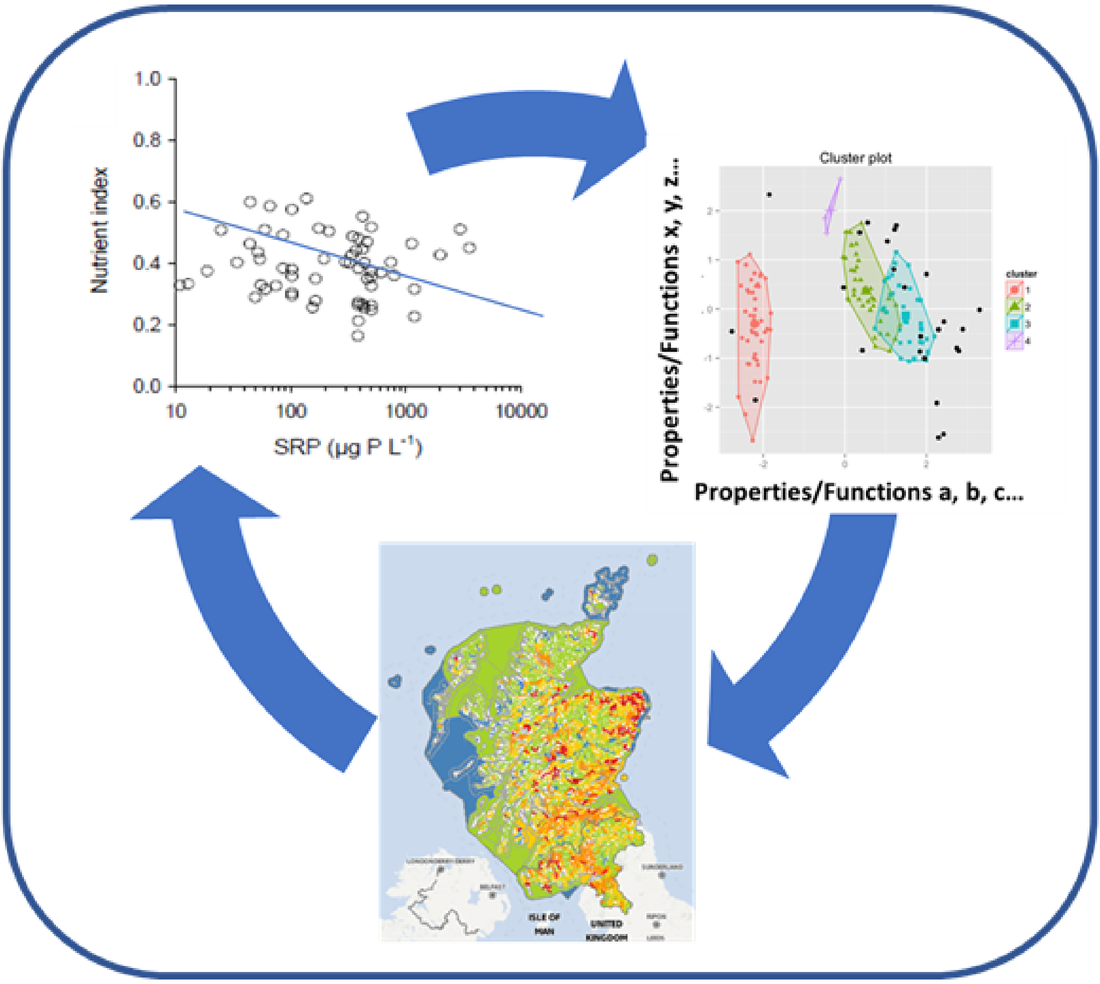
Catchment Typologies Workshop

Held, 8 February 2017, Edinburgh



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Contents

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1 Executive Summary

This report summarises the discussion and outcomes of a workshop held in Edinburgh in February 2017 to further an area of work on catchment typologies under the Scottish Government's strategic research programme area on waters. The workshop was organised and facilitated by a project team from the James Hutton Institute and Centre for Ecology & Hydrology. Key stakeholders were invited that represented regulatory and academic interests that are developing and using typology based approaches, and other aspects of spatial data synthesis, for determining grouped behaviours among catchment functions, especially in relation to risks of waterbody responses.

The aims of the workshop were to:

i) introduce the context of catchment typologies and gain a common understanding;
ii) share experiences and establish gaps and opportunities;
iii) explore the practicalities of developing typology based approaches; and
iv) share next steps in this area of work with key stakeholders.

The following synthesis and conclusions result from a set of introductory talks and a two way dialogue with stakeholders.

Typologies can be a useful approach to representing grouped behaviours across spatial data relating to catchment functions and waterbody (i.e. receptor) impacts. As such, they can represent commonalities in susceptibilities to multiple interacting stressors. This was thought to be especially useful when combined with risk based approaches that facilitate transfer from data rich to data poor areas or from present to future. There remains a need, however, to communicate the concept of typologies (or our distinct use of them) and terminology such as 'catchment families' in a simple way. This may prove useful to non-specialists as a way of conveying grouped behaviours and underlying common 'ancestry' within change trajectories.

Scaling of typology based approaches to address specific research and operational needs was considered especially important, for input data and outputs, and for different spatial and temporal scales (including, for example, longer-term changes and 'shocks' due to extreme events in waterbodies). Satisfying data requirements will constrain the development of typologies and the group acknowledged a role for modelling in filling data gaps, with a need to communicate uncertainty. Good examples of community based approaches to data acquisition, sharing, online and statistical tools were shown from the United States (National Stream Internet project, USDA) and the group recognised that softening institutional barriers and promoting better sharing of data and resources would accelerate the typologies approaches and lead to better outcomes. Finally, specific areas of application of typologies were discussed in relation to a set of case studies. These are detailed in the conclusions to this report.

2 Background and purpose to the workshop

Our work relates to developing an informed characterisation of grouped behaviours for risk and modelling purposes with a focus on three main areas:

- Water quality impacts, especially eutrophication, caused by diffuse and point source pollution
- Temperature related stress to fish and other aquatic ecology
- Impairment of drinking water sources by catchment issues that affect quantity and quality (e.g. DOC, pathogens, nutrients and algal blooms)

The overall aims of the workshop were:

1. To discuss the limitations of existing typologies within a policy/operational context
2. To establish organisational and academic needs for, and likely benefits from, new typology-based approaches for addressing current and upcoming catchment/waterbody problems
3. To share experiences of the development and operationalisation of typology-based approaches
4. To explore the mechanisms involved in applying typologies to waterbody stressor-state assessments, including:
    a. identifying appropriate scales
    b. combining multiple stressors (additive; antagonistic; synergistic)
    c. identifying thresholds in relationships
    d. incorporating risk-based approaches
5. To explore the types of data that have been used in existing typology-based approaches and determine how they could be improved, including:
    a. incorporating the latest primary spatial datasets
    b. deriving new secondary datasets
    c. representing data quality and process uncertainty
6. To present an outline project plan for the longer-term typologies work and secure stakeholder involvement to guide work over years 1-3.

