LINKING ARCTIC GRAYLING ABUNDANCE TO PHYSICAL HABITAT PARAMETERS IN THE UPPER BIG HOLE RIVER, MT

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A Summary Report
Based on the 1994 OEA Research, Inc. habitat survey of the upper Big Hole River and FWP field surveys conducted from 1992-1996

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SYNOPSIS

In 1994, OEA Research, Inc. was retained to survey the physical habitat parameters of the upper Big Hole River. The goal of this report is to correlate these findings to Arctic grayling (*Thymallus arcticus*) abundance in the survey reaches. The results of our analysis show a wide degree of spatial variability in such habitat parameters as: pool type and quality, riffle stability, stream bank cutting, width-depth ratios, and, most strikingly, the relative of abundance of overhanging vegetation. While the relative abundance of overhanging vegetation was low throughout the study area, it was this parameter that was the best indicator of Arctic grayling abundance in the upper Big Hole River from 1992-1996. Further analysis showed that this may be an indirect relationship as reaches with relatively high amounts of overhanging vegetation also had relatively high quality pools and smaller amounts of bank erosion. It was these relationships that we believe were critical in determining grayling abundance patterns. Our results also provide insight and direction for future stream riparian improvement projects and their importance in preserving this unique and valuable population of fish.

INTRODUCTION

Fish habitat is defined as a set of places in which a population can find the physical and chemical features needed for life, such as suitable water quality, migration routes, spawning grounds, feeding sites, resting sites, shelter from predators, competition and adverse weather (Hayes et al. 1996). The term carrying capacity refers to the number of individuals that the resources of a habitat can support (Ricklefs 1990). These two terms are intertwined by the fact that habitat quality determines the carrying capacity for a species and that the number of individuals in a population reflects the current habitat quality. Simply put, habitat quality in the form of pool quality, water temperature and flows, and a suite of other parameters determines the number of fish inhabiting a body of water. It is also important to remember that habitat quality fluctuates, both seasonally and annually, depending on environmental conditions and human demands of the resources associated with a body of water.

A common misconception of fish habitat, especially when referring to species of salmonids (charr, salmon, trout), is that the location where one finds an individual at any given time, provides that individual with all its habitat requirements throughout the year. In fact, many salmonids undergo large-scale migrations, often measured in miles, in order to access seasonally important habitats (Schlosser and Angermeier 1995). This is an extremely important concept to remember when attempting to manage a species like Arctic grayling (*Thymallus arcticus*). The distance between seasonally important habitats can be in excess of 20 river miles for Arctic grayling. The mobility of this fish makes it extremely difficult to maintain a high level of habitat quality throughout its annual home range, especially in a watershed, like the Big Hole, where there is a high demand for the resources associated with the river.

It has been well documented that the status of fluvial Arctic grayling in Montana is of growing concern (Shepard and Oswald 1989, Kaya 1992, Magee and Byorth 1998, Magee 2002, Magee and Lamothe 2003). The last population of fluvial grayling in Montana inhabits the Big Hole River and the population is in decline (Kaya 1992, Magee 2002, Magee and Lamothe 2003). Habitat degradation has been suggested as partially responsible for the decline of Arctic grayling in the Big Hole River (Kaya 1992). When investigators discuss the decline of habitat quality in the Big Hole River, most often they focus on the partial dewatering of the river and its tributaries during the summer months for agricultural use. The impact of dewatering can vary greatly from year to year depending on the depth of the snowpack and the amount of rainfall. While dewatering of the Big Hole River may be having an impact on grayling numbers, the overall habitat suitability and carrying capacity of the Big Hole River for Arctic grayling is determined by a suite of habitat parameters. Preventing the extirpation of Arctic grayling from the upper Big Hole River will require us to focus our attention on all these parameters.

Kaya (1992) states that very little information was available to determine the relative status of other habitat parameters, mainly stream temperatures and turbidity, for the Big Hole River and its tributaries. In 1991, the Fluvial Arctic Grayling Recovery Project began an aggressive collection of stream temperature data throughout the Big Hole watershed in order to fill part of this gap in knowledge. Along with this effort, in 1994, the Fluvial Arctic Grayling Workgroup retained OEA Research, Inc to conduct an inventory of the riparian and fisheries habitat in the upper Big Hole River. OEA

Research Inc. conducted the survey on the Big Hole River between the mouth of Warm Springs near the town of Jackson, MT and Dickie Bridge near the town of Wise River, MT. This reach of the river supports the highest observed densities of Arctic grayling. Densities of grayling decline downstream of Dickie Bridge where brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) densities increase.

This survey can serve as important baseline data for future surveys and provide the data necessary to correlate Arctic grayling population numbers to physical habitat parameters. This analysis should describe the relative importance of a suite of habitat parameters to further focus restoration efforts. Future grayling population could then be correlated to changes, both positive and negative, in habitat parameters.

The objectives of this report are to: 1) synthesize the physical habitat measurements collected during the 1994 OEA survey of the upper Big Hole River, 2) correlate these data with Arctic grayling population data collected from 1992-1996, and 3) make recommendations for future restoration and research efforts based on our results.

METHODS

Physical Habitat Data Collection

The habitat parameters surveyed by OEA in 1994 are listed in Table 1. For the sake of brevity we will only refer to the specific methodologies used to measure these parameters when needed to add clarity to this report.

Table 1. The habitat parameters measured during the 1994 OEA survey of the upper Big Hole River.

1. HABITAT TYPE	8. % AQUATIC MACROPHYTES
2. HABITAT SEQUENCE NUMBER	9. % FILAMENTOUS ALGAE
3. SUBSTRATE COMPOSITION	10. FISH PRESENCE
4. RIFFLE EMBEDDEDNESS	11. BEAVER ACTIVITY
5. POOL RATING	12. LARGE WOODY DEBRIS
6. POOL DEPTHS (MIN, MAX, MEAN)	13. CANOPY CLOSURE
7. POOL CROSS-SECTION	14. VEGETATION OVERHANG

The upper Big Hole River between the mouth of Warm Springs Creek, near the town of Jackson, MT, and Dickie Bridge near Wise River, MT was divided into 16 survey reaches (Figure 1; Table 2). The surveys reaches covered 73.4 river miles and include sections of Steel and Deep Creeks, two tributary streams used by Arctic grayling. The survey reaches were further divided into sub-reaches (Figure 2) to provide sufficient sample size and spatial variation.

Analysis of habitat parameters

Our analysis is focused on determining spatial differences in habitat parameters among the reaches. Statistically significant differences in relative availability or abundance of physical habitat parameters among habitat reaches was determined using analysis of variance (ANOVA) (alpha = 0.05) with Tukey's multiple contrast test for post hoc comparison between reaches. Data was transformed prior to analysis in order to meet the assumption of normality. The Tukey's test was used due to its robust nature in dealing with data that may violate the assumptions of normality and equal variance (Zar 1999).

Relating Arctic grayling abundance to physical habitat parameters

Arctic grayling sampling data from 1992 to 1996 were used for analysis. Five years of data was used to provide an adequate sample size and dampen the spatial variation in grayling abundance due to year to year differences in environmental conditions including: stream flow, water temperature, and physical habitat quality. Sampling sections often encompassed parts of two or more habitat reaches. When this was the case, the statistical means for each parameter from the appropriate habitat subreaches were used for analysis. While stream discharge data is available for the upper Big Hole River from the USGS gauging station located at the Wisdom Bridge, data pertaining to the spatial variation in stream discharge within our sampling sections is limited and needs to be expanded. This lack of data precludes the use of stream flow as a predictor to Arctic grayling abundance in our analysis. We used multiple regression analysis to establish the relationship between Arctic grayling abundance and physical habitat parameters in the upper Big Hole River. Parameters with associated p-values greater than 0.05 were removed from our model.

