A model to estimate the total ecological risk in the management of water resources subject to multiple stressors

Sebastian Jooste
Institute for Water Quality Studies, Department of Water Affairs and Forestry, Private Bag X313, Pretoria 0001, South Africa

Abstract

The disjunctive convolution of independent individual stressor risk is presented as a model to estimate the total expectation of ecological effect for a water resource, subject to several different and metrically disparate stressors. This method makes use of the exposure and effect assessment data of the risk assessment procedure for each individual stressor given that the end-point is the same. A hypothetical case study illustrates how total risk could be used as an ecological goal-oriented tool in catchment management.

Glossary

ERA:	Ecological risk assessment
Hazardous:	Having the potential to cause an (undesired) effect
Stressor:	An anthropogenic substance, form of energy or circumstance that may cause a change in ecosystem integrity
N(x,y) :	The normal (Gaussian) distribution with median x and standard deviation y
LN(x,y):	The log-normal distribution with median x and standard deviation y
Weibull(α, β):	The Weibull distribution with scale parameter and location parameter
[a, b] :	The interval from a to b where both a and b are included
(a, b) :	The same interval with both a and b excluded.

Introduction

The management of a water resource with a specific ecological goal in view can be particularly problematic when the water resource is subject to multiple diverse stressors such as chemical substances, deviations from expected flow, habitat degradation etc. An example of this is found in the South African National Water Act (Act 36 of 1998). It makes provision for an ecological Reserve, a quantity and quality of water to (*inter alia*) protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource. The provisions of the Act pertain not only to the regulation of discharges to surface water but also to abstraction from the water resource as well as to the quality of the instream and riparian habitat necessary for assuring the protection of the aquatic ecosystem. At the same time, it is recognised that South Africa is a semi-arid country (DWAF, 1986) and consequently a fine balance is needed in water resource management between protection and utilisation. Here the ecological goal of sustainability must be achieved in aquatic ecosystems subject to diverse stressors such as discharge of substances, the abstraction of water and the destruction of the physical habitat which occur to a greater or lesser degree.

☎(012) 808-0374; fax: (012) 808-0338; e-mail: eeg@dwaf-hri.pwv.gov.za
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It has been suggested (Jooste and Claassen, submitted to *Water SA*) that a probabilistic effect-based approach has some potential for application to the problem of multiple stressor impacted water resources. A method is suggested whereby an adaptation of the conventional ecological risk assessment methodology can be used to assess the overall risk of multiple stressors in the management of catchments with a view to maintenance of the ecological Reserve.

The problem of a multiple stressor environment

One of the difficulties of ecological water resource management in a multiple stressor environment is the problem of predicting the integrated effect of co-occurring stressors of different types. The disparity among stressor measures necessitates the separate consideration of stressors and their effects. The stressors are then regulated, assessed and controlled separately. At the same time, these stressors may add to a disruptive effect. The integration of effects has been attempted mechanistically on a physiological basis by considering the production of stress proteins (originally referred to as heat shock proteins). These are grouped into three classes:

those related to the heat shock phenomenon;
glucose regulated proteins; and
stressor specific proteins such as metallothionein (Di Giulio et al., 1995; Shugart, 1996).

The stress protein response becomes an integrated signal for environmental stress. While such a mechanistic approach is likely to produce more accurate assessments, its data requirements are extensive. At a more phenomenological level, it may be possible to estimate the probability of stress-induced changes by considering the probability of separate stress events.

Some observations regarding the aquatic ecosystem

The ecological status of a resource is determined by the dynamics and kinetics of interactions of aquatic animals, plants and processes that determine the function, composition and diversity that characterise the ecosystem. Water resource management objectives and their associated criteria must reflect the following inherent ecosystem characteristics if they are to achieve their goal: