How much is enough and where to start? Quantifying and prioritizing locations for reductions in urbanization effects to benefit coho salmon populations

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Other Title Ideas

1. Quantifying reductions in urbanization effects and prioritizing locations for conservation action with limited biological data
2. Applying structural equation models and Bayesian multilevel models to conservation prioritization
3. Applying models of urbanization-induced mortality of threatened coho populations to prioritize conservation actions
4. other ideas?

Introduction

Conservation organizations are constantly forced to prioritize where and how to take action, given limited resources (Game et al., 2013). Choosing where to act is particularly challenging in urban and urbanization areas, where there may be many competing interests and where conservation actions can be particularly expensive (Moilanen et al., 2011). Furthermore, available biological data are rarely robust and detailed enough to apply rigorous quantitative analyses to identify specific numeric targets for all populations of conservation interest (**?**). Collecting additional data may not be ideal, or even feasible, given the time and financial resources required, when threatened populations are plummeting. Thus, conservation organizations often must make tough choices in the face of limited data.

Coho salmon *Oncorhynchus kisutch* in urban areas of the Pacific Northwest exemplify these challenges. This ecologically and economically important species is threatened by urbanization: throughout Puget Sound, urban stream syndrome results in coho spawner mortality rates upwards of 50% and can approach 90% (Feist et al., 2017; Spromberg and Scholz, 2011). If such trends are not reversed, populations may go extinct in mere decades (Spromberg and Scholz, 2011). The high rates of pre-spawn mortality (PSM) in coho are thought caused by toxic run-off that accumulates in streams of urban watersheds. The precise substances responsible are not known, but are thought to be a component or by-product of motor vehicle traffic (Spromberg et al., 2016). Higher PSM rates are correlated with road density, traffic intensity, and imperviousness, as well as summer and fall precipitation patterns in less-urban areas (Feist et al., 2017). Coho are not the only species affected by urban stream syndrome (add cites), but they may be the ‘canary in the coalmine.’

Addressing the problem of high PSM in coho, as well as the broader issue of stream water quality in urbanizaing areas, may include both conservation and restoration actions (Figure 1). Conservation would involve protecting areas low pre-spawn mortality rates (and clean water). Restoration would involve reducing PSM rates in areas where it is so high that populations may not persist (Spromberg and Scholz, 2011). The toxicity of urban run-off to coho salmon can be mitigated through increasing bioinfiltration, e.g. with green stormwater infrastructure (GSI). Experiments demonstrate that filtering toxic stormwater run-off through soil can reduce spawner mortality to normal (unexposed) levels Spromberg et al. (2016). Implementing GSI, including reducing impervious surfaces and protecting vegetation in urban watersheds where toxic runoff increases coho spawner mortality, may allow populations to recover. It is not known, however, what levels of reductions would be required to reduce coho mortality rates enough to support population recovery. Implementing GSI is costly and time-consuming, so restoration efforts will need to be prioritized.

There are myriad approaches for prioritizing areas for conservation and restoration (cites). Co-benefits and bang for buck.

Uncertainty should be incorporated into approaches to priorization, given incomplete biological data. This is particularly important in areas with rapid population growth and urbanization, such as Puget Sound (cites). Add more about future scenarios here...Bayesian approaches are well-suited to addressing varying data sources and levels of uncertainty.

Here we apply structural equation and hierarchical models, in a Bayesian framework, to identify priority areas of conservation and restoration for coho in Puget Sound. Specifically, our goals were to:

1. Develop a framework and flexible tools for conservation practitioners to prioritize restoration or conservation activities that benefit coho populations in Puget Sound. We wanted the tools to be grounded in the best available data and models, and incorporate the uncertainties inherent to this problem (i.e., incomplete biological data, a rapidly changing landscape).
2. Compare how altering focal co-benefits and acceptable levels of uncertainty, and incorporating forecasting landscape change (population growth and developement) affect locations where action should be prioritized for restoration or conservation.

