North Atlantic LCC Aquatic Habitat Assessment

Incorporating future climate and land use changes into aquatic habitat assessments

Prepared for the North Atlantic Landscape Conservation Cooperative (NALCC) Assessment Project
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Contents

Introduction

Understanding potential shifts in species distribution patterns due to changing climate and land use regimes is critical for informing sustainable long-range conservation and restoration planning efforts.[i] Recent studies have shown that changes in temperature, rainfall, and runoff, along with increasing conversion of forest and agriculture lands to urban development, suggest that future range shifts of aquatic species may be substantial.[ii]

Downstream Strategies (DS) has produced predictive models for several fish habitat partnerships (FHPs) across the United States and is now leading an aquatic habitat assessment for the North Atlantic Landscape Conservation Cooperative (NALCC). These models utilize widely available landscape variables as predictors for instream aquatic responses, such as presence of certain guilds or species of fish. These models provide a broad and unique understanding of the link between terrestrial and aquatic health and allow for the determination of stressors for each response. Thus far, these models have been built to characterize present day aquatic conditions and have not included future changes such as increases in temperature, altered flow regimes, or increasing land use development.

This case study demonstrates how readily available downscaled climate change and land use development models can be incorporated into species distribution models to characterize potential future changes in aquatic conditions to better inform long-term conservation and restoration planning at the catchment level. The case study presented here for a hydrologic unit code 8 (HUC-8) coldwater guild should be viewed as a hypothetical example only. Though the climate change and land use development scenarios are based on the best available peer reviewed studies, the land use development examples are based on national averages that do not reflect local projections which would more accurately capture future local land use conditions. The project team will incorporate locally relevant land use development and climate change scenarios later in the modeling process. This case study was developed to provide stakeholders and project partners with a working example of an approach and methodology that could be employed to analyze future impacts to present day aquatic conditions.

Methodology

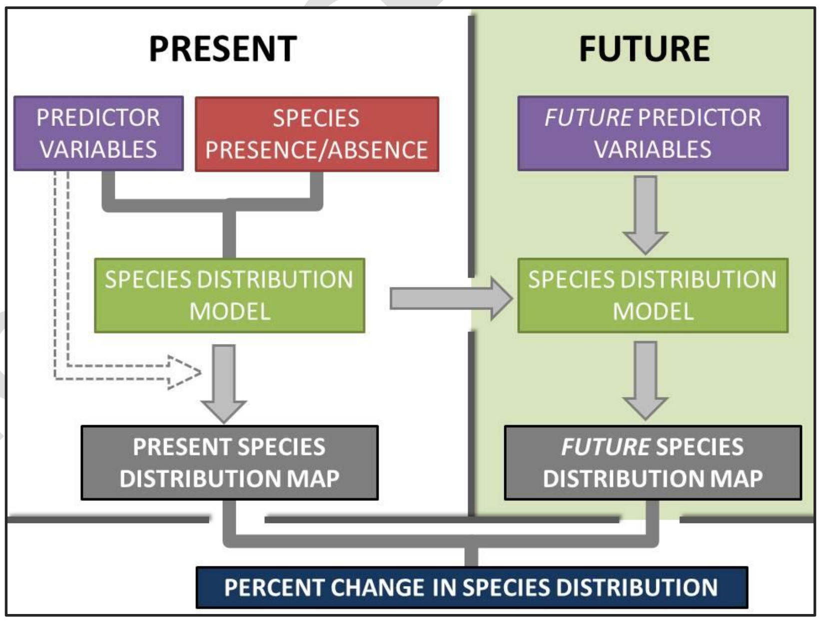
The modeling process uses boosted regression tree (BRT) models to analyze environmental predictor variables and aquatic response variables, generating a series of quantitative outcomes including predictions of expected current conditions at a catchment scale (see this example[iii] for a detailed description of methodology and report of the inputs, responses, model prediction accuracy, stressor influence, and maps). The predictions of current conditions are created by extrapolating the BRT model to each catchment within the modeling area. Model outputs can then be used to assess suitable habitats and map the expected range of species.

To illustrate how future conditions can be incorporated into the modeling process, we used peer reviewed climate change and land use projections to analyze the impact of changes in temperature, precipitation, and land use development on species distributions.[iv] The data incorporated into the future scenarios for this analysis was based on national averages and likely do not apply properly to this study area. The results shown here are for demonstration purposes only.

