HQI

Box 342
Lander, Wyoming 82520
26 November 1986

Mr. Jim Chadwick
Chadwick and Associates
5721 South Spotswood Street
Littleton, Colorado 80120

Dear Jim:

With respect to the Habitat Qual[illegible] reported for the San Miguel River by Geotr[illegible] reviewed the available information and con[illegible] the HQI method as specified in my HQI Proc[illegible]

First, I agree with your contenti[illegible] brook trout standing crop values are un[illegible] River stations 1-6, their HQI evaluati[illegible] greater than 100 kg/ha at three of the si[illegible] predicted for SMR-6 is certainly possible [illegible] found in natural fishery systems, but such a fishery is highly improbable given the type of habitat represented by the San Miguel River. In my experience, highly productive brook trout fisheries in the Rocky Mountains are often found in small streams containing at least some beaver ponds, which help the fish survive the often harsh winter conditions found in these streams.

When I examined my records for some productive brook trout streams in the Pole Mountain-Snowy Range area in southeast Wyoming, I found a peak standing crop of 251 kg/ha and this was in a very small meadow type stream. Of the 44 streams examined for development of the HQI model, only two (4.5%) had standing crops greater than 200 kg/ha. Both streams were brown trout fisheries. In my professional judgement, a stream with a brook trout standing crop of 359 kg/ha would be a rarity and would probably rank in the top 5%, or so, of Rocky Mountain trout streams. For a stream with the size and habitat characteristics of the San Miguel River, I would expect a standing crop less than 100 kg/ha. Even so, this would qualify the fishery as one of the more productive at its elevation. Sunlight Creek, a tributary of the Clarks Fork River in northwest Wyoming appears to be approximately similar in size and character to the San Miguel River. At an elevation of 6,800 feet, the standing crop of brook trout is about 47 kg/ha; above elevation 7,200 feet, the stream is essentially barren of trout due to severe winter conditions.

Here's the chronological compilation of Binns (HQI) information. Binns' original calculations changed as a result of a misunderstanding concerning nitrate values. You probably know what we think of using the HQI — this way, regardless.

HQI

Box 342
Lander, Wyoming 82520
26 November 1986

Mr. Jim Chadwick
Chadwick and Associates
5721 South Spotswood Street
Littleton, Colorado 80120

Dear Jim:

With respect to the Habitat Quality Index (HQI) evaluations reported for the San Miguel River by Geotrans et al. (1986), I have reviewed the available information and conclude that they did not apply the HQI method as specified in my HQI Procedures Manual (Binns 1982).

First, I agree with your contention that some of their predicted brook trout standing crop values are unusually high. For San Miguel River stations 1-6, their HQI evaluations predicted standing crops greater than 100 kg/ha at three of the six stations. The 359 kg/ha predicted for SMR-6 is certainly possible given the variation found in natural fishery systems, but such a fishery is highly improbable given the type of habitat represented by the San Miguel River. In my experience, highly productive brook trout fisheries in the Rocky Mountains are often found in small streams containing at least some beaver ponds, which help the fish survive the often harsh winter conditions found in these streams.

When I examined my records for some productive brook trout streams in the Pole Mountain-Snowy Range area in southeast Wyoming, I found a peak standing crop of 251 kg/ha and this was in a very small meadow type stream. Of the 44 streams examined for development of the HQI model, only two (4.5%) had standing crops greater than 200 kg/ha. Both streams were brown trout fisheries. In my professional judgement, a stream with a brook trout standing crop of 359 kg/ha would be a rarity and would probably rank in the top 5%, or so, of Rocky Mountain trout streams. For a stream with the size and habitat characteristics of the San Miguel River, I would expect a standing crop less than 100 kg/ha. Even so, this would qualify the fishery as one of the more productive at its elevation. Sunlight Creek, a tributary of the Clarks Fork River in northwest Wyoming appears to be approximately similar in size and character to the San Miguel River. At an elevation of 6,800 feet, the standing crop of brook trout is about 47 kg/ha; above elevation 7,200 feet, the stream is essentially barren of trout due to severe winter conditions.

All of the above made me wonder if the HQI method was incorrectly applied to the San Miguel River study. To check for this possibility, I examined, in detail, the color photographs of study stations SMR-1 through 6, the data in the June, 1986 Chadwick and Associates report, and the data used to calculate the HQI attribute ratings for the Geotrans report. I then selected my own attribute ratings for each station, calculated HQI scores for each station, and then compared my attribute ratings and HQI scores with the Geotrans results. While this lab exercise can not take the place of actual, on-site measurements made during the late summer period specified for HQI evaluations, I feel this approach is sufficiently accurate to allow assessment of the Geotrans results.

When my ratings and HQI scores are compared with the Geotrans results, there are some surprising differences. For one thing, my HQI scores are all quite a bit lower than theirs. At Station SMR-6, my predicted standing crop of 49 Kg/ha is close to the measured standing crop of 38 Kg/ha, but is far below their predicted 359 Kg/ha value. My attribute ratings were different in 44% of the cases and most of my ratings were lower than theirs. Note that I used the cover, water velocity and eroding stream bank ratings reported by Geotrans because I did not have other, reliable data. Otherwise, the percentage of attribute changes may well have been higher.

I believe the HQI evaluations and predictions reported by the Geotrans report are faulty because: 1) they did not follow the procedures specified for the HQI method in my procedures manual, and 2) they evidently used incorrect or inaccurate data. The HQI model is no different than any other model in that its output can be no better than the quality of the data put into it.

I conclude that the San Miguel River HQI evaluations reported by Geotrans are flawed as follows:

1) The Late Summer Stream Flow attrtibute was incorrectly rated at all stations. A "4" rating, as was used in the Geotrans report, is generally applied only to streams with stable and plentiful water flow, especially during late summer. These are almost always spring-fed, steady-state type systems. The color photos clearly show that the San Miguel River does not meet the criteria for a "4" rating at any of the stations.

2) The Annual Flow Variation attribute was incorrectly rated at some stations. Again, the color photos showing flow at different seasons document the flow pattern, as well as the ratings that I feel should have been used.

3) For the calculations in my comparison, I used the ratings in the Geotrans report for the Cover and Eroding Stream Bank

attributes. However, since they did not measure either attribute as specified in the HQI Procedures Manual, I have deep reservations about how accurate their ratings are.

4) The HQI Procedures Manual specifies that water velocity is to be measured with fluorescent dye to obtain a time-of-travel velocity estimate. Velocity measured by any other method, as was done by Geotrans, is not necessarily the same as the time-of-travel velocity because the latter measures velocity along the thalweg line and is probably higher than the mean velocity for a section. Thus, the Geotrans water velocity attribute ratings may also be inaccurate.

5) Nitrogen in streams is reported in several ways, depending on the needs of the investigator and the analytical technique used to determine the nitrogen concentration. The HQI rating table for this attribute is based on nitrogen concentrations reported as nitrate nitrogen, which is the output of the standard analytical technique in use at the time the HQI method was developed. Nitrate nitrogen concentrations are not the same as straight nitrate concentrations, and are always lower than straight nitrate values. Thus, using straight nitrate concentrations, without converting to nitrate nitrogen concentration, will produce erroneous ratings for this attribute. The vast majority of Rocky Mountain streams have very low nitrate nitrogen content; thus, the relatively high values used by Geotrans to rate this attribute make me strongly suspect that the reported nitrate values are straight nitrate, rather than nitrate nitrogen. If this is indeed the case (you might check with the analytical lab to see if it is so), then the Geotrans ratings for the nitrate attribute are way too high.

6) For best results, the HQI method should be used only in the specified late summer period, which is during August and the first half of September. Use outside of this period can provide valuable information on a stream, but natural variation in physical and ecological processes may produce errors in standing crop values predicted by the model because one of the basic assumptions of the model has been violated.

I strongly recommend that, if time permits, the San Miguel River stations be properly re-evaluated, using correct HQI methodology, during late August, 1987. This re-evaluation will resolve the questions that now exist about the Geotrans HQI evaluations and will permit a better assessment of the river's fishery potential.

If time does not permit delaying an HQI re-evaluation until next summer, then I recommend that HQI measurements should be collected this fall to help answer the questions about cover, eroding stream banks and water velocity, as well as the two flow attributes. While such work would be outside the specified time period noted above, actual, on-site measurements made this fall would do much to help dispel the present confusion generated by the apparently incorrect Geotrans HQI evaluations.

If you have any further questions, or need additional assistance, please let me know.

Sincerely,

N. Allen Binns

Dr. N. Allen Binns

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[1986]

HABITAT QUALITY INDEX

EVALUATIONS MADE

ON THE

SAN MIGUEL RIVER

NEAR TELLURIDE, COLORADO

REPORT BY

N. ALLEN BINNS, Ph.D.

December 15, 1986

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INTRODUCTION

The State of Colorado has brought legal action against the Idarado Mining Company claiming damage to the brook trout fishery, and other aquatic life, in the San Miguel River by mining activities at the Idarado mine near Telluride, Colorado (Chadwick & Associates, 1986). Various technical fishery and fish habitat data were collected by ecological consultants retained to gather information that could be used to assess this claim (Chadwick & Associates 1986; Geotrans et al. 1986). As part of these investigative activities, the Habitat Quality Index (HQI) of Binns and Eiserman (1979) was used to predict brook trout abundance at several sites on the San Miguel River. The HQI predicted values were assumed to represent the potential brook trout population that the river habitat was capable of supporting. The HQI values were then compared with trout population estimates obtained by electrofishing to support the claim that the trout population was at a low level due to metal pollution from the past mining activity.

