Development of a Rapid Method for Trout Stream Habitat Assessment--Phase II

by

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Final Report
Unit Cooperative Agreement Number
14-16-0009-1542
Work Order Number 51

July 1985

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1985
Final Report WWRC-85-41

A Final Report to
U.S. Department of the Interior
Bureau of Land Management
Cheyenne, Wyoming
Unit Cooperative Agreement Number
14-16-0009-1542

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INTRODUCTION

Measurable components of stream habitat have been shown to be related to trout standing stock and techniques to evaluate trout-stream habitat quality have been developed. Most techniques are field intensive, requiring large expenditures of time and money. A logical step in stream-habitat assessment is to develop techniques that address habitat needs of trout, but require minimal field work.

Mathematical modeling of trout standing stock in streams offers a method to assess components of habitat, and provide insight into standing stock-habitat relations. When refined and tested, these models can offer an alternative to direct measurements of trout standing stock by removal or mark-recapture methods. Such models may provide a mechanism to test the value of specific habitat components and a process to evaluate management decisions.

A widely recognized model is the Wyoming Habitat Quality Index, (HQI) (Binns 1979). During the first phase of model development, Binns (1979) rated 10 habitat variables and combined them in an index of habitat quality which correlated with trout standing stock. The fish food abundance and fish food diversity attributes used in the model were difficult and time consuming to assess, so these attributes were replaced with an index to macroinvertebrate production. The resulting model accounted for 97 percent of the variation in trout standing stock for 36 Wyoming streams. Testing of this model with eight additional streams resulted in 93 percent explained variance with a low prediction error between actual and predicted standing stock.

Wesche (1973, 1976) developed the Wyoming Trout Cover Rating (TCR) which incorporated measures of overhead bank cover, instream rubble-boulder cover and the preference for these two habitat features by adult ($\geq$15 cm) and juvenile (<15 cm) trout. The TCR was initially developed to quantify changes in cover at different flow regimes. Subsequently, Wesche (1980) modified the cover rating to include a deep water factor for large streams (discharge >2.83 cubic meters per second). Regressing the TCR against standing stock of trout resulted in a statistically significant ($P < 0.05$) relation for brown trout, but no statistically significant relations were found between the TCR and brook trout or cutthroat trout standing stocks (Wesche 1980). However, Eifert and Wesche (1983) found that the TCR was significantly correlated ($r = 0.43$; $P < 0.10$) to trout standing stock in two small Wyoming streams predominated by brook trout.

Another method of predicting habitat quality is the Habitat Evaluation Procedure (HEP) of the United States Fish and Wildlife Service (1980, 1981). Habitat quality for fish species is determined via Habitat Suitability Index models (HSI). To date HSI models have been developed for cutthroat trout (Hickman and Raleigh 1982), brook trout (Raleigh 1982), brown trout (Raleigh et al. 1984a) and rainbow trout (Raleigh et al. 1984b). Specific habitat variables are rated from zero (worst habitat quality) to 1 (best habitat quality) based upon suitability index curves developed from the literature. How well model output predicts habitat quality has as yet not been tested in the field except for a test of the brown trout HSI model being undertaken by the University of Wyoming (Dr. Wayne Hubert, University of Wyoming, Wyoming Cooperative Fishery and Wildlife Research Unit, personal communication).

Fausch and Parsons (1984) reviewed 26 models that predicted standing stock of salmonids in stream systems. Of these, 21 were based solely on measures of instream habitat and channel morphology. Five models used drainage basin geomorphology to predict salmonid standing stock (Ziemer 1973; Burton and Wesche 1974; Platts 1974; Wesche et al. 1977; Oswood and Barber 1982). Ziemer (1973) used drainage basin geomorphology to predict pink salmon (Oncorhynchus gorbuscha) escapement in Alaska, while Burton and Wesche (1974) developed an index to trout abundance in southeast Wyoming streams. Using variables from Ziemer (1973) and Burton and Wesche (1974), Wesche et al. (1977) developed an index for cutthroat trout standing stock in the Sierra Madre Range of Wyoming. Platts (1974) in Idaho and Oswood and Barber (1982) combined drainage basin geomorphology and measures of instream habitat to predict salmonid standing stocks.

In addition to these five models, Swanston et al. (1977) and Heller et al. (1983) used drainage basin geomorphology to assess salmonid habitat quality. Swanston et al. (1977) analyzed drainage basin geomorphology through multivariate analysis and was able to differentiate between "very good" and "very poor" salmon streams in southeast Alaska. Heller et al. (1983) used geomorphology to estimate fish habitat quality on the Siuslaw National Forest in Oregon. All of these studies indicate that drainage basin geomorphology, measured from United States Geological Survey topographic maps, can be used as predictors of trout standing stock.