Table 2. Spatial delineation of survey reaches from the 1994 OEA Research Inc. survey of habitat in the upper Big Hole River.

Reach ID	Reach Boundaries
A	Mouth of Warm Springs Creek to mouth of N. Branch Big Swamp Creek
B	N. Branch Big Swamp Creek to Big Lake Creek “cutoff channel”
C	Big Lake Creek “cutoff channel” to mouth of Big Lake Creek
D	Mouth of Big Lake Creek to mouth of Steel Creek
E	Steel Creek
F	Mouth of Steel Creek to mouth of Swamp Creek
G	Mouth of Swamp Creek to mouth of McVey Creek
H	Mouth of McVey Creek to mouth of North Fork Big Hole River
I	North Fork Big Hole River – cutoff channel to mouth
J	Mouth of North Fork to mouth of Pintlar Creek
K	Mouth of Pintlar Creek to York Gulch
L	York Gulch to mouth of Toomey Creek
M	Mouth of Toomey Creek to mouth of Fishtrap Creek
N	Mouth of Fishtrap Creek to mouth of Seymour Creek
O	Mouth of Seymour Creek to Dickie Bridge
P	Deep Creek

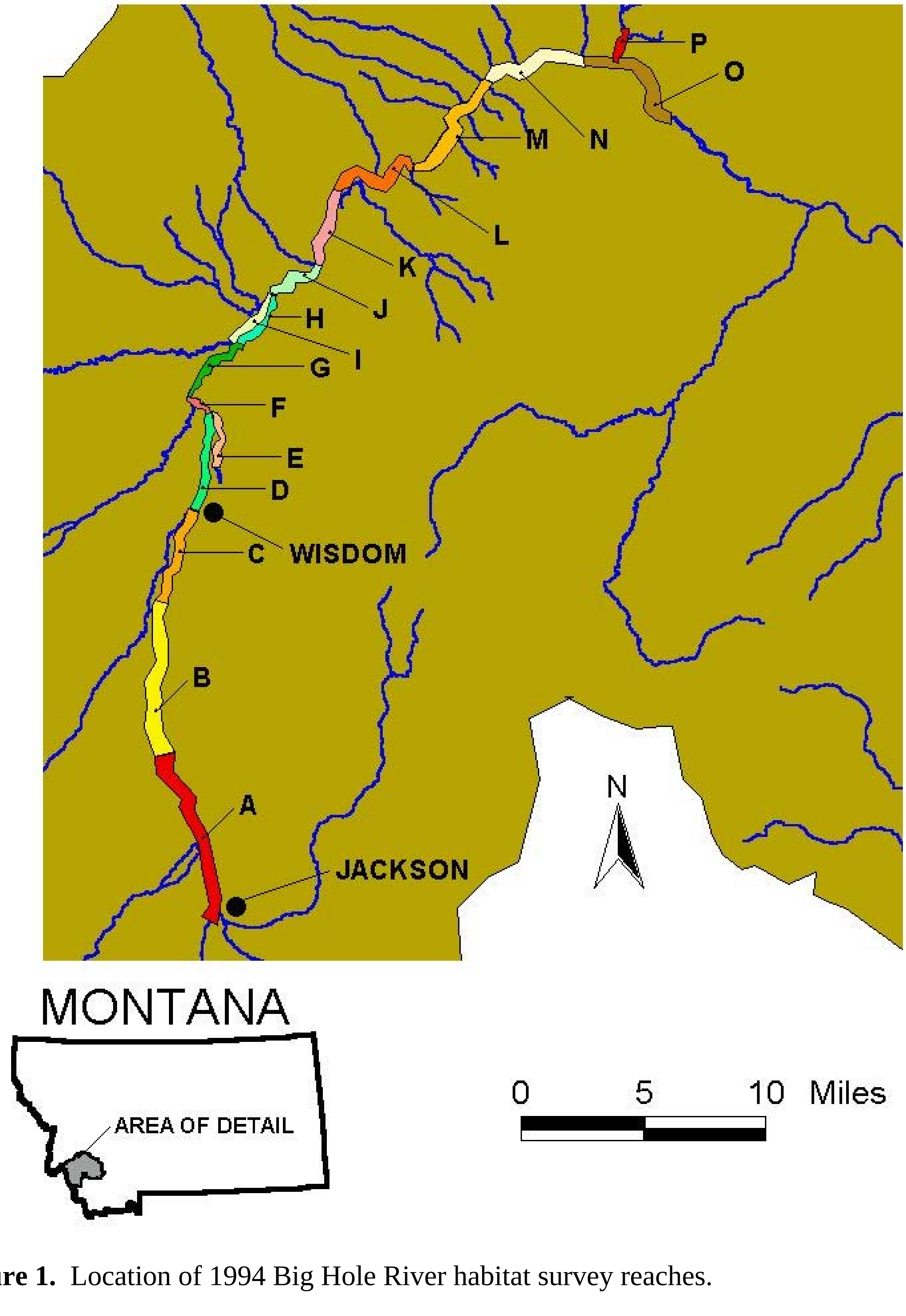

Figure 1. Location of 1994 Big Hole River habitat survey reaches.