Methods

We need the following sections here:

1. Data
   (a) Coho Pre-Spawn Mortality
   (b) Co-benefits
2. Analyses
   (a) Estimating PSM: brief model descriptions and Feist et al. (2017).
   (b)

Results

Main findings are:

1. An interactive tool allows the user to select biological attributes of interest for prioritization, and to select the levels of critical pre-spawn mortality and uncertainty levels on which the prioritization is based (shiny app). Perhaps add figure that shows how changing critical PSM and changing uncertainty affects number of sites falling below PSMcrit?
2. High priority sites for action include both conservation and restoration sites (Figures 3A, 4A, 5A).
3. High priority sites vary, depending on focal co-benefits of interest (Figures 3B, 4B,5B).
4. Something about future scenarios (e.g., XX% of high priority sites fall within basins where impermeable surfaces are expected to increase.)

Discussion

1. Quantitative prioritization tools that incorporate uncertainty and future scenarios can be developed, even with limited biological data. This is useful because...
2. Benefits/opportunities of interactive tools.
3. Challenges of interactive tools

Conclusion

References

Feist, B. E., E. R. Buhle, D. H. Baldwin, J. A. Spromberg, S. E. Damm, J. W. Davis, and N. L. Scholz. 2017. Roads to ruin: conservation threats to a sentinel species across an urban gradient. Ecological applications 27:2382–2396.

Game, E. T., P. Kareiva, and H. P. Possingham. 2013. Six common mistakes in conservation priority setting. Conservation Biology 27:480–485.

Moilanen, A., B. J. Anderson, F. Eigenbrod, A. Heinemeyer, D. B. Roy, S. Gillings, P. R. Armsworth, K. J. Gaston, and C. D. Thomas. 2011. Balancing alternative land uses in conservation prioritization. Ecological Applications 21:1419–1426.

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Spromberg, J. A., and N. L. Scholz. 2011. Estimating the future decline of wild coho salmon populations resulting from early spawner die-offs in urbanizing watersheds of the pacific northwest, usa. Integrated Environmental Assessment and Management 7:648–656.

Acknowledgements

Figures

Note: these are DRAFT figures! The maps do not perfectly correspond to the graphs next to them (for example, Zcrit might be different because the selected critical PSM might be different). Also the colors in the two plots do not perfectly match up, even though the ends of the spectrum do align (blue is always high priority, red is always low priority)

Some questions about the figures: 1. I think we should include only the maps in the main text (graphs could be in the supplement). I've included both here for you to see 2. How many examples do we want in the main text- 2, for comparison?

Figures to add: 1) Figure that shows how changing critical PSM and changing uncertainty affects number of sites falling below PSMcrit

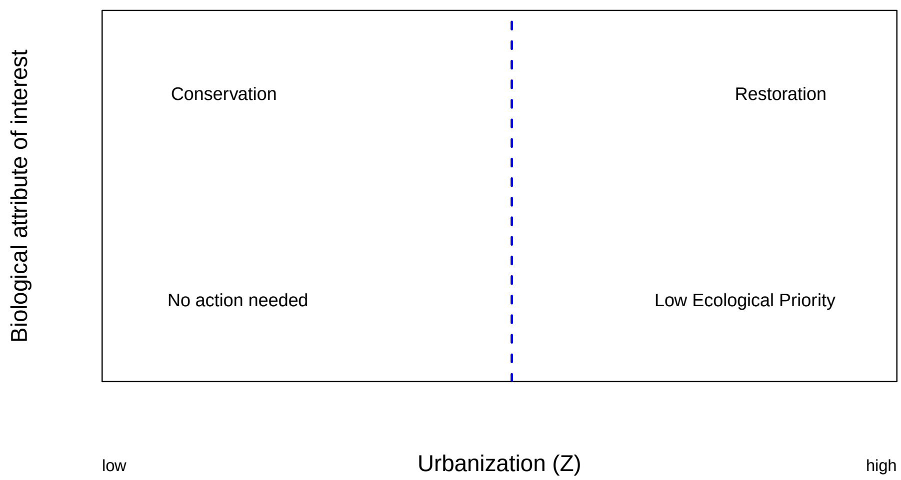

Figure 1: **Framework for prioritizing areas of conseration and restoration action** using site-level estimates of coho pre-spawn mortality and urbanization effects.(Need to make this a bit prettier.)