Stream Reach Inventory Channel Stability Evaluation (SRICSE) (Pfankuch 1975) is a visual assessment of channel and streambank stability. It's main application is in second to fourth order mountain streams for the evaluation of stream bank and channel substrate material resistance to detachment (Pfankuch 1975). Eifert and Wesche (1982) stated that insight into the entire watershed may be gained by evaluation of SRICSE scores averaged over a stream.

Several investigators have used SRICSE to assess trout habitat quality in streams. Brouha (1981) found that SRICSE scores between 77 and 83 were associated with the highest trout standing stock and that scores between 58 and 100 reflected acceptable habitat conditions in the Shasta-Trinity National Forest of California. The highest number of catchable trout were associated with SRICSE scores between 70 and 85 (Robert Rainville, United States Forest Service, Couer D'Alene, Idaho, Personal Communication). Eifert and Wesche (1982) working on small streams in southeastern Wyoming found that SRICSE scores between 65 and 91 corresponded to the best trout habitat. In addition, Eifert and Wesche (1982) compared results of Duff and Cooper's (1978) stream survey methodology and trout standing stock. Results showed that six variables: average width, average width, average reach depth, pool rating score, bank cover and stream velocity had significant relations with trout standing stock. Inclusion of these variables into the SRICSE rating could increase the biological sensitivity of SRICSE and provide a rapid method to predict trout habitat quality (Eifert and Wesche 1982).

Lanka et al. (1984) developed regression models for small Wyoming trout streams. Analysis indicated the relations between SRICSE and trout standing stock were different in forest streams (those stream reaches within National Forest boundaries) and nonforest streams (those outside). Subsequently two models were developed which accounted for 56 percent and 62 percent of the variation in trout standing stock in forest streams and nonforest streams, respectively.

Study Objectives

Many methods have been developed to assess stream habitat quality. These methods provide a means to assess stream productivity and to predict the effects of management decisions. Most methods to assess stream habitat quality are dependent upon intensive measures of instream habitat, consequently these methods are time consuming and costly. Studies of drainage basin geomorphology indicate that it may be a valuable predictor of habitat quality, while at the same time being inexpensive data to collect. Previous work has suggested a relation exists between drainage basin geomorphology and instream habitat. This study addressed the statistical relation among selected variables of both types in order to provide insight into their relation with each other and with trout standing stock.

The objectives of this study were:

1) Evaluate by use of simple-linear regression, the relationship between drainage basin geomorphology and instream habitat variables with trout standing stock.

2) Develop predictive multiple-linear regression models for small Wyoming trout streams based on variables shown to be significantly ($P<0.10$) correlated to trout standing stock.

3) Test these models with independent data.

METHODS

Sources of Instream Habitat and Standing Stock Estimates

Data used for model development were compiled from two sources. First, during 1983, contact with Bureau of Land Management and University of Wyoming personnel enabled utilization of existing file data. Second, data were gathered from additional streams by field measurements during the summer of 1984.

File data were accepted only if specific criteria were met. Instream habitat data and standing stock estimates had to be collected over the same reach within one month of each other. An SRICSE rating (Pfankuch 1975) was mandatory as were data on nine other instream habitat variables (Table 1). A minimum two-pass depletion estimate following DeLury (1947, 1951) or Zippin (1958) for each reach was required so that a reliable estimate of standing stock could be generated.

Field Data Collection Methods

In the summer of 1984, small (<10 meters average wetted width during late summer low flow), perennial streams with known populations of brown trout, rainbow trout, cutthroat trout or brook trout were chosen for assessment. It was assumed that if trout were present in a stream reach, the stream at the reach had acceptable water chemistry and temperature limits for trout survival. Seventy-five-meter reaches were chosen to include at least one pool-riffle sequence. When selecting study reaches, stream segments that were excessively cluttered with debris or overhanging vegetation, thereby making electrofishing and habitat data collection difficult, were avoided.

Within each 75-meter reach, 10 transects were established at 7.5-meter intervals. At each transect, wetted stream width was measured perpendicular to flow following Duff and Cooper (1978) and Platts et al. (1983), and mean wetted stream width was computed for the reach. Depth measurements were taken at 0.25, 0.50 and 0.75 of the wetted stream width (Duff and Cooper 1978; Platts et al. 1983). The three depth measurements for each transect were then summed and divided by four to compute mean transect depth. Division is by 4 to account for zero depths at the banks (Duff and Cooper 1978; Platts et al. 1983). The mean depth for each of the 10 transects was then averaged to obtain average reach depth. Width-depth ratio was computed as the average wetted width divided by the average reach depth. At each depth measurement location the substrate class was visually determined (Duff and Cooper 1978). The sum for each substrate class was divided by the total number of measurements to obtain the percent of each substrate class over the reach.

