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Using a DPSIR (Drivers-Pressures-State-Impact-Response) approach to evaluate river corridor climate resilience functions

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1. Summary

This report sets out the needs for and approach of using DPSIR to gain insight on three groups of climate resilience functions for river corridors, namely: increasing and maintaining organic C stores, regulating water temperatures and buffering against low river flows. The report contributes to the deliverables of Conceptualisation of Main Riparian Functions and Data Linkages (D3a and D3.1.1).

2. Introduction and aims

The DPSIR approach (drivers, pressures, state, impact, and (societal) response model of intervention) is a causal framework used to describe the interactions between society and the environment. It extends previous models of: Pressure-State-Responses. DPSIR seeks to analyse and assess environmental problems by bringing together various scientific disciplines, environmental managers, and stakeholders, and solve them by incorporating sustainable development (Fig. 1).

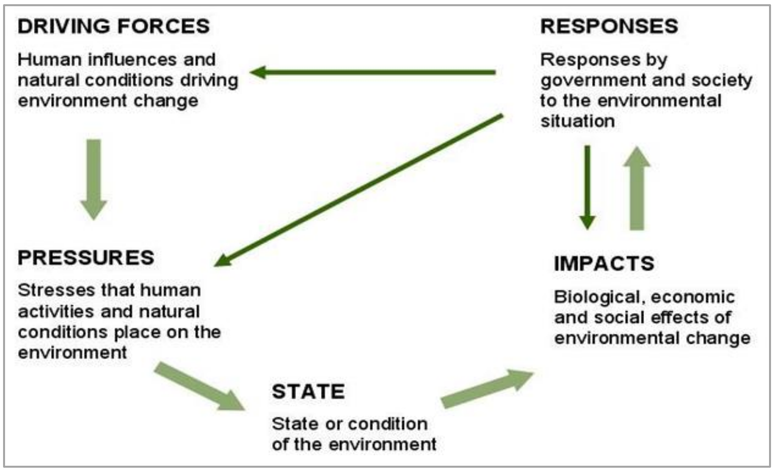

Figure 1. Definitions of DPSIR with an explanation of each step. Taken from Denla Band - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=69117435

The DPSIR framework lends itself to the evaluation of complex environmental management issues and, as such, we undertook an exercise to use DPSIR to evaluate three functions of river corridors in climate change resilience. These are: (i) increasing and maintaining organic C stores in river corridors and mediating organic C transfers, (ii) regulating water temperatures and (iii) buffering against low flows. The DPSIR framework is intended to guide future work by providing synthesis of concepts around the functions and understanding of responses to pressures.

We are developing a representation of pressures in river corridors over the next few years by compiling high quality datasets from various sources and attributing these pressures spatially against a system of river corridor units. These river corridor units will comprise the best representation of important topographic, geomorphic, soils and land cover (and where possible management) datasets and derived groupings. These derived groupings will be iteratively informed by emerging data from the project and revised. The pressures will then be represented in space against the river corridor units and statistically evaluated in terms of what groups of pressures commonly affect landscape units with certain properties that give rise to specific pressure-state-impacts. Then trajectories of change are envisaged to be derived for the three functions from case study Scottish rivers and validated with field data. Conceptually, the river corridor units may be thought of as the inherent landscape conditions that determine the potential conditions, and in turn the potential for levels of delivering those functions, then the pressures assessment may be thought of as the current realised conditions and ability to perform those functions. This examination of river corridor pressures-impacts-states against types will proceed through case study rivers with lessons for national coverage; the first being the Aberdeenshire River Dee.

Our working hypothesis is that river corridor and riparian characterisation informs river quality and process assessment to a greater degree than more simplistic catchment-wide metrics, due to their special conditions of proximity to watercourses and role as an interface zone. Hence, we propose that river corridor units and pressures-state assessment can provide improved ‘catchment covariates’ for empirical relations with monitoring/assessment data for the River Dee and wider, as well as informing on the direct management condition and needs of riparian zones.

A prerequisite for the work is the ability to attain datasets relating to the status and pressures on river corridors across differing riparian units. To do this we must first understand the pressures-states aspects of DPSIR. This critical initial step will evaluate the underpinning indicator data requirements and establish dataset gathering and primary data generation tasks for coming years. Therefore, the primary aim of this DPSIR analysis was to use the framework to look at the three specific functions of interest, understand the aspects of pressures and states (against the wider DPSIR) and what parameters of condition need data representation in the coming years.