Climate change

Downscaled climate change projections for the years 2050-2080 were downloaded from ClimateWizard.[v,vi] These projections were used to estimate changes in two environmental predictor variables used in the present-day species distribution models: mean annual temperature and mean annual precipitation. ClimateWizard provides downscaled climate change projections for a range of future time periods based on the Fourth Assessment[vii] of the Intergovernmental Panel on Climate Change[viii]. An ensemble model that averages multiple high A2 global climate models (GCM) was chosen for this example based on recent studies that have found that the A2 models might more closely match leading studies published since the IPCC Fourth Assessment in 2007. Using the A2 high ensemble model, estimated mean annual temperature changes for the example study area increases by 9° F and the mean annual precipitation changes increases by 15% for the 2050-2080 time frame.

FIGURE 1. FUTURE SCENARIO MODELING PROCESS



Land use development

Radeloff et al.[ix] predicted land-use change for the conterminous U.S. to the year 2051 under various economic and policy scenarios. For this example case study, we used national averages provided by Radeloff et al. to estimate potential land use change under a "business as usual" (i.e. no significant economic or policy changes) scenario. These projections were used to estimate changes in two predictor variables used in the present-day species distribution model: urban development/impervious surface and agricultural land use. The national average statistics under a business as usual projection estimated a decrease in agricultural land by 20% and an increase in urban development by 80%. Though national averages were used for this example case study, regional land use projections are available and could be incorporated into the species distribution models at a later date. Depending on the region within the NALCC and future economic and policy dynamics, the land use changes could vary significantly from the national averages used in this case study.

Future scenario model

Figure 1 illustrates the future scenario modeling process. Presence/absence samples for a coldwater species guild and ten biophysical and anthropogenic predictor variables were used to develop a BRT model that predicted present-day probability of coldwater guild presence. Future changes in temperature, precipitation, urban development (impervious surface), and agriculture were then incorporated into the present-day species distribution model to analyze potential shifts in species distribution ranges. Finally, a change map was generated from the mapped model outputs to illustrate potential shifts from present-day species distribution to future distribution. The example results are presented below.

Example Results

Model results

Network mean baseflow index contributed most to explaining guild presence in the species distribution model, followed by catchment mean annual air temperature (Figure 2).

FIGURE 2. MODEL PREDICTOR VARIABLES AND RELATIVE CONTRIBUTION TO PROBABILITY OF PRESENCE

MODEL CONTRIBUTION

PRESENT	FUTURE
Network mean baseflow index	Network mean baseflow index
Catchment mean annual air temperature	Catchment mean annual air temperature (+9° F)
Slope of catchment flowline	Slope of catchment flowline
Minimum catchment elevation	Minimum catchment elevation
Mean annual precipitation	Mean annual precipitation (+15%)
Network mean impervious surface cover	Network mean impervious surface cover (+80%)
Network drainage area	Network drainage area
Network percent agriculture landcover	Network percent agriculture landcover (-20%)
Network mean groundwater use	Network mean groundwater use
Network mean surface water use	Network mean surface water use

Mapped results

Figure 3 shows present-day the results of a species distribution model at the catchment scale (0 = lowest probability; 1 = highest probability). Figure 4 shows the result of an example future scenario species distribution model based on increases in temperature, precipitation, and urban development/impervious surface, and decreases in agricultural land, as described above. Only 2 out of 994 total catchments were predicted to experience increases in species distribution under the future scenarios model. The most vulnerable catchments were predicted to experience over a 50% decrease in species distribution probability under the future scenarios model (Figure 5).