Hydraulic stability can be visually estimated using SRICSE (Pfankuch 1975). Fifteen stability indicators are numerically rated over an entire stream reach. Three stream zones are examined; upper bank, lower bank and channel bottom. Each indicator was rated excellent, good, fair or poor.

Total reach score, the sum of the individual ratings, was then grouped into one of four stability classes, from excellent to poor. Total reach SRICSE score was used in data analysis.

Water velocity and discharge estimates followed float method procedures outlined by Buchanan and Somers (1969), Duff and Cooper (1978) and Orth (1983). A pencil was floated three times over a relatively straight, unobstructed subsection of the reach for approximately 20 seconds. Distance traveled and float duration were recorded. The subsection velocity (meters per second) was computed as the sum of the float lengths in meters divided by the sum of the float durations in seconds. The subsection of the reach where velocity measurements were taken was then divided into three equally spaced transects. At each transect width and depth were measured and averaged as above. Discharge through the subsection was computed following the equation given by Buchanan and Somers (1969), Duff and Cooper (1978) and Orth (1983):

(average subsection width x average subsection depth x average subsection velocity x 0.85) = discharge in cubic meters per second.

The 0.85 correction factor is used to adjust for faster than average water velocities on the water surface. It is the average of the 0.8 (rough stream bottom) and 0.9 (smooth stream bottom) correction factors recommended by Duff and Cooper (1978) and Orth (1983). This average value, 0.85, was used to avoid bias associated with deciding what was smooth or rough bottom streambeds.

Average reach velocity was computed assuming that discharge was constant through the reach. A rearrangement of the equation presented for discharge was used incorporating average reach wetted width and average reach depth:

discharge/average reach wetted width x average reach depth = average reach velocity.

Reach gradient was estimated with a clinometer following Duff and Cooper (1978).

Standing Stock Estimates

Estimates of trout standing stock were obtained at each site using the removal method (DeLury 1947, 1951). Each reach was blocked at the upper and lower end with a minnow seine (6.4 square millimeter mesh), to prevent emigration or immigration. Three depletion passes were made over the reach with a battery-powered Coffelt Model BP-2 backpack electro-shocker. At the end of each pass fish were weighed to the nearest gram and natural total length (Anderson and Gutreuter 1983) was measured to the nearest millimeter. Only trout >100 millimeters were measured and weighed. Those <100 millimeters were counted in young-of-the-year estimates. Trout population estimates for each reach were computed through program CAPTURE (White et al. 1982). Model M(bh) was chosen because it allowed for capture variability among animals and for behavioral responses to the first capture attempt (Reynolds 1983). Trout standing stock (kilograms/hectare) was then determined by multiplying the estimated number of trout of each species, by the average weight of that species captured and weighed in the reach.

Geomorphological Variables

Eleven geomorphological variables were measured from United States Geological Survey, 1:24,000 scale topographic maps (Table 2). When 1:24,000 scale maps were not available, 1:62,500 scale maps were used. Variables shown to be correlated to trout standing stock in previous studies (Ziemer 1973; Burton and Wesche 1974; Heller et al. 1983) were initially chosen for measurement, but were thought to be too difficult to measure for management purposes. Therefore, geomorphological characteristics that measured similar drainage basin processes in a more simple manner were used.

Each study site was located on a topographic map and it's drainage divide was drawn on the map. Study reach elevation was read directly from the map. Mid-range basin elevation was calculated as one-half the sum of the highest elevation on the headwater divide and the reach elevation and was used to approximate mean basin elevation. Stream order was determined by counting only those stream channels shown in blue on topographic maps following Horton (1945) as modified by Strahler (1952, 1957). Basin area (Horton 1945) was measured using a compensating polar planimeter while basin perimeter (Horton 1945), was measured using a map measurer. Basin relief (Schumm 1956) is calculated as the overall drop in elevation from the highest point on the drainage divide and the study reach. Compactness coefficient (CC) was a component variable of the Fish Habitat Index natural quality number developed for the Siuslaw National Forest by Heller et al. (1983) and is calculated by the equation:

CC = basin perimeter / [2 x (3.14 x basin area)**1/2].