During the fall of 1986, I was contacted by Chadwick & Associates, who asked me to review the HQI evaluations reported for the upper San Miguel River by Geotrans et al. (1986) (hereafter referred to as Geotrans). This report presents the results of my review.

METHODS

Chadwick & Associates furnished pertinent data, reports and color photos of six sample stations on the upper San Miguel River. This information on the brook trout fishery and the fish habitat of the stream had been collected at different seasons in 1985. I used this information to review the HQI evaluations reported by Geotrans and concluded that there was reason to believe the predicted brook trout abundance figures were incorrect. I drew this conclusion mostly because some of the habitat attributes used in the HQI model were apparently not measured or rated as specified in the HQI Procedures Manual (Binns 1982). However, no firm conclusion could be drawn without actually remeasuring the questionable attributes at the stream.

Subsequently, Chadwick & Associates arranged for HQI measurements to be collected in early December, 1986 from five of the six stations on the river. Only station SMR-1 could not be worked due to snow and ice cover. Although there was some snow cover on the stream banks, the other stations were essentially ice-free and the HQI attributes could be readily measured. I participated in this effort to insure that the HQI data was collected as specified in the HQI Procedures Manual. I then used my own observations and the HQI data from the December, 1986 visit to the river, as well as the data and photos collected in 1985, to assign my own ratings to each habitat attribute used in the HQI model. HQI Model II was used to calculate a predicted brook trout standing crop at each study station, and the results were compared with those reported by Geotrans.

RESULTS AND DISCUSSION

The HQI method was primarily developed as a trout habitat evaluation tool, but due to the nature of the statistical approach used to develop the model, the HQI can also be used to predict trout standing crop (Binns and Eiserman 1979, Binns 1979, Binns 1982). Predicting trout abundance in streams is a common use of the HQI (Remmick 1982, Bowlby and Roff 1986), but the method has also been used to assess the impact of changing habitat conditions on trout. The impact of a proposed transbasin water diversion project on a cutthroat trout population in the Sierra Madre Mountains in southern Wyoming was evaluated with the HQI (Binns 1977). The HQI has been successfully used in assessing the impact of proposed reservoir construction, and in negotiating mitigation measures (Conder and Binns 1986). Not only has the HQI been used to predict habitat improvement potential (Binns 1979), but it can provide objective evaluation of stream habitat improvement efforts (Stuber 1986, Binns 1986).

Thus, using the HQI to predict the potential brook trout standing crop that could be supported by habitat conditions in the San Miguel River is an acceptable procedure. The key question is if the HQI ratings were correctly assigned during the evaluations reported by Geotrans. The HQI model is no different than any other predictive model in that its output can be no better than the quality of the data inserted into it. Incorrect ratings will lead to inaccurate predictions of trout standing crop.

TROUT STANDING CROP

A comparison of trout standing crop estimates obtained in 1985 from the San Miguel River and the HQI predicted values obtained from the December, 1986 visit are presented in Table 1. With one exception, the December, 1986 HQI predictions of brook trout abundance were reasonably close to the estimated abundance obtained by electrofishing in 1985. The lone exception was station SMR-6, where brook trout abundance was overestimated.

At SMR-6, the observed standing crop was 37.9 kg/ha compared to a predicted value of 102.0 kg/ha, an overestimate of 64.1 kg/ha. I do not feel that this is a serious difference as I have encountered similar or larger predictive differences in past HQI evaluations on other streams. The point should be made that the multiple regression method used to develop the HQI model is basically an averaging technique - a complicated technique to be sure, but still working to average the data input. What this means is that not all predicted values will be that same as the measured values. Examination of Figures 1 and 2 in Binns (1979) will show that not all of the values coincide.

A second possible explanation for the difference at SMR-6 is simple sample variation. The estimated standing crop measured in 1985 is exactly that, an estimate. Additional samples taken at other times would very likely produce different figures.

A third, and very plausible, explanation for the difference in predicted and observed values is that the predicted figure does indeed represent the potential trout abundance, and the trout population is being stressed, and reduced to the observed level, by some limiting factor of the habitat that is not measured by the HQI. Visual examination of the stream bottom at SMR-6 is all that is needed to document the severe siltation that exists there. Since the detrimental effects of silt pollution on trout are well documented in the fishery literature, there is a very real possiblity that the brook trout population is being held below its potential by that limiting factor. Since much of the silt appears to be coming from the severe stream bank erosion that is occurring near SMR-5, stabilization of eroding banks in that area would undoubtly do much to increase trout abundance at SMR-6. Of course, stress from metal pollution could also be a factor, but a detailed chemical examination of stream sediments, water quality and trout flesh would be needed to verify that impact. Such is beyond the scope of this report.

The predicted and observed standing crop at station SMR-4 was underestimated by 17.4 Kg/ha, while at the other three sites, the difference was less than 11 Kg/ ha (Table 1). All of these values are within expected limits of the HQI method.

The December, 1986 HQI predicted standing crop values were all less than those reported for the San Miguel River stations by Geotrans. Predicted trout abundance was considerably lower at sites SMR-3 through 6, with SMR-6 showing the greatest reduction. These differences are due to changes in the ratings assigned to several HQI attributes.

HQI HABITAT ATTRIBUTES

The ratings assigned to habitat attributes in the HQI evaluation work are presented in Table 2 and Appendix I. Examination of the table shows that I changed 25 of the 45 Geotrans ratings (56%). Each attribute will be discussed below to point out rating differences or similarities.

Late Summer Stream Flow - This important flow attribute was rated a "4" at all stations by Geotrans. Examination of the limited stream flow records available for the San Miguel River downstream from Telluride during 1959-65 (six years) indicates that late summer flow is 84% of average daily discharge. This figure is well within the specifications for a "4" rating, as set out in the HQI Procedures Manual, and this attribute appears, at first glance, to have been rated correctly.

However, examination of the stream flow conditions that exist in late summer on this river, as documented by color photos taken for all stations in August and September, 1985, indicates that a "4" rating is too high. A "4" rating represents the best type of stream habitat and is assigned only to streams with stable and plentiful water flow, especially during late summer. These streams have a consistent, bank-to-bank flow and are almost always, in the Rocky Mountains, spring-fed, steady-state type systems with relatively little variation in the flow regime.

The color photos clearly show that the San Miguel River does not have the characteristics that I would expect from a "4" rated stream. Rather, I feel that late summer stream flow conditions are better represented by a "2" rating at SMR-2-4, and by a "3" rating at SMR-6.

Since the HQI Procedures Manual states that the late summer flow attribute is better rated with gage station records than from visual observation, the question can quite rightfully be raised as to why I disregarded the water flow records when rating the lower two stations. As noted above, the existing late summer flow conditions do not support the "4" rating that is indicated by the gage records. Perhaps the gage records are skewed by the short period of record and a year or two of exceptional stream discharge in this drainage. This type of situation is discussed on pages 24-25 of the procedures manual, and an example is given showing how an erroneous rating would result from the use of gage records skewed by abnormally wet or dry years. The manual urges caution when using gage records; such should not be used without checking to see if the gage records do represent actual conditions.

Annual Stream Flow Variation - The mean ASFV Ratio calculated for the San Miguel River gage was 37 during 1959-65, which meets the criteria for a "3" rating. After rating the late summer flow attribute, I did not feel the gage accurately reflected flow conditions in the river, as discussed above, and disregarded the gage data when making my ratings. I felt that the color photos taken at various seasons, and my own observations made in December, 1986, were better indicators as to proper ratings. My ratings differred from those reported by Geotrans at stations SMR-3 and SMR-6, and were lower in both cases. At SMR-3, water flows become very low during late winter, evidently because water flow sinks into the stream bed, and the stream in this section could almost be classed as intermittent in character, which is a "0" rating. However, I gave this site the benefit of the doubt and rated it a "1".

Temperature - Both Geotrans and I used the temperature data supplied by Water, Waste and Land, Inc (WWL). Our ratings are the same, except at SMR-6, where the 4.1C reported by WWL appeared to be erroneous because it was exceedingly low. Since stream temperature in the river generally increased with progression downstream, I assumed that the river at SMR-6 would warm up to the 18-21C range, a "3" rating.

Nitrate Nitrogen - Ratings assigned to this attribute by Geotrans were completely erroneous because they apparently based their ratings on total nitrate concentration rather than on nitrate nitrogen concentration. Since the HQI rating table for this attribute is based on nitrate nitrogen, using total nitrate concentrations, without converting to nitrate nitrogen (as dicussed on page 53 of the HQI Procedures Manual) will produce attribute rates that are too high.

Cover - The HQI Procedures Manual specifies in detail how the cover attribute is to be measured. This can be a difficult attribute to measure because it requires a knowledge of where trout live in streams, and what provides shelter (cover) for them. For HQI purposes, each patch of cover (undercut bank, deep pool, or whatever) is measured directly to obtain the square feet of cover available there. Measurements for all cover are later summed and divided by the total stream area in the study section to get percent cover, which is the entry parameter into the rating table. Geotrans reportedly measured cover by taking the percent of linear bank (both sides) providing cover, which was estimated by the observer. This procedure led to an erroneous rating value at SMR-6. Cover for trout at the other sites was so poor that the incorrect procedure did not cause any problems there.

