# Evaluation of the U. S. Forest Service "COWFISH" Model For Assessing Livestock Impacts on Fisheries in the Beaverhéad National Forest, Montana


BRADLEY B. SHEPARD

*Montana Department of Fish, Wildlife and Parks*
*and Beaverhead National Forest*
*610 North Montana*
*Dillon, Montana 59725 USA*



*Abstract.*—The COWFISH fish habitat model developed by the U. S. Forest Service was evaluated during 1986 and 1987 at 43 stream sites within the Beaverhead National Forest, Montana to determine the ability of the model to assess effects of livestock grazing on trout fisheries. The COWFISH model uses a field survey of five variables (percentage of streambank with overhanging vegetation, percentage embeddedness, percentage of the streambank undercut, percentage of the streambank in an "altered" condition, and width:depth ratio) in association with channel gradient and the presence or absence of granitic parent material within the drainage to predict optimum and existing numbers of catchable (152 mm total length and longer) trout. The model predicted reasonable estimates of catchable cutthroat trout *Oncorhynchus clarki*, rainbow trout *O. mykiss*, and hybrids of these species ($r^2 = 0.65$; $P < 0.01$) at 19 sites where one or more of these forms occurred; however, predicted numbers of catchable brook trout *Salvelinus fontinalis* ($r^2 = 0.14$; $P > 0.05$) were imprecise at the 26 sites containing brook trout. Habitat suitability index results for field data collected by different observers did not appear to be significantly different ($P = 0.30$), and results for sites that deviated from model site criteria were not significantly different from sites that met site criteria ($P = 0.45$). Minor modifications in the model appeared to slightly improve model performance. Us of the COWFISH model by range professionals and livestock permittees did increase their awareness of the effects of livestock grazing on aquatic resources.


Several models have been developed for predicting fish standing crops in streams using various habitat parameters (Binns and Eiserman 1979; Binns 1982; Hickman and Raleigh 1982; Raleigh et al. 1984; Scarnecchia and Bergersen 1987). These models are generally data intensive and have limited applicability in a monitoring program, particularly for non-fisheries professionals. The COWFISH model was developed by Lloyd (1986) to address the needs of the Fish Habitat Relationships Program of the U. S. Forest Service (USFS). The model was developed primarily as a tool for range management professionals to document the effects livestock grazing has on aquatic resources on lands administered by the USFS. It uses a format similar to the Habitat Suitability Index Model Series developed by the U. S. Fish and Wildlife Service (e.g., Hickman and Raleigh 1982) and was developed using data and observations collected from Nevada, Utah, Montana, and Idaho.

A need was recognized by those who developed the model (J. Lloyd and B. Platts, USFS, personal communication) and USFS land managers for site specific data to calibrate and further validate this model. The objective of this study was to test the predictive capabilities of the model in comparison to existing numbers of catchable salmonids (152 mm total length and longer) by species on the Beaverhead National Forest, Montana, compare results obtained by different observers (including fisheries, range, and hydrology professionals and technicians), and explore modifications that may enhance the performance of the model.

## Study Area Description

Forty-three study sites in 39 streams draining the Beaverhead National Forest were sampled. These streams were located in the Big Hole, Beaverhead, Madison, and Ruby river drainages in southwestern Montana. The streams ranged from first- to fifth-order tributaries, and channel gradients, average wetted widths, average water depths, and livestock grazing systems and intensities varied (Table 1).

Brook trout *Salvelinus fontinalis*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, rainbow trout *O. mykiss*, and hybrids between rainbow trout and cutthroat trout were the predominant fish species present. Generally, cutthroat trout and rainbow trout were absent or present in extremely low densities in stream sections that supported brook trout. Exceptions were observed in sample sites in Jerry and Hunter creeks, where brook trout and cutthroat trout were present in similar densities.

The difficulty in identifying the difference between westslope cutthroat trout, rainbow trout, and their hybrids (using external morphological characteristics) forced combination of all these morphs into one category (*Oncorhynchus* spp.). Most stream sections that supported *Oncorhynchus* spp. contained westslope cutthroat populations that may have been introgressed to varying degrees with rainbow trout. Many stream sections also supported populations of sculpins *Cottus* spp.

## Methods

### *COWFISH Surveys*

The COWFISH habitat surveys were conducted according to the methods described by Lloyd (1986). These surveys were conducted during the summers of 1986 and 1987 by USFS range personnel from district offices, the Forest Hydrologist and hydrology technicians, and the author and biological technicians. Surveys were generally done for basic land inventory purposes, and therefore, a specialized randomized sample design was not attempted. However, the wide geographic area covered by the surveys should have minimized bias caused by the lack of randomized sample site selection.

District range personnel surveyed tributaries in the Beaverhead River drainage, hydrology personnel surveyed tributaries in the Ruby River drainage, but the author surveyed tributaries in all drainages. At all sites, a single 30- to 100-m long segment of stream was surveyed. The length of sections surveyed by the author varied by stream class: (1) streams with wetted widths less than 3 m, a 30-m section

Table 1.—Sample site characteristics for 43 sample sites where COWFISH habitat surveys and fish population estimate data were collected.

