and industry engagement' **ACTION:** DJ to report back to group by Friday 20 May 2016
- Additional topics: Land Use relationships. LULUCF, Woodland Carbon Code, Peatland Code,
- Certified Woodlands/Managed Woodlands
- Datasets from June survey, farm business survey, Farming Connect, Single Application Form (SAF) data.
- Meeting with agri-policy leads to discuss better ways of working with NRW, NRM, - JS
- WG has SAF data available but needs analysing before release – SN

Lunch

5b Ecosystem Resilience, Provisioning and Supporting Services

Group 3 – Reporter Simon Smart

- Resilience – easy links Natural hazard data
- Glastir income forgone not Payment for Ecosystem Services (PES)?
- Lack of case studies - all have different attributes
- Food, agriculture, energy have plenty of data available. Different Scales of datasets. Does a model exist?
- Pollination – good research frontier, CEH working on this.
- Soils: models could play a role.
- Primary production – EObs/field data - widely available
- Social resilience and human wellbeing. Eco and social diversity, age, wealth – outside comfort zone.
- Study on vulnerability of communities to flooding, heat or drought – what would we measure?
- We can make the landscape more appealing but issues with social mobility
- Mental health – we can do a lot to change.

Group 1 – Reporter Dave Chadwick

- Agriculture statistics and ecosystem resilience – big picture stuff.
- Provision and supporting services
- Pollen - plenty of available data**?**
- How much milk are we producing? Welsh Farming Survey coming up ACTION: DJ to map out

http://gov.wales/statistics-and-research/survey-agricultural-horticulture/?lang=en

- Forestry Commission statistics available
- Energy and total renewables – grant scheme available for sourcing. National Grid data available.

Group 2 – Reporter Gavin Siriwardena

- Biodiversity data will come from bio surveys.
- Food web – functional diversity. Require further analysis, data not off the shelf.
- Connectivity and land cover – data available - Phase I habitat maps, hedgerow survey
- Structural diversity of vegetation
- Wildlife Trust has data on wildlife structure
- Soil formation and remediation is important – should have data on this

Health, Wellbeing, Natural Hazards and Disasters

Emergency Response Monitoring – ppt – HP

- Air quality, air deposition, water, radiation, food, species and habitats. Baseline information required for monitoring. This could become an important part of the monitoring programme. We need to understand the environment for when/if a disaster takes place.

Group 3 – Reporter Simon Smart

- Diseases, plant diseases, reporting outbreaks, need the data to see how it impacts on health and wellbeing
- Natural hazards eg: volcano – risk assessment of how we can prepare (next workshop)
- Dynamic behaviour of pollutants eg: agricultural herbage from silage – early warning system?

Group 1 – Reporter Dave Chadwick

- Need to identify categories, access to water and light pollution
- Deprivation Index data, happiness survey, use of forests survey, national park visitor survey, ramblers survey, air quality survey, urban survey from local authorities.
- Manmade and industrial hazards
- Wildfires, drought, waste – data available from local authorities
- Keep Wales Tidy, noise pollution and Light Pollution surveys
- Woodland Trust Report
- Access to green space
- Countryside Rights of Way (CROW)
- Natural Disasters: Tuberculosis (TB) well monitored
- Foot and Mouth – what's already in place?
- Plant health – Fera/NRW data/GMEP
- Volcanos – air quality monitoring
- Radioactivity – rolling monitoring in uplands. Environment Agency/Countryside Council for Wales use to take samples – is this still being done?
- What about abattoir data – could be useful.

Group 2 – Reporter Gavin Siriwardena

- Fire risks, grass, heather, forests
- Extreme weather link to climate change
- Coastal erosion, landslide, earthquakes – data on land stability
- Public Health Wales
- Met Office
- Lidar data on coastal erosion
- GMO and nuclear not discussed
- Human/livestock diseases: physical and mental health – should these be split?
- Green space not the same as green infrastructure.
- Poverty links to clean soil: grow your own food.
  Noise, waste, dark skies – local authorities

Landscapes, Historics and Recreation

Group 3 – Reporter Simon Smart

- CADW datasets on listed buildings HEF's and SAM's (changed to SM's)
- Forestry Commission (NRW) have data for Registered Parks and Gardens, Access, Historic Gardens, Photo records available
- **ACTION:** Bilateral needed with CADW - BWe

- Landmap for Wales – working with Visual Quality Index
- Enrich the landmap squares with GMEP data
- Second round of EObs has landscapes and habitats layer
- Tranquillity map for Wales 2007, to be re-done 2018
- Public Rights of Way already in GMEP
- **ACTION:** Recreation: household based survey – who owns it?