3. Meeting agenda

Table 1. Agenda of the meeting

Time	Session title	Format
10:00	Coffee on arrival	
10:30	Quick introductions	
10:30	Welcome, introduction and aims for the day	Intro talk: Context of the typologies work (Marc Stutter, Linda May)
11:00	Existing experiences of using typologies approaches	Two short talks (15 mins each) followed by a group discussion (20 mins): (i) Implementing typologies approaches for waterbodies (Laurence Carvalho, CEH) (ii) Implementing typologies approaches for soils & catchments (Nikki Baggaley, JHI)
11:50	Coffee break	*Break post-it note task: Any other initiatives exploring typologies, or data integration? What are they doing well/ not well ?*
12:05	Gaps and opportunities for the case study areas	Three talks (10 mins each) followed by a group discussion (20 mins): (i) River Basin Management Planning (SEPA) (ii) Temperature effects on ecology (Marine Scotland) (iii) Risks to drinking waters (Scottish Water)
12:55	Lunch	*Lunch time task: With a partner, discuss the most pressing need for typologies approaches, or the best/newest opportunities in one or more of the case study areas - post note it on the board (named)*
13:30	Workshop phase: Exploring the case study areas (each with a discussion lead and rapporteur): ***Breakout A:*** Water quality impacts ***Breakout B:*** Temperature and ecology ***Breakout C:*** Drinking water	Three break out groups, each capturing knowledge on the case studies and discussing: 1. Mechanistic aspects of implementing typologies for each case study (e.g. application scales and scaling issues, risk based approaches, combining data, mapping and using outputs) 2. Data requirements (what do we need, what do we have, what is the role of modelling, how should data actions be prioritised)
14:30	Coffee break	
14:40	Reporting back from the	Reporting back and discussion on each breakout group (10 mins per group)

4. Introduction

The introductory context to the typologies work area was given by Marc Stutter (JHI) and the full set of slides are given in appendix 2.

4.1 What is a typology?

A typology is a method of classifying, or grouping, entities on the basis of their physical characteristics or behaviours. When based on functional attributes, typologies can help us understand the way that waterbodies respond to catchment pressures and enable us to combine primary spatial data (such as soils, land cover, elevation) in more meaningful ways. However, to implement such as classification system across Scotland, we need to unravel the relationships between the functional behaviours of catchments and the sensitivities of waterbodies.

The concept of using typologies to group catchment pressures and waterbody responses is not new. It is already embedded within our implementation of the Water Framework Directive (WFD), which is based on well documented functional relationships derived from large datasets. An example is the varying relationship between total phosphorus (TP) and phytoplankton chlorophyll-a concentrations in lakes of different types (Phillips et al., 2008).

4.2 How can we use typologies?

There is often a lot of scatter within the relationships that link catchment pressures and waterbody responses and this creates a level of uncertainty that is not well represented within current approaches to WFD implementation. Typologies can be used to generalise responses and such reduce uncertainty. Another benefit of using typologies is that they can be used to identify a common baseline or reference condition. This approach is often used in WFD implementation (Carvalho et al., 2008).

5. Examples of existing typologies approaches

Two of the presentations illustrated how typologies are used within a catchment context; one in relation to waterbody response in terms of common behaviours (lake typologies) and the other in relation to catchment soils behaviours (soil risk mapping).

5.1 Lake typologies

This presentation was given by Laurence Carvalho (CEH).

The transfer of pressures from catchment to waterbody is mediated by waterbody characteristics or sensitivity factors. These include not only depth, colour, alkalinity (as included in WFD typologies) but also flushing rates, internal nutrient cycling capacity and grazing potential. For example, shallow clear water lochs are generally more sensitive to phosphorus (P) inputs than deep peaty lochs in terms of the amount of phytoplankton that they produce per unit of P loading.

Most waterbodies are subject to multiple pressures such as pollution, climate, abstraction, land use and morphological change. It is important to determine how these waterbodies respond to various combinations of these stressors. For example, we have examined how climate change and nutrient pressures interact to affect the likelihood of algal blooms occurring in lakes. Results suggest that some combinations of pressures are additive, while others are antagonistic or synergistic. Responses can also vary across pressure gradients. For example, evidence from the EU MARS project (26 case studies; www.mars-project.eu/) suggests that cyanobacteria can increase, decrease or remain stable in response to changing nutrient concentrations depending on where a lake is positioned along the total phosphorus gradient and by how much concentrations vary over time. In general, cyanobacteria were found to be positively correlated with higher P concentrations, but in some cases the relationship was negative or weak. In particular, in eutrophic lakes where nutrients are available in excess of biological requirements, responses to increases in P concentration were negligible.

Although lake responses to multiple pressures vary, lakes can be grouped into typologies based on the functional and physical attributes that affect their sensitivity to these pressures. This allows us to remove some of the noise and uncertainty in our prediction of how multiple stressors will affect ecological responses and target monitoring and management more effectively.

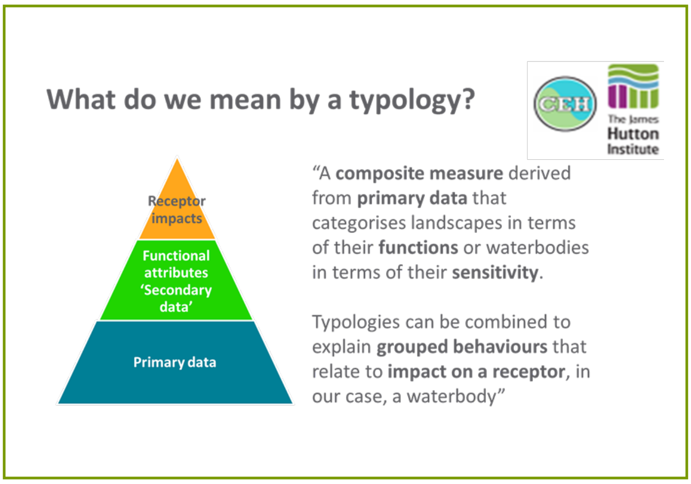


Figure 1. *Conceptual view of typologies (taken from the presentation by M Stutter)*

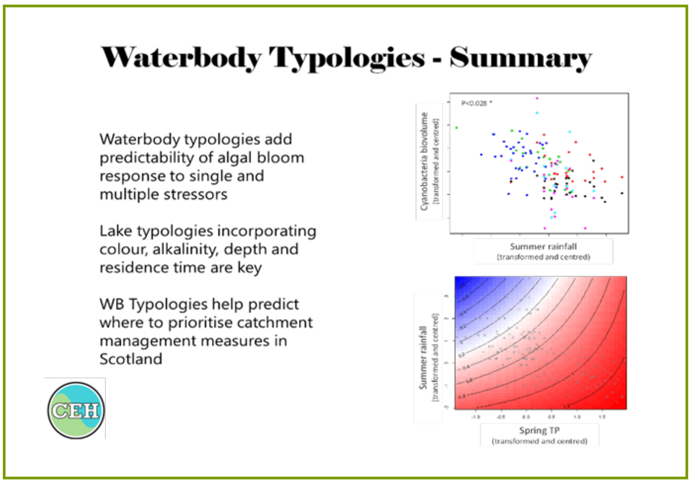


Figure 2. *Example of combining waterbody attributes relevant to grouped behaviours in response to stressors (from the presentation by L. Carvalho)*

5.2. Example 2: Soil risk mapping

The next presentation was given by Nikki Baggaley (JHI).