| Stream | Reach | Stream order | Percent gradient | Average wetted width (m) | Average depth (cm) | Grazing system[a] | AUMs[b] |
|---|---|---|---|---|---|---|---|
| Bear Wallow | 1 | 2 | 2.3 | 1.7 | 7.3 | 3P,RR | 675 |
| Bear Wallow | 2 | 2 | 2.3 | 1.5 | 14.0 | 3P,RR | 675 |
| Beaver | 1 | 3 | 3.3 | 0.9 | 20.1 | 8P,RR | 11,610 |
| Brown's Canyon | 1 | 2 | 4.4 | 2.2 | 18.2 | 4P,RR | 1,050 |
| Bull | 2 | 3 | 2.2 | 1.1 | 13.4 | 3P,DR | 318 |
| Burnt | 1 | 2 | 6.8 | 1.8 | 20.7 | 8P,RR | 11,610 |
| Coal | 1 | 2 | 1.7 | 4.9 | 22.9 | 8P,RR | 11,610 |
| Corral | 2 | 2 | 4.6 | 1.5 | 22.9 | 8P,RR | 11,610 |
| Cottonwood | 2 | 2 | 6.2 | 1.8 | 22.9 | 8P,RR | 11,610 |
| Cow Cabin | 1 | 3 | 3.4 | 0.8 | 12.8 | 1P,DR | 1,050 |
| David | 1 | 3 | 2.9 | 6.9 | 19.5 | 3P,RR | 1,500 |
| E Fk Ruby R | 1 | 2 | 3.8 | 4.9 | 33.5 | 8P,RR | 11,610 |
| Effie | 1 | 1 | 5.7 | 2.2 | 10.4 | 1P,SL | 467 |
| Elk Ck | 1 | 3 | 1.7 | 2.8 | 17.4 | 5P.RR | 1,584 |
| Elk R | 2 | 3 | 2.6 | 3.4 | 8.5 | 3P,RR | 810 |
| Gold | 1 | 2 | 2.7 | 2.8 | 14.3 | 4P,RR | 805 |
| Governor | 2 | 3 | 1.9 | 3.6 | 15.5 | PVT | |
| Hunter | 1 | 2 | 3.1 | 1.0 | 12.8 | 3P,RR | 675 |
| Jerry | 2 | 3 | 3.5 | 4.6 | 15.8 | 5P,RR | 2,745 |
| Johnson (D-3) | 1 | 4 | 0.7 | 6.2 | 20.1 | 2P,DR | 495 |
| Johnson (D-3) | 2 | 3 | 4.4 | 5.5 | 11.9 | 2P,DR | 495 |
| Johnson (D-2) | 1 | 4 | 4.8 | 4.0 | 13.1 | 5P,RR | 2,745 |
| Joseph | 1 | 3 | 0.8 | 5.0 | 21.6 | 5P,RR | 1,584 |
| LaMarche | 2 | 3 | 0.8 | 7.9 | 50.6 | CLOSED | |
| Lost Horse | 2 | 2 | 1.6 | 2.0 | 35.3 | 1P,SL | 467 |
| May | 1 | 3 | 1.4 | 5.0 | 18.0 | 5P,RR | 1,584 |
| Meadow | 2 | 3 | 7.8 | 2.7 | 13.1 | 2P,DR | 304 |
| Mono | 2 | 2 | 1.3 | 1.4 | 34.1 | 3P,RR | 1,500 |
| Morrison | 1 | 1 | 5.3 | 2.7 | 12.2 | 2P,RR[c] | 633 |
| N Fk Doolittle | 1 | 3 | 6.3 | 2.3 | 15.2 | 4P,RR | 1,465 |
| Painter | 1 | 2 | 4.7 | 3.4 | 15.2 | 4P,RR | 1,050 |
| Pass | 1 | 2 | 5.5 | 3.2 | 4.9 | 2P,RR[c] | 633 |
| Ruby | 3 | 4 | 0.8 | 4.5 | 22.6 | 1P.SL | 2,094 |
| Sheep (D-3) | 1 | 3 | 1.7 | 3.3 | 21.0 | 5P,RR | 1,584 |
| Steel | 1 | 5 | 0.5 | 7.9 | 17.7 | PVT | |
| Steel | 2 | 4 | 0.5 | 2.9 | 28.3 | 4P,RR | 1,188 |
| Teepee | 1 | 3 | 3.4 | 2.2 | 10.0 | 7P,RR | 8,565 |
| Tie | 1 | 4 | 0.6 | 5.1 | 25.2 | 2P,DR | 189 |
| Trail | 2 | 4 | 0.8 | 3.7 | 25.3 | 5P,RR | 1,584 |
| W Fk Madison R | 3 | 2 | 2.3 | 2.6 | 13.4 | 5P,RR | 1,765 |
| W Fk Ruby R | 1 | 3 | 4.6 | 1.7 | 28.0 | 8P,RR | 11,610 |
| Wyman | 1 | 4 | 3.8 | 4.7 | 18.6 | 4P,DR | 2,134 |
| Wyman | 2 | 4 | 0.8 | 5.8 | 25.9 | 4P,DR | 2,134 |

[a]Number of pastures, system code: SL= season long, RR= rest rotation, DR= deferred rotation, CLOSED= no recent use, PVT= private lands.

[b]AUM is animal unit months.

[c]These allotments had a history of season-long use with trespass.

was surveyed; (2) those between 3 and 6 m, a 150-m section was surveyed; and (3) those wider than 6 m, a 300-m section was surveyed. The range and hydrology surveyors always surveyed a 30-m long section.

Individual site applicability to site criteria described by Lloyd ("streams flowing through grass/forb riparian zones. . ." and streams that do not have "rocky streambanks") were ranked from 1 (indicating the criteria were met) to 3 (indicating the criteria were badly violated). Lloyd (1986) recommended that surveys be conducted at the end of the grazing period, but survey dates in this study did not always coincide with the removal of livestock from the pasture at the sample site. The only variable that may have been affected substantially by violating this criteria was the percentage of the streambank that contained overhanging vegetation.

Underlying parent material within the each drainage was classified as "granitic" or "non-granitic" using the "Ecological Land Unit" database developed by the Beaverhead National Forest. The database provides area estimates for geologic types in all of the study drainages (Beaverhead National Forest, unpublished data). Channel gradient at each site was estimated from U. S. Geological Survey (USGS) topographic maps (scale 1:24,000) by establishing a channel segment of at least 1.6 km which bracketed the sample site and determining the elevational difference within this segment.

In 1988, repeatability of the COWFISH survey was tested further at a single site in Antelope Creek, a tributary in the Madison River drainage. A total of six different two-person crews, ranging from those experienced with COWFISH field surveys to those with no survey experience, evaluated the same 30-m sample section. No attempt was made to train any of the surveyors. Each two-person crew completed their survey using the COWFISH instructions (Lloyd 1986).

*Fish Populations*

A 100- to 300-m long stream section was sampled at each site by the author and a biological technician to provide fish population estimates. Either a two-pass removal-depletion (Van Deventer and Platts 1985) or a mark-recapture estimator (Chapman 1951) was used to calculate abundance. Section length was determined as described above. Fish were captured by electrofishing in a downstream direction using a Coffelt BP-1C backpack shocker. An attempt was made to locate electrofishing sections with natural barriers located at the downstream end. Where no reasonable natural barrier existed, a block seine of 6.4 mm mesh was used at the lower end of the sample section.

Captured fish were measured to the nearest millimeter (total length) and held until after the second pass or marked using a fin-clip and released, depending upon the estimation technique. Separate estimates were made for fish from 75 to 151 mm and those longer than 151 mm (referred to as subcatchable and catchable, respectively, throughout the remainder of this paper). These size categories were selected to correspond with the definition of "catchable" provided by Lloyd (1986). Capture efficiencies for fish smaller than 75 mm were poor, and resulting estimates were not considered to be reliable. All estimates were expanded to the number of fish per 300 m of stream.

Fishing pressure at most sample sites was light. Many of the sites are relatively remote and support very few fish over 300 mm long, and anglers in this region generally prefer to angle for the trophy-sized trout available in all the major rivers. Since very few fish exceed 300 mm, it was felt that numbers of fish, rather than biomass, was a reasonable measure of fish standing crop.