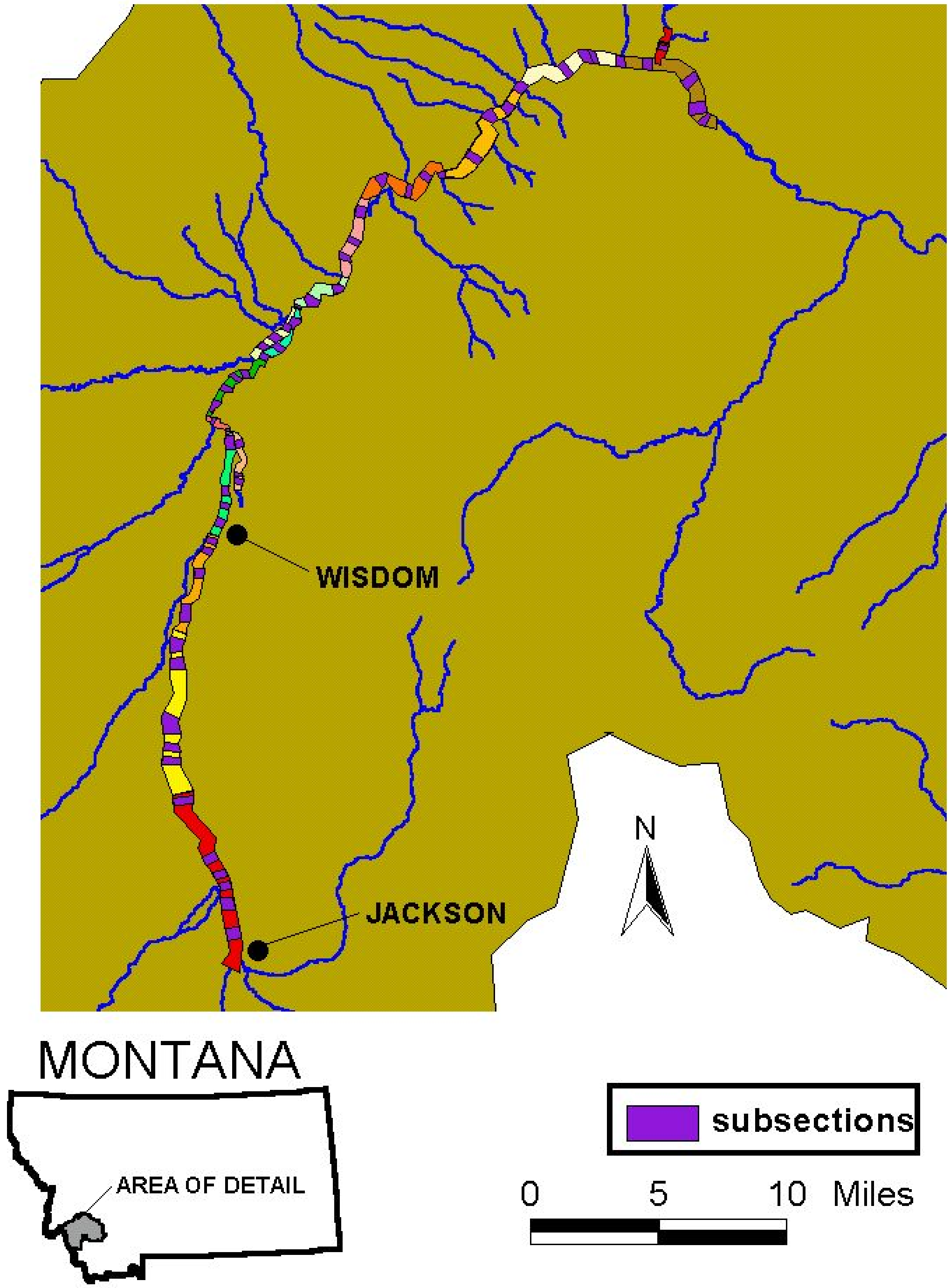

Figure 2. Location of 1994 Big Hole River habitat survey reach subsections.

RESULTS

Rosgen classification of stream survey reaches

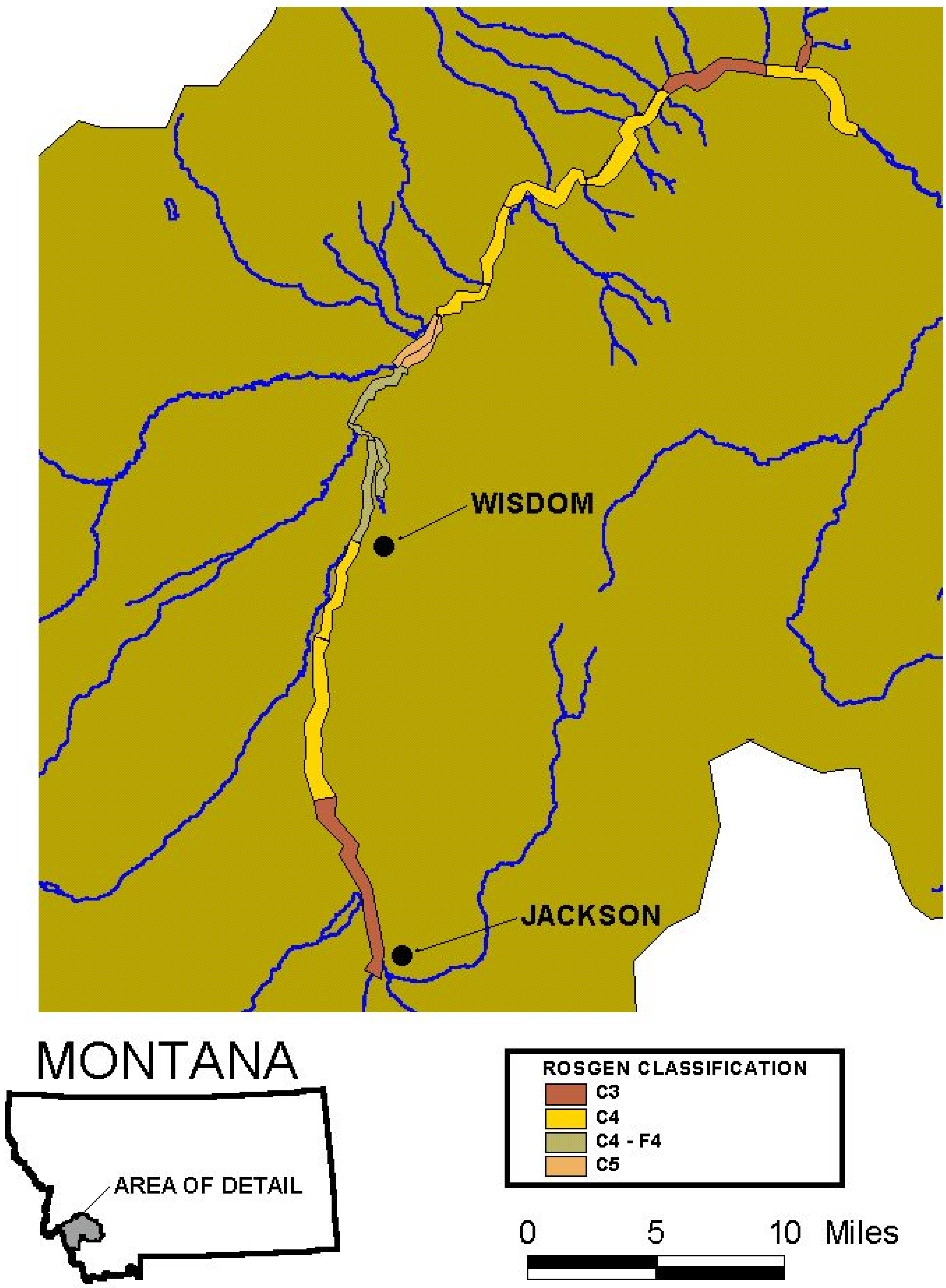

Figure 3. Spatial distribution of reach types based on Rosgen classification system.

Rosgen classification of stream survey reaches

According to the OEA 1995 report C-type stream channels (Figure 3) dominate the upper Big Hole drainage. These channels are described as low gradient, meandering, alluvial channels with broad, well defined floodplains (Rosgen 2002). The major deviation from this trend occurs in reaches D downstream to G. These reaches range from C-type channels to F-type channels. F-type channels are described as low gradient, entrenched channels that are laterally unstable with high bank erosion rates (Rosgen 2002). The OEA report suggests that this deviation is due to an increase in grazing pressure in this area of the watershed. Evidence of these impacts is in the form of streambank compaction, bank cutting, reductions in riparian vegetation and the loss of native species of grasses (OEA 1995).

Habitat types and relative abundance

Within the habitat survey reaches glides were the dominant habitat units (66%), followed by pools (20%) and riffles (14%). The spatial distribution and relative abundance of these habitat units is shown in Figure 4. The spatial availability of these habitat units drives seasonal habitat selection. Areas with riffles are important to spring spawning (Shepard and Oswald 1989) and pools and glides (Lamothe and Magee 2003) are used during the summer for feeding and thermal refugia. Pools and glides are also important for overwintering (West 1992).