Soil mapping within catchments is often based on typologies and can be used to define risk factors for lakes and rivers. Soil type and hydrology of soil type (HOST) classifications, which are based on models of how water is transported spatially and vertically through hydrologically active horizons in the soil profile, can be used to determine runoff vs. baseflow (29 classes in Scotland) and are good examples of this. However, it is also possible to look at the physical conditions of the catchment and identify risk categories for various catchment processes, e.g. run-off, leaching and erosion. These can also form the basis of typologies for Scottish catchments. For example, there are 29 classes of run-off risk in Scotland and a simple rule based decision support system has been developed to produce classifications of leaching or erosion risk for these. These are already applied to Nitrate Vulnerable Zones and have been used to inform discussions with land managers. For example, they can be used to decide where to implement General Binding Rule (GBR) measures such as buffer strips.

A risk assessment classification has also been set up based on multiple traits of soil type. This uses a rule based approach to classify soils into low, medium and high risk areas. These typologies have been used to examine risk of soil compaction on a national scale to underpin the design and stratification of risk based sampling and monitoring programmes.

Issues of scale arise when combining spatial data to develop typologies and risk based classification maps. Coarser scale data can give very different risk categories in comparison to finer scale data. To incorporate uncertainty into these typologies, the soils monitoring action plan (MAP) uses Bayesian belief networks to develop decision support tools and define soil properties in Scotland. This approach can help to target monitoring and management of soils effectively.

Gaps and opportunities for incorporating soil risk functions
The following gaps and research opportunities have been identified:

- Incorporation of soils typologies into catchment typologies to assess risks to water
- Issues of scale

6. Gaps and opportunities

A further three talks from key stakeholders were then used to identify gaps and promote discussion of opportunities for the applications of typology approaches. These were selected in relation to the case study topics noted in Section 2.

6.1 Example 3: Water quality impacts caused by point and diffuse pollution

The next presentation was given by Anna Griffin (SEPA).

SEPA are currently reviewing their monitoring and evidence plan. A new version is to be published in the coming few months. SEPA uses monitoring data to feed through to a waterbody classification (e.g. high to bad status) that incorporates a level of confidence rating (e.g. good status – low confidence). However, the monitoring & bioassessment data on which these classifications are based have uncertainties associated with environmental variability, sampling frequency, the representativeness of the sampling site within the waterbody and analytical error. All of this adds noise to the data.

When waterbody degradation occurs, SEPA identify the pressures responsible for this degradation (e.g. phosphorus inputs) and work with particular sectors (i.e. those responsible for the pressure) to reduce them. Traditionally this processes has been conducted using expert judgement but, in recent years, new tools (e.g. SIMCAT, SAGIS) have been used to identify the impact of various sectors. Recently, microbiological indicators have also been used to identify sources of pressures (e.g. septic tanks, agriculture, etc.).

Once pressures and their sources have been identified, exemptions can be applied using a rule base process e.g. to provide a longer timescale to address the pressure. We can also incorporate an understanding of the likely timescale of recovery once pressures have been mitigated. However, it is difficult to say with confidence whether any environmental response is the direct result of any particular improvement measure or when recovery has been affected by other environmental factors such as changes in water chemistry, temperature and flow.

Being able to link pollution sources with waterbody responses in landscapes impacted with different risk would help make stronger evidence on which to base a case for particular interventions. Typologies may be able to improve our understanding of the link between the occurrence and consequences of multiple pressures and how these vary spatially.

Figure 3. *Erosion risk as an example of combining spatial soil properties to inform a function related approach to erosion risk (from the presentation by N Baggaley).*

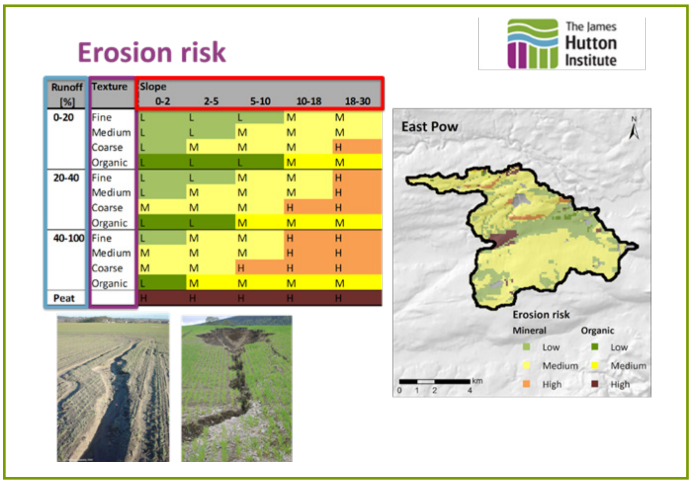
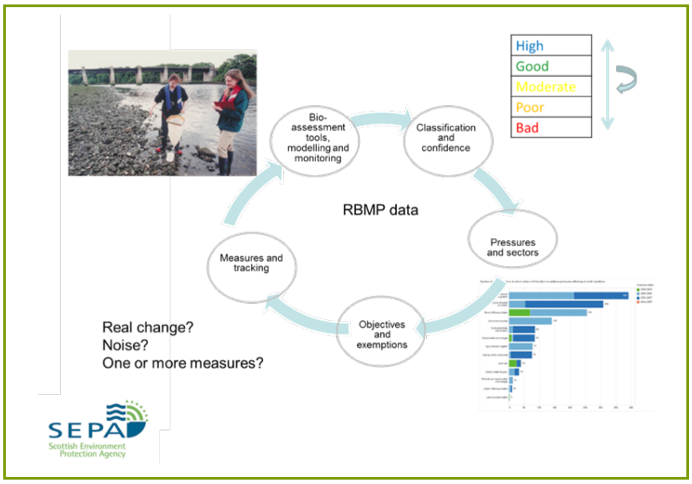


Figure 4. *The process of developing the River Basin Management Plan (RBMP) actions (from the presentation by A Griffin)*



Gaps and opportunities

The main gaps and opportunities that need to be addressed from a SEPA perspective are:

- Knowledge of effects of secondary pressures (chemistry, physical condition) on ecological responses to primary pressures and, consequently on environmental standards;
- Knowledge of the pathways of chemicals through the environment to a watercourse and how to control them (e.g. constructed wetlands, buffer strips, etc);
- Poor resolution of the source apportionment process for some sectors, which creates high uncertainty in source control actions to desired outcomes in waterbody responses

6.2 Example 4: Spatial regression modelling of river temperature

The next presentation was given by Iain Malcolm (Marine Scotland, Pitlochry)

Water temperature affects the ecological and chemical functioning of rivers and is likely to be affected by climate change. Water temperature is particularly important to cold water adapted freshwater fish such as salmonids. Under certain circumstances riparian woodland can mitigate against temperature extremes. However, a better understanding of temperature variability is required to allow fisheries managers to plan and prioritise management activities. Marine Scotland Science in collaboration with the University of Birmingham designed a large scale strategic quality controlled temperature monitoring network (The Scotland River Temperature Monitoring Network: SRTMN). The network has been delivered in collaboration with local fisheries managers (Fisheries Trusts and District Salmon Fisheries Boards) and underpins large scale spatial regression models of river temperature. River temperature is predicted as a function of landscape covariates (e.g. upstream catchment characteristics, percentage of riparian woodland, shading, width, distance to coast, maximum air temperature, etc.), which act as proxies for energy exchange processes.