Stream length (Horton 1945) was measured by following the longest watercourse shown in blue on the map with a map measurer. Relief ratio

(Schumm 1956) was calculated as the basin relief divided by the stream length. Channel slope was calculated using the equation given by Craig and Rankl (1978):

[elevation at 85% of stream length - elevation at 10% of stream length]/85% of stream length - 10% of stream length

Drainage density (Horton 1945) was calculated as the kilometers of all stream channels shown in blue in a drainage basin divided by the drainage area in square kilometers.

Data Analysis

Due to the proposed land exchange between the Bureau of Land Management and the United States Forest Service, separating stream reaches by institutional boundaries (Lanka et al. 1984) was abandoned. Instead a latitudinal-elevation gradient, demarcating high-elevation coniferous forest dominated watersheds from lower elevation sagebrush-grassland dominated rangeland watersheds was used (Table 3). The boundary elevation between forest and rangeland streams approximately follows the low elevation coniferous forest timber line in Wyoming. This system allowed placement of high elevation streams not on National Forest Lands into the forest stream data set. Separate analyses were performed on each data subset.

Statistical data analysis employed BMDP (Dixon et al. 1981) and The Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975) statistical computer programs. Simple-linear regression was used to determine the correlation, significance level and direction of the relation between each independent variable and trout standing stock. Normal probability plots and standardized residual plots were inspected to detect violations of regression assumptions and to justify log transformations of independent variables (Zar 1974). Those variables significantly correlated ($P<0.10$) to trout standing stock were analyzed using BMDP all-subsets multiple-linear regression. If log transformations of those variables whose normality or residual plots indicated transformations were justified, increased accounted for variance at least 5 percent and remained significant at the $P<0.10$ level they were chosen over the untransformed variable for all-subsets analysis. All-subsets multiple-linear regression was used to pick the set of variables with the highest adjusted coefficient of determination (R^2_a).

Adding variables can only increase the unadjusted coefficient of determination (R^2), thereby artificially inflating the accounted for variance (Neter and Wasserman 1974). A more conservative estimate of statistical fit that R^2 is R^2_a since R^2_a may decrease as more variables are added to a regression equation. Only if an additional variable adds information to the resulting model, will R^2_a increase (Neter and Wasserman 1974).

Due to the effects of colinearity, a positive relationship between one dependent variable and trout standing stock may change to a negative relation with multiple-linear regression. All-subsets multiple-linear regression does not report regression coefficients for every possible subset. Therefore, the model chosen as best based upon all-subsets regression, (one with relatively few variables yet a high R^2_a value) was reanalyzed using SPSS multiple-linear regression. The resultant reporting of regression coefficients and their significance level enable evaluation of the biological relation of each variable in the equation with trout standing stock.

RESULTS

Study stream reaches were located in ten of Wyoming's 23 counties and two of Wyoming's 4 major river drainages (Missouri and Colorado River systems). Study reaches for both forest and rangeland streams varied widely in their characteristics.

About one-half of the variables analyzed in both forest and rangeland streams were significantly ($P<0.10$) related to trout standing stock. Five of the 10 instream variables and five of the 11 geomorphological variables were significantly related to trout standing stock in forest stream (Table 4). In rangeland streams, five of the 10 instream variables and six of the 11 geomorphological variables were significantly related to trout standing stock (Table 5).

Upon inspection of X,Y plots for each independent variable and trout standing stock, three independent variables showed the peak range of standing stock spread over a narrow range of predictor variable values. These three variables, reach elevation (RE) in forest streams, mid-range basin elevation (MRE) and width-depth ratio (WD) in rangeland streams were rated from 1 (low standing stock range) to 3 (high standing stock range) to yield a more linear relation between the rated predictor variable and trout standing stock. A rating system was chosen over polynomial regression (raising predictor variables to increasing powers) due to the ease of interpretation and the management applicability of a rating system. The ratings were as follows:

reach elevation:

1 = RE<2150 m,

2 = RE>2355 m,

3 = 2150 m≦RE≦2355 m;

midrange basin elevation:

1 = MRE≦2000 m or ≧2600 m,

2 = 2000 m<MRE<2325 m,

3 = 2325 m≦MRE<2600 m;

width-depth ratio:

1 = WD≦10 or >33,

2 = 23≦WD≦33,

3 = 10<WD<23.

The effects of rating these three variables are presented in Tables 4 and 5 for forest and rangeland streams, respectively.

In rangeland streams, basin perimeter (P = 0.1330) and stream length (P = 0.1014) were not significantly related to trout standing stock at the P<0.10 level used in this study. However, the negative relation to trout standing stock shown by both these variables (Table 5) was logical and because both variables were near the significance level used in this study, they were included in regression analysis for model development.