3. Methods

An expert knowledge mini-workshop approach was used with a hybrid in-person and video conference method using shared Miro interactive, online whiteboards. This consisted of three stages. Firstly, a set of slides introducing the activity methods and aims and background concepts of DPSIR were distributed. Secondly, the interactive whiteboards were made available comprising three templates with separate DPSIR spaces, these being populated by sticky notes pre-meeting. The third step involve a review and discussion of what had been done, including adding to, moving the notes and discussion of our understanding and review of overall results.

4. Results and discussion

Firstly, the group noted difficulties in the concepts of DPSIR, such as decisions between whether a concept or parameter was associated with the Pressure, State or Impact category. Examples were found beneficial, such as: Driver = agricultural intensification; Pressure = increased cattle numbers; State = soil compaction; Impact = more soil erosion; Response = increased cattle overwintering indoors. Figures 2 to 4 show the stage 2 outputs from the group discussion day and reflect the difficulties we had as a group in comprehending DPSIR. The stage 2 involved tidying up duplication and obvious inconsistencies of applying concepts that were from stage 1 (individual post-it note additions prior to the workshop). The workshop process on the day benefitted from discussion of the problem framing around the key functions and setting some bounds on the system. It was found that a strong definition of the river corridor is necessary to apply bounds to aspects of particularly P-S-I and derive indicators that are important in setting the future work plans. A focus to the translation of State aspects was attained by thinking on the question 'what are the key things to measure' to understand each of the three functions in the river corridor?

The third stage of the exercise was to take key elements of P-S-I from each of Fig. 2-4 and summarise in Tables 1-3, respectively. This was done by group editing of the report document. The three tables show many commonalities between the three functions and this reflects some common underlying controls of vegetation, soils and hydrology between the functions. In particular, the Pressures were most consistent; this is beneficial as the compilation of indicator data on pressures is a vital next step. Simplifying aspects of State in Tables 2-4 gives focus to developing ongoing work plans. However, there is not a clear pathway to attaining existing datasets for indicators against the State and Impact aspects in all functions. Many of these will require bespoke datasets, or at least new supporting data to better understand existing datasets. For example, thermal regime for a river type may be available from national networks, or extrapolation of nearby datasets via modelling. However, aligned State and Impact datasets such as associated water quality and ecosystem impacts, or the local vegetation, or hydrological state that would be required to advance understanding of P-S-I chain aspects will require new investigations. Hence, there is a need to prioritise key new datasets against existing and to apply bounds (spatial and potentially temporal) to the river corridor extent and reach scale that is important in each case.

There will likely benefits of taking an impacted vs control/pristine reach experimental basis to understand manifestation of P-S-I effects and this should be done on some kind of river typing basis to attain appropriate 'controls/reference' conditions. This future work will call on the developing riparian units approaches that will combine simple elements of topography, soils and drainage/wetness with geomorphological elements of river scale and type.

5. Summary and next steps

This research team group exercise over several stages has shown the following:

- That the DPSIR framework provided us with a structure to organise our ideas and concepts, especially of chains of process. However, our application of this framework to evaluate three different issues and with different specificity of the aspects showed that the framework is complex and required care to ensure certain factors were not misassigned. Our understanding and effective use required definitions (Fig. 1) and examples of aspects through the D-P-S-I-R chain and, even then, it remained difficult to place our parameters clearly into particularly the PSR categories (Fig. 2-4).

- The exercise facilitated a group discussion that necessarily explored indicators in terms of the datasets that we could call on and monitoring that could be set in place to evaluate the P-S-R factors over the next years of the project. This analysis was expanded afterwards into the summary tables here (Tables 1-3).

- There were significant overlaps in the pressures acting on all three of our key river corridor climate resilience functions. In the next steps of the work these will be examined through spatial and other datasets for areas of the case study rivers (River Dee and River Forth). Subsequently, existing datasets will be explored for indicators of the State and Impact parameters (as in Tables 1-3) and this will involve prioritisation in the collection of new primary data and collation of existing monitoring data (e.g. Scotland's river temperature network) and especially where new data can enhance knowledge on the Pressure-State and Impacts-State chain aspects of existing indicator data.

- Group discussion highlighted the benefit of the exercise itself for building understanding of the many interrelated concepts and processes at play in river systems and for their management.

Fig. 2. Workshop output at stage of individual input, then group review, ordering and collecting common notes for the function of: Increasing/maintaining carbon storage in river corridors (within soils, sediments, vegetation and wider biomass). Post-it notes are contributions from individuals and where direct duplication was shown they are stacked on top of each other to avoid duplication.

Fig. 3. Workshop output at stage of individual input, then group review, ordering and collecting common notes for the function of: River corridor water reserves and supply that buffers against low river flows. Post-it notes are contributions from individuals and where direct duplication was shown they are stacked on top of each other to avoid duplication.