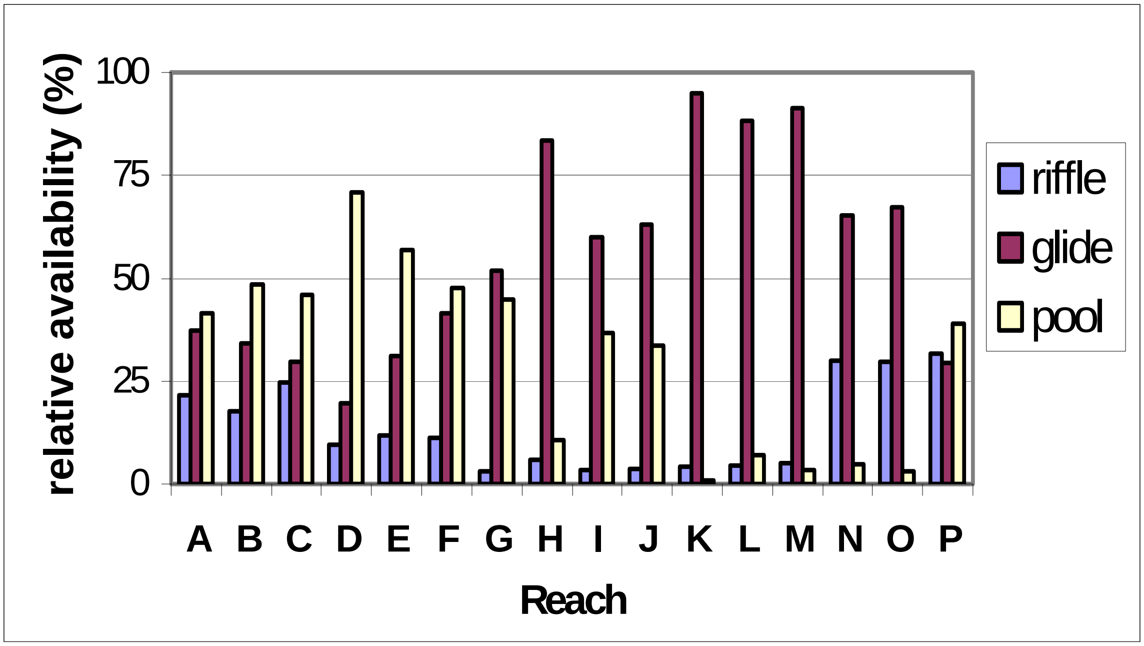

Figure 4. Spatial distribution and relative abundance of habitat units in the upper Big Hole River 1994.

The relative availability of riffle habitat was significantly greatest in Deep Creek (Reach P) and smallest in the section of river between the mouth of Pintlar Creek downstream to the mouth of Toomey Creek (Reaches K & L) (Anova, n=16, $p < 0.0001$). The relative availability of glide habitat was significantly greatest in the section of river from the mouth of Pintlar Creek downstream to the mouth of Fishtrap Creek (Reaches K, L & M) and smallest in the section of river from the mouth of Big Lake Creek to the mouth of Steel Creek (Reach D) (Anova, n=16, $p < 0.0001$). Relative pool availability was greatest in the section of river from the mouth of Big Lake Creek to the mouth of Steel Creek and within Steel Creek (Reaches D & E) and smallest in the section of river from the mouth of Pintlar Creek downstream to York Gulch (Reach K) (Anova, n=16, $p < 0.0001$).

Pool type and quality

Type and quality further classified pool habitats. Pool types delineated during the survey include: backwater, lateral scour, debris, trench, plunge, and secondary channel (OEA 1995). Pool quality was rated on a scale from 1 to 5, with 5 being the highest quality (Platts et al. 1987). This ranking system takes into account pool diameter, maximum depth, and the condition of available cover.

The relative of abundance of pool types is shown in Figure 5. Lateral scour pools were clearly the dominant pool-type (75%) delineated within the upper Big Hole River during the survey. Backwater pools was the second most common type at 20%.

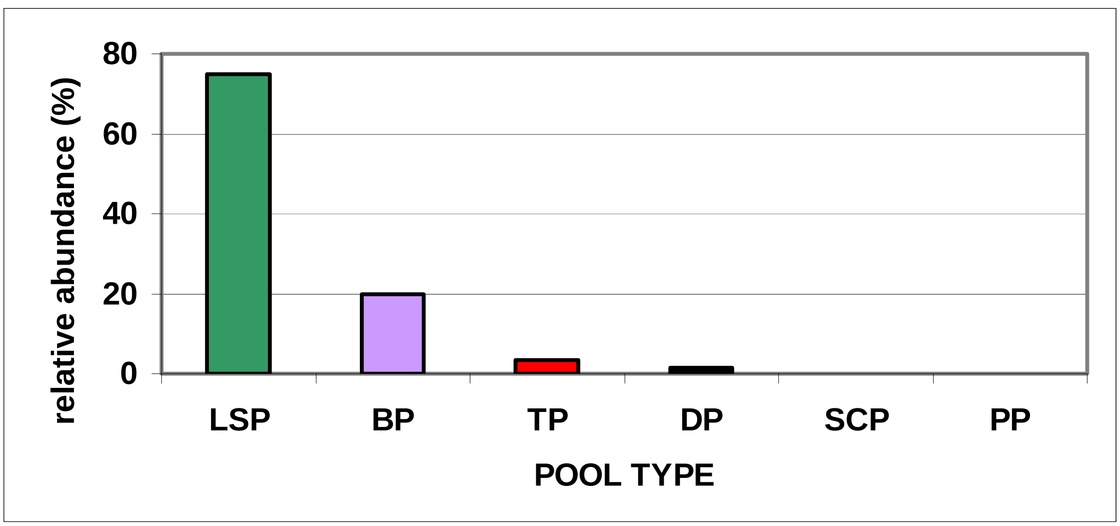

Figure 5. The relative abundance of pool types within the upper Big Hole River in 1994. (LSP=lateral scour pool, BP=backwater pool, TP=trench pool, DP=debris pool, SCP = secondary channel pool, PP=plunge pool).

The relative availability of lateral scour pools was significantly greatest in the sections of river from the mouth of Big Lake Creek downstream to the mouth of McVey Creek (Reaches D, E, F, G), in the North Fork (Reach I) downstream from its mouth to the mouth of Pintlar Creek (Reach J) and in Deep Creek (Reach P) (Anova, n=16, $p < 0.0001$). Lateral scour pools were not found in the sections of the river from the mouth of Pintlar Creek downstream to York Gulch (Reach K) and in the section of river from the mouth of Toomey Creek downstream to the mouth of Fishtrap Creek (Reach M).

The availability of trench pools was greatest in the section of river between the Big Lake Creek "cutoff channel" downstream to the mouth of Big Lake Creek (Reach C) (Anova, n=16, p= 0.001). Plunge pools and secondary channel pools were found to be very uncommon and while they were found in small numbers the abundance of these habitat types was not significantly different from zero (Anova, n=16, $p > 0.65$).

Debris pools were found in only 5 of the 16 survey reaches (Reaches A, C, D, L, and P) and analysis showed that in reaches in which debris pools were found there was no significant difference in availability (Anova, n=5, p = 0.08).

We found no significant differences in the relative availability of backwater pools between reaches (Anova, n=16, p = 0.03). The inability to differentiate availability between reaches with a p-value equal to 0.03 is due to the relative conservative nature of the Tukey multiple comparison test. The section of the Big Hole River between the mouth of Big Lake Creek and the mouth of Steel Creek has the greatest relative abundance of backwater pools, but again, this was found to not be statistically significant.