Models

Three multiple-linear regression models were developed for both forest and rangeland streams. For each stream type, those geomorphological and instream habitat variables indicated in Tables 4 and 5, respectively, were used to develop the first model. In both stream types this model gave the highest adjusted coefficient of determination and was called the "best model." The second model was based only on instream habitat variables and the third only on geomorphological variables. Field and office methods for measuring the variables used in the regression models are presented in Appendix A.

Forest Streams

The best model for forest streams (N = 65) was:

$$Y = 447.75 + 67.49(RRE) - 153.67[\log(RR + 1)] - 35.73(DD) - 263.09[\log(ARW + 1)].$$

Where: Y = predicted kilograms per hectare trout; RRE = rated reach elevation; RR = relief ratio; DD = drainage density; ARW = average wetted reach width.

This model was significantly correlated with trout standing stock (F = 17.42; P = 0.001; R_a^2 = 0.51; R = 0.73). Prediction error for this model, or the difference between actual standing stock and predicted standing stock (residual) divided by actual standing stock was 119 percent. All regression coefficients were significantly different from zero (P = 0.01).

The instream habitat model for forest streams (N = 65) was:

$$Y = 408.22 - 189.66[\log(ARW+1)] - 113.91[\log(WD+1)] - 12.41(G).$$

Where: Y = predicted kilograms per hectare trout; ARW = average wetted reach width; WD = width-depth ratio; G = percent reach gradient.

This model was significantly correlated with trout standing stock (F = 10.51; P 0.001; R_a^2 = 0.31; R = 0.58). Prediction error for this model was 139 percent. All regression coefficients were significantly different from zero (P = 0.08).

The geomorphological variable model for forest streams (N = 65) was:

$$Y = 471.54 + 99.38\ (RRE) - 138.17[\log(BR+1)] - 123.60[\log(RR+1).$$

Where: Y = predicted kilograms per hectare trout; RRE = rated reach elevation; BR = basin relief; RR = relief ratio.

This model was significantly correlated with trout standing stock (F = 12.98; P 0.001; R_a^2 = 0.36; R = 0.62). Prediction error for this model was 307 percent. However, one reach had an 11,020 percent prediction error (actual standing stock = 1.0, predicted standing stock = 110.2). When this one stream was excluded prediction error decreased to 139 percent. All regression coefficients were significantly different from zero (P = 0.03). Figure 1 shows the scatter of points about the regression line for each of the forest stream models.

<u>Rangeland Streams</u>

The best model for rangeland streams (N = 26) was:

$$Y = 200.25 + 36.05(RMRE) - 0.85(BP) - 138.73[\log(CS+1)] + 50.45\ (RWD).$$

Where: Y = predicted kilograms per hectare trout; RMRE = rated mid-range basin elevation; BP = basin perimeter; CS = channel slope; RWD = rated width-depth ratio.

This model was significantly correlated with trout standing stock (F = 11.99; P 0.001; R_a^2 = 0.64; R = 0.83). Prediction error for this model was 39 percent. All regression coefficients except RMRE (P = 0.12) were significantly different from zero at the (P = 0.01).

The instream habitat model for rangeland streams (N = 26) was:

$Y = 39.20 + 70.95(RWD) - 197.10(ARV).$

Where: Y = predicted kilograms per hectare trout; RWD = rated width-depth ratio; ARV = average reach velocity.

This model was significantly correlated with trout standing stock (F = 17.31; P 0.001; $R_a^2 = 0.57$; R = 0.78). Prediction error for this model was 56 percent. All regression coefficients were significantly different from zero (P = 0.02).

The geomorphological variable model for rangeland streams (N = 26) was:

$Y = 487.59 + 53.30(RMRE) - 160.12[\log(BR+1)].$

Where: Y = predicted kilograms per hectare trout; RMRE = rated mid-range basin elevation; BR = basin relief.

This model was significantly correlated with trout standing stock (F = 14.29; P = 0.001; $R^2 = 0.52$; R = 0.74). Prediction error for this model was 55 percent. All regression coefficients were significantly different from zero (P = 0.03). Figure 2 shows the scatter of points about the regression line for each of the rangeland stream models.

Model Testing

Each model was tested using an independent data set. In all models, except the forest instream model, higher correlations between model output and actual standing crop were observed for model testing than in model development (Table 6 and 7). All model tests had lower prediction error than those associated with model development. Rangeland stream tests resulted in higher correlation and lower prediction error than those associated with forest streams. The "best model" in each stream type, as with model development, gave the best test results.

DISCUSSION

Variation in Model Performance

The models developed for forest streams did not predict trout standing stock as well as rangeland stream models. One reason may be the wider range of physical habitat able to support trout in forest streams (Bowers et al. 1979).