The models are underpinned by spatial data sets including digital river networks, land use maps, digital terrain models and flow accumulation grids. Typologies (based on key covariates) have been created for every upstream node on the river network using bespoke functions in the software R. When combined with the regression models this allows river temperature to be predicted across Scotland for all catchments and hydrometric areas. The approach has been applied to the River Spey where mean river temperature has been described as function of elevation, riparian woodland and gradient (Jackson et al., 2017a). The transferability of catchment specific models has also been discussed by Jackson et al., (2017b)

In developing this approach, a number of technical challenges have had to be addressed:

- Trade-offs between spatial data resolution and processing time
- Matching spatial data sets that are not always aligned
- Simplifying /correcting the Digital River Network, depending on modelling requirements; issues related to each model and spatial data are cumulative.
- Tools for rapid assessment of land use/geology/soils

All outputs (maps and decision support tools) from this project will be publicly available.

Gaps and opportunities

- Open access, corrected river network of temperature
- Covariates need to be generated for each river node
- Tools need to be produced for rapidly characterising land/use/geology/soils in nested networks
- Spatio-temporal characterisation of hydrological networks is needed, e.g. incorporation of day of year
- Improved information on woodland height, density, species is required
- River width data needs to be improved; existing data are sparse and have strong biases
- Snow melt needs to be incorporated
- Incorporation of spatially-distributed discharge data.

6.3 Example 5: Risks to drinking water

The next presentation was given by Paul Rodgers (Scottish Water) The Water Resource team with Scottish Water (SW) uses catchment models that include soil coverage, land use and hydrology to assess the risk to of extreme events and changing weather patterns on water supply and availability. Catchment models are also used to examine the effects of abstraction on various typologies of rivers and lochs. The overall aim is to ensure that a supply of water is maintained. A key data requirement for catchment modelling is open access to appropriate spatial datasets as well good quality hydrological monitoring data.

The Sustainable Land Management team within SW undertake water supply catchment surveys to look at water quality risk factors then identify problems and address issues. The Drinking Water Protection Scheme (DWPS) provides financial assistance to help protect drinking water sources. The scheme helps create a partnership with land managers, owners and tenants to protect drinking water sources from diffuse pollution. By working together it is hoped that public health is protected, a sustainable approach to the improvement and protection of drinking water quality is adopted and that land managers are not disadvantaged by selecting a more sustainable approach. An ecosystem services approach might be useful when considering multiple benefits from land management schemes. Water quality issues include Cryptosporidium, dissolved organic carbon (DOC), algal blooms and various chemical pollutants.

Gaps and opportunities

The main gaps and opportunities that need to be addressed from a Scottish Water perspective are:

- Lack of hydrological monitoring data, especially in small upland catchments that are poorly monitored, limits the effectiveness of catchment models
- Hydrological data and hence model outcome uncertainty is a problem to Scottish Water.

7. Break out groups

During the afternoon, the participants formed three breakout groups to discuss the three case study topics. Where possible facilitators from out-with the project team and a project scribe were paired. There was then a plenary session reporting back from each subgroup and a related discussion. The combined aspects are captured in Tables 2 to 4.

Figure 5. *Example of pooling landscape co-variates in developing models for river water temperature (from the presentation by I. Malcolm)*

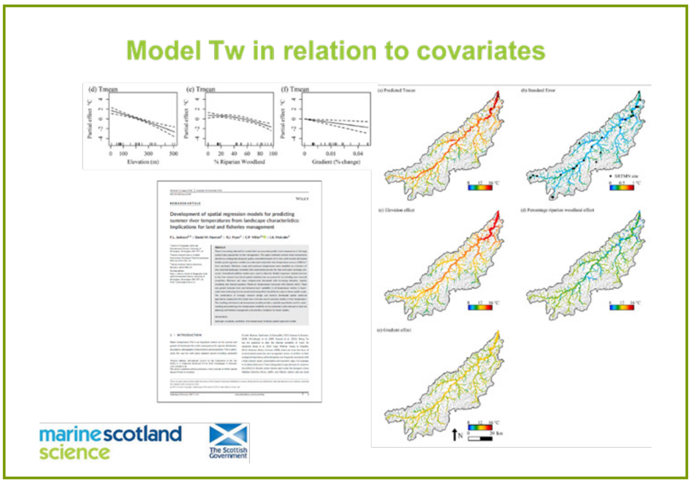


Table 2. Summary of the breakout group around case study 1: Water quality impacts from diffuse and point source pollution

Practical implementation issues	Data requirements and issues	Most pressing needs
Scales of application and how outputs are to be used needs consideration. Abilities to generate typologies across different sizes of catchments are constrained by the scales of available data that require combining point (waterbody response) data and spatial (GIS and other landscape) data. Typology units could provide an intermediate scale between the size of the target waterbodies and national scales. The resolution of the spatial data and the validation (response) data is important. There is a need to transfer data from both high to low resolution and vice versa. A question is which end to start at. Transferring data is complex and needs well-defined procedure to be put in place and communicated. Approaches should be developed and calibrated in data-rich areas before use in data-poor areas. Uncertainty in data must be reduced as far as possible, and we need to know its sources. When managing uncertainty, risk based approaches or probabilities (for process-based models) can be used to limit the problem; better knowledge of uncertainties among data sources and the use tools that incorporate uncertainty can help (stochastic modelling, Bayesian approaches, etc.) Typologies could be generated for ecosystem service delivery from waterbodies.	There is a need to review current data with respect to the development of evidence to underpin typology development. We need to understand the current state of combined data resources: what we have already, what is essential, what would be helpful to have to add value. We also need to identify data gaps and develop a strategy to fill them. Issues arise over how to manage datasets and keep them up to date. Managing local to national scale data gaps will require modelling to extrapolate from high to low resolutions of data. Whether spatially-explicit data are scalable is questionable. Regulation often requires the incorporation of site specific data (e.g. point sources; data from SEPA's catchment walks in relation to the location and types of GBR breaches). Data should be open access, if possible; If not, we need to work within constraints of ownership, costs, availability, licencing and restrictions. There is a difference between academic and regulatory data generation and use. Early collaboration and awareness of upcoming projects/initiatives would help. Issues of maintaining datasets and version control need to be addressed. Original baseline SEPA's catchment walks data determining locations of breaches of farming basic good practice has been used to develop wider modelling but subsequent data has a higher protection rating and so may be more restricted. Other recently developing data sources may provide a high data resolution link for model development toward grassland and arable land cover risk types and waterbody responses.	Typologies for ecosystem recovery from pressures (likelihood and timescales). Bringing knowledge of grouped behaviour into cost evaluation; e.g. the benefits of different styles of intensive monitoring efforts in catchments. Typologies for evaluating multiple benefits of catchment mitigation (siting, design, effectiveness, etc.) Are some typologies more responsive than others in terms of delivery/transport processes? Is temporal scale important?