*Data Manipulation and Statistical Tests*

Data from the field surveys, channel gradient, and the presence or absence of granitics within the drainage basin were used to calculate "parameter suitability indices (PSI)" for each variable, a final "habitat suitability index (HSI)", and predicted "optimum" and "existing" numbers of catchable salmonids per 300 m for each sample site (Lloyd 1986). The PSI values were calculated in a tabular fashion, and there was no attempt to interpolate between values. Statistical analyses were performed using the STATGRAPHICS program (STSC 1986), and Zar (1984) was used for statistical interpretation.

Distributions of final HSI values, actual estimated numbers of catchable *Oncorhynchus* spp. and brook trout expanded to number per 300 m of stream, and predicted "existing" numbers of catchable trout from the COWFISH model were tested for conformity to normal distributions using the Kolmogorov-Smirnov procedure. Differences in HSI values between observers and by site applicability to suggested COWFISH site criteria (Lloyd 1986) were tested for statistical significance by ANOVA. Estimates of HSI values, predicted number of "existing" catchable fish, and estimates for each of the variables in the COWFISH surveys were compared for the Antelope Creek site to evaluate differences between observers. These estimates were also compared to the estimates made by the author and the actual estimated number of catchable rainbow trout at the site.

Spearman rank correlations were computed between the estimated number of trout in the two length groups (catchable and subcatchable) and field data for the five COWFISH variables and the predicted number of catchable trout. To test the ability of the model to predict actual densities, the number of catchable trout estimated by electrofishing and the COWFISH predicted number of catchable trout by the two species groups were fit to a simple linear regression. These regressions were computed with and without forcing the intercept through the origin. Least squares methodology was used to develop curvilinear equations for converting field data to PSI values.

## Results

*COWFISH Surveys*

Estimates for the five habitat variables assessed within the COWFISH model averaged 41, 46, 36, 50, and 20 for percentage of streambank undercut, percentage of streambank with overhanging vegetation, percentage of streambank altered by livestock, percentage cobble embeddedness, and width:depth ratio, respectively (Table 2). Final HSI values ranged between 15 and 85, and individual PSI values ranged between 0 and 1.0 (Table 2). The sampled population of HSI values was normally distributed ($P > 0.99$). Mean HSI values for the 19 sections that supported *Oncorhynchus* spp. and the 26 sections that supported brook trout (these counts include the Jerry and Hunter creek sample sites for both species) were 52 and 47, respectively.

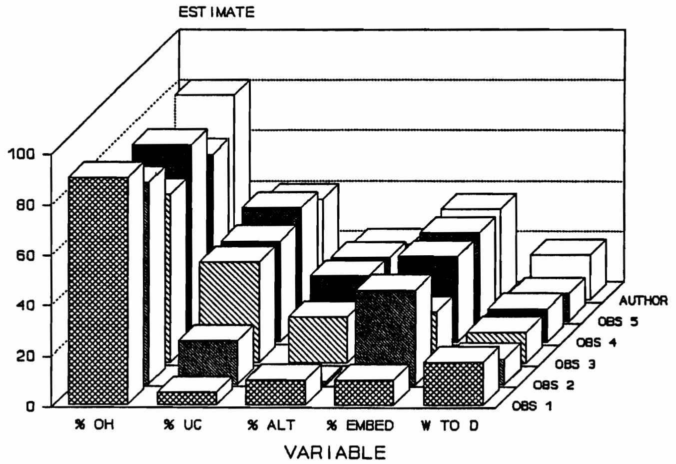
Mean HSI values stratified by observer were 46 ($N = 32$) for those sections surveyed by the author, 66 ($N = 6$) for those sections surveyed by district range personnel, and 54 ($N = 5$) for those sections surveyed by hydrology personnel. These differences were not significant ($P = 0.30$); however, this result may be confounded by site selection (sites surveyed by different groups of surveyors were often located in different river drainages) and small sample sizes for the range and hydrology surveyors. Mean HSI values for those sections that were ranked as best meeting the COWFISH site criteria, moderately meeting the criteria, and poorly meeting the criteria were 44 ($N = 10$), 52 ($N = 28$), and 51 ($N = 5$), respectively. Again, these differences were not significant ($P = 0.45$).

At the Antelope Creek site HSI values obtained from the six different survey crews averaged 60% of optimum and ranged between 54% and 62%. The author estimated the HSI value at 58% of optimum. Estimates for individual variables varied but were generally within an acceptable range (Figure 1). Estimates of the author were generally somewhat higher for individual variables; however, because of the compensatory way the variables enter the model (some enter as positive coefficients and others as negative coefficients) HSI values were similar.

*Fish Populations*

The estimates of the number of catchable and subcatchable *Oncorhunchus* spp. were normally distributed ($P > 0.99$ for both tests); estimates of catchable and subcatchable brook trout abundance were also normally distributed ($P > 0.41$ and $P > 0.22$, respectively). The distribution of

Figure 1.—Individual observer estimates for the five COWFISH variables. (OH - overhanging vegetation, UC - undercut banks, ALT - livestock bank alteration, EMBED - embeddedness, and W to D - width to depth ratio).




COWFISH model predictions of the number of catchable trout per 300 m did not deviate significantly from normal ($P > 0.21$) in *Oncorhunchus* spp. sites but did deviate from normal in the brook trout sites ($P < 0.05$).

Mean fish population estimates in sample sites containing *Oncorhynchus* spp. (number per 300 m of stream length) were 38 for subcatchable and 20 for catchable *Oncorhynchus* spp. (Table 3). Population estimates in sample sites that contained brook trout averaged 83 and 45 brook trout/300 m of stream for subcatchable and catchable length groups, respectively (Table 3). Mean population standard errors (expressed as a percentage of the estimate) were 7% and 3% for the above two size classes, respectively, in *Oncorhynchus* spp. sites and 11% and 6%, respectively, in the brook trout sites (Table 3). The Antelope Creek site contained an estimated 412 subcatchable (SE = 12.4) and 12 catchable (SE = 1.0) *Oncorhynchus* spp. per 300 m of stream length.

### *Correlations and Regression Analyses*

Spearman rank correlation coefficients between estimated numbers of catchable *Oncorhynchus* spp. per 300 m and COWFISH variables were statistically significant ($P < 0.05$) only for the embeddedness variable (Table 4). For estimated numbers of catchable *Oncorhynchus* spp., correlations were significant between catchable *Oncorhynchus* spp. and COWFISH predicted optimum ($P < 0.05$) and existing ($P < 0.01$) numbers of catchable fish per 300 m (Table 4). No significant correlations were observed between estimated numbers of brook trout per 300 m and individual COWFISH variables or predicted catchable trout per 300 m (Table 4).