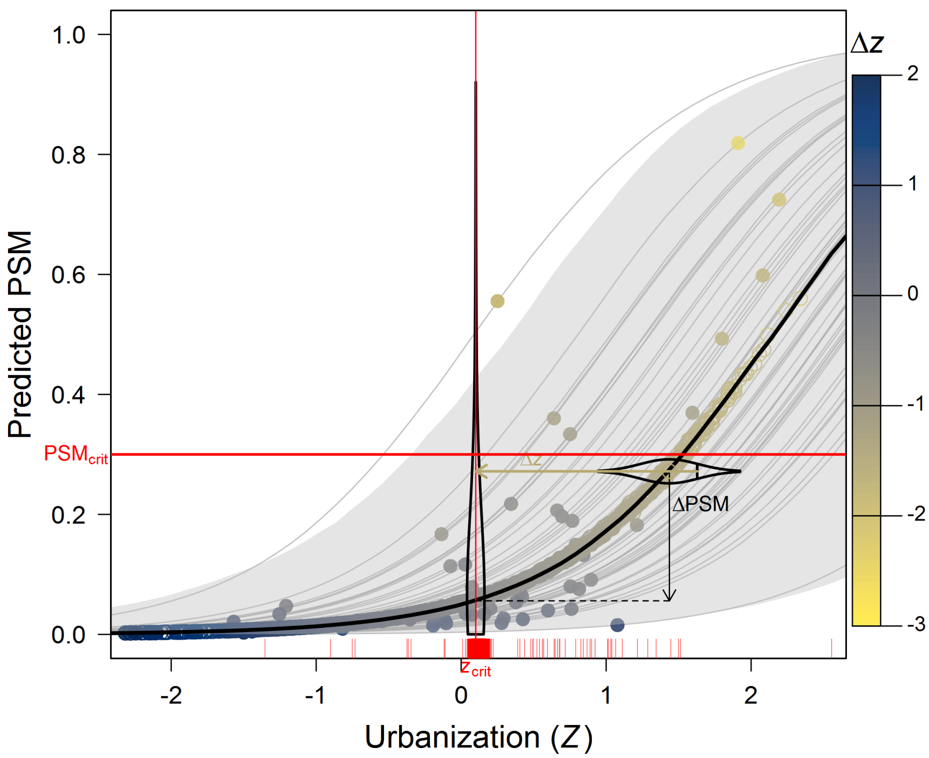

Figure 2: **Relationship between estimated pre-spawn mortality and urbanization** based on the structural equation and multi-level modeling in (Feist et al., 2017).

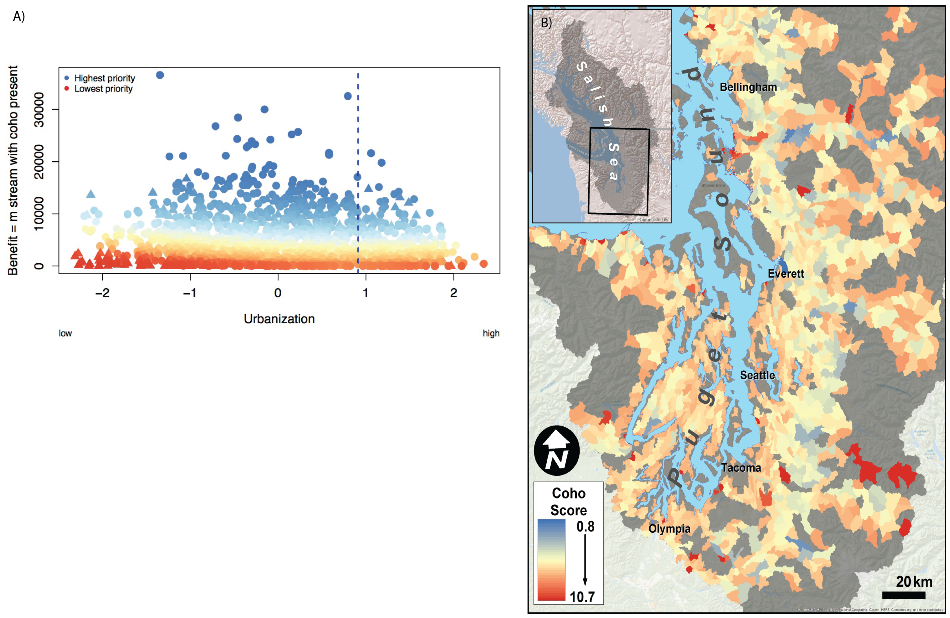

Figure 3: **Prioritization of basins, using meters of stream with coho present** and a critical pre-spawn mortality threshold of 0.25. Lower scores (blue) are higher priority.