Group 1 – Reporter Peter Henry

- PROW - Length and condition of Listed Paths
- Landscape Character assessment, historic features, Tree Preservation Orders (TPO) Ancient Woodland Inventory (AWI), Veteran trees missing from list.
- Rights of Way officers for national parks – national parks condition survey
- 2015 Access Green Spaces paper
- Important: Quality of data, how is it supplied?
- Licensing Services: eg Planning authorities
- Visit Wales
- NRW Impact on path closures, impact on local economy
- Ordnance Survey (OS) Data
- Historics: Planning/listed buildings/TPO's

Group 2 – Reporter Gavin Siriwardena

- Tourism contribution to GDP
- Outdoor activities, eg: mountaineering, canoeing, human demographics, access to green space. Accessibility and affordability issues to consider.
- Landscapes: removal of hedgerows and in-field trees
- Membership numbers for environmental charities

- Landmap: Annual bidding (tranquillity: funding 2018) for funding needs and risks – JB
- Layers within Landmap need exploration – SS
- VQI, accessibility and tranquillity – lots of data – BE
- **ACTION:** Project Team. Exploration required. Some of it significant. Potential recommendation merger - JS

6 Wrap-up

HP Thanked everyone for their participation. Lots of research to be done and good follow-up opportunities.

7 Next Steps

BE Thank you for today, next stakeholder workshop will explore new technologies eg: EObs

ACTION: (BWe) Circulate dates of workshops JS

8 AOB

Chair declared end of meeting. Achieved objectives. Date of next Workshop, Workshop 2: 23 May 2016

WORKSHOP 2

Development of a Future Natural Resources Monitoring Programme for Wales: Future Options
Stakeholder Workshop 2
23rd May, 2016, WG Office, Ladywell House, Newtown, Powys, SY16 1JB

Present: Catherine Duigan (NRW), Gavin Siriwardena (BTO), Pete Henrys (CEH), Bernard Llewellyn (NFU Cymru), Jill Bullen (NRW), Lawrence Way (JNCC), Clive Walmsley (NRW), Dylan Lloyd (NRW), Steve Lucas (Bat Conservation Trust), Si Creer (Bangor University), Davey Jones (Bangor University), Clare Horton (WG), Dylan Williams (NRW), Tara Froggatt (Dŵr Cymru), Stuart Neil (WG), Andy Davey (WRc), Jenni Hartley (WG), Dai Harris (WG), Dave Chadwick (Bangor University), James Skates (WG), Havard Prosser, Bridget Emmett (CEH), Chloe Elding (Wildlife Trusts Wales), Chris Cheffings (JNCC), Ian Johnstone (RSPB), Chris Bell (CEH), Dewi Jones (CEH), Bernard Griffiths (FUW), Tristan Hatton-Ellis (NRW), Fiona McFarlane (WG), Katie Medcalf (EnvSys), David Allen (NRW), Simon Smart (CEH), Liz Howe (NRW), Jeremy Biggs (FHT), France Gerard (CEH), Emma Waters (CEH) (Secretary)

eDNA

Bernard Llewellyn: implications for people at the end of the line, eg newts! If not 100% reliable will have implications. Jeremy eDNA we now have a promising technique to determine newt populations and as we see population trends we can adopt more sensible conservations strategies. But will still need visual surveys before development is permitted. Good tool for rapid survey and can be a good way of engaging citizen science to take the samples.
Tristan Hatton Ellis: Standard DNA techniques can be used to identify species which are present eg hair/fish eggs
Bridget Emmett: would practical key case studies be useful? **ACTION: Circulate case studies/add to website**
James Skates: mismatch between legislation and technology, until legislation catches up there is opportunity to duplicate effort by backing up with traditional approaches so does it really mean we can do more for less?
Jill Bullen: case studies useful but for this connections to other areas of work would be more useful eg link eDNA to habitat monitoring and then to landscape modelling so any links to be highlighted in case studies
Stuart Neil: useful to explore what doesn't work in new tech and what areas do not work and are beyond scope. A realistic assessment needs to be done. In early phases important to put up red flags where necessary.
ACTION: Set up a matrix red/amber/green / different media (eg lake, river, soil) and where it's the only way vs just cost efficiency / policy relevance. How do we turn data into actual information to inform policy?
Davey Jones: we can now take traditional metrics and link to biodiversity indicators within the eDNA
James Skates: we must allocate more resources to analysis not just collection of data
Tristan Hatton Ellis: eDNA great for identifying species but species richness alone not a great measure of habitat quality so now need to ID what makes a good quality habitat and be able to link the two. eDNA will work well for some species but not for others.
Fiona McFarlane: invasive species legislation requires monitoring and detection (statutory) and this would allow us to monitor on a large scale to save resources for further down the line. Need to think about how these technologies can answer the questions we need answered.
Lawrence Way: need strong examples of multi species applications

