Is there a model that predicts the upper limit of trout in streams in western Oregon?

UPRLIMET: Upstream Regional LiDAR Model for Extent of Trout in stream networks

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Topic Summary

What is the upper extent of fish distribution in Wester Oregon streams and does this change across land ownership categories? Can scientists use LiDAR, which characterizes stream network hydrography more completely than other approaches, in combination with potential environmental predictor variables to create a model development and evaluation framework to determine the best predictor of trout (fish) distribution? Coastal Cutthroat Trout are often the uppermost fish in coastal Oregon streams and, therefore, the focus for distribution upper limit mapping. Sixty-seven predictor variables were also evaluated.

What was the best model?

- The model chosen for UPRLIMET had the lowest mean absolute error between observed and predicted fish upper limit. It is a four-variable logistic regression model with stopping rule 1, which incorporates probability smoothing and upstream suitability measure with stop triggers.

Which stream and watershed features are most important?

- The four model variables are total upstream channel length, drainage area, downstream channel slope over 1000 m, elevation. Stream size is important; upstream channel length and drainage area increases led to increased probability of trout occurrence.
- Slope and elevation are related to instream habitats such as channel shape, substrate, and flow patterns, and a stream's position in the watershed, which corresponds to the finding that smaller streams are less likely to have fish.

Are there differences between privately and publicly held land?

- UPRLIMET predictions showed that more streams in general and more fish carrying streams specifically are on privately held lands than on state, US BLM, USFS, or other federal lands.

As a manager, what is the potential for these findings?

- UPRLIMET provides a consistent method to predict the upper extent of trout (fish) across all land ownership categories in western Oregon. This tool maps the probability of trout as well as the upper limit of trout distribution.
- The spatially explicit and contiguous predictions output by UPRLIMET provide managers and policy makers a comprehensive fish-distribution map across land ownership type that is better fit to field data than previous modeling approaches.

- The prediction model framework is transferable to other watersheds and fish species around the world because it can be calibrated with local fish and environmental data and LiDAR data is becoming more commonly available.

How are these findings currently being used?

- The Forest Service (USDA) has built and deployed a dashboard for UPRLIMET with an interactive map of fish distribution limits in Western Oregon. UPRLIMET: Upstream regional LiDAR model for extent of trout | Pacific Northwest Research Station | PNW - US Forest Service (usda.gov)
- This map can be used to align and streamline forest management and fish management policy measures and regulations across land ownerships, helping to balance harvest with ecosystem services like water quality.

Research Approach/Methods

- Researchers surveyed 103 streams to determine the location of uppermost fish presence using single pass backpack electrofishing and the location and type of the nearest upstream habitat barrier. Stream segments were identified using data from surveys done in 1999 and 2000.
- To ensure all spatial data was high quality, the authors used only the 21 HUC-12 sub-watersheds in western Oregon with LiDAR-derived digital elevation models and associated LiDAR-derived hydrography in the National Hydrography Dataset.
- The authors created a predictive model for determining the upper limit of trout using spatially stratified data from 67 potential environmental predictor variables, including hydro-topographic and climate variables and habitat barriers. They developed 8 sub-models, which were composed of four sub-models each for habitat data and occurrence data.
- They then tested the predictive performance using a nested spatial cross-validation using the Matthews Correlation Coefficient. One of the purposes was to determine if their broad models were better predictors than the Fransen optimal model.
- The authors calculated the Mean Absolute Error, the linear stream distance between each model's estimated trout upper limit and the actual upper limit in each of the 21 HUC12s, for all 26 models. They selected the model with the lowest MAE, the UPRLIMET model.
- To provide ecological context, the researchers compared UPRLIMET predictions to fish distribution data from four other sources in 14 randomly selected watersheds in the study area. They calculated linear stream distances between outputs from each data source and UPRLIMET predictions.
- The authors also analyzed their upper limit predictions in terms of land ownership to identify potentially useful trends for management and to add social context.

