Please complete and send back to a.dalton@uea.ac.uk by 15th November 2012. Thank you!

Principal Investigator

Name incl. title	Mr Ron Smith		
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Address	Bush Estate, Penicuik, Midlothian EH26 0QB		
Discipline	Statistician and environmental modeller		
Role in team	Team leader and expert on statistical environmental modelling		

Project team

Total number of people involved	Academics	16
	Non-academics	6
Of these, how many are	Natural scientists	10
	Social scientists	9
	Economists	3

Project title (<120 Characters)

Interdisciplinary quantitative ecosystem services team (INQUEST)

Project objectives

1. To bring together a research team encompassing a variety of disciplines, to construct an agreed vocabulary allowing for effective interdisciplinary activity and communication, and to create a typology of ecosystem services allowing wider relevance of the results
2. To identify a selection of ecosystem services for investigation in preparing the research agenda that will address issues of scale and uncertainty
3. To determine the approach to the issues of uncertainty assessment and scale dependence within ecological and environmental systems for the selected ecosystem services and to quantify the links between ecosystem functions and ecosystem services
4. To consider the role of scale and uncertainty issues within the social, management, policy and economic influences on, and responses to, ecosystem service delivery, linking these with the ecological uncertainties
5. To take forward and consider the role of the scale and uncertainty constraints in illustrative monetary and non-monetary valuation metrics and their related decision processes for selected ecosystem services

6. To generate a future inter-disciplinary research agenda to address the uncertainty, scale and response function challenges in generic ecosystem services valuations

Summary

Please provide a **one page** plain language summary of your project, aimed at a non-specialist audience. Please address the following:

- what is your project about?
- briefly state your key findings
- why are these important?
- what have you produced that other people or organisations might find useful: tools/models etc?
- who (what type of organisations) should be interested in your tools etc?

The INQUEST project brought together 22 academics, research scientists and stakeholders to investigate how we put a value on what humans take from nature, such as food and fresh water but also other benefits like participating in mountain sports or relaxing on a beach. We wanted to know how certain we could be about any value we worked out, and when and where we could use that value in helping society to make better decisions. We visited two different areas in the UK with contrasting landscapes to see what the human population gained from nature in these areas and how a value for these benefits could be derived.

The first visit to the estuary of the River Tamar and the farms upstream in Devon and Cornwall looked at the impacts of human activity on water quality for both drinking water and for keeping the river and estuary in a good condition. Our second visit took us to the Cairngorms National Park where we looked at the park plan and visited two land managers, one running a farm and the other managing land to encourage and protect birds.

We looked at two challenges in trying to value the benefits of nature. First, we understand a lot about how our environment and our human society works, but we do not understand it all. Therefore we use models to help us predict what will happen, for example when it rains heavily we have models to tell us where flooding is likely. We cannot be certain where a flood will occur, but we still use that information and advise people to take precautions. Secondly, do we have the right information to help us estimate a value? If we only have the numbers of visitors in the area, it's difficult to value the benefit of tourism to a specific village, so we need to use methods of estimating values for different geographical areas, and sometimes over different time periods.

At the study visits we found that putting a value on nature would be quite difficult. There was a lot of missing or uncertain information, and sometimes a value in terms of money was not a helpful idea. We looked carefully at several ecosystems and we could see how to use a tool (called a Bayesian Belief Network) to link together information and provide us with a value and an estimate of its uncertainty, just like in predicting a flood; it also had a good graphical presentation so users could understand what was going on. Using regional information collected for a study on a farm was difficult, and there were no tools that could really make that easy at present. We concluded that the task of valuing nature was possible, but the tools needed improvement and much of the information you needed was not easily available.

It is misleading to provide a value for the benefits from nature that pretends to be more accurate than it really is, or is actually relevant for a different area or time than the decision that you want to make. We showed that people we met understood the problems and could use the information on the certainty of the value sensibly.

If the tools were developed further, they would be relevant to any manager or policymaker with a requirement to provide values for human use of natural resources. The transparency of the process should also lead to their take up by local and national organisations interested in rural, urban or marine development.