Table 3. Summary of the breakout group around case study 2: Temperature related stress to fish and other aquatic ecology

Practical implementation issues	Data requirements and issues	Most pressing needs
Temporal and spatial scales are important in developing typologies, for example in relation to pressure types (pulse versus pressure, and magnitude, extreme events) and impacts (legacy of e.g. thermal/nutrient shock and different impacts on different ecological indicators). Models can be used to create typologies on pressures. The Freshwater Fisheries Lab's models focus on Salmonids and metrics derived from mean/min/max daily temperatures. Typologies also need to define river types more at risk (e.g. wide, shallow rivers with low velocities exacerbated by unfavourable orientation or lack of woodland are more susceptible). Models can be used to create national scale risk maps in line with categories of multiple and interacting stressors. These could include ecological stability metrics (e.g. refugia and connectivity) and ecological responses across gradients of pressures. Need to examine temperature effects in lakes and perhaps can build on existing models on ecological responses which include temperature (e.g. Protech) Multiple and interacting stressors may not be the same in all water bodies and for all response platforms. Temperature effects can be species-specific and may not be instantaneous.	River temperature is important in underpinning many Ecosystem Services and links should be made to enhancing rural economy through sport and recreation, protection of the fisheries' abilities to produce viable fish stocks allowing harvesting as well as for conservation goals. Such work should identify areas most sensitive to stressors/combinations of pressures and those of high value to society then overlay predictions to assess risk. We note also that fish harvesting draws on resources from wide parts of river networks (ie influenced by upstream conditions). It is important to develop typologies across boundaries and at larger scales. There is also a need to create model ensembles to create typologies across continuums of stressor gradients. A forthcoming science paper will present typologies of rivers and temperatures map showing those at high risk. There is an absence of tools available to help with generation of data sets for modelling and to create underpinning data sets. This needs a lot of computing power and established routines in computing (e.g. 'R'); the lack of these is currently limiting development. Organisations in the US have done this and made the tools available. Better access to SEPA ecological data for indicators of stability will be important. There is a role for modelling in exploring temporal ecological responses for different ecological components; these may be species specific and not be instantaneous. Ecological stability indicators are required to allow quantification of ecological responses across categories of stressors such as occurrence/frequency of extremes of temperature. Presently we use inferred response indicators, e.g. maximum temp tolerances, for this purpose.	Shared open access spatial datasets. In particular corrected and simplified river networks with associated covariates. River risk typologies for the spatial distribution of grouped behaviours of annual/seasonal flow rate distribution changes. Better understanding of sources of water contributions to river systems and how these affect temperature (i.e ground water, soil water etc)

Table 4. Summary of the breakout group around case study 3: Impairment of drinking water supply sources by catchment issues

Practical implementation issues	Data requirements and issues	Most pressing needs
Scales of implementation vary across <1km2 to thousands of km2 with different supply basins (it is feasible to influence at some of these scales, but not many). There is a need for typologies that cover a wide range of existing and emerging risks (stressors) that have yet to be fully understood. Presently, top risks include: water volume, dissolved organic matter and THM formation, algal blooms, manganese, pathogens and emerging contaminants. Top pressures include: climate and extreme events (data for these are rare), windfarms, infrastructure/ roads, farming. There are already risk procedures for consenting activities (e.g. sediment risks from windfarm infrastructure) and the risks are related to the severity of consents and/or levels of mitigation actions. The overall risk typology of the supply requires combining the landscape risk/types with the treatment infrastructure risk/types (including level of treatment, ability to change to alternative supply source since if one source there are no options if contaminated or runs dry). Often the risk comes back to a simple question of what comes out of the customers' taps. Hence, the treatment infrastructure informs the levels of acceptable tolerances in raw water quality. In the water industry, engineering is associated with certainty but land-based actions of mitigation tend to be more uncertain and risky (often backed up by engineering). Risk types are both spatial and/or temporal (from future susceptibility to changes in seasonal risk, e.g. pathogens, timing of mitigation/interventions). Private water supplies may come under Scottish Water remit in future; if so, these will require different typology based approaches as they are mainly sourced from springs and boreholes.	The security of our national water supply brings data sensitivities and restrictions on usage, so the industry cannot share its data. Data gaps include: water quantity and quality interactions (e.g. reduced flow/dilution interactions in relation to eutrophication), extreme events (e.g. climatic), 'noise' in microbial risks from the use of faecal indicator organisms instead of targeted evidence on actual human pathogens. Scottish Water already undertakes empirical modelling development to enable risk factors to be assessed (connecting environment and infrastructure risks). Could these approaches be improved across scales in relation to current screening levels? Typology/grouped behaviours could open up the possibility of using wider datasets from non-drinking water catchments to solve problems associated with the use of unmonitored sources of drinking water.	Improved monitoring and modelling to develop typologies for hydrological behaviour in sub-catchments and ungauged basins for water industry purposes (although these procedures already incorporate the principles of soil hydrology, could they be improved to better constrain uncertainties?) Monitoring in rural areas with a high densities of on-site sewage treatment systems, such as septic tanks.

8. Other views sought

During the breaks knowledge was captured on a couple of general topics.

8.1 Response to the question on knowledge of other initiatives and what are they doing well, or not so well

The following points were noted:

- Forest Research's (FR) Woodlands for Water is considered a good example as it has developed maps for targeting FCS woodland grants for Natural Flood Management or diffuse pollution priority areas. However, it has poor coverage (e.g. Highlands) and is constrained to SEPA's priority catchments. The Tweed Forum are building on FR's work by producing maps for areas not previously covered, e.g. the Borders.

- Wetland typologies were considered good and their graphical representation is good (however the specifics of which data are being referred to are unknown).

- The EU MARS project was considered a good example of resilience and recovery in waterbody traits.

8.2 Response to the question on improvements in how to communicate what we want to achieve around the concept of typologies

The following concepts and phrases were suggested as ways of communicating what was understood by our particular meaning of typologies:

- Family camping of groups of 'like neighbours'
- Catchment waterbody traits
- Typologies of catchment risks vs waterbody response vs characteristics vs functional response
- Sensitivity classes
- Response groups

9. Next steps

In the final summing up, the next stages of the project were presented and the timeline for workshop for reporting. After the workshop, organisers combined notes into a draft report and other participants agreed to review and comment on this draft in early March. The timeline of the next steps of the project is shown in Appendix 2.

10. Conclusions and recommendations

Ten conclusions and recommendations from talks presented in the morning and from the break-out session in the afternoon are presented:

1. The spatial and temporal scales of typology based outputs and their applications needs careful consideration; this is highly dependent on the resolutions of available data or modelling approaches used to fill gaps in required data and questions asked of the approach.

2. Typologies may need to cross boundaries to meet certain requirements for spatial scale and also consider temporal responses such as susceptibilities to future threat and extreme events/shock types, as well as longer-term changes in pressures.