Keywords fish distribution, upper extent of fish, upper fish boundary, cutthroat trout, environmental DNA, novel model development and evaluation, LiDAR-based prediction model, logistic regression model, Fransen optimal model, Random Forest model, cross-boundary fish distribution map, landscape management, streams

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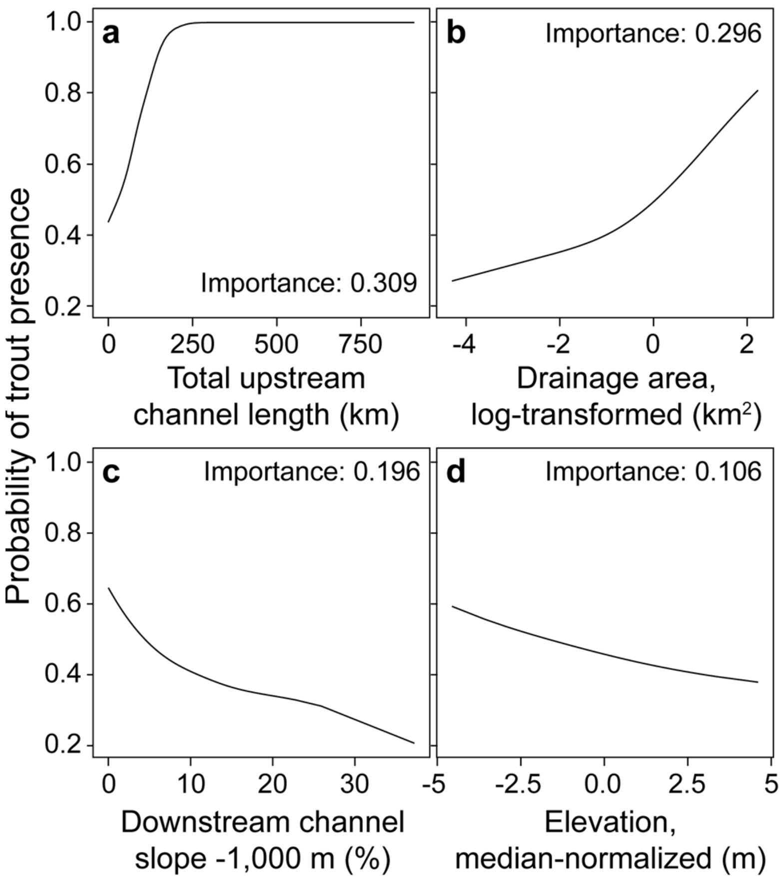

Figure 4 in Penaluna et al. 2022. Partial-dependence profile plots of the four variables in UPRLIMET in relationship to the probability of trout presence, including (**a**) total upstream channel length (km), (**b**) drainage area, log transformed (km2), (**c**) downstream channel slope over 1000 m (%), and (**d**) elevation, median-normalized (m). Plots are arrayed in decreasing order of model importance.