The upper Big Hole River has a wide range of spatial variability in pool quality. Our study results show that the upper reaches of the survey section (A – G) are dominated by high quality (class 5 & class 4) pools and in the lower reaches were dominated by lower quality (class 3 & class 1) pools (Figure 6).

While there is a spatial pattern to the distribution of pool quality in the survey reaches, we found no significant differences in the abundance of class 5 pools between reaches (Anova, n=16, p = 0.11). The Steel Creek survey section (Reach E) provided the greatest relative abundance of class 4 pools (Anova, n=16, p = 0.001). We did not find significant differences in the relative abundance of class 3, class 2, and class 1 pools (Anova, n=16, p > 0.15).

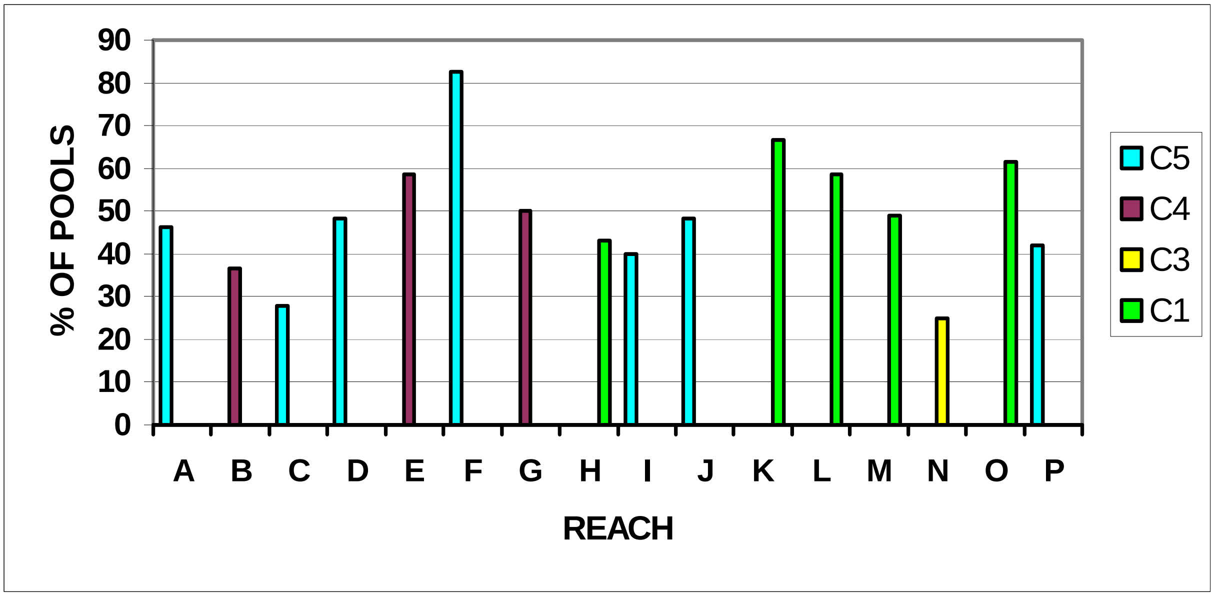

Figure 6. Spatial distribution of dominant pool quality types in the upper Big Hole River. Pool quality was determined using Platts et al. 1987 (i.e. C5 equals a class 5 pool on the Platts scale).

Channel stability parameters

Riffle Stability Index (RSI) values were generally high throughout the study section (Figure 7). Since the index for riffle stability does not have a linear relationship with stability, these results may be misleading. Systems in dynamic equilibrium generally have an RSI value between 50 and 70 (Kapesser 1993).

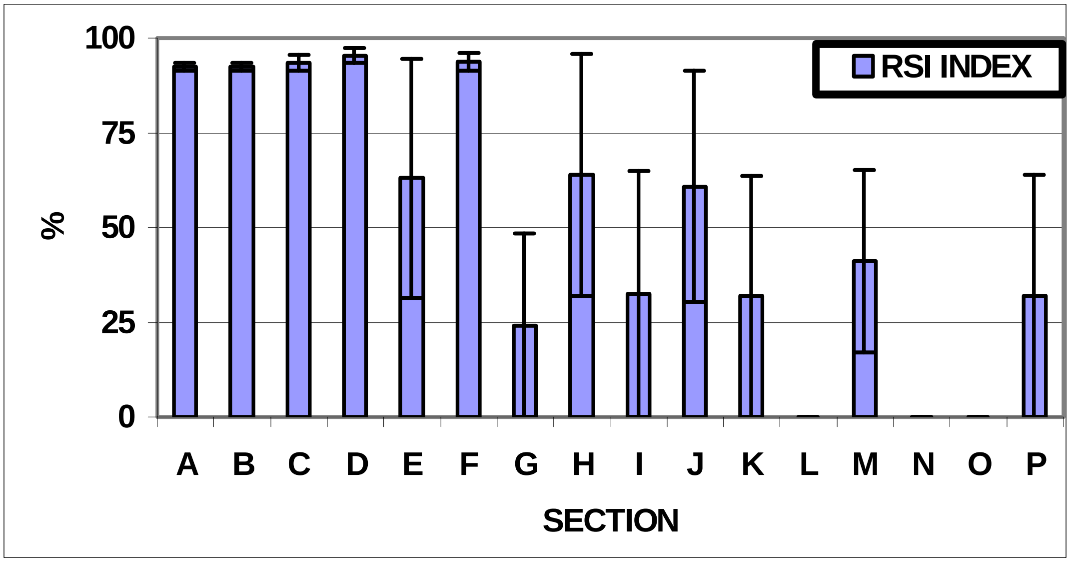

Figure 7. Results of Riffle Stability Index (RSI) measurements.

RSI values greater than 70, similar to what is found in the upper Big Hole River, show a system out of equilibrium with riffles that are mostly aggraded. It is important to remember that a dynamic system is not necessarily a negative situation in terms of habitat quality. In the case of channel instability, Shepard and Oswald (1989) found that grayling spawning sites were often located in actively aggrading or degrading side channels.

Percent of actively cutting banks was statistically greatest in sections C, F, I, and J (Anova, n=16, p<0.001) (Figure 8). The least amount of actively cutting banks was found in sections K and N. It is important to note, that it has been shown, that bank

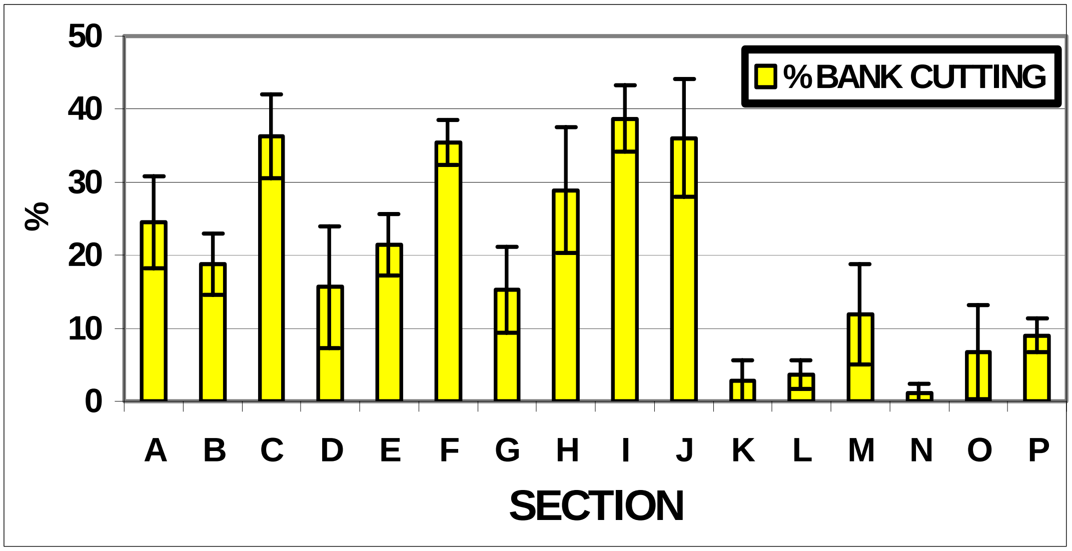

Figure 8. Results of actively cutting banks (%) measurements.

erosion is often correlated to poor riparian vegetation health (Hunter 1991).