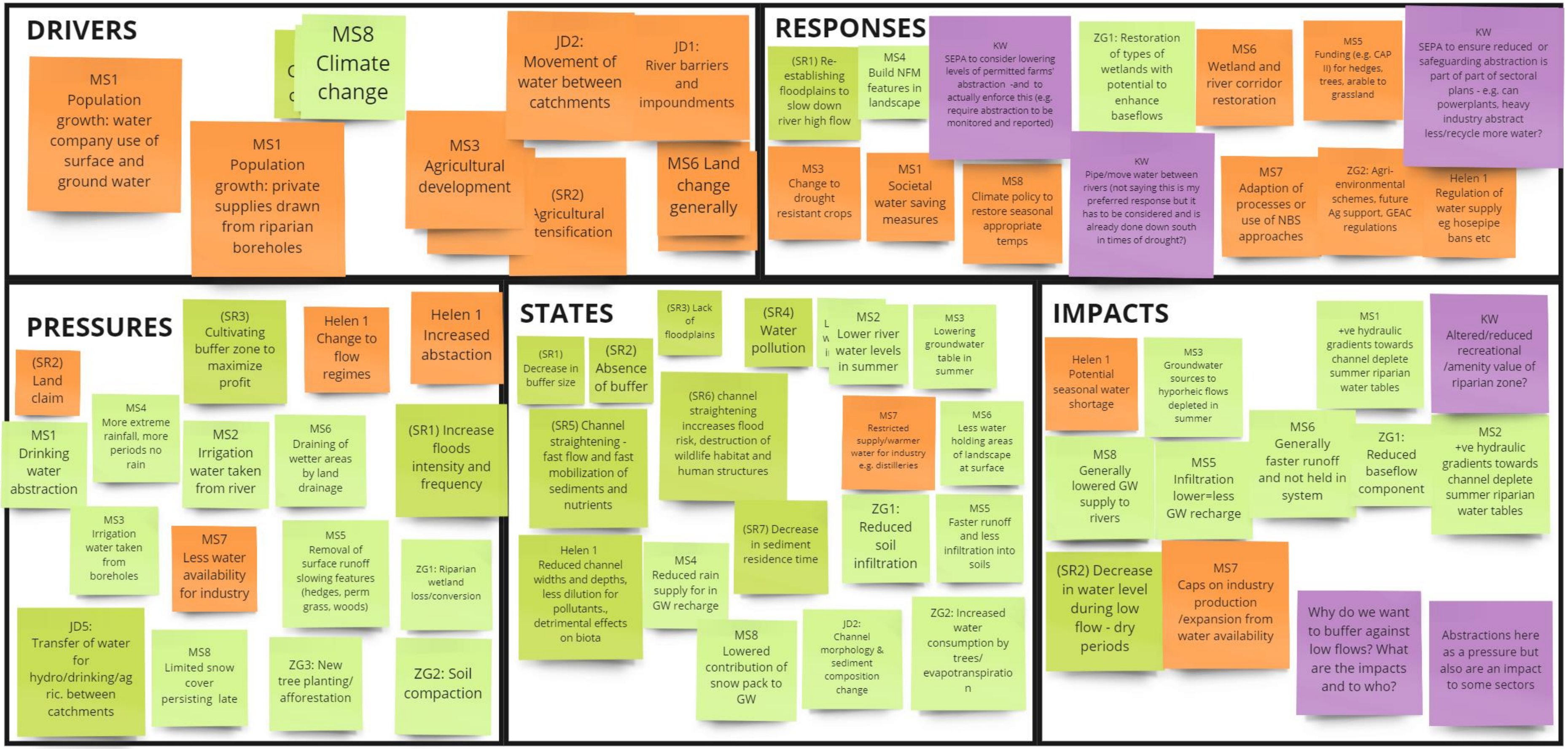

Fig. 4. Workshop output at stage of individual input, then group review, ordering and collecting common notes for the function of: Reducing extremes of river water temperature. Post-it notes are contributions from individuals and where direct duplication was shown they are stacked on top of each other to avoid duplication.

