Predicting the Total Abundance of Resident Salmonids within the Willamette River Basin, Oregon – a Macroecological Modeling Approach

United States Environmental Protection Agency

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Introduction

Freshwater fishes provide many valuable ecosystem services (e.g. recreation, ecosystem regulation, and nutrition), and are therefore key "receptors" within the USEPA's National Exposure Framework (USEPA 2009). Accordingly, EPA seeks to predict contemporary and future distributions of freshwater fishes, at scales ranging from discrete watersheds to the continental U.S. To accomplish this, several fish models are being developed and evaluated. Here, I present a relatively simple, macroecological model of fish density, which can be scaled from individual streams to entire drainage networks. I demonstrate the model by first using it to predict average salmonid densities within small (1st-2nd order), medium (3rd-4th order), and large (≥ 5th order) streams (**Box 1**). I then apply these estimates to complete river networks to predict the total abundance of salmonid fishes within forested streams of the Willamette River Basin (Oregon).

Macroecological Model

The model builds upon three key assumptions, each of which has strong empirical support (**Box 2**): (i) energetic resources are transferred between trophic levels at a predictable rate; (ii) population density is an allometric function of body size; and (iii) the ratio between annual production and mean biomass is nearly constant. When *McGarvey et al.* (*In Press*) combined these assumptions with field estimates of primary production and basic information on species' distributions, feeding behaviors, and body sizes, they were able to predict fish densities in both cold- and warm-water systems, with moderate to high levels of accuracy and precision. Their model was

$$N = (NPP_{ww}\varepsilon^{T-1}M^{-b}) / P_B$$

where N is population density, NPP_{ww} is net primary production (g C/m^2/yr, converted to wet weight), ε is trophic transfer efficiency (see **Box 2**), T is trophic level, M is average body mass (g), b is the "self-thinning" exponent (see **Box 2**), and P_B is the production:biomass ratio.

Regional-scale Prediction

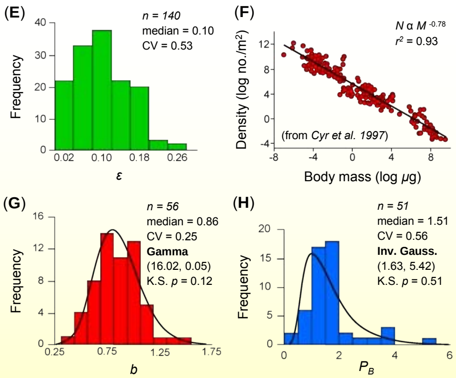
Having demonstrated that the model can predict population densities with meaningful levels of accuracy, I used it to predict the total abundance of resident (i.e. non-migratory) salmonids within the Willamette River Basin (29,500 km^2). Detailed *NPP* measurements from the small, medium, and large streams were used in conjunction with stream network maps, which were stratified by habitat type (i.e. forested vs. non-forested habitat) and stream size, and regional maps of species' distributions (**Box 3**). Specifically, the model predictions for small, medium, and large streams (see **Box 2**) were multiplied by the total surface area of each type of stream, then summed to estimate total fish abundance. This flexible approach was used to predict fish abundance within each of the Willamette Basin's 8-digit HUCs (**Box 4**). However, it can ultimately be applied at any scale of interest, so long as the model parameters can be estimated at comparable scales.

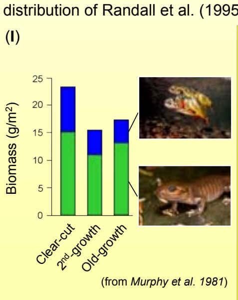
Box 1

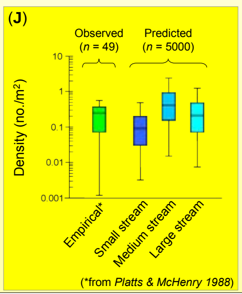
Study sites. (**A**) Willamette River Basin. (**B**) Mack Creek. (**C**) Lookout Creek. (**D**) McKenzie River.

Box 2

Parameter estimation. (**E**) The transfer of energy among trophic levels (ε) is inefficient, and often thought to be ~10%. To estimate ε, I sampled from the empirical ε distribution of Pauly & Christensen (1995). (**F**) Smaller species generally reach higher population densities than larger species, as expressed by the self-thinning relationship between population density (N) and mean body mass (M): $N \alpha M^{b}$. (**G**) To estimate b, I compiled data from 59 sources (see McGarvey et al. *In Press*). (**H**) The ratio between production and standing stock biomass (P_B) often deviates from 1. I estimated P_B with the empirical distribution of Randall et al. (1995).



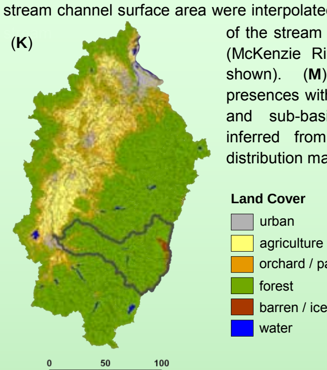


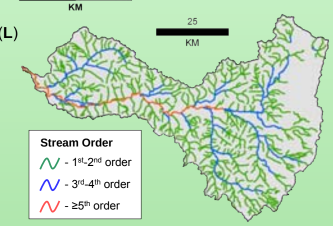


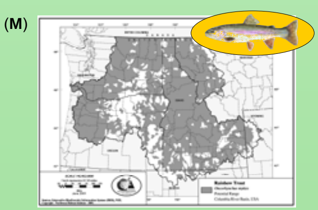
Model predictions. (**I**) Salamanders comprise a large percentage of the total predator biomass in Cascade streams. Resources were therefore partitioned equally (50:50) between trout and salamanders. (**J**) The model was run 5000 times for each type of stream (i.e., random sampling from the ε, b, and P_B distributions). ***Model predicted densities were generally similar to empirical estimates collected throughout the Cascades region*** (Platts & McHenry 1988).

Box 3

Regional application. (**K**) All stream segments (NHD-Plus, 1:100,000 resolution) that occur within forested habitat were queried using a GIS. (**L**) Stream order and stream channel surface area were interpolated for each of the stream segments (McKenzie River basin shown). (**M**) Species' presences within basins and sub-basins were inferred from regional distribution maps.

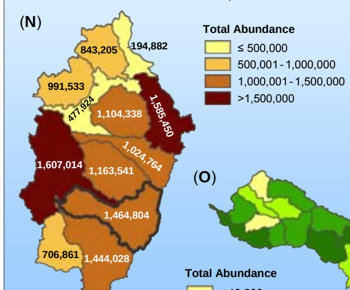


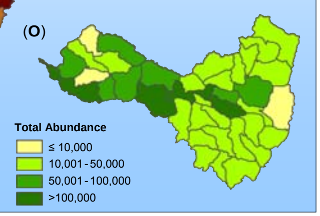




Box 4

Total abundance. (**N**) Total fish abundance was estimated for each of the major sub-basins within the greater Willamette River basin. (Total abundance within each sub-basin is shown.) (**O**) Abundance can be summarized at a variety of scales, such as catchments within sub-basins (McKenzie River basin shown).





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