Regression between estimated numbers of catchable *Oncorhynchus* spp. per 300 m and predicted numbers of catchable fish per 300 m from the COWFISH model yielded a coefficient of determination ($r^2$) of 0.65 and was statistically significant ($P < 0.01$) (Table 5, Figure 2). Forcing the y-intercept through the origin reduced the coefficient of determination ($r^2 = 0.64$) and decreased the slope from 1.9 to 1.8 (Table 5).

Regression analysis for catchable brook trout yielded a low $r^2$ (0.14) and was not statistically significant ($P > 0.05$) (Table 5 and Figure 2). The fact that the distribution for the predicted numbers of catchable trout at the brook trout sites did deviate from normal ($P < 0.05$) may have affected the results for regressions at these sites. However, the lack of normality was probably related to the relatively poor condition of many of these sites with respect to COWFISH variables which resulted in many low predicted fish values. Removing sites that poorly fit COWFISH site criteria did not appreciably change the regression equation slopes or $r^2$ values for either the *Oncorhynchus* spp. and brook trout regressions (Table 5). Regressions between estimated numbers of subcatchable *Oncorhynchus* spp. and brook trout versus COWFISH predicted numbers of catchable trout were poor with $r^2$ values of 0.08 and 0.00, respectively.

At the Antelope Creek site, the COWFISH model estimates ranged from 10 to 16 catchable fish/300 m of stream and averaged 14 catchable fish/300 m (SE:0.9) for the six different survey crews. The actual estimated number of *Oncorhynchus* spp. was 12/300 m of stream length.

### *Model Modification*

A third-order polynomial equation was used to relate field data to PSI values ($P < 0.01$) (Figure 3). The grouping of a wide range of field estimated values to a single PSI value for the embeddedness and width:depth ratios resulted in poorer fits for the respective equations. These regression equations provided a means of interpolation between tabled values and calculations within the model; however, the $r^2$ values in the regressions between predicted numbers and estimated number of catchable *Oncorhynchus* spp. and brook trout did not improve appreciably.

## Discussion

### *COWFISH Surveys*

The COWFISH survey techniques provided those in the range profession with a relatively simple, yet efficient, tool for evaluating the impacts of livestock grazing on aquatic resources. Differences in HSI values between observers or between sites that deviated from suggested site criteria were not statistically significant. These results indicate a high degree of robustness for the COWFISH model. It may be used even by surveyors with differing levels of experience and at stream sites with greatly varying habitat types such as willow *Salix* spp. and sedge *Carex* spp. communities. Fisheries and range professionals are presently refining the model for better application in willow communities, where rocky streambanks dominate, by replacing the undercut streambank component with another habitat variable. The most important feature of the methodology is that range professionals consider and observe livestock use as it affects streambanks and riparian communities.

### *Predictive Capabilities*

The ability of the COWFISH model to predict densities of catchable *Oncorhynchus* spp. was promising, given the relative ease of data collection for the five habitat variables. The fact that the regression between estimated numbers of catchable *Oncorhynchus* spp. and the number predicted by the model was statistically significant indicated that the slope (1.9) can be used as a correction factor to improve the predictive capability of the model for streams in southwestern Montana.

The ability of the model to predict densities of catchable brook trout was disappointing. Modde et al. (1986) found

Table 2.—Estimates for habitat data required for COWFISH model and model generated "parameter suitability indexes (PSI's)" and final "habitat suitability indexes (HSI's)" by sample site.