Your project and the Valuing Nature Network

Please provide up to **four pages** of detail regarding the following:

1. Your insights into which of the four VNN Key Challenges (Appendix A) you addressed, according to your proposal
2. How you have evolved the overall VNN conceptual framework (content of boxes and flows between) (see Appendix B)
3. Your thoughts on the future agenda for VNN research (following on from initial ideas in April's meeting)
4. Your recommendations regarding mechanisms to maintain and grow the network

1. The key challenges (2 pages)

Challenge 1 *How can the complexity of socio-ecological systems be incorporated into valuations of biodiversity, ecosystem services and natural resource use?*
Challenge 3 *How can issues of scale be incorporated within valuations of biodiversity, ecosystem services and natural resource use?*

The INQUEST project looked at the scale and uncertainty issues in applying the ecosystem services valuation concept. We particularly looked at place-based assessment at the regional to local scale helped by case study visits to see the multiple uses of the estuary of the Tamar and the potential forest development in the Cairngorms National Park Partnership Plan. In the Cairngorms we visited an estate owned by an NGO and a commercial farm to understand differing land management strategies. We also used evidence from strategies (including PES) to encourage reduced water pollution in the upper catchment of the Tamar and from a regional economic study for the Loch Lomond and Trossachs National Park.

An ecosystem services assessment uses data and models for ecological and socio-economic processes which are linked to specific temporal and spatial scales. We looked at information availability to see how data could be transferred between scales and at how compatible services valuations would be at different scales. We recognised the term uncertainty has a variety of technical meanings but we used it as a general concept to reflect both variability from many sources (individuals differ in the values they give, ecosystems differ in their responses to pressures) and also to reflect our levels of knowledge. Some sources of uncertainty can be quantified through sampling and measurement while others require elicitation from people or more complex model analyses. Uncertainty and scale are closely related and it is impossible to treat these independently of each other in an ecosystem services valuation. The purpose of ecosystem services valuation is to improve evidence-based decisions, so we must be clear in reporting the spatial and temporal framework and some assessment of the certainty we can ascribe to the output values, though the acceptable levels of certainty and the interpretation of the results will be determined by the context.

We found no situations in the case studies where it would have been impossible to estimate scale effects or uncertainty. The Bayesian approach allows for the combination of qualitative and quantitative information as well as expert opinion and Bayesian Belief Networks are a basic tool for combining all the relevant information and uncertainty for an ecosystem services valuation. Hierarchical models can be used for many of the scale issues, but these two approaches have not been brought together so far to tackle ecosystem services valuation.

All valuations are context specific, and it is important to define (a) the question, (b) the provisioning scale (setting the boundaries on the spatial and temporal scales), and (c) the beneficiary scale for the study. A clear set of constraints focuses the valuation and we can ensure the remaining scale transitions are traceable. However the selected bounded region will be nested within larger areas (e.g. the different regions within the Tamar catchment) and pressures from beyond the boundary also impact on the ecosystem services valuation. We include this within the assessment as a further scale issue manifestation but it can also be an uncertainty issue (lack of knowledge).

An ecosystem approach seeks to provide a holistic understanding of the system, but the resources required to implement a complete ecosystem services assessment can be substantial. Focusing on a single ecosystem service is not useful because of the interactions within the ecosystem and within human society. However if only a subset of services are chosen and the rest ignored, possibly because the user (such as a water company or a farmer) may have some control over parts of the ecosystem, this service selection process is itself a source of uncertainty which, for a holistic assessment, should be recognised and estimated.

There is a tendency to mix up cardinal and ordinal scales within a valuation, not recognising that the translation between the two systems introduces uncertainty. A standard economic model uses only cardinal scales to assign monitory values and has the further restriction of additivity; so, for example, a societal value of an ecosystem service is the sum of all the individuals' values. There are all kinds of values that do not readily become part of this economic perception of ecosystem services; a more general methodology would be able to consider multiple metrics of value, use both cardinal and ordinal

systems, and allow for non-additivity and non-linearity.

In many landscapes heterogeneity is a positive benefit, with different units delivering different sets of ecosystem services. If we want, for example, to sacrifice an area to sustainable intensification so allowing more environmental benefits elsewhere, disaggregation of regional or national data will not deliver the desired outcome unless some stochastic element is introduced in the scaling process. Heterogeneity in society can lead to a mismatch between assumed societal values and actual individual values (a more visible effect in local studies and one postulated reason for failure in uptake of some policies), so more effort is required to estimate the variations in individual values at relevant scales, to determine acceptable local societal values and to avoid biases in estimation.