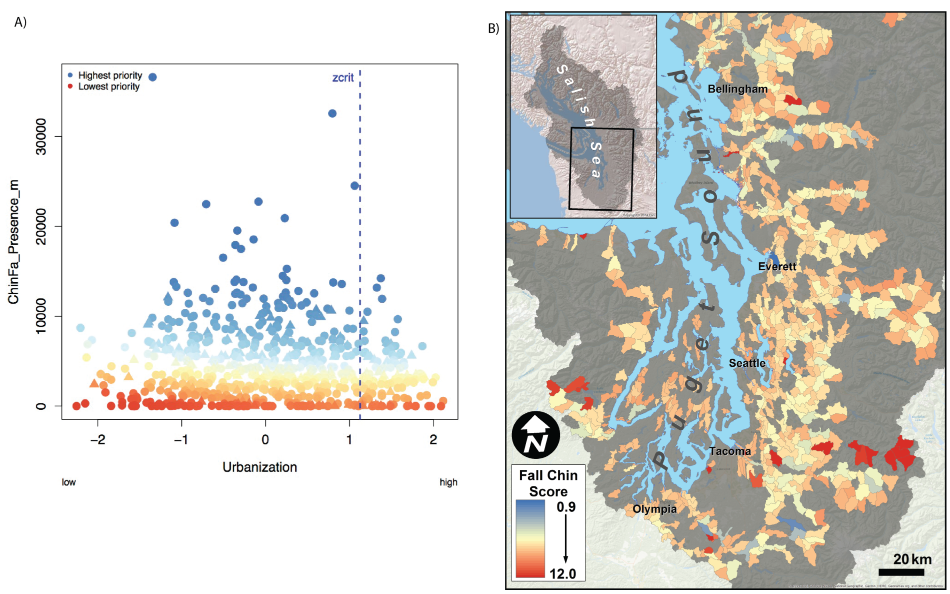

Figure 4: **Prioritization of basins, using meters of stream with fall chinook present** and a critical pre-spawn mortality threshold of 0.25. Lower scores (blue) are higher priority.

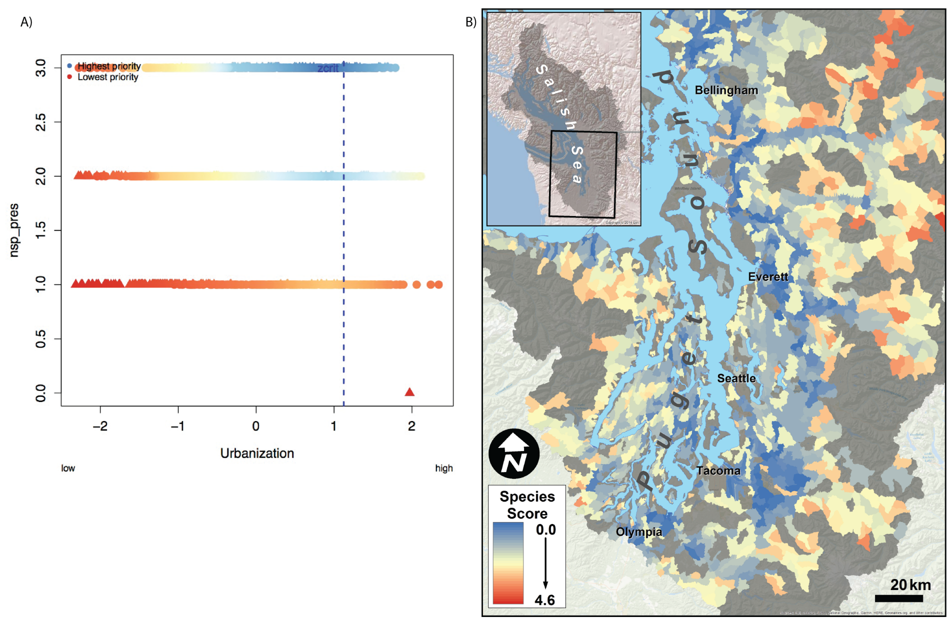

Figure 5: **Prioritization of basins, using the number of salmon species present** and a critical pre-spawn mortality threshold of 0.25. Lower scores (blue) higher priority (and generally have higher numbers of species).