Catherine Duigan: Ethics – don't have to kill things to use this method!
Tristan Hatton-Ellis: cost efficient to run but very high set up costs, statutory would need ISO accreditation before it could be used.
Need to identify where it is valid but where the costs would be too high
Gavin Siriwardena: if fundamentally about species ID in most cases abundance is much more sensitive to change then species presence so it will have a more limited use in identification of response to drivers. Jeremy: freshwater monitoring based on species presence not abundance in general. Tristan – a number of water samples taken spatially will give point abundance sample and have found correlation between this type of abundance against the rank abundance (Lake Windermere study). Add this as a case study.
Jeremy Biggs: still need to test single species against traditional methods and basic protocol comparisons. Havard Prosser– would be valuable to map these out.
Tristan Hatton Ellis: must remember there is also error around results of traditional sampling

How do we realise the benefits?
Where are we in EU level policy? James Skates: soil biodiversity will be an indicator if future policy such as soil framework directive were introduced as this is the only way of measuring it, we have mapped. Dai Harris - how does it contribute to welfare/resilience? Where does it fit in against deliverable for these?
Catherine Duigan: can we map this against policies identified in previous workshop?
Bridget Emmett: also about influencing other funders, can KES students be given time to work on these techniques? Innovation money and other sources need to be investigated to move towards more operation work. We need to move towards the middle ground between innovation and application. Possible could be LIFE funded. NERC offering direct co-funding opportunity with stakeholders.
ACTION: Bridget Emmett will write up and incorporate suggestions into report.

CITIZEN SCIENCE

What is the development potential? What are the opportunities for expanding citizen science for future NR monitoring?
Bridget Emmett: limit to control of survey locations – getting permission for access, biosecurity etc takes a lot of time for hard worked agricultural land. Gavin Siriwardena - in practice every hurdle will put off another set of people. Benefit in using unstructured data letting people do what they want to do.
James Skates: securing volunteer effort, would be very worried about people not adhering to protocols. Need to identify if CS has ever been used for species specific evaluation ans would like to explore whether there are benefits in specific cases. Eg. Urban areas. Also would like more consideration of other applications, not just biodiversity e.g. MySoil (**ACTION: move MySoil into body of report from appendix**) and PV panels on farms.
Gavin Siriwardena: different kind of engagement of people collection samples to be sent off and analysed elsewhere (e.g. water and soil)
Steve Lucas: issues of cost of specialist equipment, and issue of permission from landowners to survey for contentious species. Also costs involved in analysis of data (software)
James Skates: ID where they can add new value to what we are doing, surveillance in urban areas vs regulation on agricultural land
Andy Davey: UK EOF (CEH/WRC) useful cost benefit tool available, could also be used to compare CS with standard monitoring programme.
Gavin Siriwardena: looking at complementary remote sensed data and linking with citizen science in analysis. It can't fill in the gaps, and still need some actual records to be able to model to fill gaps (eg mid wales).