| Stream | Reach | Estimated values (model PSIs) for five COWFISH variables | | | | | Final HSI |
|---|---|---|---|---|---|---|---|
| | | Streambank undercut (%) | Streambank overhanging vegetation (%) | Streambank altered (%) | Cobble embeddedness (%) | Width-to-depth ratio | |
| Bear Wallow | 1 | 11 (0.1) | 38 (0.5) | 59 (0.4) | 45 (0.3) | 23 (0.4) | 25 |
| Bear Wallow | 2 | 53 (0.7) | 60 (0.8) | 24 (0.9) | 56 ( 0) | 11 (0.9) | 65 |
| Beaver | 1 | 77 (0.9) | 77 (0.9) | 27 (0.9) | 40 (0.4) | 5 (1.0) | 80 |
| Brown's Canyon | 1 | 48 (0.6) | 100 (1.0) | 11 (1.0) | 5 (0.9) | 12 (0.9) | 85 |
| Bull | 2 | 78 (0.9) | 92 (0.9) | 39 (0.7) | 73 ( 0) | 8 (0.9) | 65 |
| Burnt | 1 | 15 (0.1) | 25 (0.4) | 75 (0.3) | 30 (0.6) | 9 (0.9) | 45 |
| Coal | 1 | 30 (0.3) | 30 (0.4) | 50 (0.4) | 40 (0.4) | 21 (0.5) | 40 |
| Corral | 2 | 60 (0.8) | 65 (0.8) | 30 (0.8) | 40 (0.4) | 5 (0.9) | 70 |
| Cottonwood | 2 | 80 (0.9) | 100 (1.0) | 0 (1.0) | 50 (0.1) | 8 (0.9) | 75 |
| Cow Cabin | 1 | 20 (0.1) | 85 (0.9) | 40 (0.6) | 2 (1.0) | 6 (1.0) | 70 |
| David | 1 | 47 (0.6) | 6 (0.1) | 46 (0.5) | 57 ( 0) | 36 (0.1) | 25 |
| E Fk Ruby R | 1 | 7 ( 0) | 20 (0.3) | 66 (0.3) | 25 (0.7) | 15 (0.8) | 40 |
| Effie | 1 | 46 (0.6) | 28 (0.4) | 41 (0.6) | 54 (0.1) | 21 (0.6) | 45 |
| Elk Ck | 1 | 47 (0.6) | 9 (0.1) | 43 (0.6) | 64 ( 0) | 16 (0.8) | 40 |
| Elk R | 2 | 5 ( 0) | 47 (0.7) | 61 (0.4) | 58 ( 0) | 40 (0.1) | 20 |
| Gold | 1 | 27 (0.2) | 28 (0.4) | 33 (0.8) | 46 (0.2) | 20 (0.7) | 45 |
| Governor | 2 | 43 (0.5) | 52 (0.7) | 13 (1.0) | 27 (0.7) | 23 (0.4) | 65 |
| Hunter | 1 | 38 (0.4) | 58 (0.8) | 56 (0.4) | 65 ( 0) | 8 (0.9) | 45 |
| Jerry | 2 | 26 (0.2) | 38 (0.5) | 45 (0.5) | 39 (0.5) | 29 (0.1) | 35 |
| Johnson (D-3) | 1 | 36 (0.4) | 69 (0.8) | 18 (0.9) | 61 ( 0) | 31 (0.1) | 40 |
| Johnson (D-3) | 2 | 44 (0.5) | 92 (0.9) | 10 (1.0) | 56 ( 0) | 46 (0.1) | 50 |
| Johnson (D-2) | 1 | 23 (0.1) | 37 (0.5) | 38 (0.7) | 62 ( 0) | 30 (0.1) | 25 |
| Joseph | 1 | 45 (0.6) | 58 (0.8) | 19 (0.9) | 67 ( 0) | 23 (0.4) | 50 |
| LaMarche | 2 | 55 (0.7) | 55 (0.8) | 12 (1.0) | 62 ( 0) | 16 (0.8) | 65 |
| Lost Horse | 2 | 69 (0.8) | 70 (0.8) | 52 (0.4) | 95 ( 0) | 6 (1.0) | 60 |
| May | 1 | 66 (0.8) | 71 (0.8) | 22 (0.9) | 71 ( 0) | 28 (0.1) | 70 |
| Meadow | 2 | 53 (0.7) | 41 (0.6) | 4 (1.0) | 36 (0.5) | 21 (0.6) | 65 |
| Mono | 2 | 51 (0.7) | 5 (0.1) | 37 (0.7) | 98 ( 0) | 4 (1.0) | 50 |
| Morrison | 1 | 32 (0.3) | 14 (0.2) | 49 (0.5) | 15 (0.8) | 22 (0.5) | 45 |
| N Fk Doolittle | 1 | 59 (0.7) | 54 (0.7) | 29 (0.9) | 68 ( 0) | 15 (0.8) | 60 |
| Painter | 1 | 12 (0.1) | 100 (1.0) | 6 (1.0) | 5 (0.9) | 23 (0.5) | 70 |
| Pass | 1 | 52 (0.7) | 21 (0.3) | 43 (0.6) | 10 (0.9) | 67 (0.1) | 50 |
| Ruby | 3 | 11 (0.1) | 20 (0.3) | 45 (0.5) | 54 (0.1) | 20 (0.7) | 25 |
| Sheep (D-3) | 1 | 58 (0.7) | 38 (0.5) | 15 (0.9) | 73 ( 0) | 11 (0.9) | 55 |
| Steel | 1 | 22 (0.1) | 10 (0.2) | 50 (0.4) | 69 ( 0) | 45 (0.1) | 15 |
| Steel | 2 | 69 (0.8) | 24 (0.3) | 31 (0.8) | 80 ( 0) | 10 (0.9) | 55 |
| Teepee | 1 | 45 (0.6) | 49 (0.7) | 73 (0.3) | 80 ( 0) | 10 (0.5) | 40 |
| Tie | 1 | 50 (0.7) | 45 (0.7) | 50 (0.4) | 69 ( 0) | 20 (0.6) | 45 |
| Trail | 2 | 29 (0.2) | 13 (0.2) | 20 (0.9) | 15 (0.8) | 14 (0.8) | 55 |
| W Fk Madison R | 3 | 11 (0.1) | 24 (0.3) | 62 (0.4) | 72 ( 0) | 19 (0.7) | 25 |
| W Fk Ruby R | 1 | 45 (0.6) | 45 (0.7) | 35 (0.7) | 15 (0.8) | 6 (0.9) | 75 |
| Wyman | 1 | 27 (0.2) | 46 (0.7) | 28 (0.9) | 48 (0.2) | 25 (0.3) | 45 |
| Wyman | 2 | 33 (0.3) | 21 (0.3) | 44 (0.6) | 65 ( 0) | 22 (0.5) | 25 |

Table 3.—COWFISH model predicted number of catchable (fish 152 mm and longer) per 300 m of stream length and estimated number of *Oncorhynchus* spp. per 300 m of stream length and associated standard errors (expressed as the percentage of the estimate) for fish 75 to 151 mm and 152 mm and longer.

| Species / Stream | Reach | COWFISH predicted (number per 300 m) | Estimated number of fish per 300 m (SE as percent of estimate): 75 to 151 mm | 152mm and longer |
|---|---|---|---|---|
| **Brook trout** | | | | |
| Bear Wallow | 1 | 4 | 63 ( 6) | 53 ( 0) |
| Bear Wallow | 2 | 14 | 63 ( 6) | 40 ( 3) |
| Bull | 2 | 10 | 37 ( 0) | 23 (51) |
| Cow Cabin | 1 | 9 | 17 (10) | 20 ( 8) |
| Elk | 1 | 4 | 84 ( 3) | 26 ( 0) |
| Gold | 1 | 15 | 10 (24) | 10 ( 0) |
| Governor | 2 | 19 | 55 ( 8) | 156 ( 1) |
| Hunter | 1 | 7 | 87 ( 2) | 13 (15) |
| Jerry | 2 | 4 | 38 ( 4) | 8 ( 0) |
| Johnson (D—3) | 1 | 6 | 68 ( 3) | 52 ( 3) |
| Johnson (D—3) | 2 | 7 | 130 ( 7) | 26 ( 4) |
| Johnson (D—2) | 1 | 2 | 10 ( 0) | 16 ( 0) |
| Joseph | 1 | 6 | 77 ( 8) | 66 ( 2) |
| LaMarche | 2 | 68 | 121 (66) | 112 (17) |
| May | 1 | 6 | 182 ( 2) | 62 ( 1) |
| Morrison | 1 | 10 | 3 ( 0) | 10 ( 0) |
| N Fk Doolittle | 1 | 3 | 12 (38) | 6 (17) |
| Pass | 1 | 13 | 110 ( 2) | 47 ( 0) |
| Ruby | 3 | 4 | 12 (38) | 6 (17) |
| Sheep | 1 | 6 | 27 ( 4) | 22 ( 3) |
| Steel | 1 | 3 | 316 (20) | 73 ( 3) |
| Steel | 2 | 7 | 38 (18) | 14 (23) |
| Tie | 1 | 7 | 16 ( 0) | 50 ( 3) |
| Trail | 2 | 8 | 193 ( 8) | 83 ( 2) |
| Wyman | 1 | 5 | 37 ( 8) | 27 ( 4) |
| Wyman | 2 | 4 | 245 (28) | 157 ( 4) |
| Means | | | 84 (12) | 46 ( 9) |
| ***Oncorhynchus* spp.** | | | | |
| Beaver | 1 | 12 | — | 13 (15) |
| Brown's Canyon | 1 | 28 | 137 ( 4) | 77 ( 3) |
| Burnt | 1 | 12 | 53 ( 0) | 27 ( 0) |
| Coal | 1 | 16 | 44 ( 3) | 36 ( 1) |
| Corral | 2 | 16 | 43 ( 0) | 27 ( 5) |
| Cottonwood | 2 | 20 | 10 ( 0) | 18 ( 0) |
| David | 1 | 4 | 42 (29) | — |
| E Fk Ruby R | 1 | 26 | 2 ( 0) | 32 ( 4) |
| Effie | 1 | 3 | 83 ( 2) | — |
| Elk R | 2 | 6 | — | 6 ( 0) |
| Hunter | 1 | 7 | 10 ( 0) | — |
| Jerry | 2 | 4 | 42 (16) | 16 ( 0) |
| Lost Horse | 2 | 6 | 38 (12) | 26 ( 2) |
| Meadow | 2 | 3 | 18 (18) | 2 ( 0) |
| Mono | 2 | 4 | 22 ( 1) | 9 ( 0) |
| Painter | 1 | 20 | 87 ( 2) | 47 ( 2) |
| Teepee | 1 | 7 | 53 ( 8) | 13 ( 0) |
| W Fk Madison R | 3 | 7 | 14 ( 6) | 14 ( 6) |
| W Fk Ruby R | 1 | 19 | 22 ( 3) | 20 ( 3) |
| Means | | | 38 ( 6) | 21 ( 3) |