Another explanation for decreased model precision in forest streams is greater fishing pressure and exploitation. Rangeland streams in the Bighorn Basin were subject to low fishing pressure (Richards and Holden 1980; Conder 1982). In the Powder River Basin rangeland streams were on private land with trespass fees charged to fish. Streams in the Platte River Basin were on private land with little public fishing allowed (Eifert and Wesche 1982). In the Sweetwater River drainage the two rangeland streams were located on land managed by the Bureau of Land Management but they were remote brook-trout fisheries, 70 kilometers north of Rawlins, Wyoming. Forest streams were all located on public lands, had good access and presumably received substantial fishing pressure with the exception of streams in the Little Snake River Basin.

Model Reliability and Application to Management

The developed models are a quick way to evaluate trout habitat quality (See Appendix A). The "best model" for both forest and rangeland stream types incorporated three geomorphological variables and one instream habitat variable. The drainage basin variables used in the "best model" and the geomorphic variable model take a person approximately one hour to measure from topographic maps. Average wetted reach width (forest streams) and width-depth ratio (rangeland streams) were the instream habitat variables used in the "best models." These variables collected over a reach using stream transects are easily and accurately measured (Platts et al. 1983).

The variables necessary for the instream habitat models also are easily collected. Average width and width-depth ratio are collected using stream transects. Reach gradient can be measured with a clinometer (Platts et al. 1983). Average reach velocity, necessary for the rangeland stream model, took about 1.5 man hours to estimate in the field (Appendix A). If dye is available, the time of travel technique, as recommended by Binns (1979) and Eifert and Wesche (1982), is more accurate and takes less time. In contrast to HQI (Binns 1979) and HSI models (Hickman and Raleigh 1982; Raleigh 1982; Raleigh et al. 1984a; Raleigh et al. 1984b) which are field intensive, these new models require 1 - 4 hours to gather all necessary model data.

Besides being quick, model testing indicated the models to be reliable predictors of trout standing stock in small Wyoming streams. The prediction error associated with the forest stream models was about 130 percent, while that for rangelands streams was 50 percent. Binns (1979) had 23 percent prediction error during model development. While this value is much lower than that found for models developed in this study, the time involved in collecting model data for Binns (1979) is substantially longer. Model tests resulted in an average prediction error for the forest stream models of approximately 90 percent while for rangeland streams it averaged about 30 percent. When testing his model (Binns 1979) found only a 12.5 percent prediction error. The 18 percent prediction error associated with the "best model" in rangeland streams compared favorably with that of Binns (1979).

The model universe is an important consideration for future model users (Johnson 1981). Application of models to areas where they do not apply is a common problem (Fausch and Parsons 1984). The area of applicability for the models developed in this study is bounded on the east by the eastern foothills of the Laramie and Bighorn Mountain ranges and on the west by the Continental Divide. The models are applicable to all of Wyoming except the extreme west and the northeast corner of the state.

Each model is applicable to management situations depending upon the specific question to be answered. Restricted by law, or limited by equipment and personnel from making standing stock estimates, land management organizations could use the "best model" to rapidly obtain preliminary standing stock estimates for large numbers of streams. The instream habitat model could be used, to determine the effects of proposed management activities, such as stream improvement or water removal on trout standing stock. Potential trout standing stock with minimal influence of man on the watershed could be estimated by using the geomorphic variable model. Comparisons between this estimate and actual standing stock could provide information useful in mitigating habitat loses due to activities in the watershed. For baseline assessment or for preliminary management information, the models have numerous potential application to management situations.

SUMMARY

Predictive multiple regression models were developed for a wide variety of small Wyoming streams. The data set was divided into two subsets, forest streams and rangeland streams, based on a latitudinal-elevation gradient. Within each stream type, three models were developed that accounted for a significant amount of the variation in trout standing stock. One model used only measures of drainage basin geomorphology as predictor variables, while the second used only measures of instream habitat. A third model was developed that combined both measures of instream habitat and geomorphology to create a "best model." All models were tested with independent data. Tests resulted in high correlations with moderate prediction error. The models have applicability for baseline studies or preliminary analysis of habitat quality by management agencies. A statistical relation was found to exist between several instream-habitat variables and drainage-basin geomorphology.