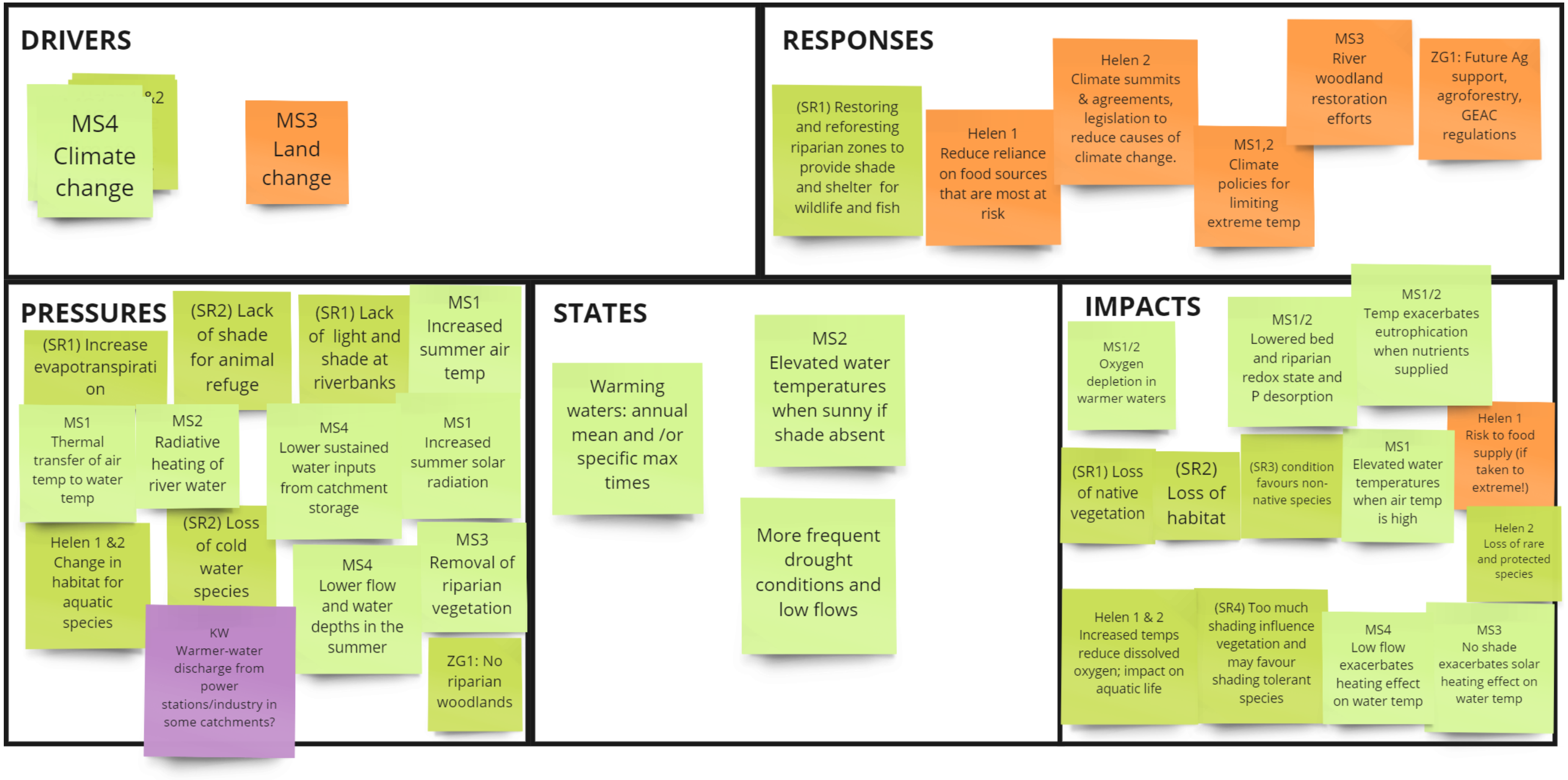

Table 1. Refined list of Pressure-State-Impact parameters together with indicators necessary for data collation in the next project phase, considering the function of: Increasing/maintaining carbon storage in river corridors (within soils, sediments, vegetation and wider biomass). Blue text denotes where parameters and indicators are common with other tables here.

Pressure	Key indicators	State	Key indicators	Impacts	Key indicators
Regulated river flow Soil sealing Soil compaction Soil drainage	Land cover datasets of broad types (moor, wooded, arable, grassland, urbanised)	Vegetation condition and C storage	Wetland vegetation C stocks Woody vegetation/tree C stocks	Reduced biomass C in vegetation or change of vegetation for less stable long term C stores	Vegetation type, age, structure and functions (e.g. roughness against flows)
Vegetation removal/change Loss of riparian wetlands Land change (farming)	Land management risk data (compaction, drainage rules e.g. arable cropping on inherently poorly drained soils)	Wider biomass average resident mass and associated C storage	River channel biofilm and algae C stocks Fish C stocks Terrestrial animal C stocks	Altered biomass C in biofilm Decreased topsoil organic matter content & incorporation from litter	Heterotrophic vs autotrophic balance of river metabolism Soil quality indicators (SOC content, water holding capacity, aggregate stability)
Land change (urbanisation and energy)	Hydromorphological assessment (channelised, barriers to flow etc)	Soil and sediment condition and C storage	Riparian soil C stocks Floodplain sediment C stocks	Greater soil C erosion passing through riparian zone & less sediment C returns from the river	Soil surface and bank erosion assessment
Elevated temperatures	Wetland inventories	Built environment C stock	Human habitation and built environment C stocks		
Altered rainfall-runoff	Regional climate change model scenarios			Increased DOC exports from riparian soils to river	Soil water DOC concentrations
				Altered thermal regime	Soil and water temperature data

