Quantifying biological constraints on stream integrity for classification and priorization

Marcus W. Beck (marcusb@sccwpr.org), Raphael D. Mazor (raphaelm@sccwrp.org), Scott Johnson (scott@aquaticbioassay.com), Phil Markle (phil@lacsd.org), Peter D. Ode (peter.ode@wildlife.ca.gov), Ryan Hill (hill.ryan@epa.gov), Eric D. Stein (erics@sccwrp.org)

Introduction

- Degraded biological condition in streams can occur from individual or multiple stressors acting at different scales (Novotny et al. 2005; Townsend, Uhlmann, and Matthaei 2008; Leps et al. 2015). Identifying and mitigating causes of poor condition requires an understanding of how stressors propogate across space and time. Incomplete knowledge on drivers of change or high level of uncertainty in how biology is linked to drivers can lead to ineffective management actions. Varying expenses and assurance of outcomes (e.g., varying costs and challenges of urban stream restoration (Kenney et al. 2012; Shoredits and Clayton 2013))
- Stream restoration relies extensively on identification and prioritization of sites where activities are expected to have desired outcomes. This requires an understanding of how stressors affect biological integrity to place bounds on reasonable expectations for what is likely to be a possible outcome of a management action. This requires identifying biological constraints or limits on the potential range of biological conditions. Identifying an appropriate context for observed conditions can be used to prioritize. Context can be defined by models, expert knowledge, and/or defined value sets.
- We don't have good constraint tools to develop a context of expectation of what's possible at a site. This can help prioritize locations where management efforts will or will not have the intended outcomes.

Biological filters act at different scales (Poff 1997) and we can use this information to describe an expectation for prioritization that is scale-specific. Landscape-level constraints are particularly relevant for macroinvertebrate communities in streams (Sponseller, Benfield, and Valett 2001)

- The goal of this study is to demonstrate application of a landscape model to classify and prioritize stream monitoring sites using estimated constraints on biological integrity. The model provides an estimate of context for biological condition that provides an expectation of what is likely to be achieved at a given site relative to large-scale drivers of stream health. The model was developed and applied to all stream reaches in California. A case study is used to demonstrate how the model can be used to classify and prioritize using guidance from a stakeholder group.

Methods

Study area and data sources

- Brief description of CA, stream types and designated uses, PSA regions, management interests (e.g., southern vs. northern CA)
- Streamcat database used to quantify watershed land use at all sites (Hill et al. 2016)
- Streamcat data linked to National Hydrography Dataset Plus (NHD) (USGS (US Geological Survey) 2014), reach as individual unit for model output

The California Stream Condition Index (CSCI) (Ode et al. 2016; Mazor et al. 2016) was used as a measure of biological condition to assess site performance relative to reach classification. Benthic macroinvertebrate data used to calculate CSCI scores were collected at nearly 4800 sites between 2000 and 2014. Field data were collected during baseflow conditions typically between May and July following methods in Ode (2007). The CSCI is a predictive index of stream health that compares the observed taxa and metrics at a site to those expected under reference conditions. Expected conditions at a site are based on models that estimate the likely macroinvertebrate community in relation to factors that naturally influence biology, e.g., watershed size, elevation, climate, etc. The CSCI score at a site is based on an observed-to-expected ratio of taxa and a predictive multimetric index (pMMI) composed of six individual metrics that describe the structure and function of the macroinvertebrate community. The index score at a site can vary from approximately 0 to 1.4, with higher values indicating an observed community with minimal deviation from reference conditions. Because the index was developed to minimize the influence of natural gradients, the index scores have consistent meaning across the state (Reynoldson et al. 1997). A threshold score based on a selected lower percentile of scores at all reference sites is used to define nominally low and high scoring sites.

Building and validating landscape models

A prediction model of the CSCI was built to estimate likely ranges of scores associated with land use gradients. Land use parameters were urgan and agricultural land cover in the stream catchment (STREAMCAT). The model is incomplete by design such that CSCI scores were modelled only in relation to landscape-level variables that are not easily targeted by management. The model provided an explanation of variation in scores related to constraints on biology and unexplained variation was considered representative of additional, unmeasured environmental variables that influence stream biointegrity. Maybe describe modelling approach in (Mazor et al. 2016) - which variables were used to develop CSCI.

Models were developed using quantile random forests to estimate a range of likely CSCI scores in different landscapes (Liaw and Wiener 2002; D. R. Cutler et al. 2007). The model predictions were used to describe where bioassessment targets are unlikely to be met or where streams are unlikely to be impacted. Calibration and validation data were selected as xyz.

Classifying streams and prioritizing sites

- Description of SGRRMP and stakeholder group
- Methods for estimating stream class - possibly/likely constrained, possibly/likely unconstrained, certainty and CSCI threshold, some sites were unclassified

Figure

- Methods for estimating site performance - over, expected, underperforming, discussion of site types
- Sensitivity analysis - how do classes, performance categories change with thresholds and certainty
- Prioritization of types - stakeholder involvement

Results

State-wide patterns

- Where does the model perform well, how does performance vary with validation and calibration datasets.
- What is the consistency of patterns? For example, percent stream miles as xyz by PSA.