Table 4.—Spearman rank correlation coefficients (probability values) between estimated numbers of *Oncorhynchus* spp. or eastern brook trout per 300 m of stream and field data collected for the COWFISH model and the model predictions of optimum and existing numbers of catchable fish per 300 m of stream.

| | Estimated number of *Oncorhynchus* spp. per 300 m | | Estimated number of brook trout per 300 m | |
|---|---|---|---|---|
| COWFISH variables and predictions | 75 to 151 mm | 152 mm and longer | 75 to 151 mm | 152 mm and longer |
| Percentage of streambank undercut | - 0.01 (0.95) | - 0.14 (0.56) | 0.23 (0.25) | 0.08 (0.68) |
| Percentage of streambank with overhanging vegetation | 0.08 (0.73) | 0.33 (0.16) | 0.03 (0.86) | 0.04 (0.84) |
| Percentage alteration | - 0.07 (0.77) | - 0.09 (0.70) | - 0.19 (0.34) | - 0.29 (0.15) |
| Percentage cobble embeddedness | - 0.31 (0.18) | - 0.60 (0.01) | 0.19 (0.35) | 0.03 (0.88) |
| Width:depth ratio | 0.22 (0.36) | - 0.17 (0.47) | 0.21 (0.29) | 0.27 (0.17) |
| Predicted number of potential catchable fish per 300 m | 0.03 (0.88) | 0.67 (0.005) | - 0.07 (0.71) | 0.24 (0.23) |
| Predicted number of existing catchable fish per 300 m | 0.08 (0.74) | 0.80 (0.0007) | - 0.14 (0.47) | 0.16 (0.41) |

Table 5. Regression equations between COWFISH predicted numbers of catchable trout and estimated numbers of subcatchable and catchable *Oncorhynchus* spp. and brook trout.

| Species group<br>Length group | Modifications to equation | Equation | $r^2$ |
|---|---|---|---|
| ***Oncorhynchus* spp.** | | | |
| Catchable | Original equation | y = 1.90x - 1.91 | 0.65 |
| | With zero-intercept | y = 1.79x | 0.64 |
| | Excluding sites with poor applicability to COWFISH | y = 1.97x - 3.28 | 0.64 |
| | Using only sites with excellent applicability | y = 1.84x - 0.77 | 0.61 |
| Subcatchable | Original equation | y = 1.23x + 23.59 | 0.08 |
| **Brook trout** | | | |
| Catchable | Original equation | y = 1.28x + 32.87 | 0.14 |
| | With zero-intercept | y = 0.17x | 0.08 |
| | Excluding sites with poor applicability to COWFISH | y = 1.13x + 38.62 | 0.12 |
| | Using only sites with excellent applicability | y = 1.26x + 33.23 | 0.14 |
| Subcatchable | Original equation | y = 0.06x + 82.71 | 0.00 |

Figure 2.—Simple linear regressions between COWFISH predicted numbers of catchable trout per 300 m and estimated numbers of subcatchable and catchable *Oncorhynchus* spp. and brook trout.