FIGURE 3. PRESENT-DAY PROBABILITY OF COLDWATER GUILD PRESENCE

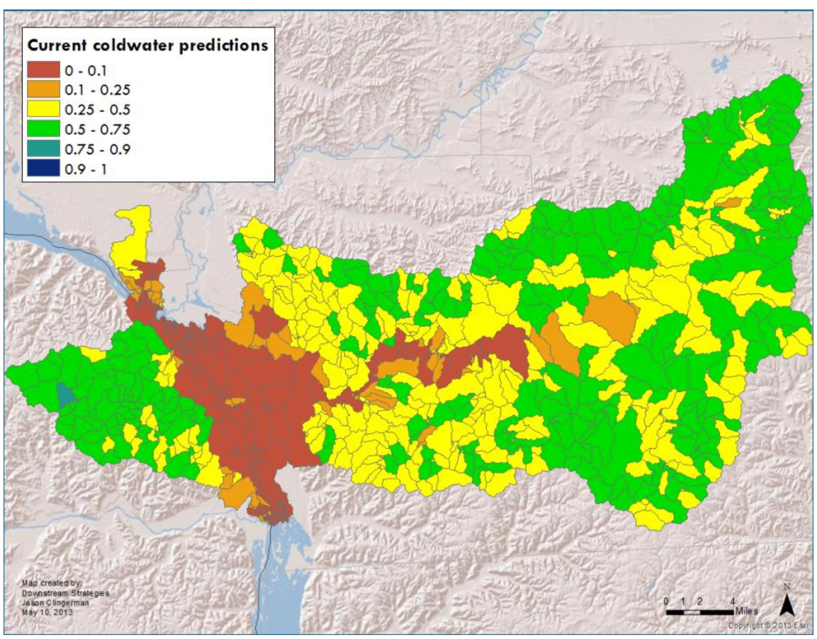


FIGURE 4. FUTURE PROBABILITY OF COLDWATER GUILD PRESENCE

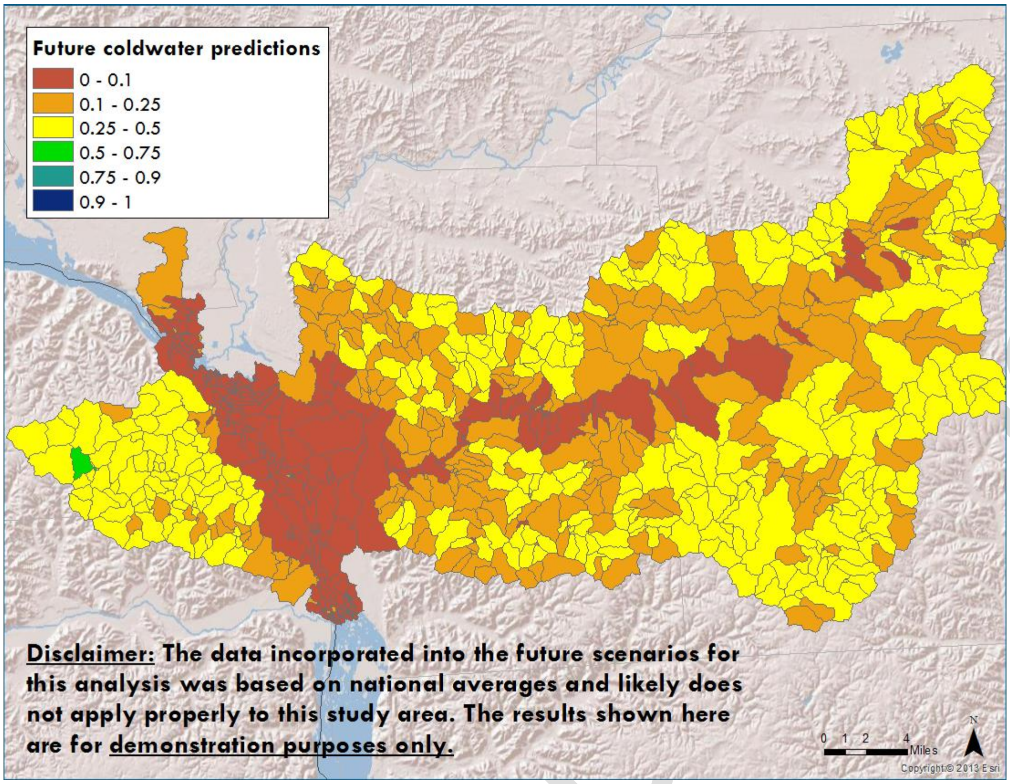
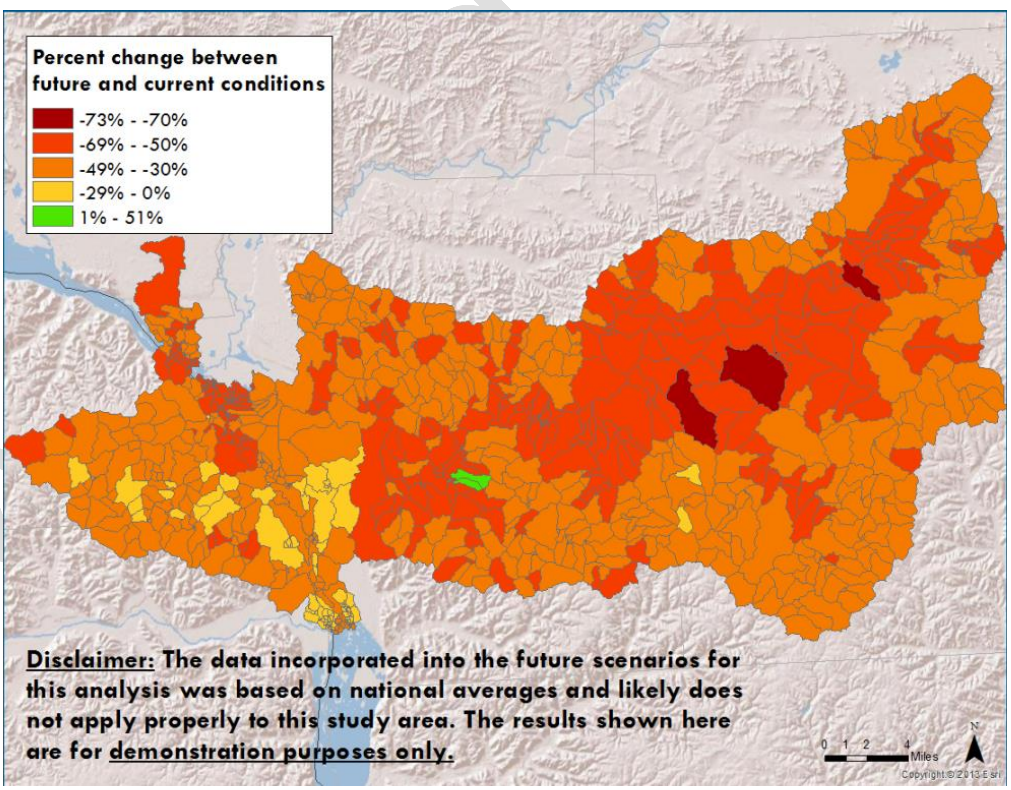