Eroding Stream Banks - For proper use of the HQI method, each eroding stream bank must be identified and measured. The total footage of eroding banks for the study site is divided by total station length to get percent eroding banks, which is the entry parameter into the rating table. My ratings for this attribute differ from those of Geotrans at four of the five sites. Geotrans reportedly also estimated this variable during electro fishing activities.

Substrate (Fish Food) - My ratings for this attribute differed from those of Geotrans at three of the five sites. They reportedly rated the attribute from aquatic vegetation abundance on the stream bottom, which is acceptable procedure according to the HQI Procedures Manual. However, the manual urges caution in applying this approach because not all streams have a clear relationship between aquatic vegetation abundance and fish food abundance. I no longer use this technique because of this problem, and prefer instead to rate a stream from actual samples of the fish food population. I rated the San Miguel River statons from actual samples of fish food collected from the stream by Chadwick & Associates.

Velocity - The accepted procedure for measuring water velocity for an HQI evaluation is to inject a slug of fluorescent dye into the stream and time its passage through the study section. The dye method was incorporated into the HQI to give a quick, easy-to-use technique for measuring water velocity. This method gives a time-of-travel velocity, in feet per second, along the thalweg, which is the line of deepest flow. Since flow along the thalweg is often the line of swiftest flow, the velocity figure produced by the dye measurement is often higher than the velocity estimate obtained by other methods. My ratings differed from those of Geotrans at all five study sites. They reportedly did not use dye to measure velocity, but rather calculated a surface velocity from instream flow measurements made by Chadwick & Associates. Their method is in error in two respects: first, they did not use dye to obtain time-of-travel velocity, and second, they used an estimate of the surface velocity. This is incorrect because the dye spreads all through the water column, as illustrated on page 70 of the HQI Procedures Manual.

Width - My ratings for the width attribute were the same as Geotrans at all stations.

CONCLUSIONS AND RECOMMENDATIONS

The information developed by the HQI measurements obtained in December, 1986 lead me to conclude that the HQI evaluations reported by Geotrans are faulty, mostly because they did not follow the correct procedures as specified in the HQI Procedures Manual.

However, the December work violated one important assumption of the HQI method. For best results, the procedures manual recommends that the HQI measurements be obtained during the late summer period. This period is specified as the month of August and the first half of September, and is when the original HQI measurements were collected during development of the model. Another reason for specifying data collection during this time period is to avoid, as much as possible, the natural variation in abundance inherent in wild populations of aquatic organisms as they respond to seasonal changes in habitat conditions.

While HQI measurements can be collected during times other than the specified late summer period, due caution must be exercised when interpreting the results, and the person doing the evaluation must keep in mind that the results may be skewed or biased by seasonal variation.

Regarding the December HQI evaluations on the San Miguel River, I feel that the work was valuable in that it gave good, on-site information that could be used to assess the validity of the HQI evaluations reported by Geotrans. However, because the work in December was outside the specified time period, not all questions raised by the Geotrans evaluation can be answered with total assurance. For example, water flows are likely different in late summer, as opposed to late fall or early winter, meaning that cover and velocity may be different. Also, judging some eroding banks was difficult at a few places because of snow cover on the stream banks in December.

Accordingly, I strongly recommend that, if time permits, the San Miguel River study stations be re-evaluated, using correct HQI methodology, during the late summer of 1987. This re-evaluation will do much to definitely resolve the questions that now exist about the HQI evaluations reported by Geotrans.

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Table 1. Comparison of observed and predicted standing crop of brook trout in the San Miguel River near Telluride, Colorado. HQI measurements collected on 12/4-5/86 were used to calculate predicted values. Values in parenthesis are those reported by Geotrans et al. 1986.

	TROUT STANDING CROP (kg/ha)		
STATION	OBSERVED	PREDICTED	DIFFERENCE
SMR-2	0.0	10.7 (19.8)	+10.7 (+19.8)
SMR-3	6.5	7.1 (39.0)	+0.6 (+32.5)
SMR-4	69.9	52.4 (114.7)	-17.5 (+44.8)
SMR-5	64.7	74.4 (135.3)	+9.7 (+70.6)
SMR-6	37.9	102.0 (359.3)	+64.1 (321.4)

Table 2. Habitat attribute ratings for the San Miguel River near Telluride, Colorado as determined from HQI measurements collected December 5, 1986. Values reported by Geotrans et al. 1986 are shown in parenthesis.

Station	CPSF	ASFV	Temp	NO_3	Cover	Eroding Banks	Substrate	Velocity	Width
	Habitat Attribute Ratings [1]								
SMR-2	2 (4)	2 (2)	2 (2)	1 (4)	0 (0)	3 (4)	1 (1)	3 (1)	3 (3)
SMR-3	2 (4)	1 (3)	2 (2)	1 (4)	0 (0)	1 (4)	1 (1)	3 (2)	3 (3)
SMR-4	2 (4)	2 (2)	3 (3)	2 (4)	1 (1)	2 (4)	2 (1)	2 (3)	3 (3)
SMR-5	2 (4)	2 (2)	4 (4)	2 (4)	0 (0)	0 (0)	3 (2)	3 (2)	3 (3)
SMR-6	3 (4)	2 (3)	3 (4)	2 (4)	1 (2)	2 (2)	2 (3)	4 (2)	3 (3)

[1] CPSF = Late summer stream flow; ASFV = Annual stream flow variation; Temp = Maximum water temperature; NO_3 = Nitrate nitrogen.

APPENDIX 1a. HQI ratings at Station SMR-2.

HABITAT QUALITY INDEX ATTRIBUTE RATING SHEET

STREAM: San Miguel River STATION: SMR-2
DATE DATA COLLECTED: 12/5/86 HQI SCORE: 10.7 kg/ha

ATTRIBUTE	DATA	RATING
Late Summer Stream Flow (CPSF)	No gage; rated from field visit & from color photos taken in 1985.	2
Annual Stream Flow Variation	No gage; rated from field visit & from photos.	2
Maximum Summer Stream Temperature	Rated from Chadwick & Assoc. records max = 9.4C	2
Nitrate Nitrogen	Rated from Chadwick & Assoc. records conc. = 0.034 mg/l	1
Cover	Rated from measurements made 12/5/86 cover = 4.0% of total area.	0
Eroding Stream Banks	Rated from measurements made 12/5/86 eroding banks = 17%	3
Substrate	Rated from Chadwick & Assoc. records fish food = 86 organisms per ft^2	1
Water Velocity	Rated from measurements made 12/5/86 velocity = 39.3 cm/sec	3
Stream Width	Rated from measurements made 12/5/86 width = 4.93 m	3

$X_1 + 1 = 3$ F + 1 = 2(1)(1)(3) = 7
X2 + 1 = 3 S + 1 = 0(3)(3) = 1
X3 + 1 = 3

HQI Score = (-0.903)+(0.807)log10(3)+(0.877)log10(3)+(1.233)log10(3)
+(0.631)log10(7)+(0.182)log10(1)
= 9.52 kg/ha

APPENDIX 1b. HQI ratings at Station SMR-3.

HABITAT QUALITY INDEX ATTRIBUTE RATING SHEET

STREAM: San Miguel River STATION: SMR-3
DATE DATA COLLECTED: 12/5/86 HQI SCORE: 7.14 kg/ha

ATTRIBUTE	DATA	RATING
Late Summer Stream Flow (CPSF)	No gage; rated from field visit & from color photos taken in 1985.	2
Annual Stream Flow Variation	No gage; rated from field visit & from photos. Water flow is very low in mid-winter, when stream is essentially dry in spots - a zero rating might be more appropriate.	1
Maximum Summer Stream Temperature	Rated from Chadwick & Assoc. records max = 9.7C	2
Nitrate Nitrogen	Rated from Chadwick & Assoc. records conc. = 0.045 mg/l	1
Cover	Rated from measurements made 12/5/86 cover = 2.6% of total area.	0
Eroding Stream Banks	Rated from measurements made 12/5/86 eroding banks = 61.3%	1
Substrate	Rated from Chadwick & Assoc. records fish food = 40 organisms per ft^2	1
Water Velocity	Rated from measurements made 12/5/86 velocity = 35.0 cm/sec	3
Stream Width	Rated from measurements made 12/5/86 width = 4.92 m	3

$X_1 + 1 = 3$ $F + 1 = 2(1)(1)(3) = 7$
$X2 + 1 = 2$ $S + 1 = 0(1)(3) = 1$
$X3 + 1 = 3$

HQI Score = (-0.903)+(0.807)log10(3)+(0.877)log10(2)+(1.233)log10(3)
+(0.631)log10(7)+(0.182)log10(1)
= 7.14 kg/ha

APPENDIX 1c. HQI ratings at Station SMR-4.

