R implementation of the Ecological Risk due to Flow Alteration (ERFA) method

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Abstract: The R implementation of the Ecological Risk due to Flow Alteration (ERFA) method is a product of "Translating Environmental Flow Research in Cambodia" (TEFRIC), a project funded by the UK Natural Environment Research Council (NERC) involving the UCL Department of Geography, the Centre for Ecology and Hydrology (both in the UK), the Institute of Technology of Cambodia and the Tonle Sap Authority (both in Cambodia). Whilst this software was developed as part of this project with a geographical focus on SE Asia (and the example data sets provided are for the Mekong River Basin), use of the code is not restricted to this region. Instead it can be applied for any situation where baseline and scenario river flow time series are available. The software is referred thereafter as TEFRIC ERFA and can be downloaded freely from NERC Environmental Information Data Centre (Laizé and Thompson, 2019).

1. Introduction

A river's hydrological characteristics exert critical controls on aquatic ecosystems. Its flow regime is central to sustaining aquatic biodiversity and ecosystem integrity. All elements of this regime influence some aspect of riverine ecosystems. Changes in river discharge therefore have the potential for ecological impacts. Tools to assess potential risks of change are required.

2. ERFA

The Ecological Risk due to Flow Alteration (ERFA) method is based on the Range of Variability Approach that uses Indicators of Hydrological Alteration (IHA), for comparing natural and altered flow regimes. ERFA was originally applied to Europe-wide climate change assessments (Laizé *et al.*, 2014; Figure 1).

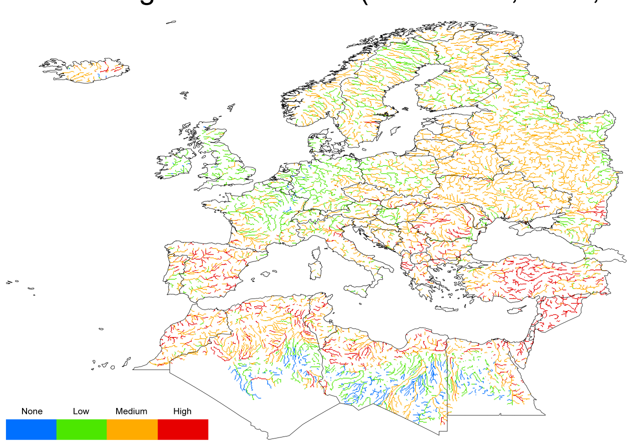


Figure 1. European-wide application of ERFA based on comparison of baseline (1961-1990) and scenario (2040-2069) river discharges simulated by WaterGAP for SRES A2 projections from the MIMR GCM.

Thompson *et al.* (2014) modified ERFA for hydrological modelling of the Mekong Basin (Figure 2). They used Monthly Flow Regime Indicators (MFRIs) to characterise the flow regime.

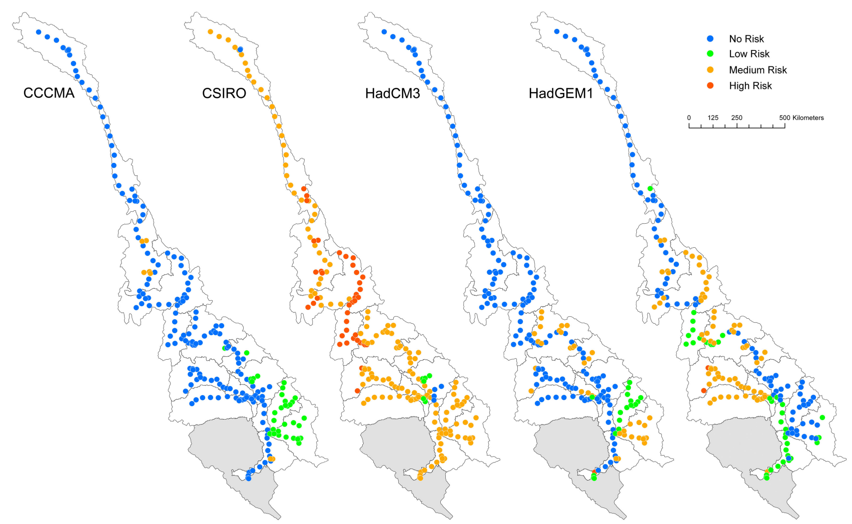


Figure 2. ERFA risk of ecological change in low flows for the Mekong derived from MIKE SHE/MIKE 11 modelling for a 2°C increase in global mean temperature for 4 GCMs (Thompson et al., 2014).