Kate Medcalf: Warwickshire council use volunteers to update habitat map in the first instance (Case study?)
Gavin Siriwardena: good engagement will lead to numbers of volunteers growing but static samples may not get such good engagement if there is no change and interest for the volunteers
James Skates: would like to explore demographics, are there examples of landowners participating in citizen science programmes in areas with low population density?
Simon Smart: NPMS plots placed in areas of high density remote sensed data.
Lawrence: good evidence volunteers can follow protocols, remote sensing needs ground-truthing so volunteers can help validate. Is it worth putting in resources to fill gaps with volunteers – what's the best balance?
Bernard Llewellyn: question mark on quantity/quality. Also would like more farmers involved – will put out into the sector.
Catherine Duigan: could we endorse key citizen science results?
Pete Henrys: can we integrate more with current CS schemes? James Skates – incremental gain and wants to see greater engagement with landowners in the next monitoring programme.
Bridget Emmett: NRM samples ½ million soil samples/year has published its ongoing trends in soil quality for England and Wales and shows complete opposite to CS/GMEP results because farmers are self-selecting for lime/pH samples. Shows you really need to understand biases.
Simon Smart: need to make better use of LERC data holdings.
Gavin Siriwardena: large scale vs local - for birds large scale surveillance is good, need to assess for different species and areas **ACTION: map where volunteer effort is currently focused**. Using EO spectral bands where are the gaps.

EARTH OBSERVATION

Recommendation from France Gerard: Get Lidar incorporated into Welsh 3 year aerial photography programme
Lawrence Way: important to be balanced and look at near term opportunities – which are with the new Sentinel 1 and 2 (optical and radar). We have good information on land cover so now need to focus on interpreting features
Katie Medcalf: some classes are easy and accurate and should concentrate on what it does well
ACTION produce list of what EO does really well and add to report eg woodland and bracken
Clare Horton: we have started discussions on using Lidar on aerial capture so interested to hear it's been done in Europe
Tristan Hatton-Ellis: any aquatic applications? France Gerard - Algal blooms can be picked up but smaller water body is then more trees in the way, useful for larger lakes but struggle with smaller ones. Possibly drones could work in these localised sites. Is it cheaper to fly a drone rather than just take a water sample? Being used for river habitat aerial surveying by a commercial company in Wales.
Lawrence Way: in England need to shrink the expense of water quality monitoring, looking at using eDNA and using land-based intelligence to produce a risk base assessment to inform water sampling.
Dave Chadwick: Heard it may be possible to estimate assess yield/productivity and infer the amount of nitrogen needed to grow that yield for potential use in GHG emission calculations? France Gerard – to do this would be very tricky
Could it be used in GHG inventory? IACS only collects information from claimants, different methods being used across the UK
Jill Bullen: would be useful to identify specific data sets with people who are interested in them, this can then encourage collaboration eg NDVI Landscape and woodland. Messages can they be fed out from each product to the whole community.
Havard Prosser: How does monitoring link to the policy areas people are engaged in – there is a gap here we need to address

ACTION: circulate papers to those interested in specific topics and find out which areas people are interested in
Lawrence Way: same basic processing is needed for several policy areas NDVI – NFI/ SSSI condition/some plant health policies. Use for risk base assessment
France Gerard: work to be done to get this used the right way, must check NDVI change is detecting what you want - need to check omissions vs commissions.
Katie Medcalf: south Wales example of grassland assessment – erred on the side of commissioning, volunteers then went out to check, found 60% more grasslands than they thought, but only c58% accurate.

FRESHWATER MONITORING – Phase II

Simon Smart: working in a more joined up way reminds me of an idea which arose after last CS when trying to interpret data on change without the expertise to look at change in different areas we wondered if there was scope to convene a biennial standing committee to sift data, take into account model data to forecast and recommending more intensive monitoring in some areas. Better way of utilising knowledge. Undertake risk-based assessment eg on ipBES/IPCC forecast.
Who would then do this monitoring? Relies on answering the question of what a future monitoring programme might look like. Coarse grain detection capability across the board would then be augmented on recommendations of such a group. Issues of funding for doing any more work. James Skates: future programme will have a designated budget which can be deployed, if coarse grain surveillance was in place we could then have a group considering priorities in terms of evidence, matched or balanced by policy priorities would be a nice balance of drivers. Noted that Future Generations and SoNaRR have a future trends requirement. Bridget Emmett: need to make sure it doesn't just follow fashion when determining risk and be aware of unknown unknowns.
Havard Prosser: Need to focus on evaluating policies
ACTION – ALL: Any more feedback on this or any of the other topics, case studies etc send to Chris Bell

ACTIONS & NEXT STEPS

- Next workshop 22 June by which we need set of actions and recommendations – all comments etc from this meeting to Chris Bell within the next 2 weeks.
- James Skates: We will produce an additional paper on data integration for comment – same timescale
- Authors - Final papers in 3 weeks' time please
- Next meeting: Broneirion, Llandinam, Newtown 22 June. Please confirm attendance by Weds 15 June.
- James Skates: next steps meeting with NRW to talk about their monitoring activities and how phase 2 & 3 of this will align. Next of these workshops we will present recommendations and benefit realisation which will form basis of discussions with ministers.