HABITAT QUALITY INDEX ATTRIBUTE RATING SHEET

STREAM: San Miguel River STATION: SMR-4
DATE DATA COLLECTED: 12/5/86 HQI SCORE: 52.36 kg/ha

ATTRIBUTE	DATA	RATING
Late Summer Stream Flow (CPSF)	No gage; rated from field visit & from color photos taken in 1985.	2
Annual Stream Flow Variation	No gage; rated from field visit & from photos.	2
Maximum Summer Stream Temperature	Rated from Chadwick & Assoc. records max = 11.2C	3
Nitrate Nitrogen	Rated from Chadwick & Assoc. records conc. = 0.05 mg/l	2
Cover	Rated from measurements made 12/5/86 cover = 10.7% of total area.	1
Eroding Stream Banks	Rated from measurements made 12/5/86 eroding banks = 45.3%	2
Substrate	Rated from Chadwick & Assoc. records fish food = 86 organisms per ft^2	1
Water Velocity	Rated from measurements made 12/5/86 velocity = 22.9 cm/sec	2
Stream Width	Rated from measurements made 12/5/86 width = 8.72 m	3

$X_1 + 1 = 3$ $F + 1 = 3(2)(2)(2) = 25$
$X2 + 1 = 3$ $S + 1 = 1(2)(3) = 7$
$X3 + 1 = 4$

$$\text{HQI Score} = (-0.903)+(0.807)\log10(3)+(0.877)\log10(3)+(1.233)\log10(4)+(0.631)\log10(25)+(0.182)\log10(7) = 52.36\ \text{kg/ha}$$

APPENDIX 1d. HQI ratings at Station SMR-5.

HABITAT QUALITY INDEX ATTRIBUTE RATING SHEET

STREAM: San Miguel River — STATION: SMR-5
DATE DATA COLLECTED: 12/5/86 — HQI SCORE: 74.44 kg/ha

ATTRIBUTE	DATA	RATING
Late Summer Stream Flow (CPSF)	6 yrs. gage records - CPSF = 84% - "4"; HOWEVER, CPSF rated "2" from field visit & photos taken in 1985 and a "4" rating appears to be too high. Perhaps the gage records are skewed by the short period of record and a wet year or two.	2
Annual Stream Flow Variation	Rated from field visit & photos - see remarks under CPSF. (6 yrs. gage records, ASFV Ratio =37, "3" rating.	2
Maximum Summer Stream Temperature	Rated from Chadwick & Assoc. records max = 13.0C	4
Nitrate Nitrogen	Rated from Chadwick & Assoc. records conc. = 0.054 mg/l	2
Cover	Rated from measurements made 12/5/86 cover = 8.4% of total area.	0
Eroding Stream Banks	Rated from measurements made 12/5/86 eroding banks = 100 %	0
Substrate	Rated from Chadwick & Assoc. records fish food = 290 organisms per ft^2	3
Water Velocity	Rated from measurements made 12/5/86 velocity = 39.0 cm/sec	3
Stream Width	Rated from measurements made 12/5/86 width = 8.75 m	3

$X_1 + 1 = 3$ — $F + 1 = 4(2)(3)(3) = 49$
$X2 + 1 = 3$ — $S + 1 = 0(0)(3) = 1$
$X3 + 1 = 5$

$$\text{HQI Score} = (-0.903)+(0.807)\log10(3)+(0.877)\log10(3)+(1.233)\log10(5)+(0.631)\log10(49)+(0.182)\log10(1) = 74.44 \text{ kg/ha}$$

APPENDIX 1e. HQI ratings at Station SMR-6.

HABITAT QUALITY INDEX ATTRIBUTE RATING SHEET

STREAM: San Miguel River STATION: SMR-6
DATE DATA COLLECTED: 12/4/86 HQI SCORE: 102.02 kg/ha

ATTRIBUTE	DATA	RATING
Late Summer Stream Flow (CPSF)	6 yrs. gage records - CPSF = 84% - "4"; HOWEVER, CPSF rated "2" from field visit & photos taken in 1985 and a "4" rating appears to be too high. Perhaps the gage records are skewed by the short period of record and a wet year or two.	3
Annual Stream Flow Variation	Rated from field visit & photos - see remarks under CPSF. (6 yrs. gage records, ASFV Ratio =37, "3" rating.	2
Maximum Summer Stream Temperature	Recorded max. temp. 4.1C appears to be erroneous; assume 18-21C range	3
Nitrate Nitrogen	Rated from Chadwick & Assoc. records conc. = 0.054 mg/l	2
Cover	Rated from measurements made 12/5/86 cover = 10.02% of total area.	1
Eroding Stream Banks	Rated from measurements made 12/5/86 eroding banks = 36.3%	2
Substrate	Rated from Chadwick & Assoc. records fish food = 118 organisms per ft^2	2
Water Velocity	Rated from measurements made 12/5/86 velocity = 61.3 cm/sec	4
Stream Width	Rated from measurements made 12/5/86 width = 10.27 m	3

$X_1 + 1 = 4$ $F + 1 = 3(2)(2)(4) = 49$
$X2 + 1 = 3$ $S + 1 = 1(2)(3) = 7$
$X3 + 1 = 4$

$$\text{HQI Score} = (-0.903)+(0.807)\log10(4)+(0.877)\log10(3)+(1.233)\log10(4)+(0.631)\log10(49)+(0.182)\log10(7)$$
$$= 102.02 \text{ Kg/ha}$$

THE STATE OF WYOMING

MIKE SULLIVAN
GOVERNOR

Game and Fish Department

BILL MORRIS
DIRECTOR

October 11, 1987

Steve Canton
Chadwick and Associates
5721 S Spotswood
Littleton, Co 80120

Steve,

You asked me to comment about my views on the use of the HQI model (Habitat Quality Index) as a predictive tool. As I expressed over the phone, I feel the model has limited use to predict fish standing crops in a stream. After doing numerous HQI`s and electrofishing population estimates at the same stream station I found too much variation to make the model a stand alone estimator. This was particularly true in small, high elevation streams where limiting factors occur (eg. winter ice conditions or high spring time runoff) that are not measured by the HQI. Data from these same streams were never used in the development of the model which could help explain why there is seldom correlation between what is actually there and what the HQI says should be there. I have enclosed a list of some streams we have measured in this area where an HQI and Electrofishing estimate were taken (through the same station). As you will see, the is a lot of variation and you can never accurately predict how much variation you will see. The only general correlation I found was HQI's on high elevation streams with a relatively straight channel will predict higher than the actual estimate and streams with numerous beaver ponds have higher populations than the HQI predicts. The trouble is you cannot predict the magnitude of the differences.

The HQI`s real value is to quantify habitat parameters that are important to trout populations before and after any activities occur that may change the habitat. From this sampling you can get a relative change if development activities were to occur or if habitat improvement structures were installed. The HQI (if done right) can point out which limiting factors in a stream could be altered to improve a fishery and how much improvement to expect.

I hope to see a refined HQI model(s) in the future that could be a good population predictor but right now any one using it for that reason is risking their professional credibility (especially if a lawsuit was ever involved). If you have any other questions be sure to give me a call or write.

Ron Remmick

Headquarters: 5400 Bishop Boulevard, Cheyenne, Wyoming 82002

STREAM NAME	LOCATION	HQI SCORE (LBS/AC)	MEASURED LBS/AC
Fish Creek	R115 T30 S27 NW1/4	21.2	68.8
Fish Creek	R115 T30 S29 NE1/4	17.8	25.9
North Piney Cr	R115 T31 S24 NE1/4	57.7	27.0
S. Cottowood Cr	Blw Guage Stn	66.0	36.1
Teepee Creek	R110 T39 S6	5.5	8.4
North Horse Cr	R114 T34 S1 SE1/4	4.1	13.7
North Horse Cr	R114 T34 S9 NW1/4	3.1	8.4
North Horse Cr	R114 T34 S8 SW1/4	3.1	14.2
New Fork River	Mocroft Ranch	80.7	131.3
New Fork River	State Land (Airport Section)	53.7	45.8
Klondike Creek	Lower Station	130.0	151.8
Klondike Creek	Upper Station	33.1	4.4
Tosi Creek	Above Moore Ranch	41.0	14.3
Gypsum Creek	R109 T39 S27	5.8	43.2
Gypsum Creek	R109 T38 S19	12.1	26.1
South Beaver	R114 T28 S3	5.0	66.0

THE STATE OF WYOMING

MIKE SULLIVAN
GOVERNOR

Game and Fish Department

BILL MORRIS
DIRECTOR

October 13, 1897

260 Buena Vista
Lander, Wyoming 82520

Mr. Steve Canton
5721 South Spotswood Street
Littleton, Colorado 80120

Dear Steve:

With Reference to your recent discussion with Bob Pistono about HQI uses, let me emphasize again that the HQI was originally designed to quantify a fishery resource in non-monetary terms. The original intent was to provide an objective and quantitative evaluation of trout habitat in terms of a standard unit of measure; namely, trout habitat units. Thus, I feel that the primary use of the HQI was, and still is, habitat evaluation. Please note that we have refined the method for calculating habitat units. The current procedure is outlined in Conder and Binns (1986), a copy of which is enclosed.

Because a regression method was used to develop the HQI model, predicting or estimating trout standing crop is a valid use of the model. However, those using the model to predict standing crop should keep in mind the natural variability associated with the process and the real fishery work. That is, while the HQI provides a good estimate of trout standing crop in the majority of cases, the HQI predicted value may not be a hard and fast figure for several reasons.

