Redband Trout: Resilience and Challenge in a Changing Landscape
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Effectiveness and Applicability of EMAP Survey Design in Status Review of Great Basin Redband Trout

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Extended Abstract—The redband trout *Oncorhynchus mykiss* ssp. occurs in interior basins of the Pacific Northwest. Oregon's Great Basin populations of redband trout persist in fragmented habitats that are a result of the area's geologic history, more recent hydrologic cycles of flood and drought, and anthropogenic disturbance. Concern about the status of these fish prompted the development of a new approach to accurately estimate the distribution, abundance, and biomass of resident redband trout in six geomorphically isolated basins of eastern Oregon (Table 1).

The large geographic area (42,000 km^2) of these basins and discontinuous distribution of fish in each basin was not conducive to population estimation methods based on *a priori* census of habitats (e.g. Hankin and Reeves 1988). Therefore, an alternative method that coupled accurate results at the individual basin scale with sample efficiency at a landscape scale was necessary. A sample design that combined statistical rigor with spatial distribution was developed and employed using procedures standardized by the U.S. Environmental Protection Agency's Environmental Monitoring and Analysis Program, or EMAP (Stevens and Olsen 2004).

Methods

Information on redband trout distribution was compiled from field biologists and was incorporated into a database that tracked source and type of data (field verified or professional opinion). This distribution was input into a Geographic Information System (GIS) and became the sampling universe for selecting sample sites (Figure 1). The GRTS (Generalized Random-Tessellation Stratified) design (Stevens and Olsen 2004) is a powerful survey design for stream networks because sites are selected in a spatially balanced array with variable probability of site selection across multiple basins—an approach that was developed by the Environmental Protection Agency for use in EMAP. Sites can be replaced if the selected sites cannot be visited, and post-stratification of sample sites is possible.

The goal of the study was to assess the status of redband trout by estimating the abundance of fish age 1 and older (designated age 1+) in each of the six basins, within 95% confidence intervals of $\pm$ 50%. A minimal sampling intensity of 35 sites per basin was chosen (210 for the six basins) based on levels of between-site variance in abundance estimates of age-1+ Great Basin redband trout from previous sampling (*Coefficient of Variation* as high as 150%, unpublished data J.M.D.). A base sample of 35 sites in each of the six basins was selected, with an "over sample" of 35 sites per basin to replace sites that could not be visited. Replacement sites were similar in location, size, elevation, and ownership to sites not sampled, to preserve the spatial balance (by selecting nearby sites) and to avoid introduction of possible bias.

We used a "local variance estimator" (Stevens 2003), which takes advantage of any spatial autocorrelations in the abundance of redband trout, to generate more precise estimates of variance than those obtained with the Horvitz-Thompson algorithm (1952). Uncertainty in estimates of total abundance also comes from sampling error of the fish survey method (electroshocking), although it is a minor component of the total variance in the population estimates.

Field sampling was done by two three-person crews that sampled an average of two sites per day. Each sample site was roughly located with topographic maps, after which the fine-scale proximity was determined with handheld GPS units. Sample reaches were enclosed with blocknets separated a distance of about 20 stream widths. Removal-depletion estimates of fish abundance were made within the netted reach of stream channel (Dambacher et al. 2001).

Results and Discussion

We sampled 185 sites in the six basins, representing about 1% of the stream distance occupied by redband trout. The estimated abundance of age-1+ redband trout was about 970,000 fish ($\pm$ 146,000 or 15%) (Table 1). Population estimates for age-1+ fish in individual basins ranged from 57,270 ($\pm$ 13%) in the Silver Lake basin, to 435,045 ($\pm$ 29%) in the

Table 1. —Population estimates of age-1+ Great Basin redband trout with 95% confidence limits (CL) expressed as percent of estimate.

Basin	Population estimate	± 95% CL
Silver Lake	57,270	13%
Lake Abert	149,103	30%
Goose Lake	98,409	26%
Warner Valley	171,715	28%
Catlow Valley	59,771	14%
Malheur Lakes	435,045	29%
Total	971,313	15%