Table 2. Refined list of Pressure-State-Impact parameters together with indicators necessary for data collation in the next project phase, considering the function of: maintaining and/or increasing water reserves and supply that buffers against river low flows. Blue text denotes where parameters and indicators are common with other tables here.

Pressure	Key indicators	State	Key indicators	Impacts	Key indicators
Regulated river flow Altered hydrological connections and water storage Ground water abstraction River water abstraction Soil sealing Soil compaction Soil drainage Vegetation removal/change Loss of riparian wetlands Land change (farming) Land change (urbanisation and energy) Altered rainfall-runoff	Location data for boreholes, Scottish Water abstractions & farm abstract CAR licences direct from watercourses Data on water (reservoir) storage and pipe connection infrastructure Land cover datasets of broad types (moor, wooded, arable, grassland, urbanised) Land management risk data (compaction, drainage rules e.g. arable cropping on inherently poorly drained soils) Wetland inventories Regional climate change model scenarios	Vegetation cover balancing evapotrans-piration effects & rainfall-recharge Appropriate groundwater reserves & river connectivity Appropriate river flow regime & connections to standing waters River corridor wetlands maintained Soil generally maintains water storage Soil-ground profile-vegetation resists fast surface runoff River maintains meandering structure and floodplain connections	Altered vegetation form and (hydrological) function Loss of riparian wetlands & water contributions Lowered groundwater tables River data shows annual flow distribution and extremes altered Soil loss of water holding capacities Signs of fast runoff and erosion River morphological data	Decreased, seasonally depleted, or disconnected groundwaters Loss of available supply for abstraction Reduced water depths and wetted area of channel/floodplain for rivers Loss of key water-loving species (invertebrates, fish, birds) Warmer waters & exacerbated eutrophication Loss of recreation amenity.	Soil quality indicators (SOC content, water holding capacity) Abstraction records data Groundwater depth variation & soil moisture monitoring data Plot study tracer data for connectivity (e.g. stable isotopes) Ecological survey data (birds, invertebrates, channel algae and macrophytes) River water temperature, chlorpohyll and nutrient concentration data. Survey data on access and recreation. Soil runoff and erosion assessment

Table 3. Refined list of Pressure-State-Impact parameters together with indicators necessary for data collation in the next project phase, considering the function of: reducing extremes of river water temperature. Blue text denotes where parameters and indicators are common with other tables here.

Pressure	Key indicators	State	Key indicators	Impacts	Key indicators
Regulated river flow River water abstraction Vegetation removal/change Loss of riparian wetlands Land change (farming) Land change (urbanisation and energy) Altered temperature & rainfall-runoff	Location data for Scottish Water & farm abstractions direct from watercourses Land cover datasets of broad types (moor, wooded, arable, grassland, urbanised) Regional climate change model scenarios	Vegetation cover appropriately balancing shade effect and other hydrological aspects (e.g. evapotranspiration water losses, surface runoff) River water thermal regime is appropriate to river type and dependant ecosystem River flow regime is appropriate to river type and ecosystem & resists periods of drought	Altered vegetation form and shade function (e.g. loss of trees) River flow data & morphological assessment shows flashy regime & insufficient summer baseflow Soil loss of water holding capacities Signs of fast runoff and erosion in riparian zones	Loss of shade and direct solar radiation transfer increases Decreased, seasonally depleted, or disconnected cooling groundwaters Reduced water depths and wetted area of channel/floodplain for rivers Loss of aquatic ecological species sensitive to temperature extremes & depressed oxygen Warmer waters & exacerbated eutrophication Loss of recreation amenity.	Light level & solar radiation monitoring data Groundwater level and temperature monitoring data Ecological survey data (birds, invertebrates, channel algae and macrophytes) River water temperature, chlorpohyll and nutrient concentration data. Survey data on access and recreation. Soil runoff and erosion assessment