FIGURE 5. PERCENT CHANGE BETWEEN PRESENT-DAY AND FUTURE COLDWATER GUILD PREDICTED PRESENCE



Conclusion

As shown here, this type of analysis could be incorporated into the NALCC's aquatic habitat assessment to quantify habitat vulnerability to potential climate and land use development changes. Depending upon objectives, timeline, and budget, this type of analysis could be added to one or more model endpoints. Depending upon the structure of the predictor variables and data availability, a similar analysis could be possible for estuarine/coastal habitats as well.

While this type of analysis is built from the same basic methodology as the futuring tool—refer to the scope of work document posted on the project website— which will be included for each model in the decision support tool, there are some important differences. The futuring tool gives users a dynamic interface to manipulate local level conditions to assess anthropogenic alterations at a very fine scale, likely based on intimate local knowledge of impending land use conversion. The process described here is focused on providing a static analysis of broad-scale patterns of change based on best available long-term future conditions.

References

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[ii] Markovic D, Freyhof J, Wolter C (2012) Where Are All the Fish: Potential of Biogeographical Maps to Project Current and Future Distribution Patterns of Freshwater Species. PLoS ONE 7(7): e40530. doi:10.1371/journal.pone.0040530.

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[iv] Markovic D, Freyhof J, Wolter C (2012) Where Are All the Fish: Potential of Biogeographical Maps to Project Current and Future Distribution Patterns of Freshwater Species. PLoS ONE 7(7): e40530. doi:10.1371/journal.pone.0040530.

[v] http://www.climatewizard.org

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[vii] http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

[viii] IPCC: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.) IPCC, Geneva, Switzerland. pp 104.

[ix] Radeloff, VC et al. Economic-Based Projections of Future Land Use in the Conterminous United States under Alternative Policy Scenarios. Ecological Applications. 22: 1036-1049.