First, the HQI model is derived from a multiple regression analysis and is such, in simplified terms, is an "averaging" technique. As with all averaging methods, there will be HQI values that fall both above and below the true value. This is a normal process.

Second, there is variation associated with collecting the habitat measurements. Even using the same measuring team, if we make successive measurements, normal sampling variation will cause a scattering of the results from the measurements. Perhaps the crew gets tired or hungary, or bored, or cold/hot and so on. If we use different people or different sample times, then variability is further increased. Likewise, if one takes "short cuts" while making habitat measurements, then greater variability should be expected in the output from the HQI model.

Third, we are predicting, (I think estimating is a better term) a natural population with all its built in natural variability. A trout stream is in a constant state of flux. The habitat conditions that we measure to plug into the HQI model change constantly. An HQI evaluation done today and repeated, at the same site, next month and next year quite likely will yield different predictions of standing crop, due to changing habitat conditions, if nothing else. Restricting the HQI measurements to the "critical period" is an attempt to reduce variability from natural sources, but nature being nature, its elimination is impossible. At the least, HQI evaluations intended to measure habitat perturbations, such as habitat improvement projects, should be repeated as far as possible under the same habitat conditions. For example, water flows should be approximately the same both times.

The point to keep in mind is that a given HQI evaluation may or may not yield the "true" trout standing crop value. A HQI evaluation of a stream is like one electrofishing evaluation. Both are simply "grab-samples" that give us an ESTIMATE of the true standing crop value. For best results, we would need to take 20-30 HQI or electrofishing samples and calculate mean, standard deviation and confidence limits. We could then state with confidence that the determined value is "THE" expected value for that stream.

Quite obviously, none of us have the time, patience, and money for that type of evaluation. Thus, we are reduced to relying on our "grab-sample" evaluations to indicate the fishing value for a given stream. Which is fine, provided we remember that our predicted value is only an estimate of the true value, and is not necessarily the real McCoy. Our estimate is only one of an array of estimate-points that cluster around the true value.

Forgive me if I have belabored the point here, but too many times, professional biologists tend to treat the output from electrofishing evaluations, or models, such as the HQI, as "magic" values that are engraved in stone and handed down from on high.

The HQI has worked quite well for us and we consider it to be a valuable habitat evaluation tool. We use the model for general trout habitat assessment, in the planning phase for stream improvement projects, and in evaluating the effects of habitat improvement work.

If you need further information, feel free to let me know.

Sincerely,

N. Allen Binns, Supervisor
Fish Habitat Crew

Enclosure

NAB:rk

Proceedings of the 21st Annual Meeting, Colo-Wyo Chapter American Fisheries Society, Fort Collins, Colorado March 5-6, 1986.

RESERVOIR IMPACT ANALYSIS USING HABITAT UNITS FOR TROUT STREAMS

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ABSTRACT

Two habitat quality indices are used in Wyoming to analyze impacts of proposed reservoirs on trout streams. The habitat quality index (HQI) is used on stream habitats and a reservoir quality index (RQI) is used to predict reservoir habitat. Both habitat quality models define habitat in terms of standing crop and can be used to develop estimates of habitat units (HU).

The predictive capability of the HQI allows habitat improvement strategies to be developed which would mitigate stream HU losses associated with reservoir construction. A mitigation strategy based on habitat units addresses the basic issue of the fishery resource and allows a fishery manager a position of greater strength for negotiation.

INTRODUCTION

Fishery managers have long been concerned with the value of fishery resources, especially when dealing with benefit-cost evaluations of proposed water development projects. Attempts to assign monetary values to fishery resources for use in benefit-cost analysis have not always been realistic or successful. However, federal legislation in the early 1970's led to drastic changes in the evaluation of water resource projects.

In response to the Water Resources Planning Act (Public Law 89-80), the Water Resources Council (1973) established principles and standards for planning water and related land resource projects. These rules required both an economic and environmental evaluation before approval of any federal project with potential impact on environmental quality. This meant that both monetary and non-monetary evidence must be considered when analyzing project feasibility. Thus, for the first time, non-monetary evaluations of fishery resources became an accepted procedure. This new approach contrasted with past practices where project feasibility was often decided soley by monetary (benefit/cost) considerations.

Unfortunately, procedures for non-monetary measurement of aquatic habitats were primitive when the new rules were issued and a methodology gap soon became evident. The need for an objective, standard habitat evaluation procedure soon became acute.

Accordingly, projects were initiated by the Wyoming Game and Fish Department to develop standard procedures for evaluating trout habitat. Two models have been developed to assess trout habitat in Wyoming. The habitat quality index (HQI) (Binns and Eiserman 1979, Binns 1982) is used to evaluate stream habitat. A second model, reservoir quality index (RQI) (Whitworth 1985) is used to evaluate reservoir habitat. Both models assume that the best habitat for trout would be associated with a high standing crop of trout and that standing crop is a consistent index of existing habitat quality. The purpose of this paper is to present analysis for proposed reservoirs on trout streams using the habitat quality models developed in Wyoming. A mitigation strategy based on the use of these models is also presented.

HABITAT UNIT CONCEPT

The concept of a standard unit of habitat measured called a Habitat Unit (HU) was introduced, but not defined by Anonymous (1974). There was a need to define and quantify this measurement unit so it could be used in habitat evaluations. For our purposes, a trout HU was defined as follows: one trout HU is the amount of habitat quality required to perpetuate one pound of trout standing crop per surface acre. Since both habitat quality models define habitat in terms of standing crop, they can be used to develop estimates of HU.

STREAM HABITAT UNIT ANALYSIS

A key work in our HU definition is perpetuate. Since stream habitat normally provides an ecologically completed habitat (i.e., trout are able to complete their life cycle), standing crop in a stream is a measure of HU. Thus, a stream habitat unit (SHU) is equal to an HU.

The HQI model (model II) was developed using multiple regression analysis from data on 44 Wyoming streams (Binns and Eiserman 1979). The relationship of HQI score to standing crop was defined by the equation of the regression analysis (Figure 1). Since the HQI was developed, it has been used on many Wyoming streams. Although it has been used mostly as an index to habitat condition and model performance, when used to predict standing crop, it has generally been satisfactory.

An HQI Model II score is calculated from the HQI model, using nine habitat attributes:

$$\text{HQI score} = \log_{10}(Y + 1) = (-0.903) + (0.807)\log_{10}(X1 + 1) + (0.877)\log_{10}(X_2 + 1)\,(1.233)\log_{10}(X_3 + 1) + 0.631\log_{10}(F + 1) + (0.182)\log_{10}(S + 1)$$

Where: Y = HQI score
X_1 = Late summer flow
X_2 = Annual stream flow variation
X_3 = Maximum summer stream temperature
X_4 = Nitrate nitrogen
X_7 = Cover
X_8 = Eroding stream bank

X_9 = Substrate (submerged aquatic vegetation)
X_{10} = Stream width
F = Food index = $X_3(X_4)(X_9)(X_{10})$
S = Shelter index = $X_7(X_8)(X_{11})$

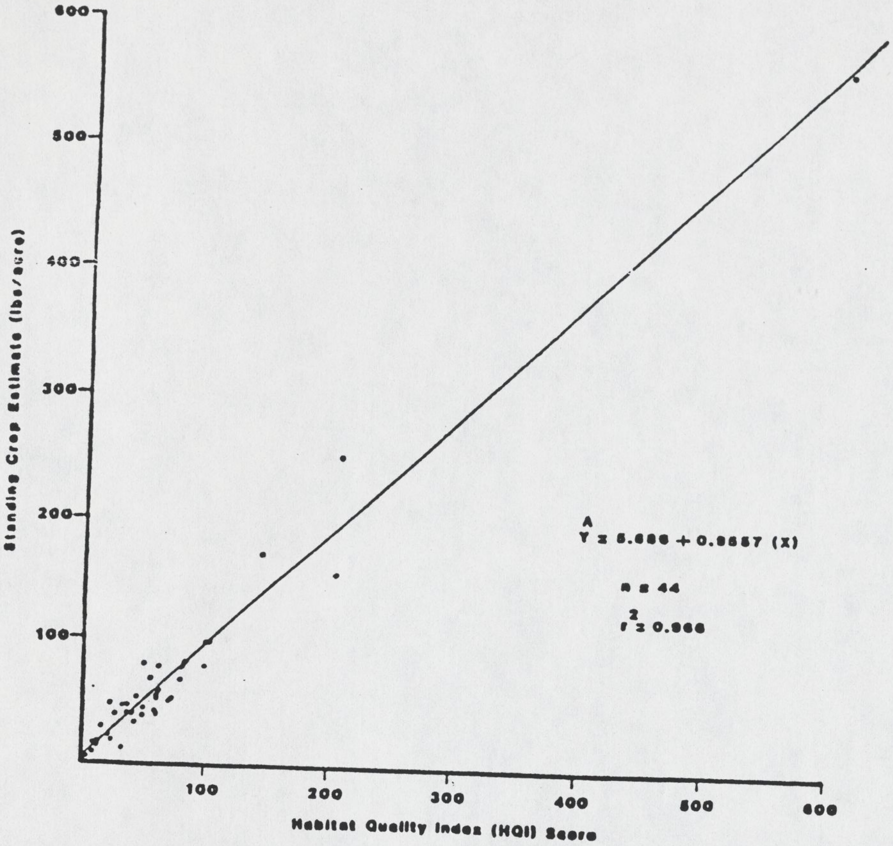

Figure 1. Relationship between Habitat Quality Index (HQI) score and standing crop at 44 Wyoming Streams evaluated with the HQI model II in 1975-1979.