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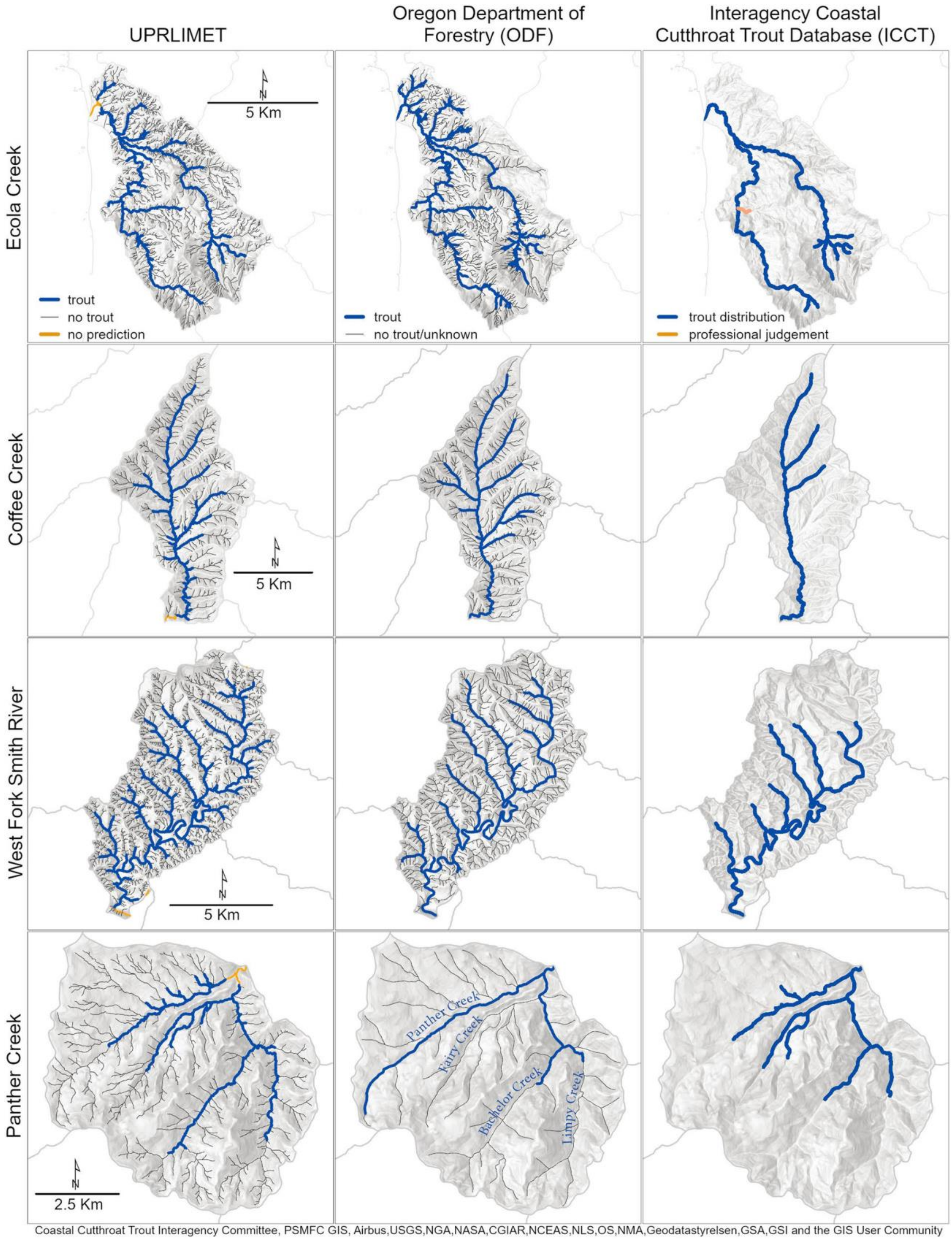

Figure 5 in Penaluna et al. 2022. Examples of fish distributions in four HUC12 sub-watersheds, including Coffee Creek [Rogue River], Ecola Creek [Coast Range], and Panther Creek [North Umpqua River], and

West Fork Smith River [Umpqua River]. Left panel shows predictions of presence and absence of trout using UPRLIMET. Middle panel shows trout occurrence and habitat distributions from Oregon Department of Forestry (ODF). Right panel shows trout occurrence distributions from the Interagency Coastal Cutthroat Trout (ICCT) database. The flowlines vary across the three databases owing to differences in hydrography associated with each database.

