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fishStan: Hierarchical Bayesian models for fisheries

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Summary

Fisheries managers and ecologists use statistical models to estimate population-level relations and demographic rates (e.g., length-maturity curves, growth curves, and mortality rates). These relations and rates provide insight into populations and inputs for other models. For example, growth curves may vary across lakes showing fish populations differ due to management actions or underlying environmental conditions. A fisheries managers could use this information to set lake-specific harvest limits or an ecologist could use this information to test scientific hypotheses about fish populations. The above example also demonstrates how populations exist within hierarchical structures where sub-populations may be nested within a meta-population. More generally, these hierarchical structures may be both biological (e.g., different lakes or river pools) and statistical (e.g., correlated error structures). Currently, limited options exist for fittings these hierarchical models and people seeking to use them often must program their own implementations. Furthermore, many fisheries managers and researchers may not have Bayesian programming skills, but many can use interactive languages such as R. Additionally, programs such as JAGS often need long run times (e.g., hours if not days) to fit hierarchical models and programs such as Stan can be more difficult to program because it is a compiled language. Lastly, the Stan language only has a limited number of ecological examples. We created `fishStan` to share hierarchical models for fisheries and ecology in an easy-to-use R package.

Statement of need

We designed `fishStan` to be used by research, managers, and students wanting to apply hierarchical models to fisheries and ecological data (Erickson et al., 2020). The package enables users to take advantage of lower-level languages (e.g., C++, Stan) for speed without losing the flexibility or ease-of-use of R. Specifically, `fishStan` uses RStan (Stan Development Team, 2020) to call Stan for fisheries models included hierarchical growth models, hierarchical linear regression, hierarchical logistic regression, and a catch-curve model.

The initial model incorporated in `fishStan` was a hierarchical von Bertalanffy model presented in Midway et al. (2015) who used JAGS as their programming language. We included

this model and other common fisheries models developed as part of ongoing research and management. These include hierarchical logistic models (e.g., maturity curves), hierarchical liner models (e.g., log-log length weight relations), and other growth curves. Applications of our Stan-based models include the growth models in ASMFC (2020) and Caves et al. (In press). Books such as Ogle (2018) provide an introduction and overview to the fisheries models including within the package. Books such as Gelman & Hill (2007) provide an introduction to and overview of hierarchical Bayesian modeling.

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References

Atlantic States Marine Fisheries Commission (ASMFC). (2020). *American shad benchmark stock assessment and peer review report*. ASMFC. https://doi.org/10.1002/nafm.10515

Caves, S., Baumann, J. R., & Stich, D. S. (In press). Density-dependent changes in grass carp growth and mortality in long-term aquatic plant management. *North American Journal of Fisheries Management*, *n/a*(n/a). https://doi.org/10.1002/nafm.10515

Erickson, R. A., Daniel S. Stich, & Hebert, J. L. (2020). *fishStan: Hierarchical bayesian models for fisheries*. U.S. Geological Survey software release. https://doi.org/10.5066/P9TT3ILO

Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevelhierarchical models*. Cambridge University Press New York, NY, USA.

Midway, S. R., Wagner, T., Arnott, S. A., Biondo, P., Martinez-Andrade, F., & Wadsworth, T. F. (2015). Spatial and temporal variability in growth of southern flounder (paralichthys lethostigma). *Fisheries Research*, *167*, 323–332.

Ogle, D. H. (2018). *Introductory fisheries analyses with r*. CRC Press.

Stan Development Team. (2020). *RStan: The R interface to Stan*. http://mc-stan.org/