3. Development of TEFRIC ERFA

New MFRIs incorporate outcomes from workshops attended by experts from Cambodian academic, governmental and conservation organisations. Ten MFRIs (five for both high and low flows, Table 1) capture magnitude (median) and variability (interquartile range, IQR) of hydrological variables calculated for each year of a baseline and scenario period. Indicators associated with timing of high and low flows are described by the mode of the month in which extreme flows occur.

Table 1. Monthly Flow Regime Indicators (MFRIs) used in ERFA

Hydrological variables (one per year)	MFRI[c] (one per period)	Flow type	Regime characteristics
Number of months above threshold	Median (HF1) IQR (HF2)	High	Magnitude; Frequency
Month of maximum flow / flooding (1-12)	Mode (HF3)	High	Timing
Maximum flow	Median (HF4) IQR (HF5)	High	Magnitude; Frequency
Number of months below threshold[b]	Median (LF1) IQR (LF2)	Low	Magnitude; Frequency
Month of minimum flow / flooding (1-12)	Mode (LF3)	Low	Timing
Number of periods >= two months with flow below threshold	Median (LF4) IQR (LF5)	Low	Magnitude; Frequency; Duration

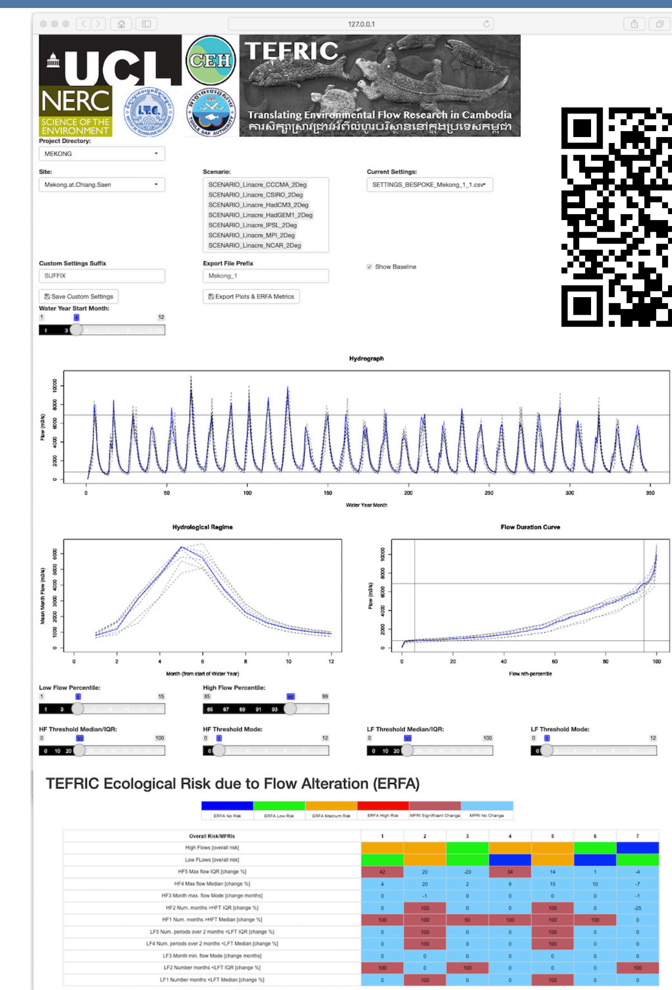
Significant departures from the baseline are assumed when differences in MFRI exceed defined thresholds. A traffic-light coding system (Table 2) classifies overall risk of change based on the number of MRFIs undergoing significant change.

An interface. developed using *shiny*, provides a "front end" to the TEFRIC ERFA R code (Figure 3). This (i) enables selection of a site (gauging station) and any number of scenarios; (ii) plots summary graphs including river regimes and flow duration curves. (iii) enables modifications to TEFRIC ERFA parameters (water year, high and low flows percentiles, significant change thresholds, and (iv) summarises overall risks of change in high and low flows and the MFRIs undergoing significant change.

Table 2. Risk classes

Risk	Number of MRFIs
High	4-5
Medium	2-3
Low	1
No	0

Figure 3. The TEFRIC ERFA user interface (QR code to download)



TEFRIC ERFA is freely available to download. The method is currently being used in a range of studies including global-scale assessments of climate change impacts on environmental flows.

Laizé, C.L.R., Acreman, M., Schneider, C., Dunbar, M.J., Houghton-Carr, H.A., Flörke, M. and Hannah, D.M. 2014. Projected flow alteration and ecological risk for pan-European rivers. *River Res. Applic.* 30, 299–314.

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Thompson, J.R., Laizé, C.L.R., Green, A.J., Acreman, M.C. and Kingston, D.G. 2014. Climate change uncertainty in environmental flows for the Mekong River. *Hydrol. Sci. J.* 59, 259–279.