Width – depth ratios were statistically different between habitat reaches (Anova, n=16, p<0.0001) (Figure 9). Reaches H, G, and F had the statistically highest ratios. Width depth ratios were not calculated for reaches K,M,N, and O. While the width depth ratios in reaches H, G, and F are relatively high, the ratios observed in the upper Big Hole River are within the typical range for the C type channels that dominate the drainage (Rosgen 2002).

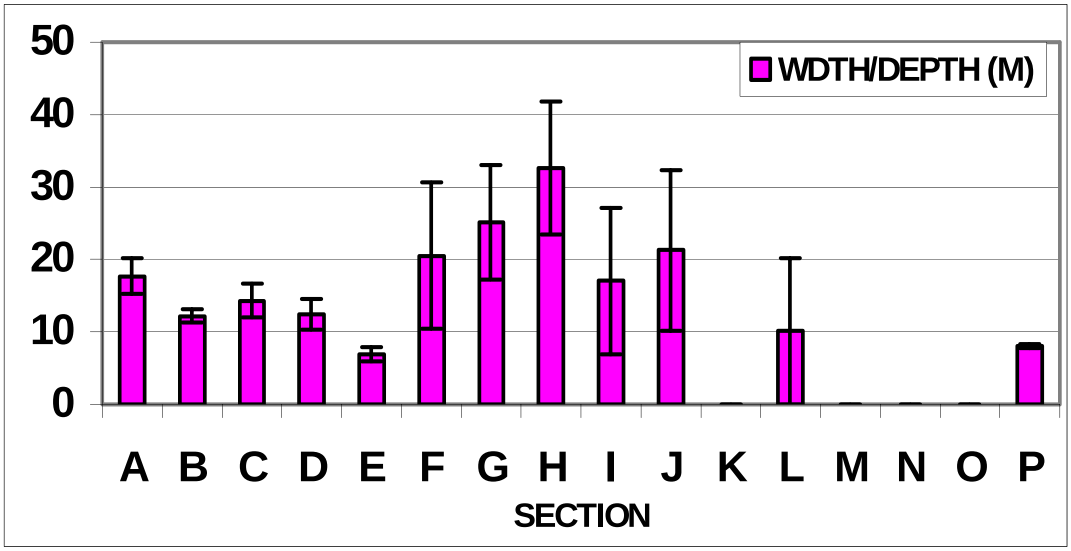

Figure 9. Width-depth ratios for the upper Big Hole River.

Percent overhanging vegetation and canopy closure

The amount of overhanging vegetation was measured along riffle transects within each study section. The percent of transects with overhanging vegetation is shown in Figure 10. Values range from 0 in reaches C, F, H, I, J, M, and P to 67% in Reach E. The percentage of canopy closure was found to be less than 5% at all transects in the study reaches. Hunter (1991) found canopy closures of 40 to 60% to be typical of “good” trout streams.

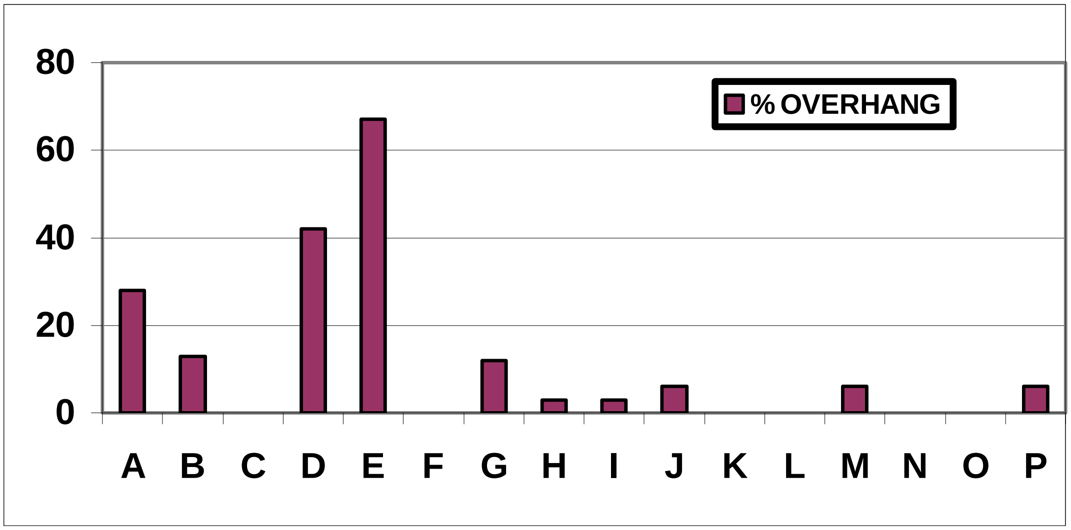

Figure 10. The percent of transcects within each study section with overhanging vegetation.

Stock pressure

Stock pressure was found to be heavy in 49% of the 57 subreaches (Figure 11). Seventy-five percent of subreaches were found to have either heavy or moderate stock pressure.

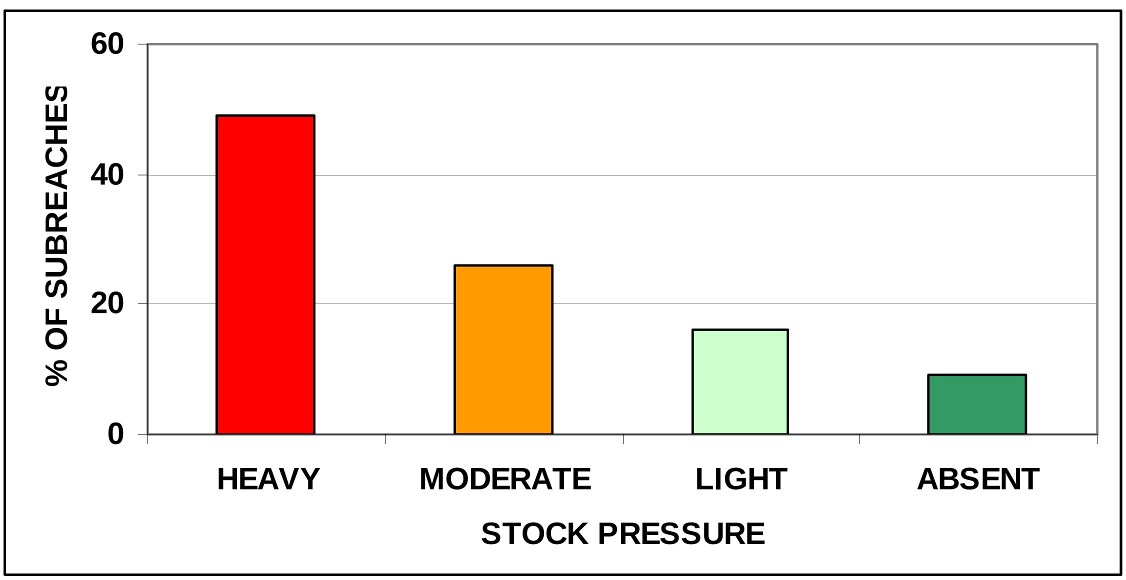

Figure 11. Stock pressure within subreaches measured in the 1994 OEA, Inc. survey.