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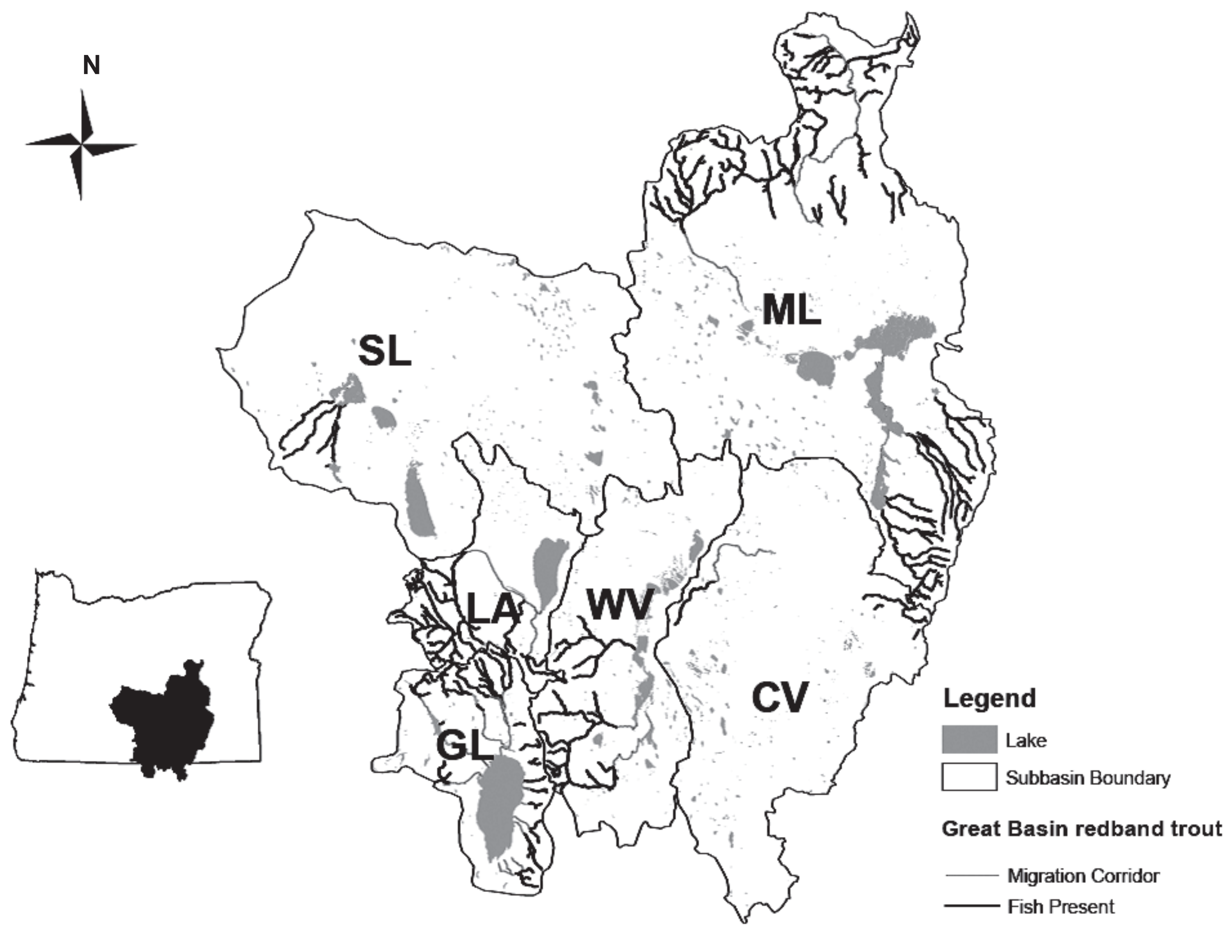

Figure 1.—Stream reaches identified in the mapping process as containing year-round rearing habitat (fish present category) for age-1+ redband trout. These stream reaches became the universe from which sample sites were selected. SL = Silver Lake; ML = Malheur Lakes; LA = Lake Abert; WV = Warner Valley; CV = Catlow Valley; GL = Goose Lake.

Malheur Lakes basin. The stream channel distance supporting year-round rearing for redband trout was estimated to be 2,167 km in the six basins (Figure 1), with another 1,017 km estimated to be used as migration corridor. A more detailed account of these estimates is available in Dambacher et al. (2001). Use of the local variance estimator reduced the 95% confidence interval an average of 30% for each basin compared to a simple random sample variance estimator.

A comprehensive query of data archives and professional opinion allowed us to approach a landscape assessment of an aquatic species within narrow time and financial constraints. Other landscape assessment techniques such as GAP (Kagan et al. 1999) require an extensive investment of time and resources in the development of data sets that may be used to model features of interest. The actual population assessment required a GIS approach for mapping and site selection, but would not have been reliable without the statistical tools developed for EMAP by EPA for the assessment of spatially balanced and randomly sampled sites. The GRTS sample design allowed us to maximize the statistical power of a relatively limited number of samples. The combination of all these tools made the spatial assessment of redband trout at a landscape scale possible and cost effective. The result was a novel approach to a common problem. This approach has the potential for broad application to species whose geographic distribution is widespread and discernible.

The sampling design was not suitable for examining fine-scale distribution of redband trout, because we sampled just 0.2 to 3.7% of the stream habitat in the six basins. A denser sample selection or census survey might have identified locally extirpated subpopulations or highlighted discontinuous distributions, although it was impractical at such a large scale. The decision by the U.S. Fish and Wildlife Service not to list Oregon's Great Basin redband trout as threatened or endangered was based partially on our estimated abundances of the fish in each of the six basins. Although the overall population of redband trout in the Great Basin may be considered viable, the vulnerability to extirpation of a spatially isolated subpopulation or a life history strategy within this widely distributed species may not be detectable with this survey design.

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