DEVELOPMENT OF HABITAT PREFERENCE CRITERIA FOR HOLDING ADULT SPRING CHINOOK SALMON

by

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ABSTRACT

Habitat criteria, in the form of suitability curves adjusted to reflect relative preference for instream characteristics, were developed for holding adult spring chinook salmon. This study was conducted during 1984 and 1985 in the Wind River, tributary to the Columbia River. Data collection was comprised of two separate efforts, i.e., utilization data were collected where holding spring chinook were actually observed, while availability data were collected in a representative portion of the total habitat that was available to holding spring chinook. Snorkel observations of 537 holding fish were used to guide utilization measurements of total depth, fish nose depth, mean column velocity, velocity at nose depth, dominant substrate, and proximal protective cover. During the same time periods, availability measurements of total depth, mean column velocity, dominant substrate, and protective cover were made within a representative reach. Frequency analyses of the utilization characteristics were performed, and utilization curves were constructed. Frequency analyses of the availability data were performed, and availability functions were derived. Relative preference functions for each instream characteristic, excluding fish nose depth and nose velocity, were then determined from the ratio of utilization to availability functions. Finally, for each set of preference functions, preference curves were constructed.

The preference curve optimums, i.e., the characteristic value(s) or category most preferred, were as follows: total depths $\geq$ 14.1 ft.; a mean column velocity range of 0.0 to 3.7 ft/sec; for dominant substrate, small cobble; and for protective cover, overhead wood. Associated assumptions and curve application considerations are discussed.

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John Drotts, during 1984, and Curtis Stanley, during 1985, did excellent work as my field assistants. I am especially grateful to them for their effort during the field work.

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INTRODUCTION

Fish habitat criteria, in the form of suitability curves, have been unavailable or inappropriate for certain anadromous salmonid life history stages in Pacific Northwest streams. Among the unavailable criteria were suitability curves for the adult holding stage of spring chinook salmon. The U.S. Fish and Wildlife Service (USFWS) and the Washington Department of Fisheries (WDF) recognized this information gap and felt that it hindered their ability to protect spring chinook runs from man-made habitat alterations. The Fisheries Assistance Office, Olympia, WA (FAO) undertook a study to develop those suitability curves in 1984.

Habitat criteria developed from suitability curves are of greater value in habitat protection than fish utilization curves. The Instream flow and Aquatic Systems Group (IFG) at Ft. Collins, Colorado, described the concept of creating a suitability curve that is essentially environment independent (Bovee 1982). Baldridge and Amos (1981) further defined suitability as the ratio between habitat utilization and habitat availability. They described habitat utilization as the percent occurrence of a fish life stage using an increment of a habitat characteristic (variable). They described habitat availability as the percent occurrence of the same increment of habitat characteristic within the available area. The suitability ratio was then expressed as a weighted curve.

Following is an example of how an individual suitability ratio might be determined. Data analysis might show that one percent of all adult spring chinook in a stream were found holding in (i.e., utilizing) flow velocities falling within the range increment of 3.0 to 3.19 ft/sec. Analysis of the data for flow velocities actually available to those spring chinook might show that two percent of all existing velocities, by stream surface area, fell within the range increment of 3.0 to 3.19 ft/sec. The suitability ratio for this velocity range increment, i.e., 1:2 or 0.5, is then weighted relative to the largest ratio for any increment. A velocity suitability curve is then constructed from a plot of all weighted ratio values spanning the full range of velocity increments.

The suitability curve reflects use of habitat that is more independent of habitat availability. This curve should be appropriate for application in other streams occupied by the same life stage. It should also reflect true fish preference. Therefore, I will refer to suitability curves as preference curves in this report.

The Wind River, a tributary to the lower Columbia River, was selected as the study stream (Figure 1). Wind River water clarity, abundance of holding spring chinook, and diversity of instream habitat types provided the prerequisites for a suitable study stream. The Carson National Fish Hatchery (CNFH), located at about river mile 17.4, supports a run of spring chinook that has numbered up to several thousand adults. This run was closed to fishing, which enhanced the opportunity to find sufficient numbers of unharassed adults in natural locations. In addition, access to the Wind River, upstream of the town of Stabler, was generally good.

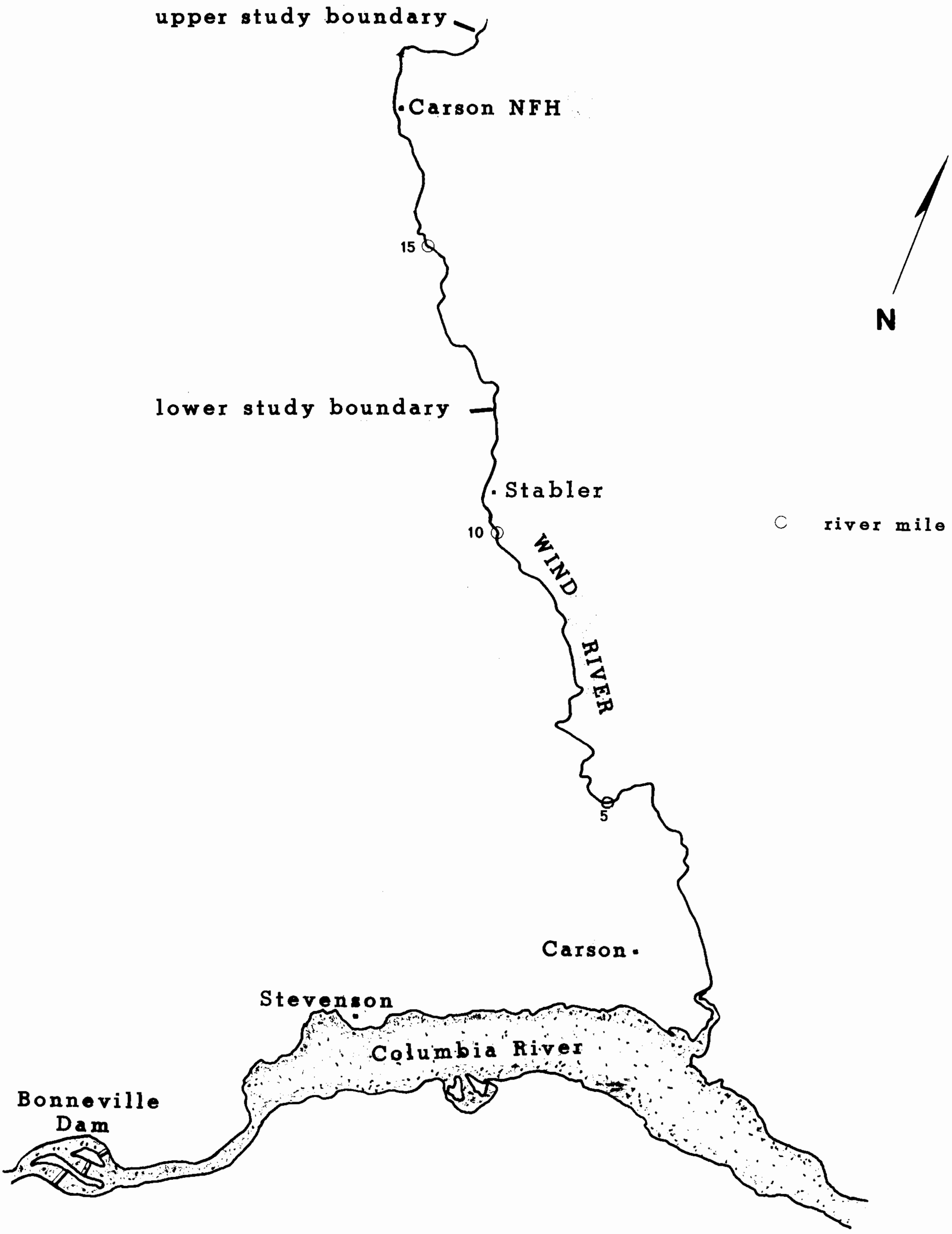


Figure 1. Location of Wind River and the study area.

METHODS

The field procedure that I used was largely guided by recommendations of the IFG staff (K. Bovee, P. Nelson, and C. Stalnaker, personal communications) and related material in IFG publications (Bovee and Cochnauer 1977, Bovee 1982). Baldrige and Amos (1981) described the general method I employed to analyze field data and develop preference curves. My collection of field data fell into two principal categories, utilization data and habitat availability data.

Utilization Data Collection

Data collection to develop utilization generally followed established guidelines for gathering probability-of-use (Bovee and Cochnauer 1977) or habitat utilization curve data (P. Nelson, unpublished). I determined from preliminary foot and snorkel surveys on the Wind River that the reach from about river mile 12.0 to 19.0 was most suitable for study. Figure 1 shows the approximate boundaries of the study reach. Only the river section immediately downstream of the CNFH was excluded from data collection because of possible bias due to the concentration of spring chinook in this area. Those fish were waiting to enter the hatchery.

Based upon my previous experience and discussions with biologists who had observed holding adult spring chinook, I concluded that observations must be gathered by snorkeling in an upstream direction.