If the HQI model could be refined to the point where a 1:1 relationship exits between standing crop and HQI score, the HQI score and standing crop would be synonymous. However, unless this point is reached, the linear regression model provides a conversion factor to estimate standing crop from the HQI score:

If for example 50 = HQI score,
then, y = 5.686 + 0.9557 (50)
y = 53.5 which is the estimated standing crop/acre.

Thus, if given a trout stream had an HQI score of 50, the value of the habitat would be 53.5 trout/HU/surface acre.

The HQI, and resultant HU provides objective and quantitative evaluations of the stream trout fishery resource in non-monetary terms. This provides a useful method for quantitative impact analysis of stream habitat with a proposed reservoir. Determining stream fishery losses may be done by first determining the acres of stream habitat inundated by a proposed reservoir alternative. Acres inundated multiplied by the HU value per acre provides a quatitative estimate of stream fishery losses. A hypothetical example of this procedure is presented in Appendix A.

RESERVOIR HABITAT ANALYSIS

Two concepts have been used to debate the value of reservoir habitat as a trout producer. First, reservoirs do not provide an ecologically complete habitat. Reservoir habitats usually can support trout, but trout are unable to complete their life cycle (egg to egg). This contrasts with stream habitats which generally provide all habitat attributes necessary to perpetuate trout. A trout population in a reservoir without the hatchery product, would be unstable and under extreme circumstances, it could be extirpated.

A second concept, that of habitat integrity, has also been applied to reservoirs. Habitat integrity is a measure of the geological and biological aging of a reservoir with reference to trout productivity. That is, how long can a reservoir be expected to function as a trout producer before it fills up with silt and organic debris or facilities (dam) decay? Although geological and biological life expectancies are not synonymous from the standpoint of trout production, generally the reservoir aging process will depreciate trout production. Actual habitat is lost by silt deposition, and perhaps more important, by a depreciation of the available nutrients and by an increase in fish species other than trout. While most reservoirs have a relatively short life span, a stream, in the same time span, should remain basically the same.

We recognize the fact that reservoirs can generally support trout, but we also must acknowledge the limitations inherent with reservoir habitat. Standing crop in a reservoir is, therefore, a measure of reservoir habitat units (RHU) and not HU. For our purposes, a RHU is defined as: the amount of reservoir habitat quality to support one pound of trout standing crop per acre. Because reservoir habitat declines in value (i.e., trout production) and recruitment is from an external source, a comparison of RHU and HU is not possible.

Ryder (1965) developed the Morphoedaphic Index (MEI) as an estimator of biomass in lentic habitats. Work by Facciani (1976) on several Wyoming reservoirs demonstrated an apparent relationship of fish biomass to the MEI. Work by Whitworth (1985) has refined the MEI relationship for Wyoming reservoirs and developed a Reservoir Quality Index (RQI). A close relationship has been demonstrated between the RQI and fish density ($r^2 = 0.97$).

Since new reservoirs on Wyoming trout streams are almost always essentially trout producers for the first few years after impoundment, the assumption is usually valid that the RQI is a good measure of the potential trout density (RHU) in a proposed reservoir. Determination of RHU in a proposed reservoir follows a procedure similar to that used for the HQI in stream habitats.

Assume that a proposed reservoir will have a maximum depth of 30 meters and estimated total dissolved solids (TDS) of 300 mg/l, the RQI is used to predict RHU as follows:

$$\log_e \text{Density per area} = 4.0016 + 0.004\ (\text{TDS}) - 0.0241\ (\text{maximum depth})$$

$$\text{Density per area} = 88 = \text{trout per hectare}$$

Since an average trout in Wyoming reservoirs is 0.34 kilograms,

88 trout per hectare X 0.34 kg = 29.9 kg/ha

then, by using an English conversion factor

29.9 kg/ha X 0.892 = 26.7 pounds/acre.

We have estimated a potential standing crop of 27 pounds/surface acre or 27 RHU/acre. Calculations of RHU assume that an adequate minimum pool and recruitment (hatchery product) are provided.

Calculation of potential RHUs is similar to calculations used to evaluate stream habitat. The RQI provides an estimate of potential standing crop per acre. This value multiplied by reservoir acres at the normal high water line provides a quantitative estimate of potential RHUs that could be developed (Appendix A).

MITIGATION ANALYSIS

Once the HU evaluation is completed, a mitigation plan can be developed. A mitigation policy was adopted by the Wyoming Game and Fish Commission in 1985. Four resource categories with mitigation planning objectives of decreasing stringency were developed (Table 1). Resource categories are determined by four criteria: 1) species present, 2) stream class, 3) management concept and 4) special use.

Table 1. Resource categories and mitigation objectives.

Resource Category	Mitigation Objective
Irreplaceable Habitat	No loss of exisiting habitat value.
High Value Habitat	No net loss of in-king habitat value.
Moderate Value Habitat	No net loss of habitat value while minimizing loss of in-kind habitat value.
Low Value Habitat	Minimize loss of habitat value.

Consistent with the mitigation objectives and the Wyoming Game and Fish Department's strategic plan for maintaining stream mileage and fishermen days on streams, development of reservoir habitat (RHU) cannot mitigate the loss of stream habitat (HU). Development of reservoir habitat is viewed as fisheries enhancement and a mitigation plan must be developed to address stream habitat losses associated with reservoir construction.

Perhaps the greatest value of using the HQI for impact analysis is its predictive capability to assess mitigation issues. Creation of new stream habitat areas is extremely difficult at best. Thus, mitigation of lost stream habitat normally entails improvement of existing stream habitat to supporting a high enough standing crop to compensate for fishery losses. Use of the HQI allows us to evaluate various "what if" habitat improvement strategies. By simulating improvement in one or more of the habitat attributes incorporated in the HQI model, quantitative predicitive estimates of HU gains can be made. Developing mitigation recommendations becomes a process of determining which habitat improvement measures are needed over a prescribed area to provide adequate HU gains to compensate for a project's negative impacts.

Development of a mitigation plan using the HU concept offers many advantages to the fisheries resource manager:

1. Analysis using the HU concept evaluates the resource which could be lost and addresses compensation of this resource with a like resource.

2. Fisheries mitigation is a project responsibility to alleviate project impacts to a public resource. Presentation of non-monetary evidence presents a simple "buy out" of a public resource.

3. Compensation is not based on the monetary value of the fishery resource lost, but the cost of implementing the mitigation measures to develop a suitable amount of habitat. The formidable task of determining an equitable estimation of the monetary value of the fishery resource is not necessary and should not be included in the negotiation process.

4. Since various habitat improvement strategies could be employed to develop the HU needed for mitigation, several avenues for negotiation are open. With the flexibility of several mitigation options, a plan can more often be developed and negotiated.

5. Knowledge of the habitat improvement measures needed to provide adequate mitigation allows for cost estimates of the mitigation measures to be incorporated into the project cost. This is important for fisheries mitigation to effectively be a project responsibility.

6. The habitat quality models and HU values developed from them are consistent with U.S. Fish and Wildlife Service's Habitat Evaluation Procedure and can be used in the Coordination Act Report.

Several water development projects have been successfully negotiated using the HU concept in Wyoming. The HU concept has been accepted by laymen because it equates the nebulous concept of habitat directly to pounds in fish. By addressing the basic issue of fishery resource, a fishery manager is freed from monetary evaluation and is allowed to negotiate from a position of greater strength.

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United States Department of Agriculture
Forest Service
Medicine Bow National Forest
605 Skyline Drive
Laramie, WY 82070-6003

Reply to: 2610

Date: October 14, 1987

Steve Canton
Chadwick and Associates
5721 South Spotwood Street
Littleton, CO 80120

Dear Steve:

Regarding our phone conversation on October 13, I am sending background information leading to the development of the modified Habitat Quality Index (HQI) models. I could not include the modified rating for stream width and the modified models because the information was unavailable to me at this time.

The study was funded by the Medicine Bow National Forest as part of the Fish Habitat Relationships System. All stream reaches were located in watersheds which were relatively unimpacted by man. My research indicated that brown trout and brook trout abundance and habitat features were similar between B2 and B3 channels (Rosgen's channel classification system), while C3 channels differed from both B2 and B3. Also, habitat features correlated with trout abundance varied between species and channel type (B and C). A paper regarding this work was published in the Proceedings of the Colorado-Wyoming Chapter of the American Fisheries Society 1987.

The streams Binns used to develop the HQI included both B and C channel types. Development of a generalized model, like the HQI, from my data may be an over-simplification and lead to erroneous results.

The second aspect of my study was to evaluate six models which assess stream habitat quality and predict trout abundance and to modify them for use on the Medicine Bow National Forest. The HQI (Model II) was one of the six models. The first part of my research indicated that separate habitat models were needed for different species within a channel type.