Often indicators are used as helpful summary statistics, but it is not clear what their role is within an explanatory or decision support tool. There is extra complexity in deriving uncertainty on an indicator, especially if you then impose a threshold on the indicator as part of its perceived usefulness. Indicators are, and should be seen to be, scale dependent. Therefore, if they are a part of an ecosystem services assessment, care must be taken to adjust for scale and assess uncertainty.

Regulation is a major factor in land and marine management, but in ecosystem service terms it brings an effectively infinite value into the system. It's not clear in many cases that society really does assess the ecosystem service as worth that value, so to include regulation within the holistic management of an ecosystem there should be further debate on the translation of the regulatory system into a value system with possibly more flexibility than is currently apparent.

It is convenient to disaggregate national or regional data to local scales using a simple GIS approach with overlays of different data polygons. However if there are spatial correlations or interactions, the inclusion of these additional local and global processes make the downscaling of data a non-trivial task. Other challenges include estimating uncertainties introduced when applying scale disaggregation by proxy variables, with several examples from the regional accounting exercises. Successful data aggregation also depends on adequate spatial and temporal sampling of the area and of the services to ensure any interactions or non-linearities are reflected in the responses at the aggregated scale.

As valuation depends on an individual's perspective of the service, the selection of the beneficiaries is a major factor in determining the value of the ecosystem services. Pump-storage hydro schemes, for example, provide no local jobs and so no local value in derived data from National Accounts. This is further complicated by no good estimate of market value of the electricity, because the product is traded on a spot market and the real price of that particular supply is not generally known, and it's not clear who are the beneficiaries. For any local ecosystem services valuation the beneficiaries are likely to give the hydro scheme zero value while at other spatial scales a positive benefit would be expected.

Different processes operate on different timescales, e.g. with farming timescales being generally much shorter than forestry timescales when considering an increase in on-farm woodland. Long temporal scales bring substantial uncertainty in both ecological response and valuation, complicated by monetary values being temporary and context specific with different assessment and discounting methods leading to non-equivalent valuations. Some ecosystem services rely on functions that are neither time constrained nor diminished by service provision, such as those dependent on a continuing biodiverse system. If all these services are included in the same assessment, there is an uncertainty from the mismatch of temporal scales that should be estimated.

An issue highlighted by the farm studies are the value of services such as reduction of runoff into rivers. Each component is generally small and potentially quantifiable, but it is the cumulative effect that is important, and that effect may depend on other inputs from diverse sources and subsequent ecological/hydrological processing of the combination. This leads to substantial uncertainty on any value then ascribed to the service at farm level.

There was often an assumption that because some data were more readily available at the local scale (e.g. a farm) there would be less uncertainty in any ecosystem services valuation, but in practice it appears some services are better estimated and some relatively worse than at the regional or national scale. Overall the levels of uncertainty may remain similar across scales, so it is necessary to manage with uncertainty rather than hope it can be removed from the decision process.

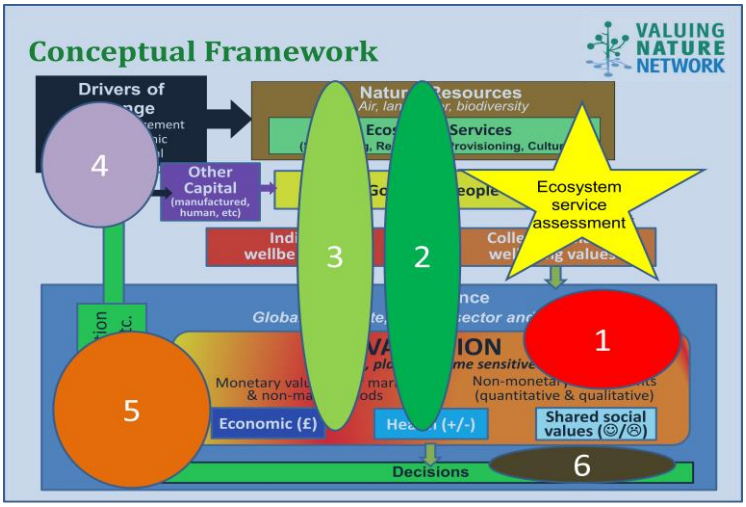
Cultural ecosystem services are particularly difficult to assess, with several examples from the Cairngorms visit including the benefit of just being there. For many recreational activities it's difficult with current data to determine their value, who are the beneficiaries and over what timescale. With many non-market and non-monetary values to be considered, it remains a significant problem to deliver a value for cultural services and a further substantial task to assess its uncertainty.