ACKNOWLEDGMENTS

Dr. Michael Parker and Dr. Stephen Bieber are acknowledged for their manuscript review. Many individuals shared data and helped in collecting additional field data:

BUREAU OF LAND MANAGEMENT

Fred Stabler
Richard Kroeger

UNIVERSITY OF WYOMING

Walter Eifert
Ian Chisholm

WYOMING GAME AND FISH DEPARTMENT

John Baughman
John Mueller
Lawrence Peterson
Jack McMillian
Brad Welsch
Charles Viox
Kerry Connell
Dewey Eaton
David Dufek
Michael Snigg
Randall Tullis

Additional thanks are extended to those who helped by working on field crews during the summer of 1984; Eric Featherston, Carrie Frye, Gregory Melka, Barry Deibert, Randall Blake and Phillip Hubert. Funding for this project was provided by the United States Department of the Interior, Bureau of Land Management (Agreement Number 14-16-0009-1542) and the Wyoming Water Research Center, project number (USGS-6943-03).

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Table 1. Instream habitat variables used in data analysis.

Stream Reach Inventory and Channel Stability Evaluation Composite Score
Average Wetted Reach Width in meters
Average Reach Depth in meters
Average Reach Velocity in meters per second
Width - Depth Ratio[a]
Percent Bedrock and Boulder Substrate (≧30.1 centimeters diameter)
Percent Rubble Substrate (7.6 - 30.0 centimeters diameter)
Percent Gravel Substrate (0.26 - 7.5 centimeters diameter)
Percent Silt-sand Substrate (≦0.25 centimeters diameter)
Reach Gradient in percent

Table 2. Characteristics of drainage basin geomorphology analyzed for relations to trout standing stock in this study.

Variable	Units
Reach Elevation	Meters
Mid-Range Basin Elevation	Meters
Stream Order	
Basin Area	Hectares
Basin Perimeter	Kilometers
Basin Relief	Meters
Compactness Coefficient	
Stream Length	Kilometers
Relief Ratio	Meters/Kilometer
Channel Slope	Meters/Kilometer
Drainage Density	Kilometers/Kilometer^2

Table 3. Elevation at which forest streams were separated from rangeland streams at different latitudes.

Minutes of Latitude	Elevation (meters)
41-42	2287
42-43	2135
43-44	1982
44-45	1830

Table 4. Adjusted R^2 values (n=65) for those variables significantly ($P < 0.10$) correlated to trout standing stock (Kg/Ha) and the influence of log transformations used to correct for violations of regression assumptions in forest streams. X=Nonsignificant relation.

Variable	Raw Data	Log Transformed
SRICSE Reach Score	X	X
Average Wetted Reach Width	-0.12	-0.18[a]
Average Reach Depth	X	X
Average Reach Velocity	X	X
Width Depth Ratio	-0.09	-0.21[a]
Percent Bedrock Boulder Substrate	X	X
Percent Rubble Substrate	-0.05[a]	-0.08
Percent Gravel Substrate	0.05[a]	X
Percent Silt-Sand Substrate	X	X
Percent Reach Gradient	-0.03[a]	-0.03
Reach Elevation	-0.03[b]	-0.04
Mid-Range Basin Elevation	-0.14[a]	-0.17
Stream Order	X	X
Basin Area	X	X
Basin Perimeter	X	X
Basin Relief	-0.07	-0.14[a]
Compactness Coefficient	X	X
Stream Length	X	X
Relief Ratio	X	-0.12[a]
Channel Slope	X	X
Drainage Density	-0.05[a]	-0.05

[a]Variable forms used in model development.

[b]Rated form of this variable used ($R^2 = 0.25$)

Table 5. Adjusted R^2 values (n=26) for those variables significantly ($P < 0.10$) correlated to trout standing stock (Kg/Ha) and the influence of log transformations used to correct for violations of regression assumptions in rangeland streams. X=Nonsignificant relations.

Variable	Raw Data	Log Transformed
SRICSE Reach Score	X	X
Average Wetted Reach Width	-0.22	-0.27[a]
Average Reach Depth	X	X
Average Reach Velocity	-0.25[a]	-0.27
Width Depth Ratio	-0.23[b]	-0.16
Percent Bedrock Boulder Substrate	X	X
Percent Rubble Substrate	-0.23[a]	-0.20
Percent Gravel Substrate	X	X
Percent Silt-Sand Substrate	0.13[a]	0.14
Percent Reach Gradient	X	X
Reach Elevation	0.27[a]	0.25
Mid-Range Basin Elevation	X[b]	X
Stream Order	-0.31[a]	-0.32
Basin Area	-0.08[a]	X
Basin Perimeter	-0.05[a,c]	X
Basin Relief	-0.30	-0.43[a]
Compactness Coefficient	X	X
Stream Length	-0.07[a,d]	X
Relief Ratio	-0.08	-0.16[a]
Channel Slope	-0.07	-0.14[a]
Drainage Density	X	X

[a]Variable forms used in model development.