Correlation analysis was performed with the HQI variables and trout abundance. The stream width rating was modified because of its consistent negative correlation with trout abundance. The rating criteria was reversed from that of Binns. Since stream width was one of the components of the shelter index, the modified stream width rating was substituted for the original rating, and a new shelter index was calculated. Two modified regression models were developed for B channels; one for total standing stock and for brook trout standing stock.

I hope this background information is of some help. It would be of help to us if you could send information on how well the model performed (stream names, location, and measured and predicted standing stocks.

Sincerely,

STEVEN J. KOZEL
Fishery Biologist

SJK:pah

modeling.hqi

CHADWICK & ASSOCIATES

5721 South Spotswood Street
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October 19, 1987

SUPPLEMENTAL REPORT

TROUT HABITAT MODELLING IN THE SAN MIGUEL RIVER NEAR TELLURIDE, COLORADO

Background

Trout fisheries and habitat in San Miguel River have been studied extensively during the past few years by the State and the Idarado Mining Company. Particular attention has been paid to the trout biomass and the potential for increases in trout biomass. Biomass has been estimated using two different methods: 1) Empirical estimates based on field electrofishing by Chadwick & Associates (1986) and 2) modelled estimates based on the Habitat Quality Index (HQI) as used by both the State (Geotrans *et al.* 1986) and Idarado. This model estimates trout biomass from habitat measurements and was developed by Dr. Allan Binns, Wyoming Game and Fish Dept. This supplemental report briefly describes past electrofishing and modelling efforts as well as recent revisions to the HQI model and the effects of those revisions on the biomass estimates in the San Miguel River.

Discussion

Trout biomass predicted by the State using the HQI often exceeds the actual trout biomass estimate determined by Chadwick & Associates (1986) from stream electrofishing (Table 1). Even a later reevaluation by Dr. Binns (1986) of the State's application of the model resulted in predicted biomass greater than actual biomass at the stations downstream of Telluride (Table 1).

TABLE 1: Trout biomass estimates (kg/ha) from the San Miguel River.

	SAN MIGUEL RIVER				
METHOD	2	3	4	5	6
Electrofishing (Chadwick & Assoc. 1986)	0	6	72	66	40
HQI (Binns' current predictions)	27	18	78	147	157
HQI (State's current prediction)	27	18	103	225	312
Modified HQI (total trout)	(not calculated)		76	54	76
Modified HQI (brook trout)	(not calculated)		33	12	33

Differences between observed and HQI predicted biomass are not uncommon, with predicted biomass often falling above or below the true value (Remmick 1987, Binns 1979). This can be a result of a number of factors not taken into account by the HQI such as siltation, extreme flow events, winter ice cover, etc. Additionally, it is important to understand that both the actual biomass and HQI predicted biomass are *estimates* with their own variability and confidence limits.

In order to understand the seeming disparity between modelled and actual biomass noted above, it is important to understand the nature of the HQI and other models comparing trout habitat with trout biomass. Relationships between habitat and trout biomass can vary widely with stream type and trout species. The original HQI model was developed from a large data base of streams ranging from small, high altitude, high gradient streams to large, low gradient, low elevation rivers (Binns 1979). As such the general HQI model is not necessarily the best predictor for trout biomass in all stream types or for all trout species. In fact, the HQI was not originally intended as a predictor of biomass, but rather as a tool for trout habitat management (Binns 1987, Remmick 1987). Used correctly it can quantify habitat parameters and help in determining what habitat enhancement measures can be taken to improve a fishery. When used in this manner, the discrepancies between modelled and actual trout biomass become meaningless.

In a recent study concentrating on the relationship between habitat and trout biomass in mountain streams, a number of indices were compared, including the Habitat Quality Index (HQI) of Dr. Allan Binns (Kozel 1987). When the biomass predicted by the HQI was compared to actual biomass for 48 streams, there was only a slightly significant correlation ($r = 0.49$). This results in a coefficient of determination (R^2) of only 24%, meaning that only 24% of the variability was accounted for by the HQI biomass/actual biomass correlation. When compared to brook trout populations only, the R^2 decreased to 18%.

A modified HQI has been developed by Kozel using only those factors found to be significantly correlated to trout biomass. Two revised HQI equations were developed for streams similar to the San Miguel River; one for total trout biomass and one for brook trout. The modified HQI formulae are as follows:

$$\text{Total trout biomass (kg/ha)} = 3.57\ (X_7 \cdot X_8 \cdot X_{11}) + 54.21$$

$$\text{Brook trout biomass (kg/ha)} = [3.57\ (X_7 \cdot X_8 \cdot X_{11}) + 35.44 \cdot X_8] - 94.46$$

where X_7 = cover rating

X_8 = eroding streams bank rating

X_{11} = stream width rating

The revised models were developed for permanently flowing streams. Therefore they can only be applied to the three sites downstream of Bear Creek (Table 1). Figure 1 compares the results of this reanalysis using the modified HQI for total trout, the actual numbers of trout collected in 1985, and the results of modelling by the State and Dr. Allan Binns using the original HQI. The modified HQI total trout values are virtually identical to the actual biomass at SMR 4 and diverge only slightly at SMR 5 and 6 (Table 1). This modified HQI has confidence limits of ±40% based on comparisons to actual trout biomass (Kozel 1987). In the San Miguel River, actual and predicted biomass confidence limits overlap at SMR 4 - 6 indicating no real difference between the estimates at these sites.

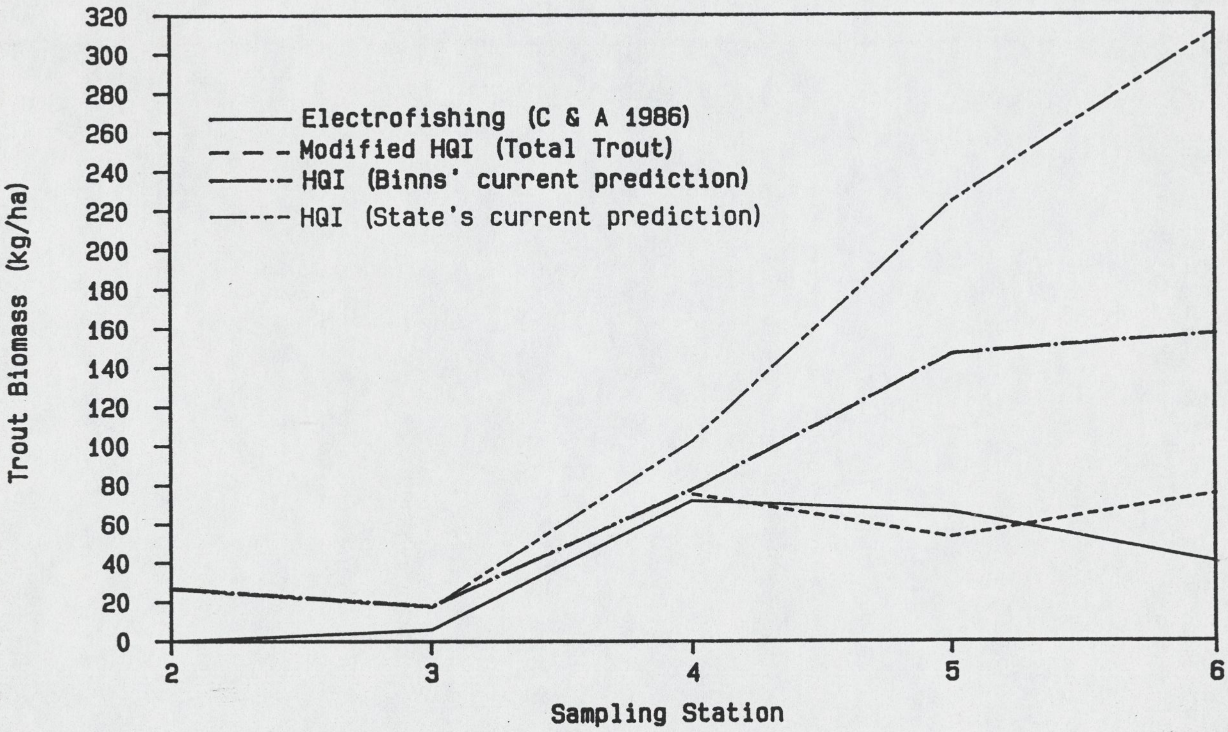

FIGURE 1: Trout biomass estimates from the San Miguel River.

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DEVELOPMENT OF FISH HABITAT RELATIONSHIP MODELS FOR THE MEDICINE BOW NATIONAL FOREST WYOMING

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ABSTRACT

The goal of the Fish Habitat Relationship (FHR) program of the U.S. Forest Service is to integrate fish habitat inventory and evaluation into interdisciplinary forest resource planning and management. The Medicine Bow National Forest (MBNF) is one of 12 forests participating in the FHR program. The FHR system will use selected stream habitat and geomorphic variables to predict potential trout standing stock in forest streams. Habitat was measured over 200-m stream reaches using the transect method on relatively undisturbed stream systems in the MBNF. The influence of three important channel types (Rosgen's B2, B3, and C3) on trout standing stock, measured habitat variables, and geomorphic features were determined using analysis of variance and correlation analysis. Variables which influence trout abundance in streams on the MBNF were identified for use in FHR model development.