3. Having the correct data across spatial scales requires a 'community' approach (across organisations/sectors), an improved inventory of what we have and associated uncertainties in the data, better awareness and data sharing, and realistic prioritisation and modelling approaches to fill gaps.

4. Modelling can be used to assist in data transfer from (i) data rich to data poor locations, and (ii) high resolution (in space and/or time) to low resolution datasets (and vice-versa). However, approaches need to be developed to validate models in data-rich areas and to reduce uncertainty (using specific modelling tools e.g. Bayesian methods).

5. Typology based approaches for responses of aquatic ecology to stressors such as temperature need to incorporate factors such as (species-specific) ecological structure rather than just using inferred response thresholds (e.g. maximum temperature tolerance).

6. Typologies may represent grouped behaviours not only for biophysical response attributes but also for ecosystem services.

7. Developing modelling capabilities and automated routines to work with spatial data (e.g. river networks) will need computing developments (e.g. coding of statistical software). We should look at examples from countries like the U.S., where this is done and made available as a community resource.

8. Specific considerations for working with the water industry include that: (a) data sensitivities due to national water supply security issues, (b) overall risk to the supply, which equates to a combination of the landscape risk/types and the treatment infrastructure risk/types, and (c) uncertainties in hydrological processes across scales.

9. For the water industry, catchment risks cover small to enormous scales of supply basins; however, we can learn from risk based approaches already used to consent activities in drinking water catchments and empirical work that is on-going with the aim of deriving risk models.

10. Key targets requiring risk-based response approaches were typologies for:

- Ecosystem recovery following changes in pressures (with diffuse pollution and ecological applications) and the timing of recovery

- Benefits vs. costs for different monitoring options (applicable across all case studies)

- Multiple benefits of restoration/mitigation (applicable across all case studies)

- For aquatic ecology, risks that layer both ecological sensitivity to stressors (e.g. temperature and Salmonids) with locations of high value of ecosystem services gained from fishing (e.g. rural economy and sporting, recreation)

- River risk typologies for change in flow rate over time (suggested in relation to temperature and ecology, but applicable across all case studies)

- For the water industry, risks that layer both the catchment-based landscape risk types with those related to the tolerances and risks of the supply and treatment infrastructure

- Hydrology of ungauged water supply basins (in relation to water industry needs)

11. References

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National Stream Internet Project, USDA. Website: https://www.fs.fed.us/rm/boise/AWAE/projects/NationalStreamInternet.html. Last Accessed March 2017.

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12. Appendices

Appendix 1: Workshop attendees

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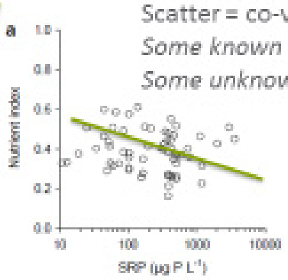
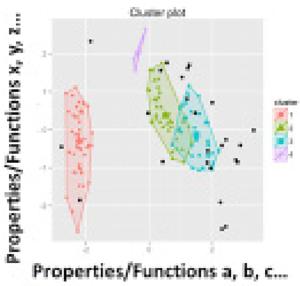
Appendix 2: Introductory slides

What is grouped behaviour?

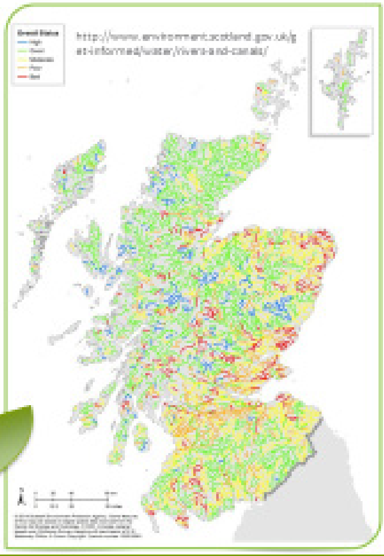
Scatter = co-variates
Some known
Some unknown



Help to characterise variation in response to complex multi-stressor relationships?



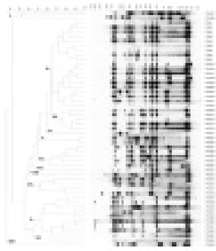
Typologies to generalise response and reduce uncertainty

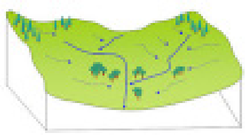


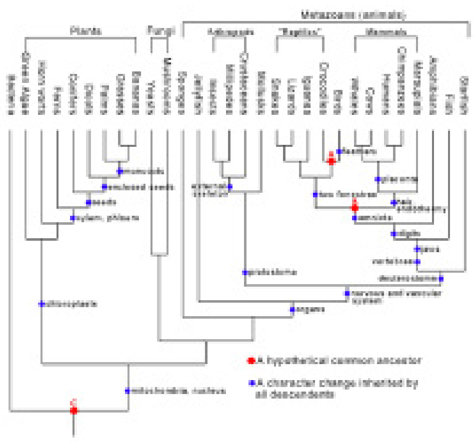
Uncertainty in responses *(e.g. ecological)* to change *(e.g. P conc)*

What are the benefits of using typologies?

Typologies, once fully developed, could comprise many characteristics helping us to quantify, group and predict different responses; like a catchment's 'genetic fingerprint'



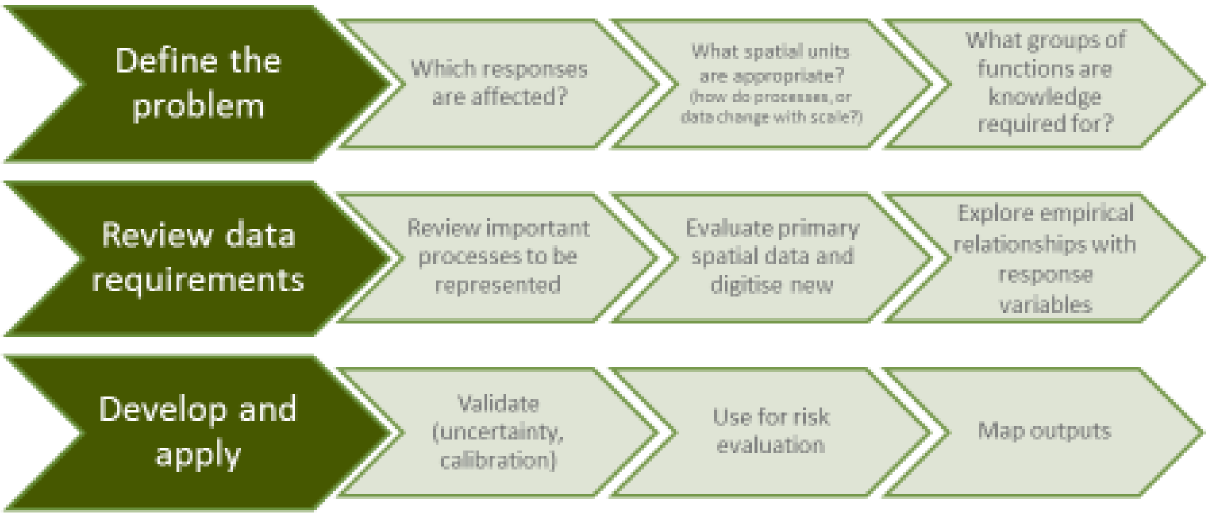




A phylogenetic tree looks at clusters that are grouped according to common characteristics/ancestry.