Fitted with full wet suit, mask and snorkel, and felt-soled canvas shoes, one person cautiously moved upstream until an adult spring chinook was located. At that point, the following tasks were performed: (1) the fish (one or more) was observed from a distance to determine if it was an adult spring chinook and if it was holding, i.e., stationary, and at exactly what position in relation to the stream bed and the water column; (2) once a fish was determined to be holding, and its location data were relayed to an assistant on the stream bank, the observer moved to the point of location to gather additional information; (3) total depth and depth of the fish (nose depth) were read from a six-foot top-setting wading rod placed at the stream bed point over which the fish's nose had been; (4) flow velocities of the mean water column and at nose depth were measured over the point of location (using either a Swoffer model 2200-adapted Price AA or a Pygmy current meter on the wading rod); (5) the dominant substrate category and its percent, and the subdominant substrate category at the point of location were recorded (particle size categories were developed by an interagency substrate committee (WDF 1983)); and (6) presence or absence and category of overhead protective cover, within about four feet of the point of location, were recorded. The substrate and protective cover categories used are listed in Appendix Tables 1a and 1b, respectively.

I gathered utilization data within different segments of the study reach on each sample day. This approach eliminated the risk of repeating measurement of a particular fish at the same location. I assumed that if a given fish was remeasured at a new location in another river segment, then it was useable data.

A sample size of 150 to 200 observations is usually sufficient to develop satisfactory suitability curves, but a statistical test should provide the final guidance as to sample size (P. Nelson, unpublished). Following the completion of data collection in 1984, I tested the data for sample size (Snedecor and Cochran 1972). At the 95% probability level the test indicated that larger samples were required for the continuous characteristics, i.e., total depth, fish depth, mean column velocity, and velocity at nose depth. As a result, one additional year to collect fish observations was required in 1985. We were unable to collect additional data beyond 1985.

Following advice offered by the IFG (K. Bovee, personal communication), sampling effort exerted during 1985 equalled but did not exceed that of 1984. Water temperature was recorded occasionally during the work period, but not during all sampling days. Presence or absence of shade at a fish location was recorded for each fish observation during the second year only. With few exceptions, depth and velocity measurements were made at the correct location. In a few instances, however, depths were too great to measure precisely. On these occasions, depths were estimated to the nearest foot and velocities were measured as near to the correct location as possible. At the end of each sampling day, data collected were reviewed for accuracy. Biological data on fish size were obtained from adult sampling performed at CNFH.

Availability Data Collection

An assessment of the holding habitat available to spring chinook was required in addition to the utilization data. Characteristics in this habitat had to be assessed during the approximate period that fish observations were made to permit meaningful associations between utilized habitat and available habitat. I determined habitat availability by sampling within a sub-reach of the study reach.

Conditions in the availability sub-reach (AR) were determined to be representative of the conditions found within the study reach. I performed vehicle and foot surveys of the study reach, which supplemented initial observations from snorkel work, to permit suitable selection of the AR. I also used maps and a set of aerial photos to make the selection. The sub-reach I selected for the AR was located at about river mile 16.3. Total length of the AR was about 600 feet.

Data collection procedures employed within the AR generally followed standard procedures of the instream flow incremental methodology (IFIM) developed by the IFG. Ten transects, perpendicular to the direction of river flow, were established within the AR. At transect verticals, i.e., points along a transect having marked change in any instream characteristic, measurements were made. Total depth, mean column velocity, substrate, and cover were measured to determine the total AR wetted surface area having specific values or codes of instream characteristics. Actual measurement procedures were identical to those used in utilization data collection.

A temporary staff gauge within the AR was used to determine when to collect data in the AR. I placed the staff gauge there prior to beginning collection of utilization data in 1984. Frequent monitoring of day to day river stage, as read on the staff gauge, was used to guide decisions on when to collect data sets in the AR. These decisions were made somewhat subjectively. But, they were based on my conclusions that significant change in river stage had occurred, thus requiring a new set of availability data to be used to adjust utilization data for the corresponding collection period. Availability data sets were collected in the AR on three occasions, once midway through the 1984 fish utilization data collection period, and twice during the 1985 collection period. Each data collection in the AR required about two days effort with a two or three person crew.

One unexpected development arose from comparing the ranges of respective instream characteristics among utilization data with those among availability data. Development of the total depth preference required that the relative proportion of all increments of total depth available to holding fish be accounted for in the calculations. Maximum water depth in the AR was not as great as at some locations where fish were observed in the utilization reach. It became obvious that those greater depths must be represented in the AR. To correct this, I devised a means of estimating the lineal proportion of the total study reach that consisted of increments of total depth exceeding the maximum depth found in the AR. This task was accomplished by making map planimeter measurements on a composite set of aerial photos of the study reach. I relied on my familiarity with the deepest sections of the utilization reach to mark these sections on the photos. The correct proportion of surface area representing water depths greater than in the AR was then added to the calculated AR surface area for total depth. This added area was divided equally among the increments of depth ranging between the maximum depth in the AR and the maximum depth observed anywhere in the utilization reach.

Utilization Data Analysis

I performed frequency analyses upon the utilization data for all instream characteristics, first for individual sampling periods, and then for combined sampling periods. From 1985 data, I also calculated the percentages of fish found in shade, in partial shade, or in direct sunlight.

It is useful to compare utilization curves with respective preference curves. Therefore, I performed several operations on the combined data sets to permit construction of utilization curves. For the continuous characteristics such as water depth, i.e., having adjacent values that can be logically combined (grouped), I selected value intervals for grouping observations within the frequency distributions. In the case of total depth, the wide range of values and the presence of gaps between some observations at higher values led to grouping observations into one-foot intervals. For mean column velocity I used group intervals of 0.2 feet per second (ft/sec). The discontinuous characteristics, dominant substrate and protective cover, were not grouped. I then tested all frequency distributions, whether continuous or not, for chi-square goodness-of-fit

(Snedecor and Cochran 1972) to see if distributions were significantly different from uniform distribution. If a distribution was found to deviate significantly from uniformity, then that distribution's group (or category) having the greatest frequency was assigned a weighting factor of one, and other groups were respectively standardized (Baldrige and Amos 1981). For mean column velocity, velocity at nose depth, and fish nose depth, I assigned group intervals according to similarity among fish frequency values and my interpretation of frequency trends.

Having assigned standardization weighting factors to frequency distributions, I then constructed the respective utilization curves. Following the procedure of Baldrige and Amos (1981), I plotted midpoints of characteristic intervals having weighting factors of less than one. For each curve having an optimum weighting (1.00) that extended over some interval, e.g., water depths from 2.1 to 3.0 feet, I constructed the curve peak across the optimum interval. I constructed curve tails so that they dropped to zero weighting at the outer boundaries of the outermost weighted intervals.

The last step in analyzing utilization data was the calculation of percent fish occurrence for each value or category. The key products required from the process of analyzing utilization data were the utilization functions. The utilization functions for a given instream characteristic were simply the percentages of all holding fish observed at respective values or categories of that characteristic. For example, 18.2 percent of holding fish were observed at locations having mean column velocities ranging from 0.0 to 0.19 ft/sec (Appendix Table 3). These percentages were calculated for all characteristic values and categories.

Availability Data Analysis

The final objective of the availability analysis was to derive availability functions. This required the calculation of total stream surface areas for all characteristic values or categories found in the AR. For each data set collected in the AR I diagrammed the values and categories recorded along all transects. Then, using lineal measurements across and between transects, I calculated the required stream surface areas. I used standard IFIM procedures to assign surface areas.

I completed this analysis by constructing a table for each AR instream characteristic. Each table contained the complete range of measured values or categories, the respective total surface areas, and the respective percentages of total available habitat. The latter percentages were, in fact, the availability functions. Unlike Baldrige and Amos (1981), I did not eliminate any portion of the surface area contained in AR measurements. I assumed that no tolerance limitations for any instream characteristic restricted holding spring chinook from using any portion of the available habitat.

Relative Preference Curve Development

The development of relative preference curves required two additional calculation steps before curves could be constructed. For each value interval or category of each instream characteristic, the relative preference ratio was calculated. I derived this ratio, or quotient, by dividing each value interval or category's percent utilization by the respective percent of combined available habitat. I then standardized these quotients, yielding relative preference weighting factors. Finally, for each instream characteristic (excluding fish nose depth and velocity at nose depth), I plotted weighting factors against values or categories to create preference curves.

RESULTS

Snorkel Sampling

Gathering observations of exact holding locations of adult spring chinook by snorkeling in an upstream direction worked well. Excellent water clarity and mid-morning to late afternoon daylight generally provided very adequate viewing conditions. Typical water clarity permitted the snorkeler to see stream bed detail in the deepest pools. Fish were usually sighted before they appeared to detect the snorkeler's presence, and they normally tolerated the snorkeler within the distance required to secure data, even after detection. Some fish refused to leave their holding location despite the immediate presence of the snorkeler and sampling equipment; but some fish swam away rapidly.

Holding Behavior

I found holding adult spring chinook behavior to be generally consistent within the study reach. Certain stream habitat types appeared to attract holding fish, regardless of river mile. Deep pools or glides with some form of overhead cover often contained concentrations of holding fish. However, one form or another of overhead cover frequently sheltered one or more holding fish when located in more shallow water.

Early in the process of collecting utilization data I observed that adult spring chinook frequently used cavities formed under large boulders or stream banks. If possible, they would position themselves entirely under an object so that they were not visible except to the observer viewing them from the same depth. On several occasions such fish were observed respiring at a depressed rate. When touched by the snorkeler these fish did not react normally, but instead appeared to be quite lethargic.

The activity level of holding spring chinook appeared to increase with increased presence of other holding fish. This was most apparent in the larger, deeper pools. One or two fish holding alone usually remained stationary until the snorkeler moved close to take measurements. However, in this situation larger groups of holding fish usually began moving about the pool, and individuals appeared to react to the movements of other fish. Similar behavior among holding spring chinook has been observed in other rivers in western Washington (B. Wunderlich, FAO, personal communication). Because of this behavior I entered deep pools with increased caution, to avoid displacing holding fish before they could be observed.

Water Temperature

Water temperatures measured during the course of utilization data collection ranged from 50 to 55°F in June, from 53 to 64°F in July, and from 50 to 59°F in August. As expected, on a given sampling day the daily low temperature occurred during the first hour of the sampling period. Typically, water temperature gradually increased through the day until it peaked during late afternoon. These temperature ranges reflect only those temperatures that occurred during hours of snorkeling, and not the full temperature range experienced by fish during respective 24-hour periods.

Shade vs Sunlight

A large majority of the observed spring chinook, 86.3 percent, were found holding in full or partial shade (Appendix Figure 1). Only 31 of 383 fish observed were holding in sunlight. Among the 408 observations gathered during 1985, 25 did not contain a record of fish position relative to sunlight.

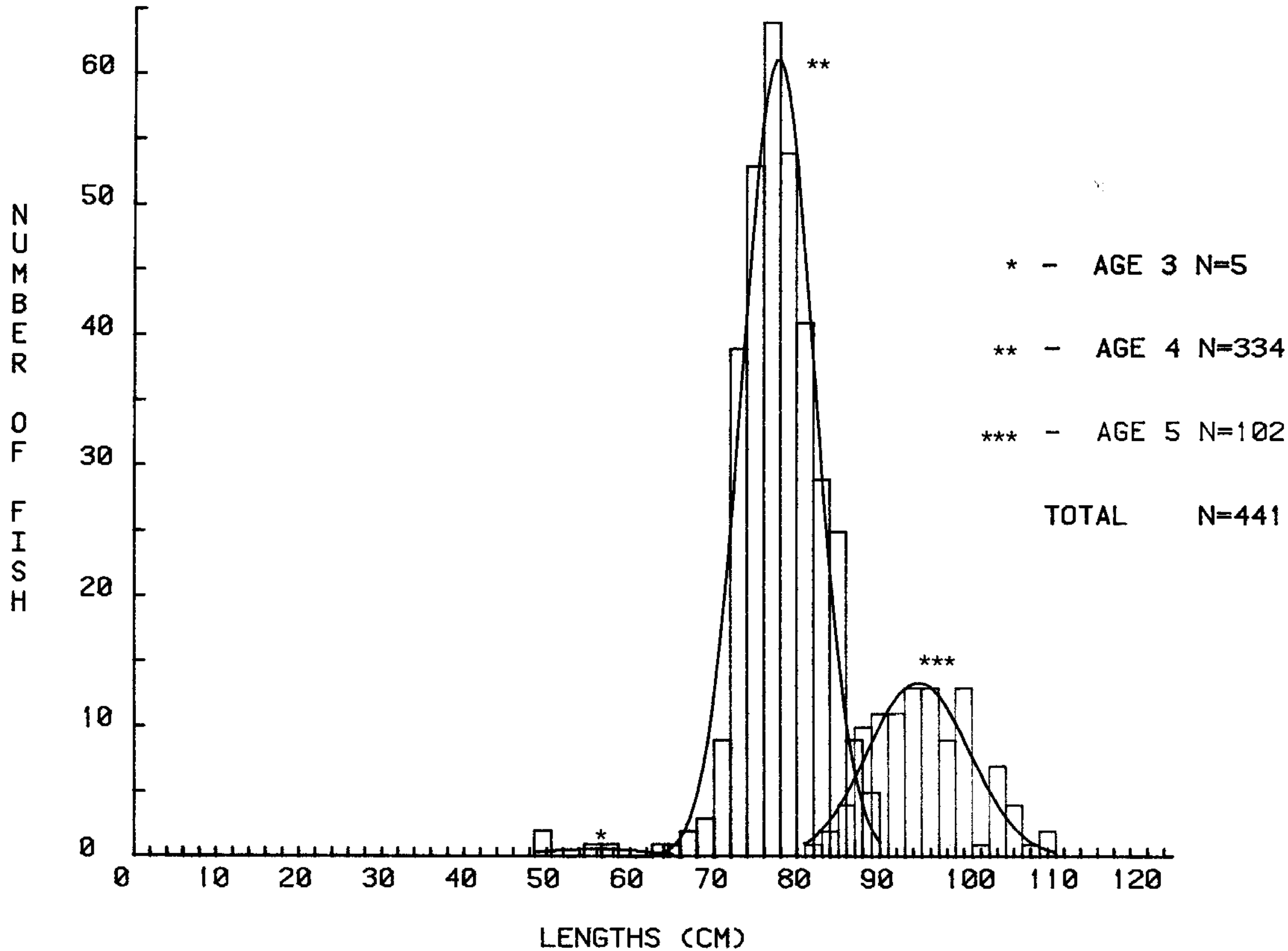
Fish Size

Biological sampling of adult spring chinook that returned to the rack at CNFH provided information on the size of fish observed in this study. In 1984, USFWS staff sampled 423 spring chinook having an average fork length (FL) of 84.9 cm (S. Olhausen, USFWS, Vancouver WA, personal communication). Analysis of data from adults sampled in 1985 provided more detailed information (Figure 2). Of 441 useable fish in the 1985 sample, 102 were age 5, 334 were age 4, and five were age 3. Average FL of males and females age 5 were 97.7 cm and 90.7 cm, respectively. Average FL of males and females age 4 were 80.8 cm and 75.7 cm, respectively. All age 3 chinook sampled were males having an average FL of 55.4 cm.

Combined Utilization Data

I performed frequency analysis of the combined 537 utilization data sets for each instream characteristic (Appendix Tables 2 through 7). The null hypothesis that data for an instream characteristic had uniform frequency distribution was in each case rejected ($P = .01$). The modes assigned optimum weighting factors of 1.00 occurred at the following value intervals or categories: for total depth, 2.1 to 3.0 feet; for mean column velocity, 0.0 to .19 ft/sec; for dominant substrate, large cobble; for protective cover, turbulence overhead; for fish nose depth, 0.4 to 1.0 foot; and for velocity at nose depth, 0.0 to 0.3 ft/sec. Standardization weightings of the remaining intervals or categories in Appendix Tables 2 through 7 are

Figure 2. Length distribution by age group of spring chinook sampled at the Carson National Fish Hatchery rack during 1985. Provided by the Fisheries Assistance Office, Vancouver, WA.



shown under the respective column heading, and are separated by horizontal lines. To the right in each table I have listed the percent fish occurrence (utilization function) for each value interval or category.

Utilization Curves

From the utilization weighting factors and respective value intervals or categories, I constructed utilization curves (Appendix Figures 3 through 6). The X and Y coordinate pairs beneath each plotted curve describe the respective points in the curve.

Availability Data

Results from the availability data analysis are presented in Appendix Tables 8 through 11. For each characteristic value interval or category the tables list respective surface area of total available habitat. In the last column the tables also list respective percentages of total available habitat. These percentages are the equivalent of availability functions.

Relative Preference Curve Development

The utilization functions, listed in Appendix Tables 2 through 5, and availability functions, listed in Appendix Tables 8 through 11, provide the required values for developing relative preference ratios. Tables 1 through 4 present these values and respective preference ratios for value intervals or categories of total depth, mean column velocity, dominant substrate, and protective cover. Within each table, final weighting factors are listed opposite respective preference ratios.

Preference Curves

From the preference weighting factors and respective value intervals or categories, I constructed preference curves (Figures 3 through 6). The X and Y coordinate values below each graph describe the respective points in the curve.

DISCUSSION

Compared Utilization and Preference Curves

A glance between any of the above utilization curves and the respective preference curve tells that considerable differences exist. The extent of these differences is shown in Figures 7 to 10. The optimum weighting for total depth shifted from three feet in the utilization curve to about 14 feet in the preference curve (Figure 7). This shift of the preference curve resulted from increased observations of fish in the 14.1 to 15.0 feet

Table 1. Relative preference curve development for total depth.

Depth (ft.)	Percent Fish Occurrence Per Combined Utilization Total Depth	Percent Occurrence Per Combined Available Habitat Total Depth	Relative Preference Ratio	Weighting Factor
0.3 - 1.0	1.1	22.6	0.049	.00
1.1 - 2.0	11.9	39.1	0.304	.02
2.1 - 3.0	20.3	12.9	1.574	.08
3.1 - 4.0	19.6	11.2	1.750	.09
4.1 - 5.0	14.9	5.2	2.865	.14
5.1 - 6.0	11.9	2.8	4.250	.21
6.1 - 7.0	8.9	1.3	6.846	.34
7.1 - 8.0	1.7	1.1	1.545	.08
8.1 - 9.0	0.6	1.0	0.600	.03
9.1 - 10.0	0.2	0.8	0.250	.01
10.1 - 11.0	0.0	0.7	0.000	.00
11.1 - 12.0	5.6	0.6	9.333	.47
12.1 - 13.0	0.0	0.4	0.000	.00
13.1 - 14.0	0.03	0.3	0.100	.00
14.1 - 15.0	2.8	0.14	20.000	1.00

Table 2. Relative preference curve development for mean column velocity.

Velocity (ft/sec)	Percent Fish Occurrence Per Combined Utilization Mean Column Velocity	Percent Occurrence Per Combined Available Habitat Mean Column Velocity	Relative Preference Ratio	Weighting Factor
0.0 - 0.19	18.2	14.9	1.221	.19
.2 - .39	9.7	8.2	1.183	.19
.4 - .59	5.6	8.6	0.651	.10
.6 - .79	9.1	11.5	0.791	.12
.8 - .99	8.9	9.0	0.989	.16
1.0 - 1.19	3.4	12.6	0.270	.04
1.2 - 1.39	3.0	5.7	0.526	.08
1.4 - 1.59	3.9	3.5	1.114	.18
1.6 - 1.79	2.0	5.8	0.345	.05
1.8 - 1.99	7.3	2.3	3.174	.50
2.0 - 2.19	7.1	3.2	2.219	.35
2.2 - 2.39	6.1	4.2	1.452	.23
2.4 - 2.59	2.6	2.0	1.300	.21
2.6 - 2.79	2.4	0.9	2.667	.42
2.8 - 2.99	1.3	2.4	0.542	.09
3.0 - 3.19	0.9	1.4	0.643	.10
3.2 - 3.39	0.7	0.8	0.875	.14
3.4 - 3.59	2.8	0.5	5.600	.88
3.6 - 3.79	1.9	0.3	6.333	1.00
3.8 - 3.99	0.4	0.3*	1.333	.21
4.0 - 4.19	0.0	0.6	0.000	.00
4.2 - 4.39	0.0	0.3	0.000	.00
4.4 - 4.59	0.0	0.3	0.000	.00
4.6 - 4.79	0.9	0.3*	3.000	.47
4.8 - 4.99	0.0	0.3	0.000	.00
5.0 - 5.19	0.0	0.0	0.000	.00
5.2 - 5.39	1.5	0.3	5.000	.79
5.4 - 5.59	0.2	0.3*	0.667	.11
5.6 - 5.79	0.0	0.3	0.000	.00
5.8 - 5.99	0.0	0.0	0.000	.00

* This percent occurrence in available habitat was subjectively assigned, based on general instream observations.

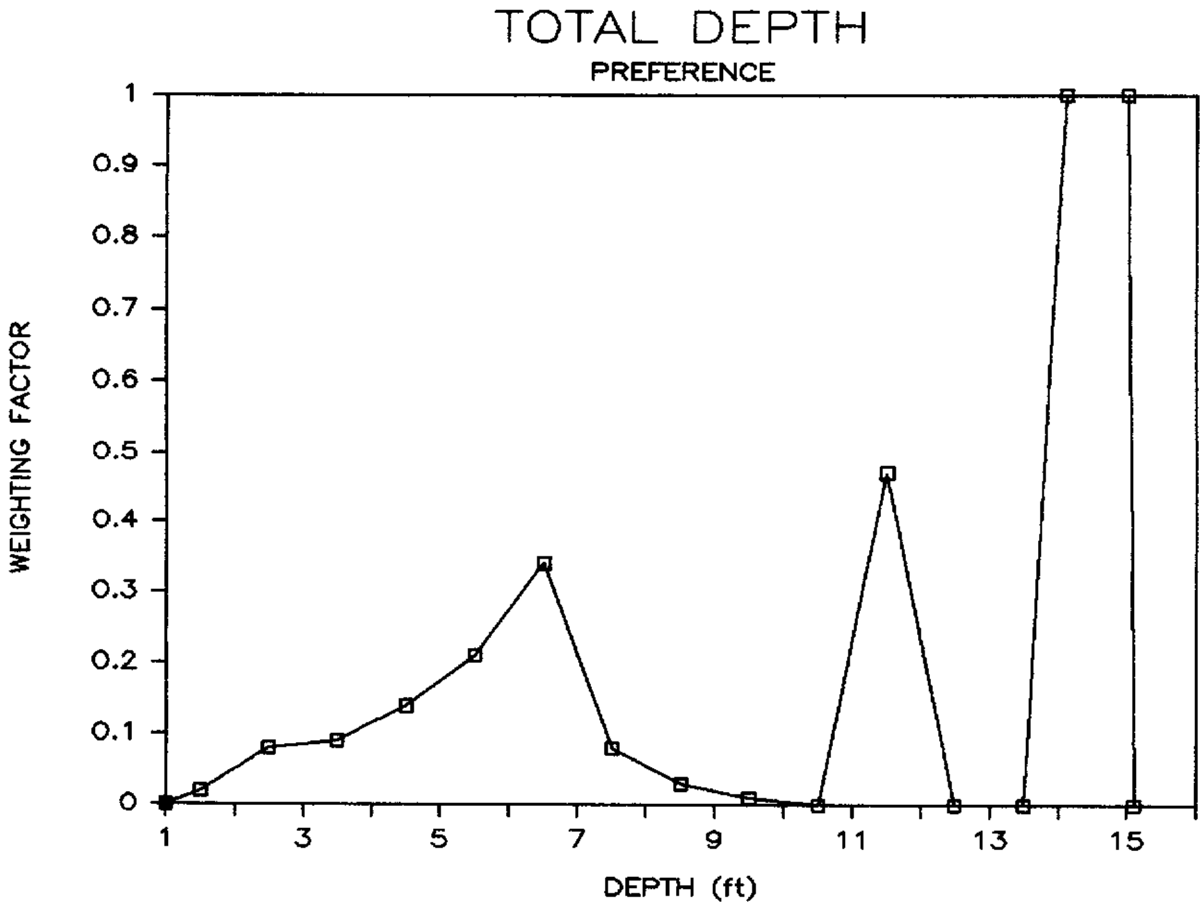
Table 3. Relative preference curve development for dominant substrate.

Substrate Category		Percent Fish Occurrence Per Combined Utilization Substrate Category	Percent Occurrence Per Combined Available Habitat Substrate Category	Relative Preference Ratio	Weighting Factor
Description	Code				
organic detritus	0	0.93	2.00*	0.465	.29
silt, clay	1	1.12	2.04	0.549	.34
sand	2	1.12	1.94	0.577	.35
small gravel	3	0.56	0.82	0.683	.42
medium gravel	4	2.05	1.72	1.192	.73
large gravel	5	7.82	9.67	0.809	.50
small cobble	6	23.09	14.18	1.628	1.00
large cobble	7	45.44	45.52	0.998	.61
boulder	8	15.27	24.11	0.633	.39
bedrock	9	2.61	2.00*	1.305	.80

* This percent occurrence in available habitat was subjectively assigned, based on general instream observations.

Table 4. Relative preference curve development for protective cover.

Cover Category Description	Code	Percent Fish Occurrence Per Combined Utilization Cover Category	Percent Occurrence Per Combined Available Habitat Cover Category	Relative Preference Ratio	Weighting Factor
no cover	0	0.56	38.97	0.014	.00
turbulence overhead	1	40.78	33.96	1.201	.16
rock overhead	2	15.27	15.48	0.986	.13
wood object overhead	3	37.62	5.10	7.376	1.00
streambank overhead	4	5.77	6.49	0.889	.12
vegetation overhead	5	.00	.00	.000	.00

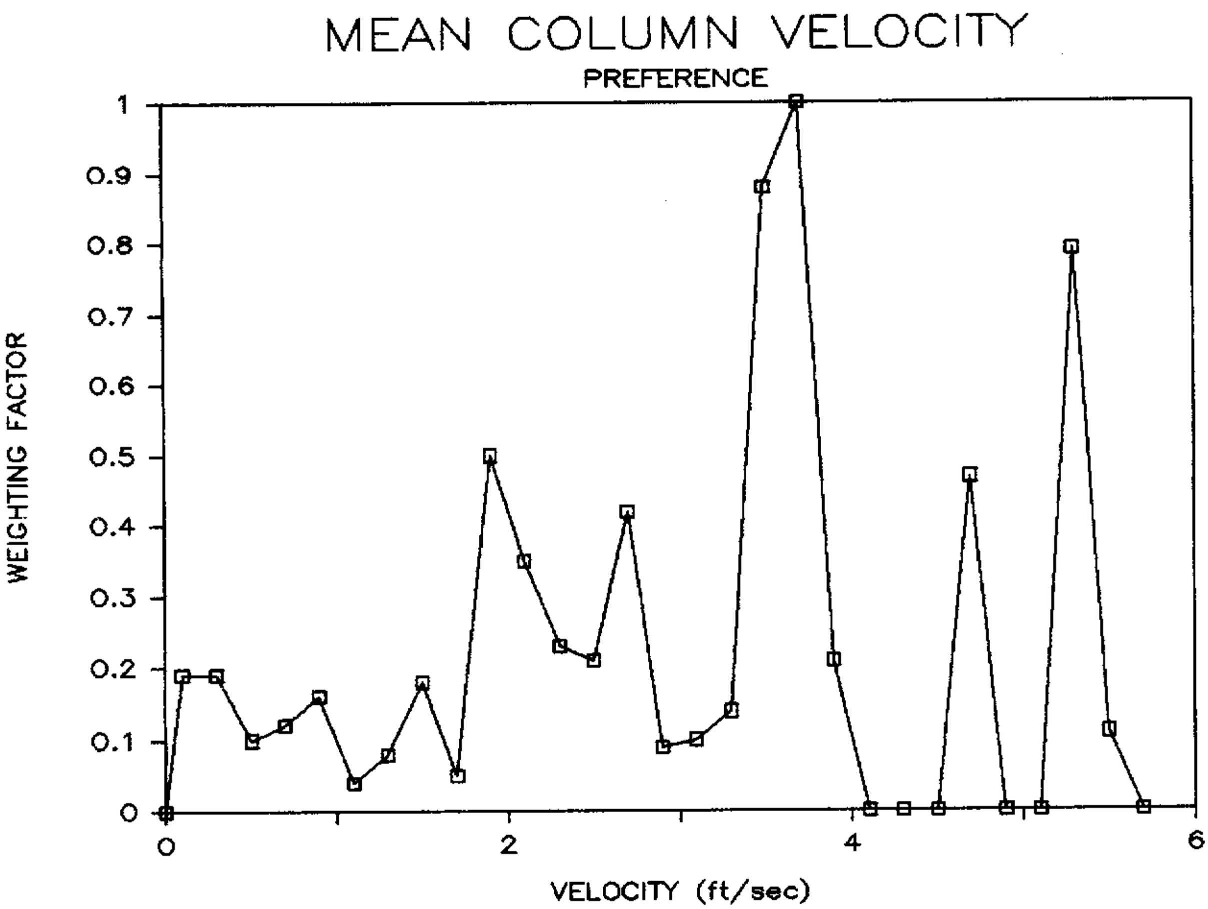


Coordinates

X	1.0	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5
Y	.00	.02	.08	.09	.14	.21	.34	.08	.03

X	9.5	10.5	11.5	12.5	13.5	14.1	15.0	15.1
Y	.01	.00	.47	.00	.00	1.00	1.00	.00

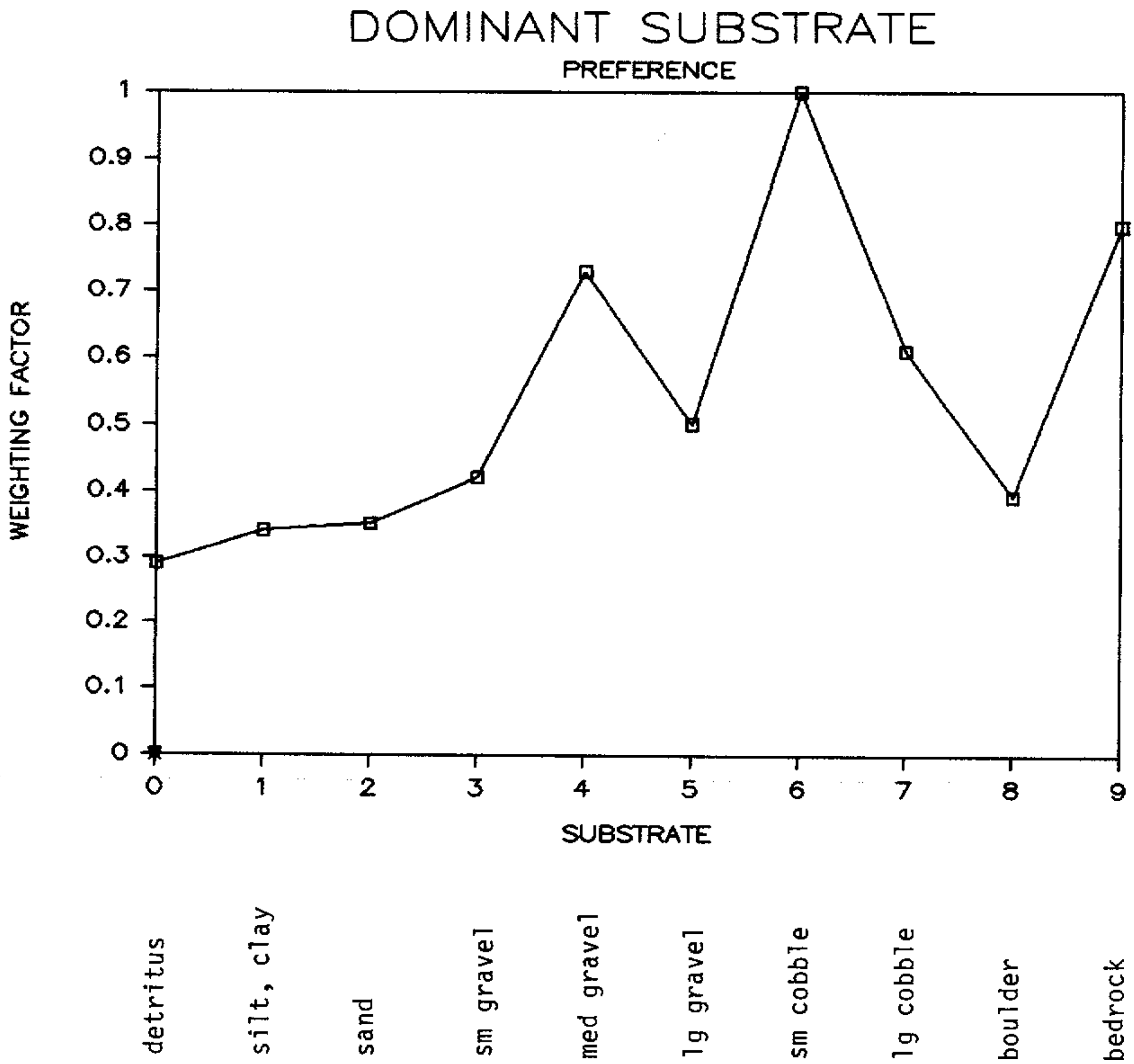
Figure 3. Preference curve for total depth, and respective curve coordinates.



Coordinates

X	0.0	.1	.3	.5	.7	.9	1.1	1.3	1.5
Y	.00	.19	.19	.1	.12	.16	.04	.08	.18
X	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3
Y	.05	.50	.35	.23	.21	.42	.09	.10	.14
X	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1
Y	.88	1.00	.21	.00	.00	.00	.47	.00	.00
X	5.3	5.5	5.7						
Y	.79	.11	.00						

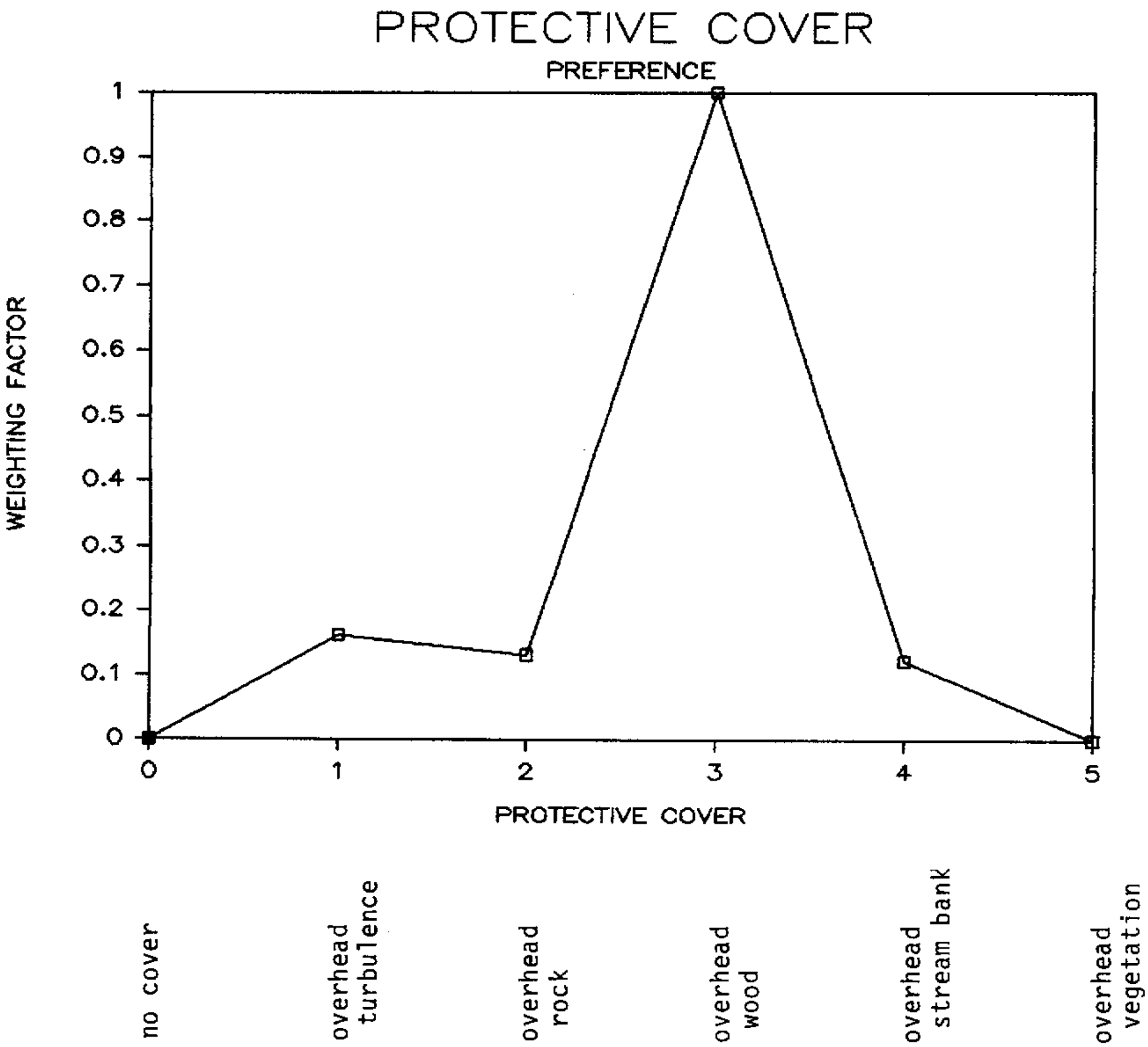
Figure 4. Preference curve for mean column velocity, and respective curve coordinates.



Coordinates

X	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
Y	.29	.34	.35	.42	.73	.50	1.00	.61	.39	.80

Figure 5. Preference curve for dominant substrate, and respective curve coordinates.



Coordinates

X	0.0	1.0	2.0	3.0	4.0	5.0
Y	.00	.16	.13	1.00	.12	.00

Figure 6. Preference curve for protective cover, and respective curve coordinates.

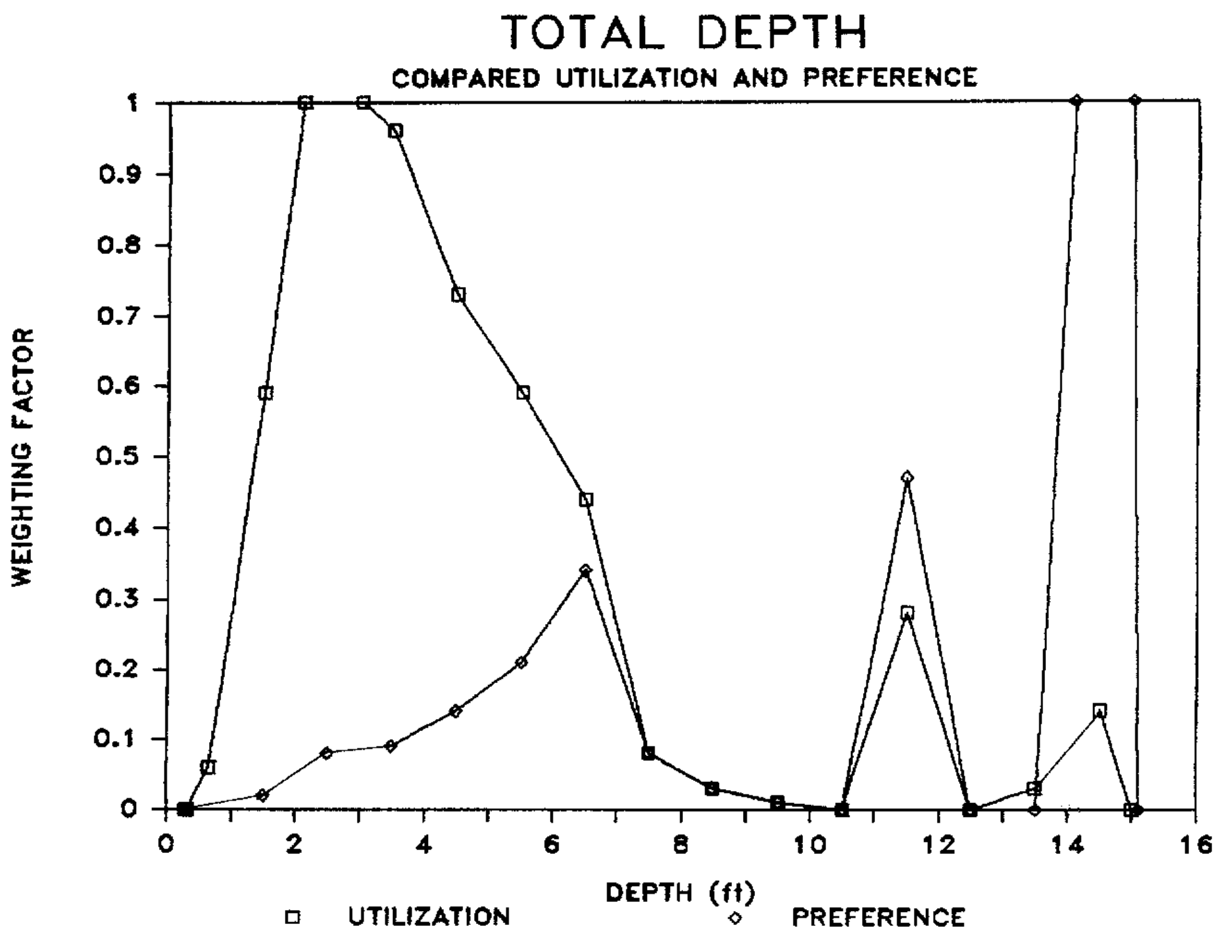


Figure 7. Compared utilization and preference curves for total depth.

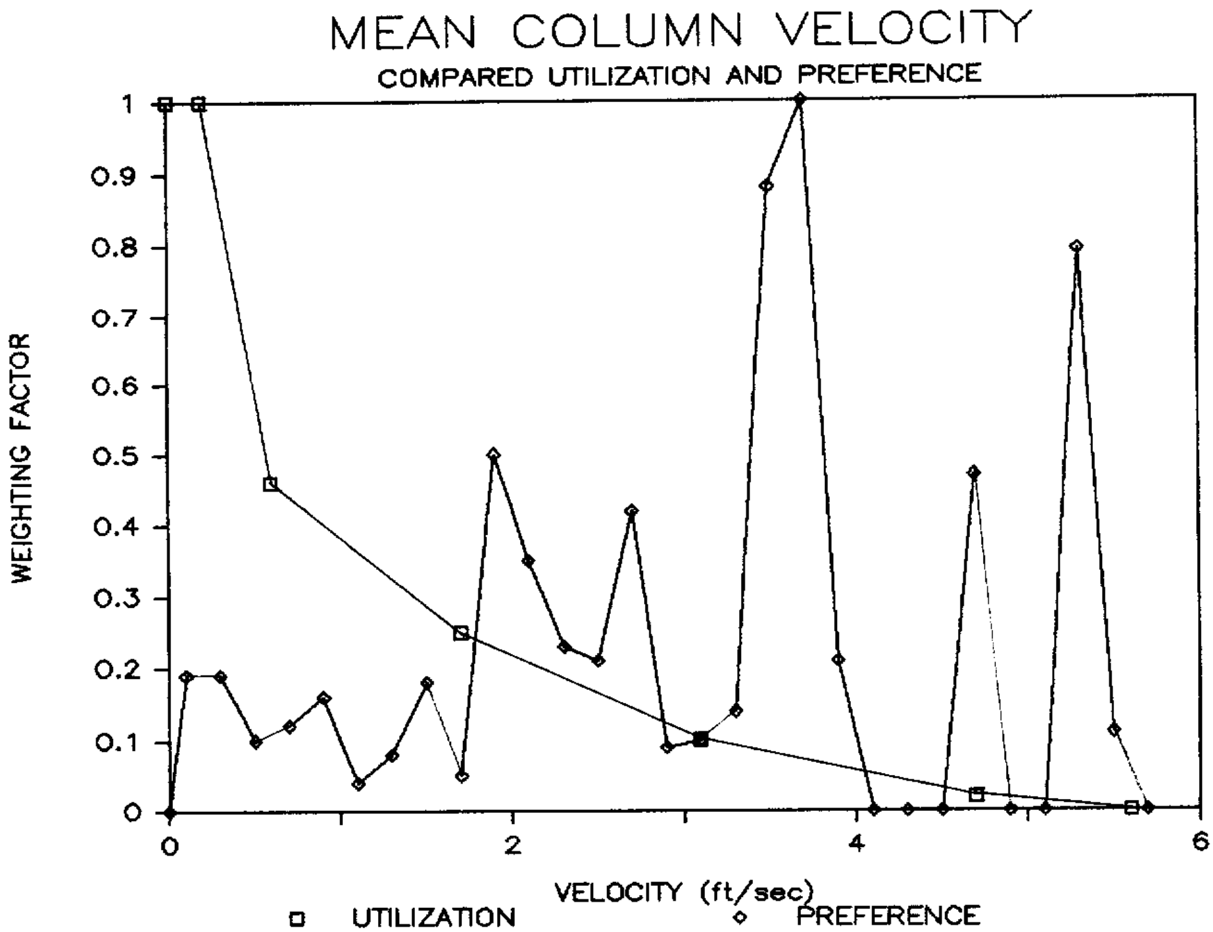


Figure 8. Compared utilization and preference curves for mean column velocity.

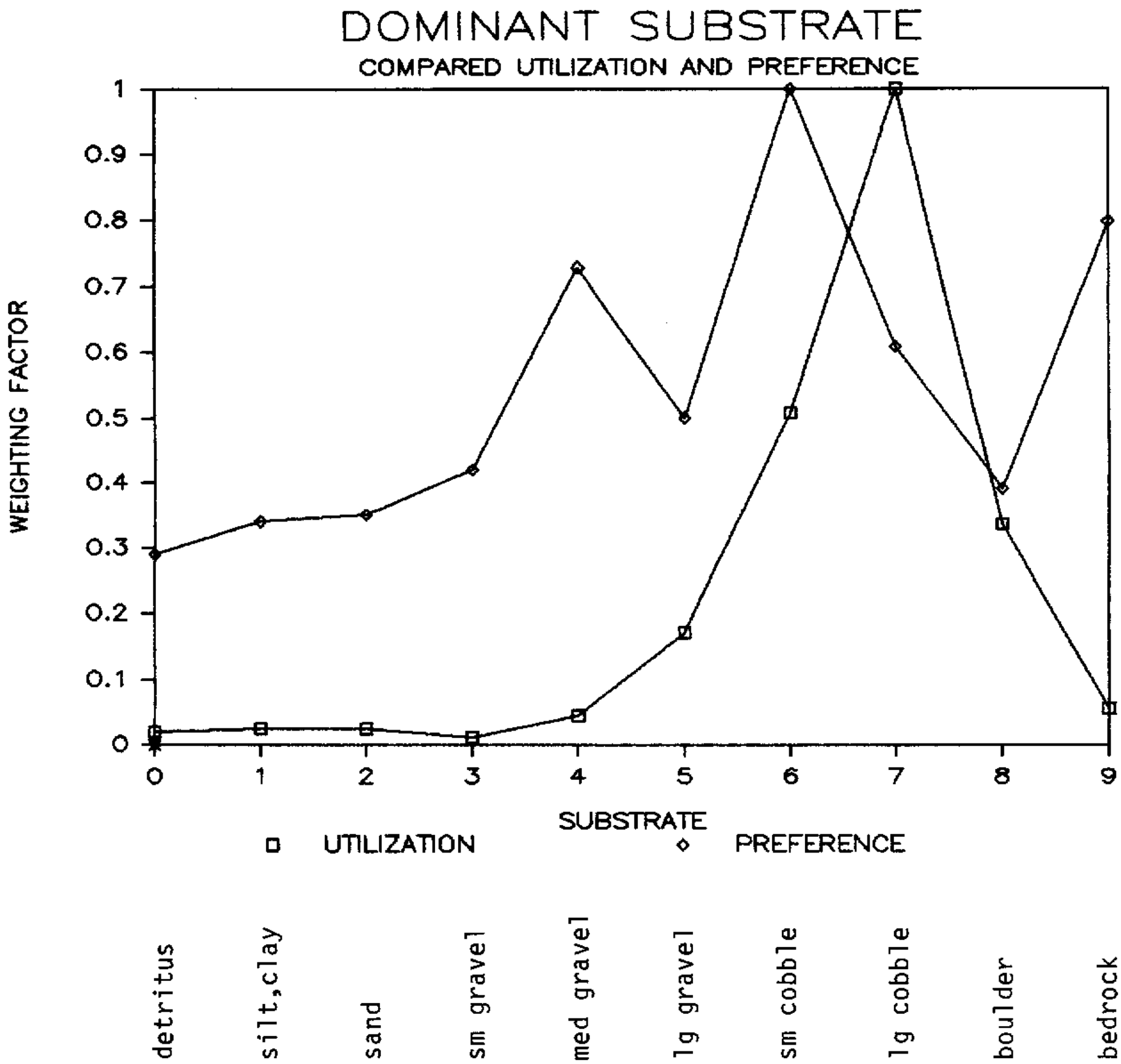


Figure 9. Compared utilization and preference curves for dominant substrate.

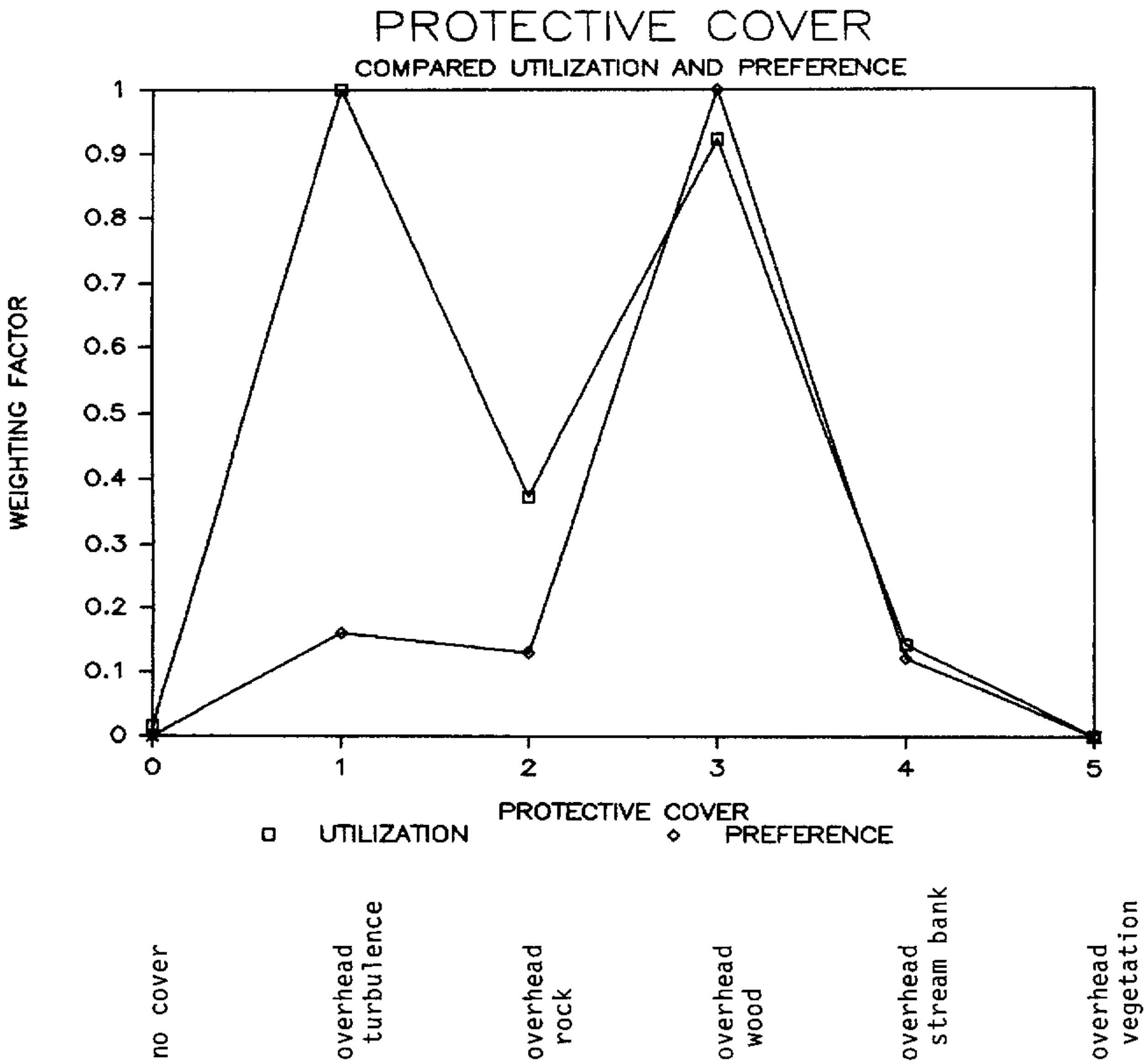
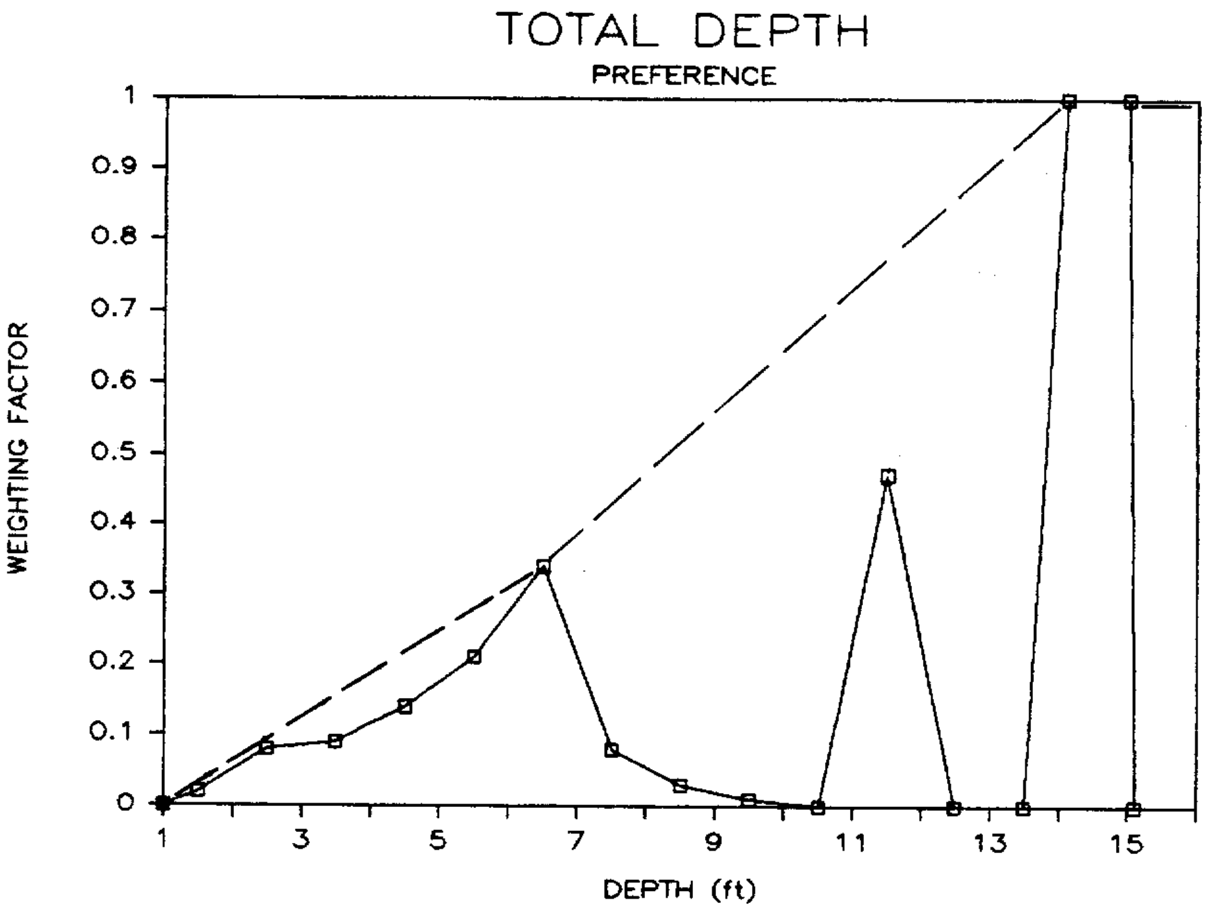