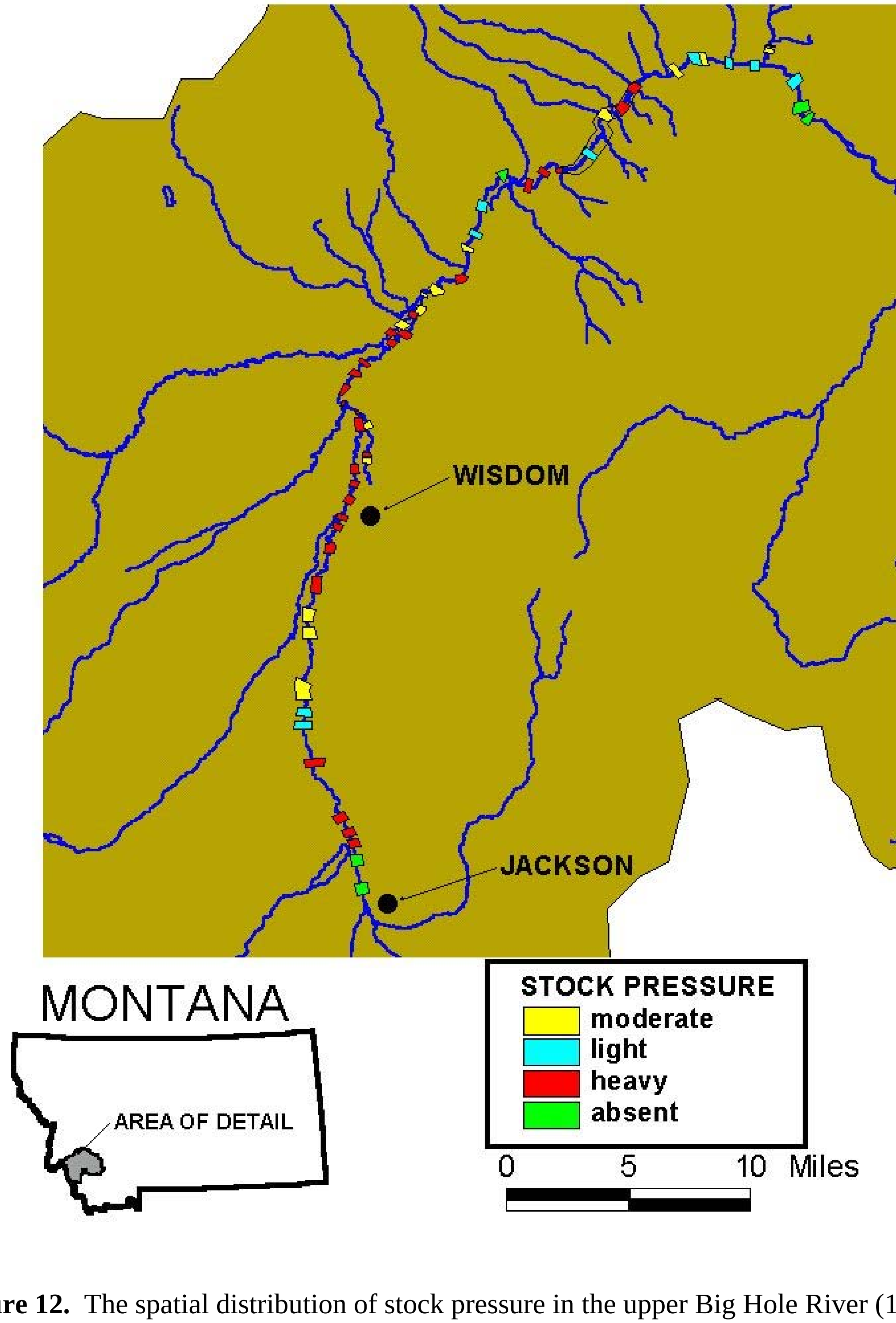

Figure 12. The spatial distribution of stock pressure in the upper Big Hole River (1994).

The spatial distribution of stock pressure in the upper Big Hole River is shown in Figure 12. An important observation from this map is that there is a noticeable area of concentration of stock pressure near the town of Wisdom. This is important because: 1) this area of Big Hole River is considered a critical reach in determining the status of fluvial Arctic grayling populations in the river (MFWP 1996), and 2) this area overlays the reaches that are migrating from C-type channels to F- type channels (Figure 3). The 1994 OEA Research Inc. report states that this change in channel types is due primarily to intense grazing pressure.

Arctic grayling abundance and sampling reaches

Montana Fish, Wildlife & Parks annually conducts intensive sampling of the upper Big Hole River in order to determine the status of the Arctic grayling population. From the 11 sampling sections within the habitat reaches, 1459 grayling were captured from 1992-1996 (Table 3). A five-year span of data was used to provide for adequate sample size for statistical analysis. Five years of data also helps to smooth the variation of sampling success within sampling reaches due to variable environmental conditions, changes in habitat quality, and the relatively high mobility of Arctic grayling.

Table 3. Results of seasonal sampling of Arctic grayling in the upper Big Hole River from 1992-1996.

Sampling section	Habitat reaches	# of grayling captured
McWisdom	C-D-E-F	227
Steel Creek	E	199
Wisdom West	D-F	169
Sportsmans – Eastbank	N-O	164
Deep Creek	P	143
Sawlog – Sportsmans	M-N	140
McDowell	C-D	133
North Fork	F-G-H-I-J	130
Wisdom East & West	D-E-F	78
Upper North Fork	F-G	26

The relationship between Arctic grayling abundance and physical habitat parameters in the upper Big Hole River

Our analysis correlated Arctic grayling abundance in the upper Big Hole River to the relative abundance of overhanging vegetation (multiple regression, $r^2=0.73$, $p<0.03$), (Figure 13). This suggests that 73% of the variation in Arctic grayling abundance from 1992 to 1996 is best explained by the relative abundance of overhanging vegetation. These results seem to contradict previous studies investigating the habitat selection of Arctic grayling (Lamothe & Magee 2002).