INTRODUCTION

The Fish Habitat Relationships (FHR) System is a nationwide program being conducted by the U.S. Forest Service. The objective of the FHR program is to integrate fish habitat inventory and evaluation into interdisciplinary forest resource planning and management. The Medicine Bow National Forest (MBNF) is one of 12 test sites across the United States. Two objectives of this study were to determine if there are differences in stream habitat and trout standing stock in B2, B3, and C3 channel types as defined by Rosgen (1985) and to determine the statistical relationship between trout standing stock and selected habitat variables.

METHODS

In 1985 and 1986, 48 stream reaches were sampled in the MBNF. All stream reaches were located in drainages which were relatively unimpacted by man's practices. Streams located on the MBNF were primarily B2, B3, and C3 channel types. Therefore, sampling effort was concentrated on these three channel types.

The B2 channel type was moderate in gradient (1.5-4.0%) and dominated by large cobble substrate. The B3 channel type also was moderate in gradient (1.5-4.0%), but the dominant substrate was gravel and cobble. The C3 channel type were found primarily in headwater and foothill streams. They were low in gradient (.5-1.0%), and dominated by gravel.

The sampling protocol was based on 200-m-long stream reaches. To estimate habitat parameters, the line transect method was used. Transects were spaced 4 m apart and seven equally spaced points were measured. At each point, stream microhabitat was classified into 14 categories as defined by Bisson et al. (1981). Substrate (6 categories; Platts et al. 1983) and percent embeddness were estimated at each point.

Undercut bank and overhanging vegetation were measured at the left and right bank. Canopy cover was measured at 40-m intervals using a solar densiometer.

Estimates of trout standing stock were obtained at each stream reach using the removal method. Three depletion passes were made with a backpack electroshocker. Only fish 100 mm were weighed and measured. Program CAPTURE was used to estimate trout standing stock.

One-way analysis of variance was used to determine if significant differences existed between channel types. Arcsine transformation was performed on all proportional data. Actual means are reported. A pair of means underscored indicates no significant difference between the means. Scheffe's test was used for pairwise comparisons. Pearson's correlation was used to determine statistical relations between trout standing stock and selected habitat variables.

RESULTS

Total brook trout and brown trout standing stock was highest in C3 channels and significantly differed from both B2 and B3 channels (Table 1). Total brook trout and brown trout standing stock did not significantly differ between B2 and B3 channels.

Percent embeddedness was highest in C3 channels and was significantly different from the other two channel types (Table 2). The B2 channels had the highest width-depth ratio and only B2 and C3 channels were significantly different. Canopy cover in C3 channels was significantly different from the two other channel types. Undercut bank was greatest in C3 channels and differed significantly from the other two channel types. No significant difference existed among channel types for overhanging vegetation and average reach velocity. In most cases B2 and B3 channels did not differ significantly.

All six substrate classes were significantly different between channel types (Table 3). Cobble was the dominant substrate in B2 channels while gravel dominated B3 and C3 channels.

Riffle, rapid, trench pool, plunge pool, and glide microhabitat abundance was significantly different among channel types (Table 4). Secondary channel pool abundance was not significantly different among channel types. Again, in most cases B2 and B3 channels did not differ significantly in stream microhabitat.

Backwater pool and dammed pool abundance were significantly different among channel types (Table 5). Lateral scour pools due to boulder/bedrock were nonsignificant while lateral scour pools due to rootwads and debris were significantly different among channel types. Pools due to rootwads were common in C3 channels, while pools due to debris predominated in B2 and B3 channels.

It was determined that very few differences existed between B2 and B3 channels, so the two channel types were combined for further analyses. Correlation analysis between total trout standing stock and habitat variables indicated the importance of different variables to total trout standing stock in different channel types (Table 6). Undercut bank was positively correlated to total trout standing stock in C3 channels, but not correlated in B channels. On the other hand, cobble was negatively correlated to total trout standing stock in B channels, but not correlated in C3 channels.

Total standing stock was broken down into brook trout and brown trout standing stock for each channel type and correlation analysis was performed (Table 7). The analysis indicated again that variables associated with species abundance were related to a particular channel type. Also, certain variables were specific to a species of trout. For example, average reach velocity was negatively related to both brook trout and brown trout abundance in C3 channels while not related to the abundance of either species in B channels. Width-depth ratio was a species specific variable being negatively correlated to only brook trout abundance in both channel types.

CONCLUSIONS

Trout standing stock and stream habitat features did not differ greatly between B2 and B3 channel types, but the C3 channel type differed substantially from the two B channel types. Correlation analysis revealed that different variables were related to abundance of specific species of trout in different channel types. Managers must be aware that factors governing trout abundance in one channel type may not be the same factors as in another channel type. Also, factors appear to be dependent on trout species composition.

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Table 1. One-way analysis of variance for trout standing stock

Variable (Kg/ha)	Channel Type C3(n=16)	B3(n=16)	B2(n=16)
Total Standing Stock[1]	267.31	112.19	91.58
Brook Trout Standing Stock[1]	207.76	88.84	64.13
Brown Trout Standing Stock[1]	59.29	23.40	27.36

[1]Significant difference between channel types ($P \leq 0.05$)

Table 2. One-way analysis of variance for a stream characteristics

Variable (%)	C3(n=16)	Channel Type B3(n=16)	B2(n=16)
Embeddedness[1]	58.66	33.88	28.92
Width-Depth Ratio[1,2]	6.97	10.04	11.22
Canopy Cover[1,2]	8.66	25.14	34.06
Undercut Bank[1,2]	53.03	31.16	21.16
Overhanging vegetation[2]	44.10	29.73	29.71
Average Reach Velocity (m^3/s)	0.36	0.35	0.45

[1]Significant difference between channel types ($P \leq 0.05$)

[2]Arcsine transformation

Table 3. One-way analysis of variance for substrate

Variable (%)	C3(n=16)	Channel type B3(n=16)	B2(n=16)
Large Boulder[1,2], (610 mm)	0.89	0.88	7.14
Small Boulder[1,2], (305 mm - 609 mm)	4.92	5.18	17.85
Cobble[1,2] (76.1 mm - 304 mm)	21.36	38.59	51.96
Gravel[1,2] (4.81 mm - 76.0 mm)	46.99	50.76	21.23
Large Fine Sediment[1,2] (0.83 mm - 4.80 mm)	12.83	3.25	1.36
Small Fine Sediment[1,2] (0.83 mm)	13.00	1.35	0.46

[1]Significant difference between channel types ($P \leq 0.05$)

[2]Arcsine transformation

Table 4. One-way analysis of variance for selected microhabitats as defined by Bisson (1985).

Variable (%)	C3(n=16)	Channel Type B3(n=16)	B2(n=16)
Riffle[1,2]	25.38	37.01	42.71
Rapid[1,2]	0.23	0.36	3.26
Secondary Channel Pool[2]	0.29	1.07	0.59
Trench Pool[1,2]	30.30	7.99	2.39
Plunge[1,2]	0.48	3.39	4.63
Glide[1,2]	31.56	32.26	22.53

[1]Significant difference between channel types ($P \leq 0.05$)

[2]Arcsine transformation

Table 5. One way analysis of variance for three microhabitat pool types as defined by Bisson (1985).

Variable (%)	Channel type C3(n=16)	B3(n=16)	B2(n=16)
Backwater Pools			
Boulder[1,2]	2.14	3.34	14.90
Rootwad[1,2]	5.49	2.43	1.44
Debris[1,2]	0.58	5.08	1.51
Lateral Scour Pools			
Boulder/Bedrock[2]	0.13	0.76	0.41
Rootwad[1,2]	1.88	0.79	0.28
Debris[1,2]	0.09	1.79	0.49
Dammed Pools			
Boulder[1,2]	0.99	0.08	1.78
Debris[1,2]	0.46	3.58	2.79

[1] Significant difference between channel types ($P \leq 0.05$)

[2] Arcsine transformation

Table 6. Correlation coefficient for those variables significantly ($P \leq 0.05$) related to total trout standing stock in C3 and B2-B3 channel types.

Variable	Channel type C3(n=16)	B2-B3(n=32)
Embeddedness		0.51
Width-Depth Ratio	-0.61	-0.37
Undercut Bank	0.60	
Overhanging Vegetation	0.48	0.40
Average Reach Velocity	-0.69	-0.37
Small Boulder		-0.34
Cobble		-0.30
Large Fine Sediment		0.50
Small Fine Sediment		0.48
Riffle	-0.44	
Trench	0.48	
Plunge	0.45	
Glide		0.46
Backwater Pool Rootwad	0.55	0.60
Backwater Pool Debris	-0.35	
Lateral Scour Pool Rootwad		0.31

Table 7. Correlation coefficient for those variables significantly ($P \leq 0.05$) related to brook and brown trout standing stock in C3 and B2-B3 channel types.

Variable	C3		B2-B3	
	BNT(n=9)	BKT(n=15)	BNT(n=18)	BKT(n=28)
Embeddedness				0.39
Width-Depth Ratio		-0.75		-0.52
Overhanging Vegetation				0.54
Average Reach Velocity	-0.71	-0.78		
Small Boulder	0.60			
Large Fine Sediment				0.39
Small Fine Sediment				0.44
Glide			-0.45	0.47
Trench Pool	0.61			
Plunge	0.62			
Backwater Pool Rootwad			0.41	0.49
Backwater Pool Debris				-0.36