WORKSHOP 3

Future Options Stakeholder Workshop 3, 22 June 2016, Llandinam, Powys

Attendance list is recorded elsewhere.

Initial Comments

ACTION Steve Spode – SNRM should be SMNR
Stuart Neil – remember reporting is not the end of the process you need to do something with it
ACTION: Bridget add feedback loops to central box
Ian Johnstone - How to know what to measure – BE there will be a coordination board to consider this
Paul Sinnadurai – national evidence gathering won't negate local info gathering? BE hoping we can agree at least on method for local reporting to inform against national trends. Make these methods available for people to use for local monitoring but would not be made mandatory.
Havard - Landuse future land management, climate change – risks. Coordination board needs to identify likely pressures and has monitoring in place
ACTION Co-ordination board - Policy Priorities needs to be added as arrow on diagram

PANEL SESSSION

Recommendation 1
Steve Spode must be able to adapt – James – this is issue of language. It is more responsive and resilience and allows more rapid allocation of resource.
ACTION will add in word 'adaptive'
Jill Bullen– bullet point 3 – issue about Designation - BE we will double check this is clear. James – 'seek a better aligned programme'. take out designation? But designation is a policy instrument. So add in Wider environment and…'
Pete Jones – would add condition to habitat mapping on diagram and needs something to reflect ecosystem services
ACTION BE - 10 evidence categories should become the bubbles so will include these.
Paul Sinnudarai – need to be able to demonstrate benefit of designation
Gavin need to be specific about timescales for risk/adaptation or there could be misunderstanding of interpretation. James - will be different depending on issues which arise

David Allen - slight concern about standard monitoring method being used for everything, do we need to build in a bit of flexibility? Havard there will be particular investigations on individual sites but this will be at a different scale, this is national monitoring
(??) - Opening paragraph – do we need to be specific there are resources outside wales we need to exploit.

Recommendation 2
Paul S - resources are going down, opportunity to look at workforce planning. James – this recommendation addresses these issues. It's here because there is a shared desire to work better together and in doing so there is potential to offset decline in resources but need realistic timescale, it takes time to do this. We need to align ourselves with other reviews and activities and align timescales to theses and reporting cycles. BE this is also partially covered under 4 and 10.
The NRMF co-ordination board will be tasked with resourcing.
David Allen – interested in way it initially talks about WG/NRW framework and then talks about partners afterwards, why is framework just NRW/WG.

ACTION take out initial reference to just WG/NRW, it's not a bilateral partnership
Dylan Williams – anything in here about looking for external funding? James this comes under recommendation 4

Recommendation 3
Stuart Neil – focus always on WG/NRW what are links outside wales? Almost all of these things are part of UK/Europe/International scale. We can only control within wales but need to make sure we think that we can learn from outside. James partners extend outside wales. The programme will be aligned where possible to those taking place at a wider geographic scale. Regards international reporting – should always be on our mind when constructing monitoring programme. Havard this is encapsulated in top set of boxes – add bubble 'other monitoring/... outside Wales' coordination board - needs to be outward looking.
ACTION – rewrite 3 so it makes more sense

Recommendation 4
James essentially about funding, capacity building, making best use of funding opportunities.?? – possible change order of recommendations
Bob Vaughan - involving industry etc horizon scanning and how best to exploit new ideas. James – we are trying to identify funding sources for a new programme and some may come from new areas we haven't tapped into before. Cannot underestimate importance of capacity building
Gavin – good reason for having existing surveillance systems to measure responses and you can then measure pressures