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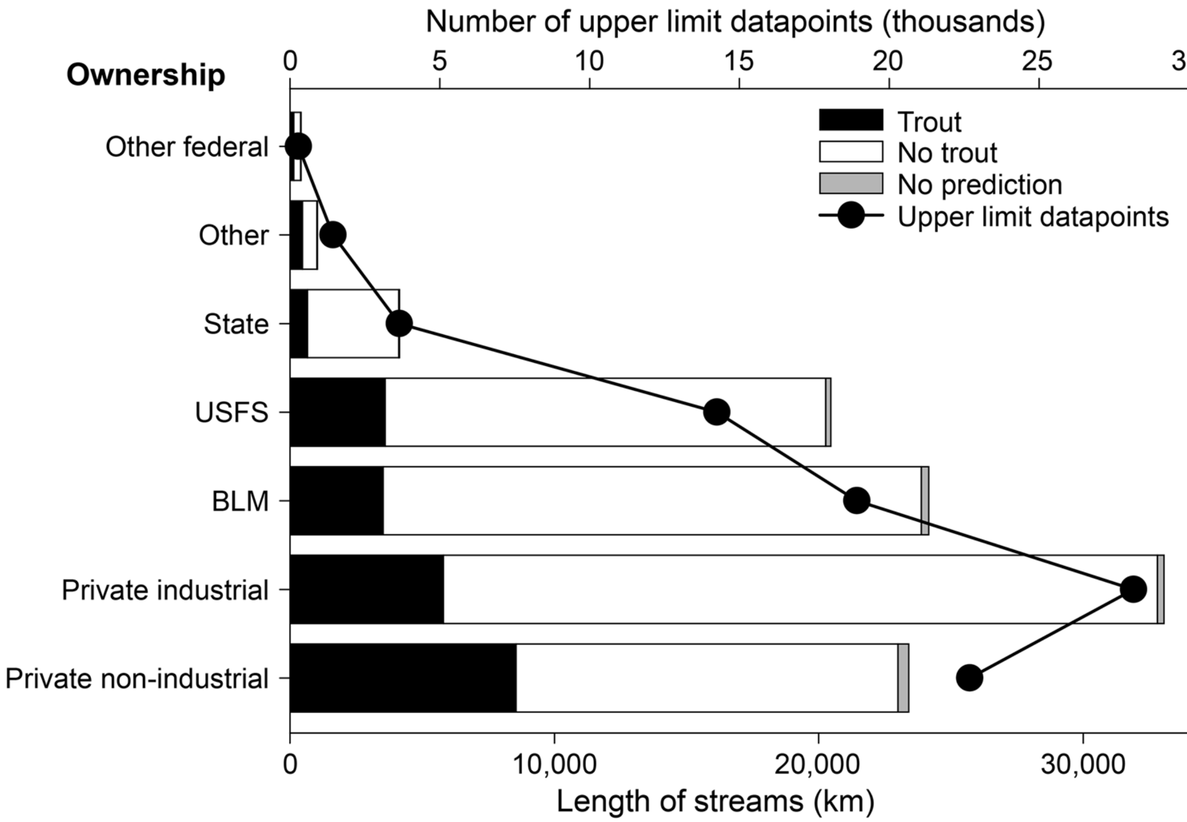

Figure 7 in Penaluna et al. 2022. Distribution of the length of streams (km) with trout, with no trout, and with no predictions, along with the number of upper limit datapoints (thousands) predicted by UPRLIMET across land ownership categories of other federal, other, state, USFS (USDA Forest Service), BLM (Bureau of Land Management), private industrial, and private non-industrial. Stream length was estimated from the HUC12 scale. Note that streams without predictions occur when there is less than 1000 m of stream length over which to evaluate slope, or for channel-initiation reaches where upstream drainage area cannot be calculated.

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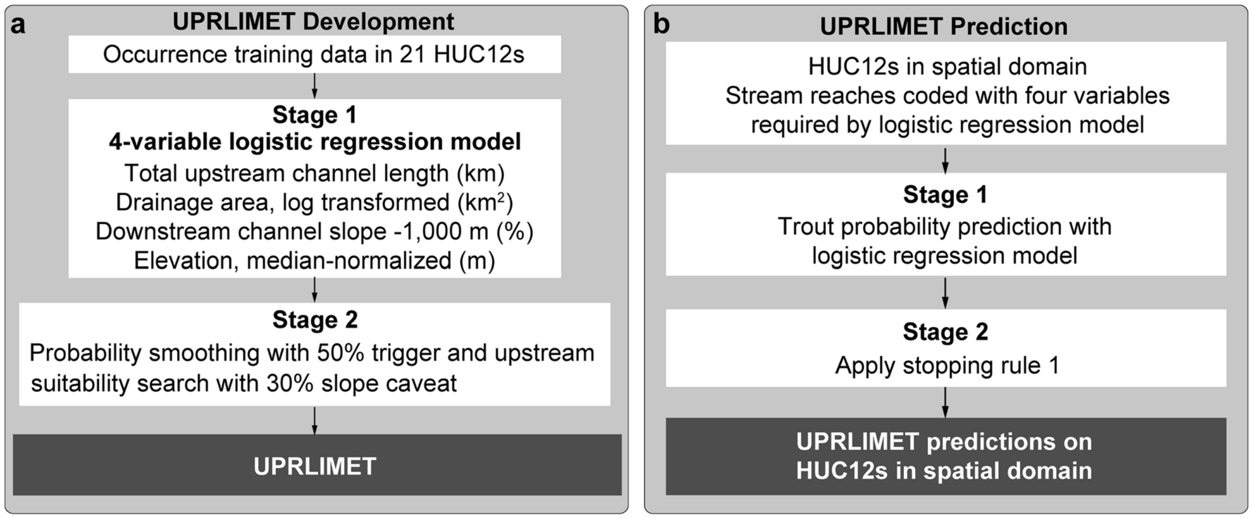

