



Eco-hydraulic Signature of Colombo Dutch Canals and Implications for Rehabilitation

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Declaration

I hereby declare that to the best of my knowledge, this submission is my own work and it neither direct material previously published nor written by another person or material, which to substantial extent, has been accepted for the award of any other academic qualification of a university or other institute of higher learning expect where acknowledgement is made in the text.

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Abbreviations

CMC	Colombo Municipal Council
DC	Dutch Canal
DCA	Detrended Correspondence Analysis
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPT	Ephemeroptera, Plecoptera, Trichoptera
GWF	Grey Water Footprint
HC	Heen Canal
kg	kilogram
L	Liters
MCUDP	Metro Colombo Urban Development Project
mg	milligram
MPH	Mesoscale Physical Habitats
PTI	Pollution Tolerance Index
PTIA	Percentage of the Total Impervious Area
S	Seconds
SLLRCD	Sri Lanka Land Reclamation and Development Corporation
SWI	Shannon Wiener Index
TC	Talangama Canal
TS	Total Solids
TSS	Total Suspended Solids
UNESCO	United Nations Educational, Scientific and Cultural Organization
WQI	Water Quality Index

List of publications

Journal papers

Gomes, P. I. A., Wai, O. W. H. and **Dehini, G. K.** (2018). Vegetation dynamics of ephemeral and perennial streams in mountainous headwater catchments. *Journal of mountain sciences*, Accepted.

Gomes, P. I. A., Fernando, B. A. V. W. and **Dehini, G. K.** (2019). Assessment of Pollution Sources, Fate of Pollutants, and Potential Instream Interventions to Mitigate Pollution of Earthen Canals of Urban to Rural-Urban Fringe. *Water, Air & Soil Pollution*. 230 (11), 262

Dehini, G. K. and Gomes, P. I. A. (2019). Variation in benthic macroinvertebrate populations in urban and rural urban-fringe tropical canals of Sri Lanka. *Tropical Ecology* (under review). Manuscript ID: TROE-D-20-00010.

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Conference proceedings

Gomes, P. I. A., **Dehini, G. K.** and Weerasinghe W. D. G. B. (2016). A comparative eco-hydrologic study of perennial and non-perennial streams of a headwater catchment in 72nd annual sessions of the Sri Lanka Association for the Advancement of Science.

Dehini, G. K. and Gomes, P. I. A. (2019). Response of macroinvertebrates to water quality and canal hydraulics: A comparative study using urban canals of Sri Lanka in 75th annual sessions of the Sri Lanka Association for the Advancement of Science.

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Abstract

Dutch canals (DC) in Colombo, the commercial hub of Sri Lanka, play a significant role in surface drainage. Although flood control is the contemporary use of urban waterways such as DC, their importance in provision of ecological services is started to value and is the case with the changing socio-economic and environmental requirements. Once the basic economic development is achieved and urban dwellers are satisfied, need for a better environment (also referred as green environment) emerges – this is one important socio-economic need legislative authorities of developed countries have to work on. Even though yet to be realised, Sri Lankan government agencies time to time have shown commitment on ecological rehabilitation of DC. Ecological rehabilitation can be defined as rehabilitation strategies that make the canal self-sustainable, whilst providing ecosystems services similar to a pristine stream/river.

One major constraint faced in canal ecological rehabilitation is a lack of a reference state. Reference conditions would define a feasible status quo of the rehabilitated canal with estimations of thresholds of governing variables. Identification of optimum conditions in engineered systems or laboratory are not new, yet, ecosystems, especially those threatened by anthropogenic activities are rather unfound or limited to developed countries, which is particularly the case with running water (lotic) ecosystems. Those countries have straightened and concrete lined urban waterways, in many cases with fast moving waters which are close to super critical conditions. Ecological rehabilitation studies dealing subcritical urban waterways are rare, and this study's focus is on such a lotic system. DC is subject to rather somewhat basic maintenance - such activities only consider flood safety and have largely decreased the natural variability of the flow regime and channel morphology. However, no actions taken so far have introduced eco-hydraulic functions that would make canals self-viable and provide ecosystem amenities expect from a natural stream/river.

The aim of this study was to investigate the eco hydraulic signature of DC to identify optimum eco-hydraulic conditions that correspond to an ecologically healthy canal. The specific objectives were to investigate eco hydraulic data against varying spatial

and temporal scales to identify the impact of space and time on macroinvertebrate responses, model eco-hydraulic data with macroinvertebrate responses to derive optimum eco-hydraulic conditions and compile guidelines based on those optimum conditions that can be used in ecological rehabilitation works.

Three canals including DC within urban, peri-urban (Talangama canal: TC) and rural-urban fringe (Heen canal: HC) catchments were studied for a two year period against different spatiotemporal scales. The methodology involved a comprehensive set of field observations and data analysis. Targeted optimum conditions for eco-hydraulic variables (hydraulic, habitat quality and water quality parameters) were derived according to the response of macroinvertebrate (diversity, and pollution tolerance index (PTI)) data. Hydraulic variables included velocity, depth, discharge, Froude number etc.; and habitat quality variables included a set of variables such as epifaunal substrate, pool substrate characterization, channel alteration etc. that can be observed *in situ*. Water quality variables included dissolved oxygen, electrical conductivity (EC), pH, turbidity etc. Relationships among eco-hydraulic variables and macroinvertebrate responses were built firstly via multiple linear regression followed by bivariate models using curve estimation regression. Statistically acceptable (co-efficient of determination (R^2) > 0.3 and $P < 0.1$) relationships were solved for a targeted PTI of 11. PTI was decided as the most suitable macroinvertebrate index, amongst macroinvertebrate indices, as it was more generic and representative.

HC showed the greatest spread of diversity, PTI and richness; an indication that macroinvertebrate composition was dynamic than TC or DC. A majority of macroinvertebrates in DC belonged to the most pollution tolerant category, while they were mostly under intolerant category in HC. TC had a mixed composition of all four categories of pollution tolerance. Habitat quality of DC was always lower than TC and HC; therefore, belonged to poor, marginal and sub optimal categories, respectively. Based on water quality parameters, HC had better water quality than TC and DC, where in many cases with a statistical significance at $P < 0.05$. Two-dimensional variation of EC and turbidity of three canals suggested the dominance of molecular diffusion in longitudinal as well as lateral directions. Patchy distribution of turbidity of HC indicated that attenuation also playing a major role on the fate of

pollutants. According to the grey water footprint analysis, the urban and semi-urban canals have already exceeded their natural assimilation capacities and the situation was critical in DC.

The study revealed that hydraulic and habitat quality parameters dominated over water quality in explaining the response of macroinvertebrates. Some of the eco-hydraulic variables showed a significant relationship with diversity, but only a few parameters from that showed a significant relationship with PTI and most of them were from HC. Having a positive correlation only with diversity suggested that the pollution tolerant species had contributed to the diversity more than the pollution intolerant species. Furthermore, numerous significant relationships were observed in dry season than that of wet season. Eco-hydraulic variable response curves that gave significant relationships either in linear or quadratic forms were solved with the targeted PTI of 11 and solutions were suggested as target conditions that can be incorporated in ecological rehabilitation. Out of 24 eco-hydraulic variables, dry season gave 15 feasible solutions, whereas wet season gave only six. Most of the feasible solutions were from hydraulic and habitat quality parameters. The study gave optimum ranges for velocity, standard deviation of velocity, Froude number, depth, number of mesoscale physical habitats, diversity and percentage areal coverage of transverse vegetation, score of epifaunal substrate, pool substrate characterization, bank vegetative protection, riparian vegetative zone width, electrical conductivity, dissolved oxygen, ammoniacal nitrogen and pH. Also, the study validated some generic understanding of interrelationships within lotic ecosystems such as the fact that increased mesoscale physical habitats positively correlate with a healthy canal.

The study gave quantifiable target conditions that could be vital in rehabilitation of DC. Results would be applicable not only for DC, but also similar canals within the same climatic conditions in Sri Lanka and elsewhere. It is recommended to liaise with government agencies in pilot studies, and in tandem making knowledge and data transfer with similar research groups. As future studies, it is recommended to validate the models and/or solutions obtained in this study with more lotic waters within the same geo-climatic conditions, and develop similar target conditions for different geo-climatic zones.

Key words: Dutch canals of Colombo; eco-hydraulic; macroinvertebrates; optimum conditions for rehabilitation; pollution tolerance index; urban canals; water quality