Figure Statewide map.

Case study

- San Gabriel River Regional Monitoring Program
- Extent, classification, prioritization - probabilistic assessment to make broader conclusions.
- Relationships with environmental variables for constrained/unconstrained locations. Maybe apply to hardened/non-hardened reaches in constrained locations.
- What to do with unclassified streams - typical urban, typical ag.

Tables Priority by type, by perspective

Discussion

- What do priorities really mean? Depends on your interests, needs, values, etc.

- Link with engineered channels study.

Supplement

Online application.

References

Cutler, D. R., T. C. Edwards Jr., K. H. Beard, A. Cutler, K. T. Hess, J. Gibson, and J. J. Lawler. 2007. "Random Forests for Classification in Ecology." *Ecology* 88 (11): 2783–92. doi:10.1890/07-0539.1.

Hill, R. A., M. H. Weber, S. G. Leibowitz, A. R. Olsen, and D. J. Thornbrugh. 2016. "The Stream-Catchment (StreamCat) Dataset: A Database of Watershed Metrics for the Conterminous United States." *Journal of the American Water Resources Assocation* 52: 120–28. doi:10.1111/1752-1688.12372.

Kenney, M. A., P. R. Wilcock, B. F. Hobbs, N. E. Flores, and D. C. Martínez. 2012. "Is Urban Stream Restoration Worth It?" *Journal of the American Water Resources Association* 48 (3): 603–15. doi:10.1111/j.1752-1688.2011.00635.x.

Leps, M., J. D. Tonkin, V. Dahm, P. Haase, and A. Sundermann. 2015. "Disentangling Environmental Drivers of Benthic Invertebrate Assemblages: The Role of Spatial Scale and Riverscape Heterogeneity in a Multiple Stressor Environment." *Science of the Total Environment* 536: 546–56. doi:10.1016/j.scitotenv.2015.07.083.

Liaw, Andy, and Matthew Wiener. 2002. "Classification and Regression by randomForest." *R News* 2 (3): 18–22. http://CRAN.R-project.org/doc/Rnews/.

Mazor, R. D., A. C. Rehn, P. R. Ode, M. Engeln, K. C. Schiff, E. D. Stein, D. J. Gillett, D. B. Herbst, and C. P. Hawkins. 2016. "Bioassessment in Complex Environments: Designing an Index for Consistent Meaning in Different Settings." *Freshwater Science* 35 (1): 249–71.

Novotny, V., A. Bartosová, N. O'Reilly, and T. Ehlinger. 2005. "Unlocking the Relationship of Biotic Integrity of Impaired Waters to Anthropogenic Stresses." *Water Research* 39 (1): 184–98.

doi:10.1016/j.watres.2004.09.002.

Ode, P. R. 2007. “Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessment in California.” Surface Water Ambient Monitoring Program. Sacramento, CA.

Ode, P. R., A. C. Rehn, R. D. Mazor, K. C. Schiff, E. D. Stein, J. T. May, L. R. Brown, et al. 2016. “Evaluating the Adequacy of a Reference-Site Pool for Ecological Assessments in Environmentally Complex Regions.” *Freshwater Science* 35 (1): 237–48.

Poff, N. L. 1997. “Landscape Filters and Species Traits: Towards Mechanistic Understanding and Prediction in Stream Ecology.” *Journal of the North American Benthological Society* 16 (2): 391–409.

Reynoldson, T. B., R. H. Norris, V. H. Resh, K. E. Day, and D. M. Rosenberg. 1997. “The Reference Condition: A Comparison of Multimetric and Multivariate Approaches to Assess Water-Quality Impairment Using Benthic Macroinvertebrates.” *Journal of the North American Benthological Society* 16 (4): 833–52.

Shoredits, A. S., and J. A. Clayton. 2013. “Assessing the Practice and Challenges of Stream Restoration in Urbanized Environments of the USA.” *Geography Compass* 7 (5): 358–72. doi:10.1111/gec3.12039.

Sponseller, R. A., E. F. Benfield, and H. M. Valett. 2001. “Relationships Between Land Use, Spatial Scale and Stream Macroinvertebrate Communities.” *Freshwater Biology* 46 (10): 1409–24. doi:10.1046/j.1365-2427.2001.00758.x.

Townsend, C. R., S. S. Uhlmann, and C. D. Matthaei. 2008. “Individual and Combined Responses of Stream Ecosystems to Multiple Stressors.” *Journal of Applied Ecology* 45 (6): 1810–9. doi:10.1111/j.1365-2664.2008.01548.x.

USGS (US Geological Survey). 2014. “National Hydrography Dataset available on the World Wide Web.”