2. Conceptual framework (1 page)

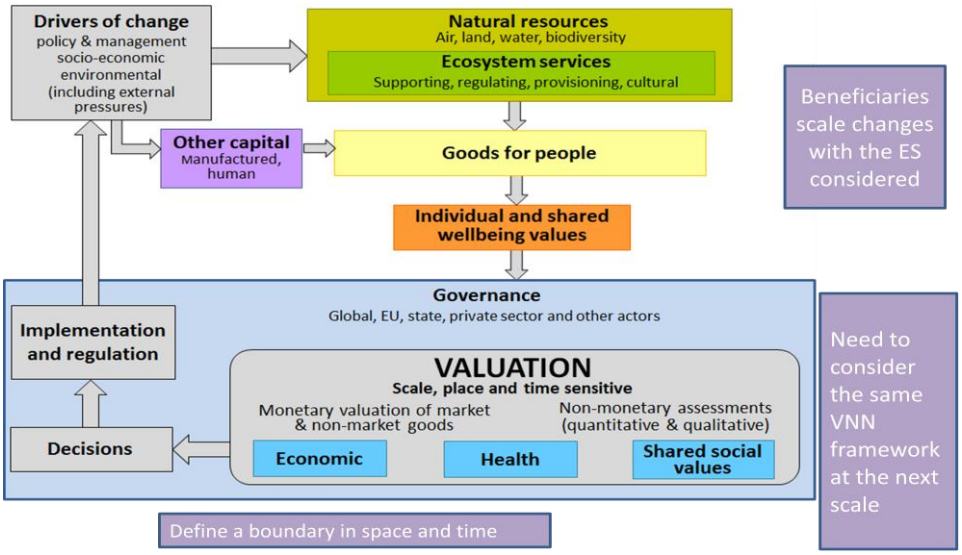
The conceptual framework was used to develop the 6 taskforce themes which were investigated at the two case study visits:

1. Valuation of adjustment capacity
2. Valuation of water resource
3. Valuation of biodiversity
4. Influence of pressures and drivers
5. Influence of regulations on valuations
6. Creation of a Bayesian Belief Network model

Four of these themes directly mapped to single elements of the conceptual framework while the remaining two cut across several elements.



Through the case studies several points were clarified as to how to use the framework and adapt it further. Importantly, there is the need to define the boundary in both space and time to which the whole framework should be applied. The issue of scale, place and time should not be solely restricted to the valuation stage of the framework. Also, the entire framework could then be applied at the next scale up to complete a further valuation and so on. We discussed that the major issue with incorporating scale into the framework was mainly due to the mismatch between the scale of the drivers, the scale of the beneficiaries, and the scale of the actual assessment of ecosystem services. Therefore, the beneficiaries scale would have to be formally included in a framework.



Uncertainty is pervasive and comes to the framework through both the links between the elements and the quantification of the elements. The impacts of drivers of change on natural resources, for example, are uncertain and could be modelled, while the assessment of natural resources introduces uncertainty through sampling variability. Variability in economic, health and social values comes through uncertainty in the valuation process but is also related to variability in the links delivering the services. Regulation, often driven at EU level and very prescriptive traditionally, is dealt with in silos. Links between management, regulation, and effects of regulation can be quite unclear.

3. Future agenda (half a page)

The Bayesian Belief Networks (BBNs) provide a good tool to link together the elements of an ecosystem services valuation. There are two obvious constraints: most software implementations use only categorical data and there is a limit on the complexity of the links between nodes. In practice these constraints are generally not a major issue, but BBNs could be developed further for use in ecosystem services valuation by using different computing algorithms and moving to more generic Bayesian graphical tools.

The BBN structure is a good platform from which to develop an ecosystem services working tool for end-users/stakeholders, and this would benefit the community. Possibly associated with this would be developments to link BBN inputs and outcomes with GIS software. To enable this, the BBN framework needs to be developed in a spatial context to cope with the change in probability distribution across space of different outcome nodes.

The ecological side of ecosystem services valuation relies a lot on models, many being complex with multiple interactions. Linking these biophysical and chemical models with the BBN framework demands a substantial simplification of the processes with the risk of losing the information on interactions. The statistical developments in model uncertainty estimation using model emulation could usefully be explored to see if these prove to give better links from ecological process models to BBNs.

Routinely quantifying uncertainty in data sources, including environmental indicators, and clearly identifying scale dependence would be a substantial benefit to supporting evidence-based decisions through ecosystem services valuation.

A statistical approach to scale issues, particularly if scales are nested, uses hierarchical models. It would be useful to see if some of the scale issues, particularly with data acquisition from different levels of aggregation/disaggregation of data sources, could use these approaches.

Context-specific valuation, attribution of services provided at the regional level to local ecosystem assessments, and the extent to which societal values are reflected in the value for site/land managers are linked challenges related to a coherent use of ecosystem services valuations across scales, and developments in this area would particularly assist in understanding how effectively policy can be implemented.

Regulation is focussed on process rather than on the intended outcomes, but an ecosystem services approach could change that emphasis if there was development of methodology to fit regulation into the ecosystem services framework.

4. Maintaining and growing the network (half a page)

The inter-disciplinary network has taken time to develop and establish, and the first challenge over the next year is to maintain that network without funding. It is unlikely the INQUEST network would grow over that period, and if resources for individuals become available from other funding sources it is more likely to fragment.

A major outcome of the VNN projects was pulling together the disciplines, and we suggest that maintaining these links would require more structured communications from the different disciplines across the VNN network, possibly carried out via an occasional series of webinars or video conferences.

It is suggested that the VNN conference in March 2013 should be available on the web either live or as a recording. It is useful to promote topic based sessions at other conferences/meetings e.g. BES, ENVECON, European Society for Ecological Economics, Intercol, ESP, where people are already attending and this has potential either to grow the VNN network or to combine with other networks.

Specific project details

Please provide brief details (**100 words** for each question) to address the following:

Progress

Did the research proceed as expected and on time?
If NO give details.

The research activities proceeded to the original time scale and the project will be completed within the agreed time. The research had 2 components – academic interrogation of the issues of scale and uncertainty and extensive case study interaction with stakeholders, with some members of the team having routine contact with the stakeholder community. The latter component was extremely valuable to the project team and raised many questions that had not been originally included in our agenda. However it did also alter our expected outputs and reporting mechanisms, and a much greater emphasis has been placed on informal dialogue.

Was there any significant change in the research compared with the original proposal?
If YES give reasons for changes.

We simplified the research agenda as suggested by the VNN management team in the initial project implementation discussions and concentrated more in the latter stages on the statistical elements of the research as requested at the mid-term review.

Were there any circumstances that aided or impeded research progress?
If YES explain how the work was affected and how any problems were overcome or opportunities exploited.

We discovered, when we visited in spring 2012, that ecosystem services concepts were hazily understood at the regional planning scale; there was a steep learning curve and a considerable degree of scepticism about some elements of the ecosystem services concepts by actors at the local geographical scale. Therefore discussions of the second order concepts of uncertainty and scale were inhibited until all had agreed on what reasonably would constitute an ecosystem services valuation. Faced with this extra work, lack of staff time within the team has made it challenging to fulfil all objectives.

Publications

Dissemination of results.
List the following types of output: papers (both published and in press) and reports directly arising from the research; conference proceedings; book chapters; etc.

In press (conference proceedings):

Rognvald Smith, Jan Dick, Hamish Trench, and Marcel van Oijen (2102) Extending a Bayesian Belief Network for ecosystem evaluation. In proceedings of the 2012 Berlin conference on the Human Dimensions of Global Environmental Change: Evidence for Sustainable Development. Freie Universität Berlin.