Figure 2 in Penaluna et al. 2022. UPRLIMET (**a**) generalized development workflow and (**b**) prediction workflow. We constructed and compared 26 models to select the top performing model, termed UPRLIMET, based on the lowest overall error between observed and predicted upper extent of trout distributions across western Oregon. (**a**) Generalized development workflow for UPRLIMET, a single logistic regression model fit to trout occurrence observation data. Stage 1 involved fitting the 4-variable logistic regression to the occurrence observation data. Stage 2 included implementing Stopping Rule #1 (Fig. S1). (**b**) Generalized prediction workflow where the two-stage UPRLIMET prediction process is applied to all HUC12s in our study area producing a trout distribution map. The four environmental predictor variables in a and b are characterized at the scale of the individual reach (5–7 m) and derived from a 5-m LiDAR-derived digital elevation model (Data S1).

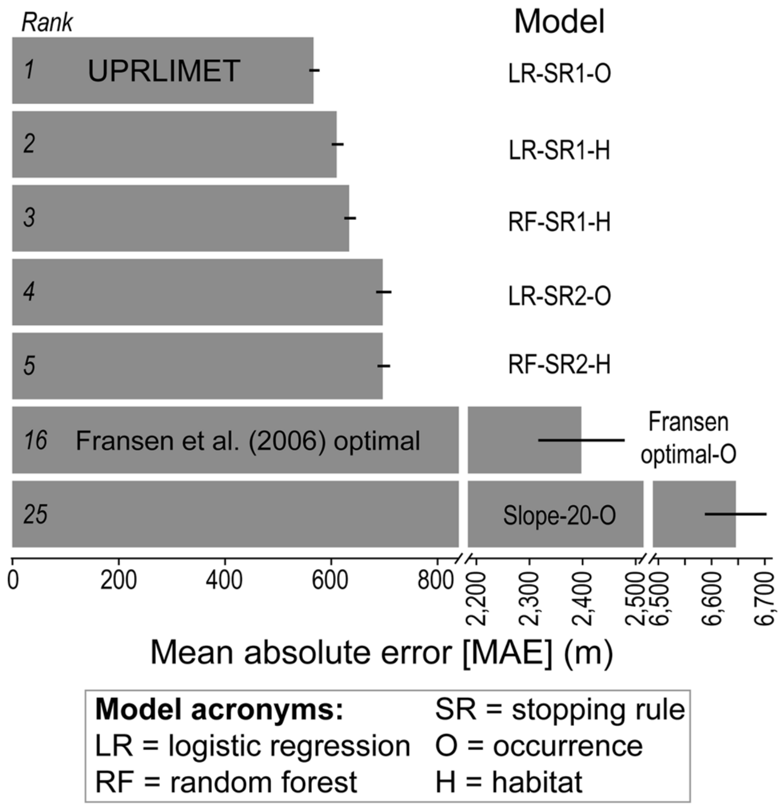

Figure 3 in Penaluna et al. 2022. Comparison among selected models ranked by mean absolute error (MAE; m) of linear distance between the observed upper limit and the predicted upper limit. For the top five models, the model description specifies the development algorithm [*e.g.,* Random Forest (RF) or logistic regression (LR)], the stopping rule (SR) and its number (1, 2, or 3), and the type of training data [occurrence (O) or habitat (H)] used. In addition to showing the MAE for the top five models, two additional models are included, the Fransen et al. model, and a 20% slope cut off, where the lowest point on the network with a slope greater than or equal to 20% becomes the upper limit point. The model with the smallest MAE is called UPRLIMET.