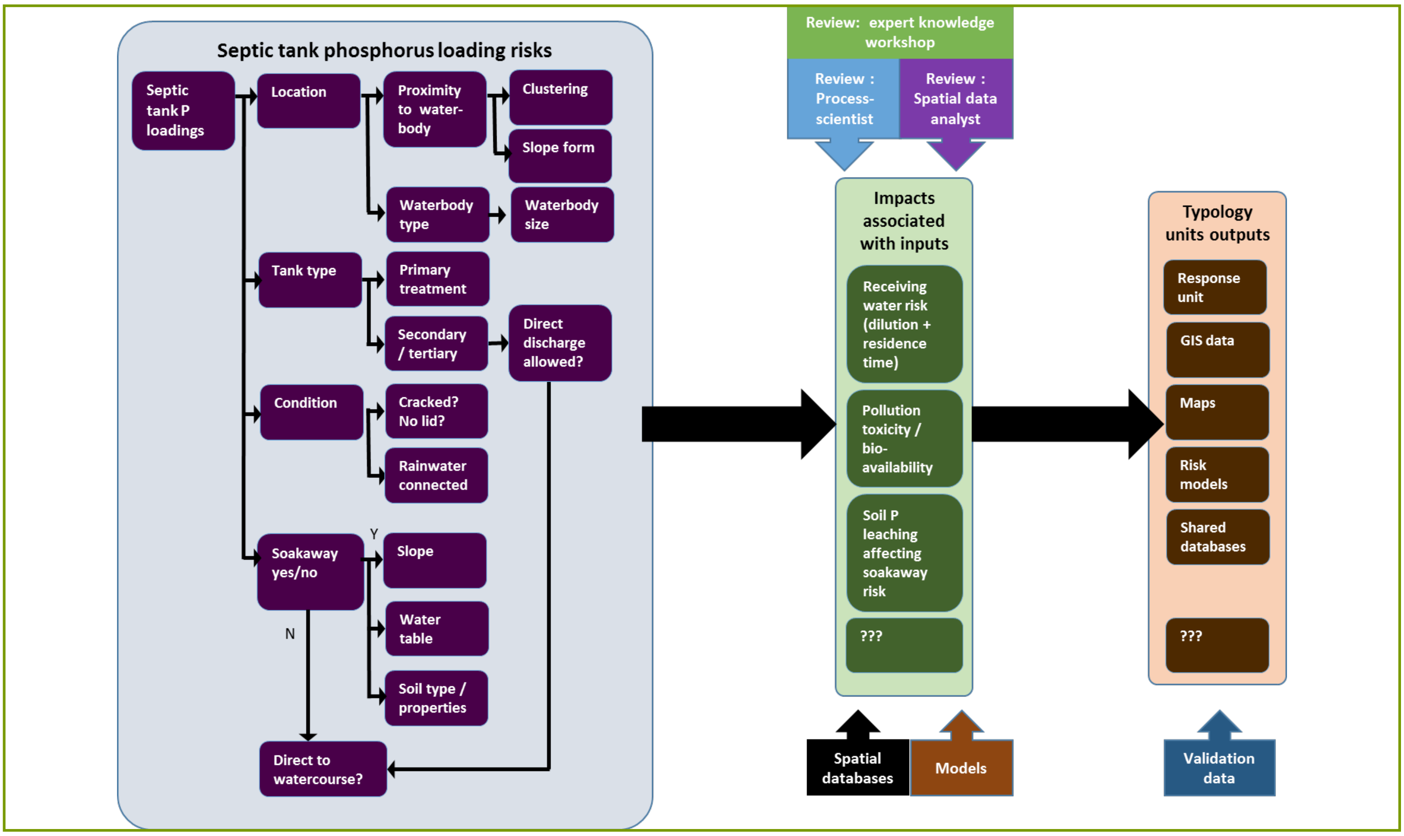
When applied to catchments, this approach could statistically cluster commonalities in governing behaviours, e.g. in terms of how risks from certain pressures are controlled or reference conditions established.

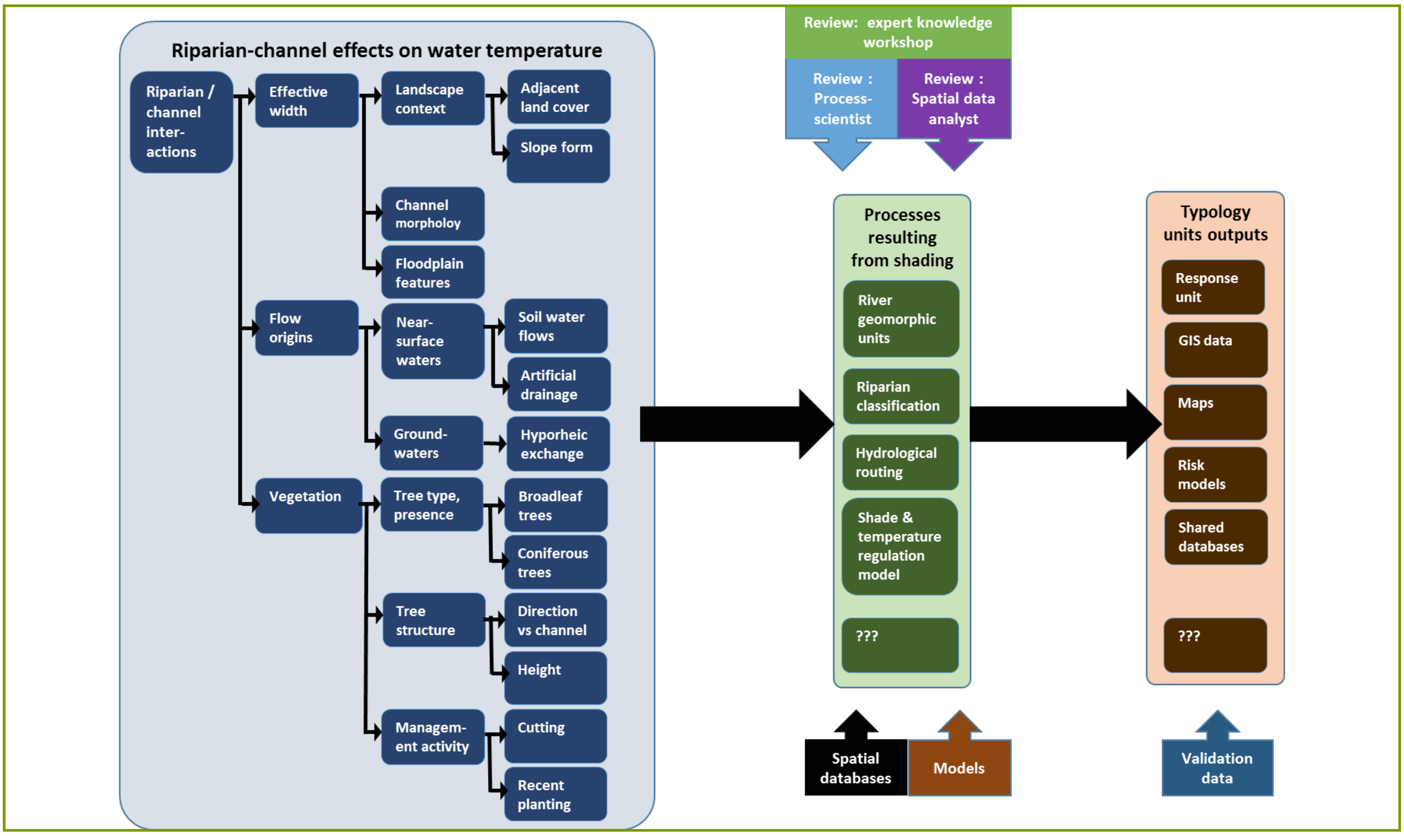
How can we use typologies?