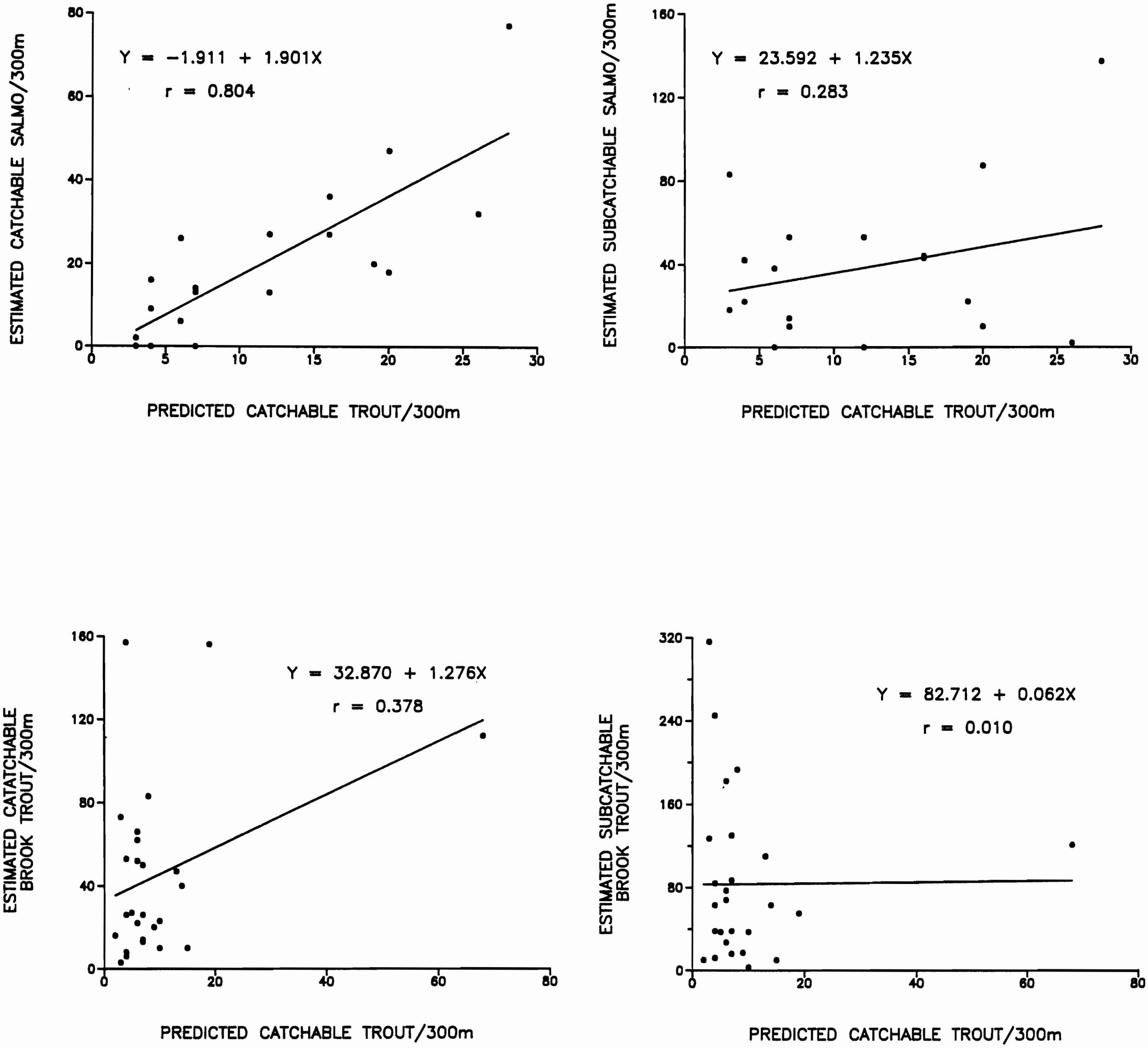
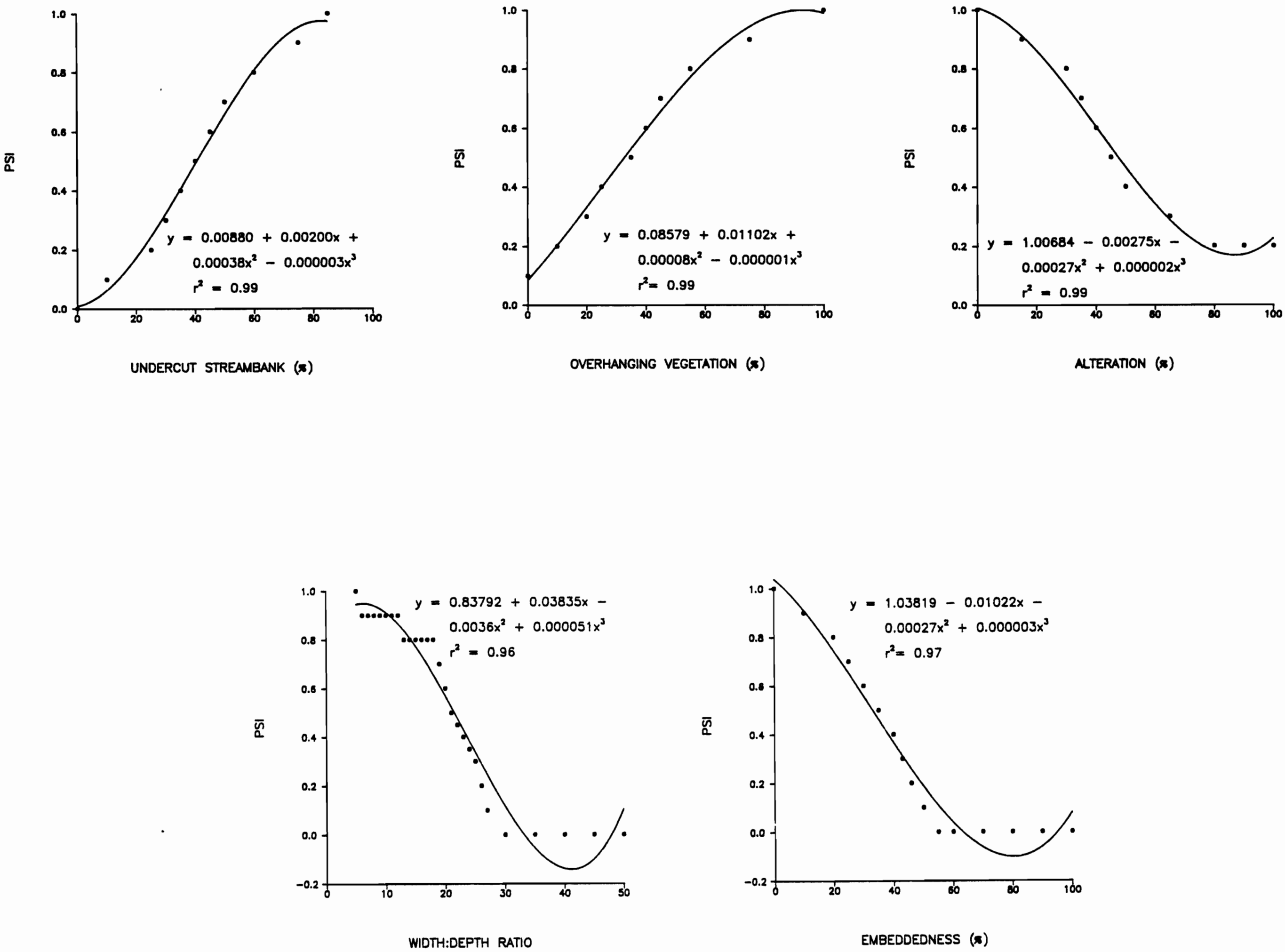


Figure 3.—Curvilinear relationships between actual measured values of percentage of the streambank undercut, percentage of the streambank with overhanging vegetation, percentage of the streambank in an "altered" condition, percentage cobble embeddedness, and width:depth ratio versus parameter suitability indices (PSIs).




that brook trout density was a poor indicator of moderate change in water quality associated with livestock grazing along a small stream in the Black Hills, but changes in density could be used as indicators of physical perturbations within the stream channel. Variables that have been related to brook trout abundance include instream cover, the presence or absence of beaver activity, and the presence of groundwater recharge to the stream channel (Stewart 1970; Fausch and White 1981; Cunjak and Power 1986). These variables have not been included in the model at present.

Predictive equations to convert field data to PSI values improved the performance of the model slightly. This improvement is related to the use of the equations to interpolate between tabled values. It may be possible to further refine the model for use in streams supporting brook trout by substituting different habitat variables assessed; however, the relationships between livestock use and the five variables now being surveyed have been well documented (Platts 1979, 1981a, 1981b; Platts and Raleigh 1982; Hubert et al. 1985; Marlow and Pogacnik 1985; Platts and Nelson 1985a, 1985b; Platts et al. 1985; Stuber 1985; Weltz and Wood 1986). Additional variables affected by livestock grazing that have been shown to influence trout abundance include invertebrate abundance (Rinne and Tharlson 1986), water temperatures (Theurer et al. 1985), and groundwater volume (Groeneveld and Griepentrog 1985). These additional variables would be extremely difficult for range personnel to assess in a simple survey.