In preparation (papers):

**Spatial and temporal scale dependencies and uncertainty in the delivery of ecosystem services and their valuation* (the synthesis paper) – introductory text was circulated and discussed by end March, first draft of this version to be sent round by end November – Ron Smith leading

**Scale and uncertainty in the valuation of natural capital and ecosystem services: case study within Cairngorms National Park* – on second draft – Jan Dick leading,

Connecting scales for the balanced delivery of ecosystem services – second draft with core authors – Mark Everard leading

Socio-economic challenges in addressing ecosystem service effects arising from land use change: a Cairngorms case study – draft with comments with authors – Bill Slee leading

In discussion at present:

BBN paper to be developed from reports and text in above conference proceedings – intended to have draft by mid to end November

**Scale and Uncertainty in Ecosystem Service Assessment and Valuation: the Search for the Holy Grail* (paper on the Tamar case study) – sketch of paper circulated 30th May and some subsequent comments – Paul Somerfield leading

**** indicates that all members of the INQUEST team will have the option of being on the authorship list, other authorship decisions will be made on an individual paper basis

Results and outputs

Have any significant datasets been generated from this research?
If YES give details.

During the Cairngorms site visit, data on the 109 Ecosystem Services variables reported in the Dick et al. paper were collected from the land managers. These data could go into the NERC portal with the agreement of the stakeholders.

Were there any circumstances that aided or impeded research progress?
If YES explain how the work was affected and how any problems were overcome or opportunities exploited.

As discussed above, we discovered many of our stakeholders were sceptical about ecosystem services concepts and we had to spend more time on low-level explanations and discussions with stakeholders – indicating a need for much simpler explanations and outputs than were readily available.
The graphical outputs we proposed were readily accepted and the challenges resulted in us putting together more introductory material to explain the development of a BBN, and it confirmed that the approach was useful.

The wording of results was an issue, particularly with some misunderstandings between team members and stakeholders, reinforcing the idea that even discussions of ecosystem services have to be set within a defined context and that taking data and expert opinion out of context is dangerous.

The low level of funding for the VNN projects and the consequential constraints on staff time were a continuing issue throughout the project. It was worth having the spread of expertise and the project benefitted from it enormously, but the patience of and inputs from the participants has been stretched.

Results exploitation and knowledge transfer

Who do you think are the main users of this research?
Include any that apply: industry (please specify which sector); policymakers and regulators (e.g. Defra, Environment Agency), NGOs (e.g. RSPB, conservation bodies; other academics).

This research would apply to all ecosystem services valuations so main users would range from those developing national policy to those who would like an ecosystem services approach in local planning and land management decisions. Our current identified users are: local site owners in the case studies, researchers within INQUEST team and VNN more generally, Cairngorms National Park Authority, Scottish Environmental Protection Agency, Tamar stakeholders including the Tamar Estuary Authority and the Tamar catchment pilot study.

Have any potential beneficiaries and/or users of the research outputs (in particular non-academic research users, such as private or public sector organisations) been involved at any stage in the research activity and/or been informed of the research outputs and achievements?
If YES give details.

The following invited stakeholders for the Tamar case study made presentations to the meeting and joined in the discussions:

Paul Cottington	National Farmers Union, South West
Lewis Jones	South West Water
Kaja Curry	Tamar Estuaries Consultative Forum and Plymouth City Council
Richard Smith	Deputy Queen's Harbour Master
Angie Gall/Liz Bailey	Natural England
Christine Hollis	Plymouth City Council, Environmental Health
Matthew White	European Centre for Environment and Human Health
Mary Rose Fitzgerald	Environment Agency

and the following invited stakeholders participated in the discussions:

Jeremy Sabel	Plymouth City Council
Jody Leigh	Plymouth City Council
Kathryn Bate	Plymouth City Council
Jude Eze	was University of Glasgow, now Scottish Environmental Protection Agency
John Bruun	Plymouth Marine Laboratory
Tara Hooper	Plymouth Marine Laboratory

Andy Rees	Plymouth Marine Laboratory
Tim Smyth	Plymouth Marine Laboratory

The following invited stakeholders for the Cairngorms case study made presentations to the meeting and joined in the discussions:

Kirsten Olsen	IOD PARC
Rebecca Badger	Scottish Environmental Protection Agency
Ali McKnight	Agroecosystems
Gregory Valatin	Forest Research
Hebe Carus	Royal Society for Protection of Birds, Cairngorms Futurescape Officer
Matthew Hawkins	Cairngorms National Park Authority
Will Boyd Wallis	Cairngorms National Park Authority
Mary Christie	Scottish Natural Heritage
Ann MacLennan	Balliefurth Farm
Mike Smith	Forest Research
Alastair MacLennan	Balliefurth Farm/National Farmers Union Scotland
Jeremy Roberts	Royal Society for Protection of Birds, manager of Abernethy NNR

Has the research led to any further collaborations with potential users or other academics?
If YES give details.

EU FP7 OPENess project is using the Cairngorms as a case study. This has arisen due to collaborations formed through INQUEST.

Science in society

Has an opportunity arisen to promote the public understanding of the scientific results from this research?
Give details of work/activity undertaken

A major component of the case study visits to the Tamar and the Cairngorms was taken up with knowledge exchange familiarising stakeholders on the usefulness of the ecosystem services approach and debating how it could fit with and enhance processes they already undertake.
The team propose a research agenda, and so have limited scientific results from this scoping exercise, but those that we have are being promoted at international workshops and are communicated to the whole team including land managers, local planners, etc. involved in the work's development.
We will attend the VNN organized conference in March and are in the process of organising a day meeting at the Royal Statistical Society to promote the results to a statistical and policy oriented audience.

Interdisciplinary working

To what extent did the project enable new working relationships a) between different academic disciplines and b) with non-academics?
Please give details

The INQUEST team was a deliberate mix of academics and non-academics and crossed several of the relevant disciplines for ecosystem services valuation, including challenges which might not generally be considered such as risk of complete loss of service to a whole area (e.g. no usable water supply in the region). The team worked well together and increased in number during the project as it attracted extra stakeholders and other interested parties. There were many new and hopefully continuing working relationships forged.

What were the main challenges of working as a team consisting of people from different disciplines/sectors?
Please give details

The vocabulary is an issue with interdisciplinary teams, particularly with (a) words that have a standard English meaning but also have a technical meaning within one of the disciplines, and (b) words which have different technical meanings in the different disciplines. Some of the subtleties of misunderstandings only became apparent after extended dialogue. Therefore it takes time to develop an understanding across the disciplines and achieve a common understanding of language and technical

terms.

The differences in interpretation of technical terms reflect underlying philosophical differences between the ecological, social and economic sciences, which are more deep-rooted and difficult to tackle. An easy example is how the different disciplines understand and assess uncertainty, and the importance they place on the concept.

The dissemination of information or expert knowledge on the case studies and the ecosystem services topics to stakeholders from a mixed discipline team, and vice versa, is challenging when there are different understandings of issues among team members.

What methods did you use to successfully address these challenges?
Please give details and also include any recommendations for future VNN research.

The initial meeting started with think pieces from each participant highlighting data and methodological issues related to scale and uncertainty from their discipline perspective. The discussion at the first meeting collated the main issues from the think pieces to set up an agreed framework for the project. Several members also noted that, although much of the social and environmental literature and vocabulary were different, there was remarkable similarities at a higher level in the issues raised in the 'think pieces' of both social and environmental participants which bode well for the project.
In general we adopted the more general or common meaning of a term in discussion and in the papers, recognising that the nuances associated with technical definitions would be lost – though generally slightly longer explanations overcame any difficulties.

Anything else?

If there are any other outcomes from your project that have not been captured above, or if you have any further comments, please add them here

Data availability and access were flagged up as significant issues in undertaking an ecosystem services valuation, particularly in tackling the application of an ecosystem services valuation to local land management units.

Appendix A

The four Key Challenges

1. How can the **complexity of socio-ecological systems** be incorporated into valuations of biodiversity, ecosystem services and natural resource use?
2. How can **stock sustainability** be incorporated within valuations of biodiversity, ecosystem services and natural resource use?
3. How can issues of **scale** be incorporated within valuations of biodiversity, ecosystem services and natural resource use?
4. How do we integrate natural and social science information on values for biodiversity, ecosystem services and natural resources into governance and so improve **decision-making** and implementation?

Appendix B

The conceptual framework