Climate Change Adaptation Research Grants Program
- Freshwater Biodiversity Projects

Project title:
Adapting to climate change: a risk assessment and decision framework for managing groundwater dependent ecosystems with declining water levels.

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Objectives:
To develop and test a risk assessment and decision framework for climate change adaptation capable of promoting resilience and biodiversity in groundwater dependent ecosystems (GDEs)that can be adapted for use Australia-wide.

Project design and methods

Site locations:
This study will focus on three sites representing two GDEs: Wetlands on the data· rich Gnangara Mound (2200 km^2) and in the data-poor Blackwood catchment (Yarragadee surface-expression zone 400 km^2) and caves (Jewel and Lake Caves, Margaret River (2x2 km^2). The sites are of sufficient size (landscape and subcatchment scale) to test the framework but remain manageable within the project timeframe.

Hazard identification:
The primary hydrological hazard identified for GDEs is declining surface- and groundwater levels (associated with declining rainfall, groundwater pumping and land management practices) and, indirectly, its impacts on water quality. This will be the hazard assessed in this study using standard risk assessment protocol.

Ensuring and utilising a broad knowledge base:
Key expertise on GOEs in Western Australia is included on the project team ensuring a wide knowledge of relevant research across Australia. The work builds on work by the WA Department of Water on groundwater modelling, by CSIRO delivered as the South West Sustainable Yields project, more recent work such as climate sensitivity of groundwater recharge and work by Froend and others on the response of ecological communities to climate. Linkages and input from relevant projects across the country will be facilitated by the national advisory.

Quantifying hydrological change:
Groundwater level and its impact on surface expression of water in wetlands and caves will be the focus of this framework. Interaction between groundwater and water depth, volume and extent (both spatial and temporal) has been quantified for both wetlands on the Gnangara Mound in Perth and in the Blackwood River and its tributaries. Data is similarly available for cave ecosystems through the "Lake Cave Eco-Hydrology Recovery Project" which is supported through grant funding to Augusta Margaret River Tourism Association (AMRTA) from the Government of Western Australia's Natural Resource Management Grant Scheme State NRM . This information is already available in the form required by this project, as both vertical and spatial mapping of surface water fluctuations Future scenarios of groundwater fluctuation (based on wet extreme, median and dry extreme future climates for 2030) are similarly available in appropriate form (GIS mapping and profiles) for direct input into the framework from the South-West Sustainable Yields project. Regional groundwater models 'PRAMS' (Perth Regional Aquifer Modelling System) and 'SWAMS' (South West Aquifer Modelling System are capable of evaluating the impacts of various factors (including abstraction, climate and various landuse practices) that can contribute to water level declines. Utilisation of proven published scenarios makes the time frame of this project feasible and precludes the need for intensive groundwater expertise. However, to ensure data and models are correctly used and limitations of the data are transparent and acted upon, the researchers who developed these resources are part of tile project team. These data will be entered on a GIS platform to show the range of surface water extent and seasonal fluctuation in the wetlands and caves in the two study areas. Data will be presented as the change in extent and fluctuation from an historical baseline, resulting from recent drying and predicted by future scenarios.

Determination of hydrological habitat requirements and tolerances*:*
The impact of changes in water level on water quality parameters such as pH, temperature and nutrients have been determined for the wetlands and caves in each catchment. Long-term data on aquatic macro invertebrates, phreatophytic and riparian vegetation, fish and amphibians together with groundwater, surface water, rainfall and water quality will form the basis of this component. With a restricted timeframe, published information and existing data will be used to identify functional biotic traits (eg salinity tolerances, life history requirements for surface water) that indicate vulnerability and response to changes in groundwater levels. Well-established data reduction and multivariate analysis techniques will initially be used to identify responses at ecosystem-scale for abiotic and biotic variables to changes in groundwater levels. These techniques will then be used to identify responses at a smaller scale for individual biotic groups. Hydrological habitats will be identified. This will be based on the relationship between surface and groundwater levels and quality, rainfall recharge processes and biota requirements. A combination of Classification & Regression Tree (CART) and Multivariate Regression Tree (MRT) analyses will be used to determine ecological thresholds that define the hydrological conditions and indicator traits for each habitat. The data required for this framework and its availability have already been identified.

Risk Characterisation*:*
In developing the framework, the focus is on 'risk characterisation'. Initially, this will involve identifying the combination of physical and biotic traits that best characterise the dependency of the biotic community on specific groundwater regimes. The risk, or ecological endpoint, is an unacceptable change to these physical and biotic traits defining the GDE. A GDE will be represented by the combination of physical attributes and functional biotic traits that best define its condition and vulnerability to change. This approach not only reduces the number of response variables from potentially hundreds of species to a few functional attributes, but also enables the method to be applied in different locations regardless of differences in species composition. To characterise risk, the response over time of the GDEs to changes in groundwater induced by climate will be analysed with existing hydrological projections. The GDE response will be represented as a change in the proportional representation of each key trait to different groundwater levels and resulting surface water expression. For example, the capacity to survive a period of drying by macroinvertebrates or the tolerance of ambient salinity by freshwater fish will vary depending on inflow from groundwater. Multivariate Regression Tree analysis will then be used to pick ecological thresholds ('splits') that best explain the variability in GDE response and the best traits for predicting responses. The Netica program (Norys Software Corp. TM) will be used for Bayesian belief networks to model uncertainty by combining expert opinion and observational evidence, particularly in data-poor situations. These models have already proven useful in capturing knowledge and understanding ecosystem response and effectiveness of adaptation options under different climate change scenarios They will be used here to assess the likelihood (as percentage probability) of different groundwater levels supporting the functional traits of GDEs given projected changes in groundwater induced by climate. Workshops including objective reviewers outside the research team will be used to populate these models. Application and representativeness of the framework developed from the data-rich Gnangara Mound study area will be tested on the data-poor GDEs of the Blackwood catchment. The multivariate approach will define an index of a few key traits that will define the probability of survival of the biotic community in a GDE to different groundwater levels, and hence surface expression of water.

The spatio-temporal framework (GIS) and risk management*:*
The levels of risk will be incorporated spatially into the GIS risk assessment framework based on the different groundwater levels predicted by climate-induced and/or anthropogenically-induced scenarios. Each of these, together with the suite of hydrological variables that define them, will be mapped on a GIS platform using the ArcGIS software. Tools that can be integrated into the ArcGIS toolbox will be developed in the Python scripting language and made available to managers for use with ArcGIS standard software. The risk of impact to GDEs posed by climate change, groundwater extraction and various land uses can be assessed by considering differences in their distribution, in particular significant change in the areal extent, between current and future climate scenarios. Concurrently, the effectiveness of proposed adaptation responses (eg reducing groundwater extraction volumes) on reducing risk can be assessed. Thus, the outcome of this project component will be a spatio-temporally explicit tool that will enable prediction of responses to identified environmental drivers (including climate change) at the ecosystem scale. Similar approaches have been used for the Coorong, oak woodlands in the USA, soft coral communities in the Great Barrier Reef and in other situations where the objective was to predict the consequences of environmental change.