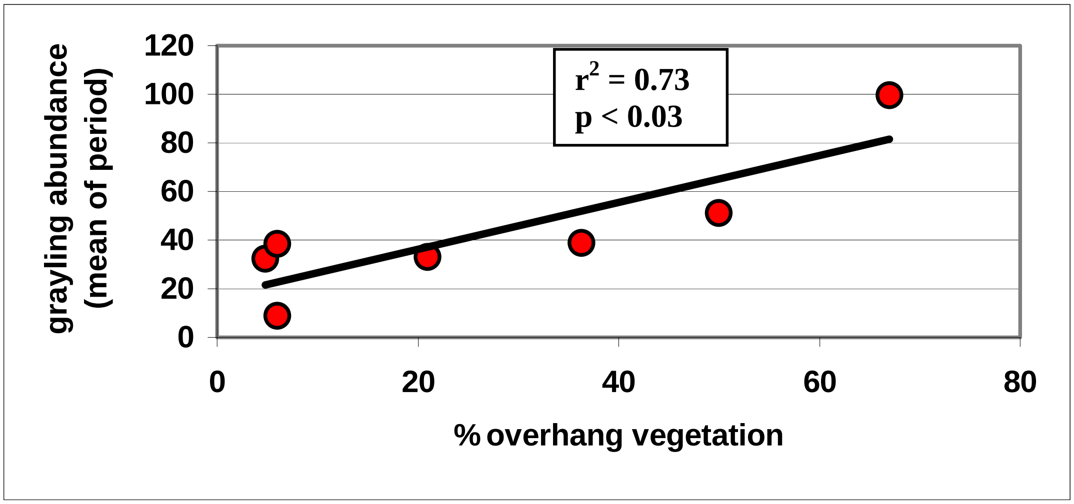

Figure 13. Regression relationship between Arctic grayling abundance and percent of transects within a reach with overhanging vegetation.

Previous reports and the scientific literature show that pools are the critical habitat-type that grayling select for feeding and refuge from seasonal extremes (West et al. 1992, Lamothe and Magee 2002). Then why did our analysis show that overhanging vegetation was the single most important parameter in predicting grayling abundance? A common perception is that areas of the river with large amounts of woody debris will support high densities of brook trout *(Salvelinus fontinalis*) leading to reduced numbers of grayling through the mechanism of competition. While previous studies have shown a correlation between woody debris and trout numbers (Wesche 1985, Riley and Fausch 1995), is there a mechanism for abundant riparian vegetation to benefit Arctic grayling numbers?

Further analysis of our results show that the abundance of overhanging vegetation was correlated to the availability of relatively high quality pools (class 4), debris pools, and lateral scour pools (Table 4). The abundance of overhanging vegetation was negatively correlated to the percent of actively cutting banks (Table 4). These results show that sections of the Big Hole River with high quality pools and a diversity of pool types support a relatively high abundance of Arctic grayling. The biological mechanism that creates these high quality habitats is healthy riparian vegetation.

Table 4. Summary results of step-wise multiple linear regression relating the relative abundance of overhanging vegetation to stream habitat parameters.

Habitat Variable	F-Value	DF	r^2	direction of effect	P-value
class 4 pools	6.79	15	0.62	positive	0.05
% actively cutting banks	10.37	15	0.28	negative	0.04
debris pools	39.96	15	0.08	positive	0.02
lateral-scour pools	175.43	15	0.01	positive	0.04

DISCUSSION

The results of our study strongly suggest that there is a link between the abundance overhanging vegetation, the quality of instream habitat, and Arctic grayling abundance in the upper Big Hole River. River reaches with healthy riparian vegetation have a high degree of bank stability, pool quality and habitat diversity. A healthy, functioning riparian corridor also provides shade to the stream, water storage during flooding, and a food source for stream microbes and insects (Hunter 1991). The current condition of much of the riparian vegetation and stream banks along the upper Big Hole River is poor (personal observation). Has this reduction in habitat quality led to reductions in grayling numbers throughout the river? Recently, there has been discussion on the importance of the smaller tributaries in the watershed to the Arctic grayling population. In recent years, fall population surveys have shown relatively high numbers of Arctic grayling in these smaller streams. The current perception is that grayling use these streams mainly as thermal refugia from drought conditions. Stream temperatures (i.e. daily means and maxima) in these tributaries are often significantly cooler than the temperatures in the main channel of the Big Hole River. But are there other parameters that make these streams more suitable to Arctic grayling than the main channel of the upper Big Hole River? A striking difference between many of these streams and the main channel of Big Hole River is the health of the riparian vegetation. These streams offer stable banks, high quality pools, cool water temperatures, and protection from predators through overhanging vegetation and water depth.

While the results of our study show the importance of healthy riparian vegetation to stream habitat quality and Arctic grayling abundance, it does not intend to diminish the importance of streamflow within the Big Hole River to Arctic grayling population health. Montana Fish Wildlife and Parks along with private landowners, the Big Hole Watershed Committee, and other state and federal agencies have worked together to ensure the greatest possible instream flows throughout the Big Hole River. While these efforts have begun to bear some positive results, the prolonged drought conditions that have recently plagued southwest Montana continue to make securing adequate instream flows extremely difficult. This drought, along with Montana Water Rights Law, creates a situation where significant increases in future stream flows seem very unlikely. Water issues are critical to the future of fluvial Arctic grayling and should not be ignored, but we believe the results of this report offer alternative approaches to assisting in the restoration of the Arctic grayling population in the upper Big Hole River.

A disturbing trend with regards to riparian vegetation in the upper Big Hole River is the continued removal and suppression of riparian vegetation (personal observation). This trend of continued reductions in riparian vegetation abundance and quality seems to be having a negative impact in pool quality. Many pools within Montana Fish, Wildlife and Parks fish population sampling sites have suffered reductions in depth and overall quality (personal observation). These recent reductions in pool quality are likely in part correlated to the recent downward trend in Arctic grayling numbers within our sampling sites due to the importance of pools in terms of Arctic grayling habitat selection.

MANAGEMENT RECOMMENDATIONS

The results of our study show that the riparian health of the upper Big Hole River plays a critical role in determining both the health and quality of instream habitat and the resident Arctic grayling population. The importance of riparian health to the river demands the preservation and restoration of the riparian community to the upper Big Hole. Where it is possible riparian vegetation should be protected with sound grazing practices and fencing to reduce the potential impacts of livestock and wild game. Areas of the river that have been cleared of riparian vegetation should be re-vegetated and fenced. Fencing is a critical component of these restoration efforts, since it will provide the vegetation the protection needed to reestablish quickly. Funding must be generated to conduct these restoration efforts, maintain the projects upon completion, and compensate landowners for reductions in grazing acreage and access to the river for stock watering.

If possible, the focus of restoration efforts should be from the mouth of Big Lake Creek downstream to mouth of McVey Creek , including Steel Creek. It is these reaches of the river that were responding to the impacts of grazing pressure in 1994. Channel type in this section of the river were documented to be migrating from C- type to F-type. This section of river is also considered a “critical” Arctic grayling reach. Restoration efforts in this section of the river should be a priority due both to need and the possibility of increasing Arctic grayling numbers.

It is also our belief that an entire or partial re-inventory of the habitat parameters measured in the 1994 OEA Research Inc. survey be conducted. This survey would provide us with the data necessary to conduct a time series analysis (i.e. is it getting better or worse) of habitat quality in the upper Big Hole River. The results of this analysis would allow us to focus future restoration efforts, determine the impact of habitat projects conducted after 1994, and determine how the Arctic grayling population is responding to changes in the habitat suitability of the river.

Lastly, it is critical that we expand our collection of data pertaining to the spatial variation in stream flows within our sampling reaches and determine how this spatial variation affects Arctic grayling abundance. At the current time we simply do not have the amount of stream discharge data necessary to incorporate this important parameter into the types of analysis presented in this report. We suggest that stream discharge monitoring equipment be purchased and installed in a minimum of 5 sampling reaches. This will build upon the current effort to map the spatial variation of stream discharge in the upper Big Hole River initiated by Mike Roberts of the DNRC. This data will allow us to determine the seasonal importance of stream discharge as well as critical minimum and even maximum discharge that correlate to variations in the abundance of Arctic grayling in the upper Big Hole River.

ACKNOWLEDGEMENTS

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