Recommendation 5
Steve Spode – align with topic areas- SEA , EIA's and wider compliance. Must emphasize the economic and social benefits. James potential cost saving is huge (check what he said) Must be careful when data is gathered for natural resources monitoring programme but may be used for cross compliance. Landowners will be reluctant to allow monitoring if gathering data for cross compliance too.
Dai Harris –underplaying social(?) etc aspect. James will welcome this in breakout groups later.
Stuart Neil – can't argue with principal but devil in detail and a lot of examples out there from government where big initiatives to bring things together have made things worse. Not a reason to not do it but we need to be realistic and manage expectations. BE see recommendation 8
ACTION change spelling to Principle not principal

Recommendation 6
James this will be incremental gain, we have monitoring and reporting requirements which could act as a foundation for a surveillance programme and we need to be aware of requirement to respond to other drivers when needed. It won't do everything for everyone.
David Allen – should we say something about the process under which board should operate – CD we can agree TOR etc once we have agreement in principle. James function and role and membership will need serious thought

Recommendation 7
Internal walls? = Cannot pass on data collected for one purpose to everything else. Eg landowner permission for data for one purpose only.
Stuart Neil – quality of data is important, it may not be fit for purpose for another purpose for which it wasn't collected. Meta data is very important.
Katherine Raymond(?) - Lot of ambition focusing on evidence need. James not a lack of ambition but need to temper with what is achievable.
??– can't underestimate it must be underpinned by the data, good to see it mapped up front.

Recommendations 8&9
Paul – urge coordination with LERCs and use open source data
James – high on everyone's agenda, but hard to realise
BE point to UKSO as exemplar of data sharing between very fragmented communities.
Gavin – lots of data exists for other reasons not for monitoring state of natural resources. So there is funding or effort from elsewhere which could reduce budget but other side of this is that data may not be handed over. Data subgroup for coordination board. Number 9 step before that needs to be explicit – determine if evidence product is tractable by mapping evidence needs against data and data not necessarily right data to answer the question so need objective measurement of the mapping.
Dave Allen - adequate resourcing – this needs to be at every step of the programme – rephrase – rebalancing seems to be key point.
Havard need to understand importance of data management and importance of collecting right data.
Steve Spode – be ruthless about what you don't need

Recommendation 10
Benchmarking role for co-ordination board for knowing which is best.
James – this will probably move to being recommendation number 2.
Gavin – line in there about citizen science needs to be re-written, doesn't capture what was agreed
Highlight these are examples only
Paul S – opens source and free not good method of categorising (….?) Whole array of software suites, we don't know which is best to use. Reason people collect data often nothing to do with conservation but we are dependent on what they do.
James – we may need some form of vision statement
BE have we missed a recommendation about engagement
Steve Spode – some of these points are design others principals so need organising in a more accessible way.

Have we missed anything vital?
JS absence of engagement
Dave Chadwick - cost benefit on when to let old technology go - BE see last paragraph of 10 if this doesn't capture it let me know
Will there be an annual conference?

Comments after breakout sessions

Chloe Elding - How long for comments and input into benefits and technology? James – realistically report needs to be completed asap. Send comments to Chris with regard to recommendations but we have taken as much consultation as we can and we can't make any fundamental changes. Bridget – we have to have full report and recommendations so any comments must be with us in the next week.

ACTTION comments must be sent to Chris by end of next week at the latest.
ACTION James we have agreed additional recommendation focused on engagement, this draft recommendation to be circulated to this group. Comments again by end of next week.

Intentionally blank

NERC SCIENCE OF THE ENVIRONMENT

PEER

INVESTORS IN PEOPLE

Athena SWAN Bronze Award

BANGOR
Centre for Ecology & Hydrology
Environment Centre Wales
Deiniol Road
Bangor
Gwynedd
LL57 2UW
United Kingdom
T: +44 (0)1248 374500
F: +44 (0)1248 362133

EDINBURGH
Centre for Ecology & Hydrology
Bush Estate
Penicuik
Midlothian
EH26 0QB
United Kingdom
T: +44 (0)131 4454343
F: +44 (0)131 4453943

LANCASTER
Centre for Ecology & Hydrology
Lancaster Environment Centre
Library Avenue
Bailrigg
Lancaster
LA1 4AP
United Kingdom
T: +44 (0)1524 595800
F: +44 (0)1524 61536

WALLINGFORD - Headquarters
Centre for Ecology & Hydrology
Maclean Building
Benson Lane
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB
United Kingdom
T: +44 (0)1491 838800
F: +44 (0)1491 692424

enquiries@ceh.ac.uk
www.ceh.ac.uk