[b]Rate form of this variable:
Mid-Range Basin Elevation R^2 = 0.40
Width Depth Ratio R^2 = 0.45[a]

[c]P=0.1330

[d]P=0.1014

Table 6. Correlation coefficient and percent prediction error for the 8 streams used to test the rangeland stream models.

	Best Model	Instream Model	Geomorphic Model
Correlation Coefficient	0.96	0.90	0.69
Percent Prediction Error	18	29	50

Table 7. Correlation coefficient and percent prediction error for the 11 streams used to test the forest stream models.

	Best Model	Instream Model	Geomorphic Model
Correlation Coefficient	0.80	0.32	0.75
Percent Prediction Error	73	103	101

Appendix A. Computation of regression model variables.

Twelve variables were incorporated into the regression models, five instream habitat variables and seven geomorphological variables. Computation methods for each variable are presented.

Instream Habitat Measurements

Instream habitat is measured using the transect method. It is recommended that 75-meter study reaches be established with 10 transects established at 7.5-meter intervals. At each transect wetted stream width is measured perpendicular to the current. Depth measurements are taken at 0.25, 0.50 and 0.75 of the wetted stream width. The three depth measurements are summed and divided by four to compute mean transect depth (Platts et al. 1983).

1. Average wetted reach width (ARW): the sum of the measured wetted stream widths (meters) divided by the number of wetted stream widths summed.

2. Width-depth ratio (WD): average wetted reach width divided by average transect depth (meters) over the study reach.

3. Rated width-depth ratio used in rangeland stream (RWD): rating = 1, if $WD \leq 10$ or $WD > 33$; rating = 2, if $23 \leq WD \leq 33$; rating = 3, if $10 < WD < 23$.

4. Percent reach gradient (G): percent gradient from clinometer estimate Reach gradient is measured between the upstream and downstream boundaries of the study reach using a clinometer following the procedures of Duff and Cooper (1978).

5. Average reach velocity (ARV): discharge (cubic meters per second) divided by the product of average wetted reach width (ARW) and average reach depth.
   Average reach velocity is computed from estimates of discharge, average wetted reach width and average reach depth. A 20-meter subsection of the reach which has a straight channel free of obstructions is used to estimate discharge. Subsection velocity (meters/second) is computed by floating a pencil through the subsection three times and averaging the three time measurements. Three transects at the upper, middle and lower points of the subsection are used, to determine average subsection width (meters) and average subsection depth (meters). Discharge through the subsection is computed as:

   Discharge = average subsection width (meters) x
   average subsection depth (meters) x
   average subsection velocity (meters/seconds)
   x 0.85.

Geomorphological Variables

Geomorphological variables are measured from United States Geological Survey topographic maps (1:24,000 scale). Study reaches are located on the topographic and the drainage divide is drawn on the maps encompassing the drainage.

6. Reach elevation is read directly from the map. The reach elevation is rated for forest streams using the following criteria.

Rated reach elevation (RRE): rating = 1, if reach elevation <2150 meters; rating = 2, if reach elevation < 2355 meters; rating = 3, if 2150 ≦ reach elevation ≦ 2355 meters.

7. Midrange basin elevation is used to approximate the average basin elevation. It is computed as the highest elevation on the headwater divide divided by the reach elevation. Midrange basin elevation is rated for rangeland streams using the following criteria:

   Rated midrange basin elevation (RMRE) = rating = 1, if midrange basin elevation ≦ 2000 meters or ≧ 2600 meters; rating = 2, if 2000 meters < midrange basin elevation < 2325 meters or 2475 meters < midrange basin elevation < 2600 meters; rating = 3, if 2325 meters ≦ midrange basin elevation ≦ 2475 meters.

8. Basin perimeter is measured using a map measurer (Horton 1945).

   Basin perimeter (BP): distance (kilometers) around the edge of the drainage basin.

9. Basin relief is a measure of variation in elevation over the drainage basin (Schumm 1956).

   Basin relief (BR): the highest elevation on the headwater divide (meters) minus the reach elevation (meters).

10. Relief ratio is calculated as the basin relief divided by the stream length. Stream length is measured following the longest watercourse shown in blue on the map with a map measurer (Schumm 1956).

    Relief ratio (RR): basin relief (meters) divided by stream length (kilometers).

11. Channel slope is a measure of stream gradient over the basin. It is computed using the equation of Craig and Rankl (1978):

    Channel slope (CS): (elevation at 85% of stream length minus elevation at 10% of stream length) divided by (85% of stream length minus 10% of stream length).

12. Drainage density (Horton 1945) is calculated as:

    Drainage density (DD): the length (kilometers) of all stream channels shown in blue in a drainage basin divided by the drainage area (square kilometers).