The COWFISH model should not be used as a substitute for assessing changes in fish populations by quantitatively sampling those populations. Rather, the COWFISH model, and the survey data needed to use the model, allows for assessing trends in stream habitat condition and emphasizes the importance of maintaining high quality stream habitat to maintain fish resources. It can be used by range management personnel and grazing permittees to illustrate potential impacts of livestock grazing on stream fisheries.

## Acknowledgments

The U. S. Forest Service and the Montana Department of Fish, Wildlife and Parks provided funds that made this research possible. U. S. Forest Service personnel including Don Bartschi, Jim Lloyd, Ron Prichard, Dan Pence, and individuals from the Ranger Districts and Supervisor's Office of the Beaverhead National Forest provided invaluable assistance. Individuals within the Montana Department of Fish, Wildlife, and Parks, especially Jerry Wells and Dick Oswald, provided logistic and technical assistance. Field data were provided by Pete Bengeyfield and Susie Stokke and field personnel under their supervision. Greg Gibbons assisted the author in field data collection. My thanks to the two anonymous reviewers who provided valuable comments and suggestions.


## References


Binns, N. A. 1982. Habitat quality index procedures manual. Wyoming Game and Fish Department, Cheyenne.

Binns, N. A., and F. M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108:215-228.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publication of Statistics 1:131-160.

Cunjak, R. A., and G. Power. 1986. Winter habitat utilization by stream resident brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Science 43:1970-1981.

Fausch, K. D., and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. Canadian Journal of Fisheries and Aquatic Science 38:1220-1227.

Groeneveld, D. P., and T. E. Griepentrog. 1985. Interdependence of groundwater, riparian vegetation, and streambank stability: a case study. Pages 44-48 *in* R. R. Johnson, technical coordinator. Proceedings of the symposium on riparian ecosystems and their management: Reconciling conflicting uses. University of Arizona, Tucson.

Hickman, T., and R. F. Raleigh. 1982. Habitat suitability index models: cutthroat trout. U. S. Fish and Wildlife Service Biological Serviced Program, FWS/OBS-82/10.5.

Hubert, W. A., R. P. Lanka, T. A. Wesche, and F. Stabler. 1985. Grazing management influences on two brook trout streams in Wyoming. Pages 290-294 *in* R. R. Johnson, technical coordinator. Proceedings of the symposium on riparian ecosystems and their management: Reconciling conflicting uses. University of Arizona, Tucson.

Lloyd, J. R. 1986. COWFISH: Habitat capability model. U. S. Forest Service, Northern Region Fish and Wildlife Staff, Fish Habitat Relationship Program, Missoula, Montana.

Marlow, C. B., and T. M. Pogacnik. 1985. Time of grazing and cattle-induced damage to streambanks. Pages 279-284 *in* R. R. Johnson, technical coordinator. Proceedings of the symposium on riparian ecosystems and their management: Reconciling conflicting uses. University of Arizona, Tucson.

Modde, T., H. G. Drewes, and M. A. Rumble. 1986. Effects of watershed alteration on the brook trout population of a small Black Hills stream. Great Basin Naturalist 46:39-45.

Platts, W. S. 1979. Livestock grazing and riparian/stream ecosystems — an overview. Pages 39-45 *in* O. B. Cope, editor. Proceedings of the forum - grazing and riparian/stream ecosystems. Trout Unlimited, Denver.

Platts, W. S. 1981a. Effects of sheep grazing on a riparian-stream environment. U. S. Forest Service, Research Note INT-307.

Platts, W. S. 1981b. Impairment, protection and rehabilitation of Pacific salmonid habitats on sheep and cattle ranges. Pages 82-92 *in* T. J. Hassler, editor. Proceedings: Propagation, enhancement, and rehabilitation of anadromous salmonid populations and habitat in the Pacific Northwest. Humboldt State University, Arcata, California.

Platts, W. S., K. A. Gebhardt, and W. L. Jackson. 1985. The effects of large storm events on basin-range riparian stream habitats. Pages 30-34 *in* R. R. Johnson, technical coordinator. Proceedings of the symposium on riparian ecosystems and their management: Reconciling conflicting uses. University of Arizona, Tucson.

Platts, W. S., and R. L. Nelson. 1985a. Impacts of rest-rotation grazing on stream banks in forested watersheds in Idaho. North American Journal of Fisheries Management 5:547-556.

Platts, W. S., and R. L. Nelson. 1985b. Stream habitat and fisheries response to livestock grazing and instream improvement structures, Big Creek, Utah. Journal of Soil and Water Conservation 40:374-379.

Platts, W. S., and R. F. Raleigh. 1979. Impacts of grazing on wetlands and riparian habitat. Pages 1105-1117 *in* Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management, Westview Press, Boulder, Colorado.

Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. U. S. Department of Interior, Fish and Wildlife Service Biological Services Program, FWS/OBS-82/10.60.

Rinne, J. N., and T. Tharlson. 1986. Effects of domestic livestock grazing on montane streams: Aquatic macroinvertebrates. Proceedings of the Western Association of Fish and Wildlife Agencies 65:91-98.

Scarnecchia D. L., and E. P. Bergersen. 1987. Trout production and standing crop in Colorado's small streams, as related to environmental features. North American Journal of Fisheries Management 7:315-330.

Stewart, P. A. 1970. Physical factors influencing trout density in a small stream. Doctoral dissertation. Colorado State University, Fort Collins, Colorado.

STSC (Statiscal Graphic Corp.). 1986. STATGRAFICS User's Guide. STSC Inc., Rockville, Maryland.

Stuber, R. J. 1985. Trout habitat, abundance, and fishing opportunities in fenced vs [sic] unfenced riparian habitat along Sheep Creek, Colorado. Pages 310-314 *in* R. R. Johnson, technical coordinator. Proceedings of the symposium on riparian ecosystems and their management: Reconciling conflicting uses. University of Arizona, Tucson.

Theurer, F. D., I. Lines, and T. Nelson. 1985. Interaction between riparian vegetation, water temperature, and salmonid habitat in the Tucannon River. Water Resources Bulletin 21:53-64.

Van Deventer, J. S., and W. S. Platts. 1985. A computer software system for entering, managing, and analyzing fish capture data from streams. U. S. Forest Service, Research Note INT-352.
Weltz, M., and M. K. Wood. 1986. Short-duration grazing in central New Mexico: effects on sediment production. Journal of Soil and Water Conservation.
Zar, J. H. 1984. Biostatistical analysis. 2nd edition. Prentice-Hall, Incorporated, Englewood Cliffs, New Jersey.