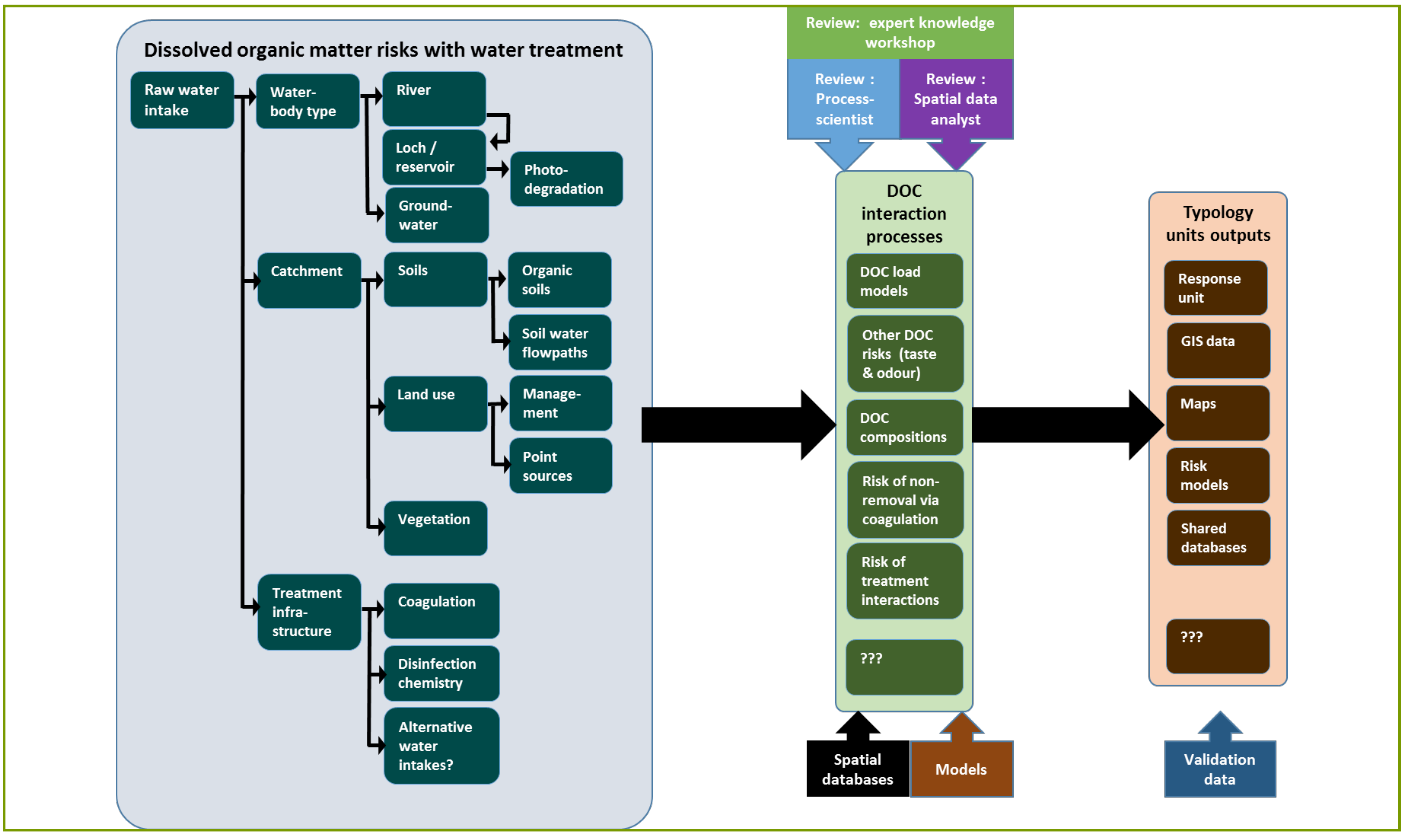


We will focus on 3 case studies

1. Water quality impacts, especially eutrophication, caused by diffuse and point source pollution
2. Temperature related stress to fish and other aquatic ecology
3. Impairment of drinking water supply sources by catchment issues affecting quantity and quality (e.g. DOC, pathogens, nutrients and algal blooms)


Septic tank phosphorus loading risks
Septic tank P loadings
Location
Proximity to water-body
Clustering
Slope form
Waterbody type
Waterbody size
Tank type
Primary treatment
Secondary / tertiary
Direct discharge allowed?
Condition
Cracked? No lid?
Rainwater connected
Soakaway yes/no
Y
Slope
Water table
Soil type / properties
N
Direct to watercourse?
Review: expert knowledge workshop
Review : Process-scientist
Review : Spatial data analyst
Impacts associated with inputs
Receiving water risk (dilution + residence time)
Pollution toxicity / bio-availability
Soil P leaching affecting soakaway risk
???
Typology units outputs
Response unit
GIS data
Maps
Risk models
Shared databases
???
Spatial databases
Models
Validation data


Riparian-channel effects on water temperature
Riparian / channel inter-actions
Effective width
Landscape context
Adjacent land cover
Slope form
Channel morpholoy
Floodplain features
Flow origins
Near-surface waters
Soil water flows
Artificial drainage
Ground-waters
Hyporheic exchange
Vegetation
Tree type, presence
Broadleaf trees
Coniferous trees
Tree structure
Direction vs channel
Height
Managem-ent activity
Cutting
Recent planting
Review: expert knowledge workshop
Review : Process-scientist
Review : Spatial data analyst
Processes resulting from shading
River geomorphic units
Riparian classification
Hydrological routing
Shade & temperature regulation model
???
Typology units outputs
Response unit
GIS data
Maps
Risk models
Shared databases
???
Spatial databases
Models
Validation data



CEH

The James Hutton Institute

Final session:

summing up,
next steps after the workshop,
and wider work plans

Next steps

Date	Actions
8th Feb	Workshop
10th Feb	Rapporteurs complete brief notes
14th Feb	JHI and CEH team meet to develop report materials
Late Feb	Project team comment on draft report
Early March	Draft report circulated to workshop attendees for comment