Figure 10. Compared utilization and preference curves for protective cover.

depth increment while availability at this depth increment was at its lowest level (Table 1). A similar combination of utilization and availability levels for the 11.1 to 12.0 foot depth increment accounts for the next highest peak in this curve. The two resulting gaps in the curve, between 6 and 14 feet, are primarily the product of finding few or no holding fish at these depths. Deeper pools, i.e., pools deeper than about 7 feet, were relatively scarce during summer low flow. Moreover, it appeared that holding fish sought out the deepest pools available to them. The deepest pools in the utilization reach happened to be approximately 12 feet deep or over 14 feet deep. My general observations of spring chinook holding behavior, in the Wind River and other streams, support the weighting of the total depth preference curve. Deep stream segments, when they exist, appear to attract and provide suitable holding for the greatest number of fish. More holding fish per stream surface area in the Wind River could always be found in such stream segments. I suspect that unlimited additional data for utilization and availability would lead to construction of a different preference curve. One that steadily ascends from minimal weighting near one foot depth, to optimum weighting beginning near 14 feet depth, and remaining at the optimum for any and all greater depths. Figure 11 shows my recommended modification of the total depth preference curve that resolves the problem of curve gaps and also optimizes weighting of total depths greater than 14 feet. While this curve was subjectively constructed, I believe it approximates the logical interpretation of the relative preference results for total depth.

Compared utilization and preference curves for mean column velocity (Figure 8) indicate that holding fish, in general, did not prefer low velocities relative to the availability of higher velocities. The multiple peaks of the preference curve indicate that, here too, additional unlimited data would lead to construction of a better defined curve. This preference curve appears to suggest that mean column velocity holds a lessor priority for fish selecting holding microhabitats. That is, if a particular microhabitat contains one or more preferred conditions of other instream variables, then a holding fish might select that microhabitat whether the mean column velocity is near 0.0 ft/sec or is near 5.0 ft/sec. This rationale suggests that subjective modification of the preference curve is needed. Figure 12 shows this modification, which is based on my assumption that mean column velocities less than about 4 ft/sec are all acceptable, but those exceeding approximately 5.5 ft/sec are intolerable. The reader should bear in mind that the typical holding spring chinook was found facing into nose velocities less than 2 ft/sec (Appendix Figure 7). Such reduced nose velocities can occur simultaneously at points having high mean column velocity because : (1) mean column velocity at points having depth exceeding two and one-half feet is determined as an average of two velocity measurements which can vary considerably between upper and lower measurement; and (2) nose velocity can be much reduced by the flow deflection effect of some upstream object or by location just off the stream bed where velocities are usually much reduced.

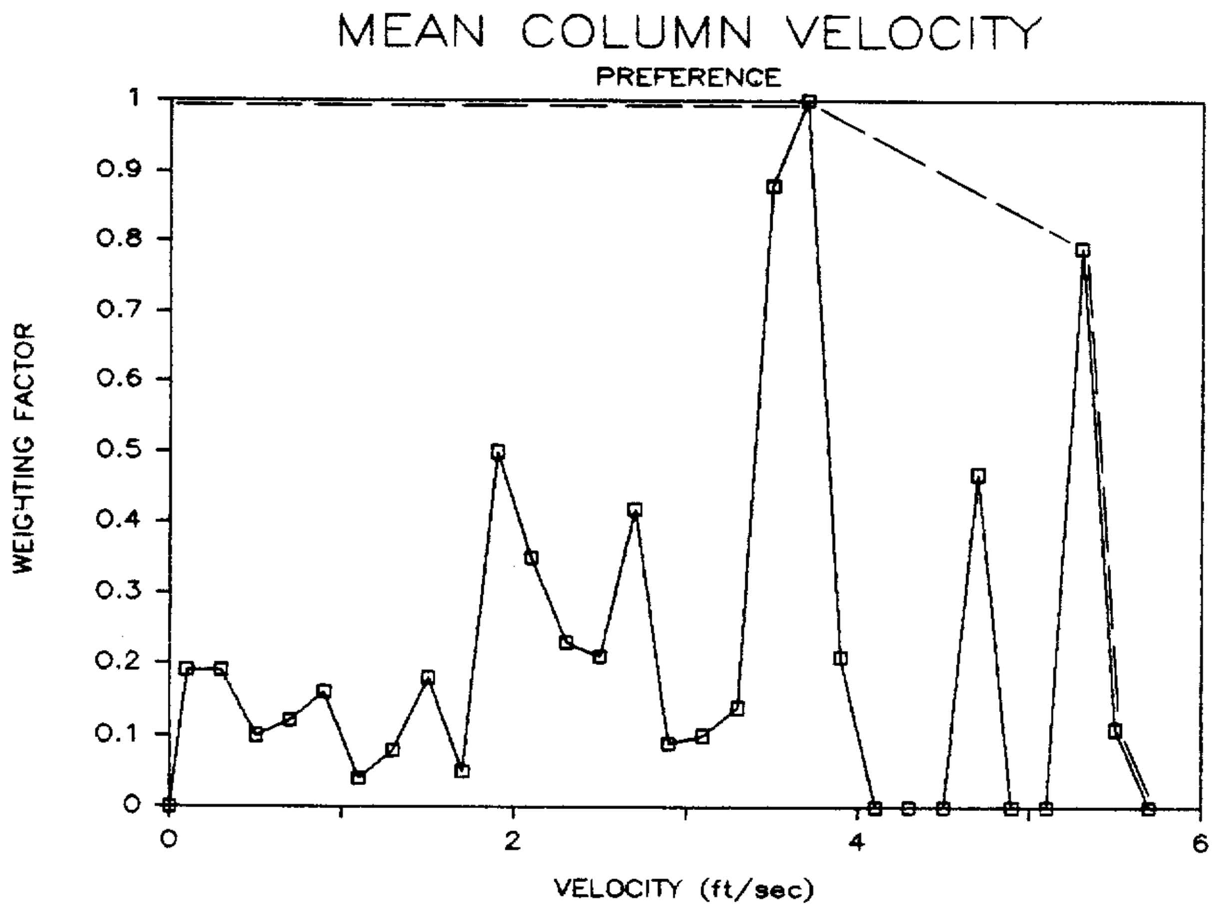
Before taking relative availability of dominant substrate into account, the optimum category in the utilization curve was clearly large cobble (Figure 9). The preference curve, adjusted to reflect the ratios between utilization and availability substrate categories, shifts the optimum weighting to small cobble. It increases the weighting of all other



Coordinates

X	1.0	6.5	11.5	14.1	50.0	51.0
Y	.00	.34	.47	1.00	1.00	.00

Figure 11. Modified preference curve for total depth, and respective curve coordinates. The dashed line represents the modified curve.



Coordinates

X	0.0	3.7	5.3	5.5	5.7
Y	1.00	1.00	.79	.11	.00

Figure 12. Modified preference curve for mean column velocity, and respective curve coordinates. The dashed line represents the modified curve.

categories except large cobble. In general, however, the preference curve indicates that larger substrate categories, i.e., medium gravel and larger, were preferred by holding spring chinook.

When the utilization and preference curves for protective cover are compared (Figure 10), a shift to a different and more prominent optimum weighting occurs in the preference curve. Overhead wood is clearly the most preferred form of protective cover after availability in the habitat is considered.

I believe that it is very important for the reader to recognize the importance of overhead cover to holding spring chinook, whatever form it might take. Recall from Table 4 that the percent of surface area in the available habitat having no protective cover was large. However, less than one percent of the fish were found without cover overhead. It appears that holding fish preferred overhead wood when it was available. But, if some other form of overhead cover was the only kind available, they clearly preferred it to having no overhead cover at all.

Other Utilization Curves

The utilization curve for fish nose depth (Appendix Figure 6) adds useful information to that provided by the preference curves. The nose depth curve indicates that although spring chinook prefer to hold in water having a total depth of several feet or more, they will physically position themselves close to the stream bed, i.e., from about 0.4 to 1.0 foot above it. This behavior is probably the result of several factors. Positioning close to the stream bed must afford fish some added protection by offering a less visible profile in the water column for any instream predator to detect. The threat of capture by a raptor is also reduced. It likely provides easier orientation to maintain stream position. And there is likely to be less turbulence nearer the stream bed in some locations, thus reducing the fish's energy expenditure.

The velocity at fish nose depth may be another factor that influences spring chinook in their selection of depth. In most circumstances the nearer to the stream bed a fish is positioned, the lower the flow velocity. The utilization curve for velocity at nose depth (Appendix Figure 7) confirms that microhabitats having the lowest velocities were occupied by fish with the greatest frequency. Note that there is little difference between the utilization curves for velocity at nose depth and mean column velocity. It is difficult to predict how important velocity at nose depth actually is. But, logic says that an adult spring chinook holding for many weeks is unlikely to stay long in a microhabitat containing high velocities that can rapidly drain a fish's energy reserve.

Future Applications

Before the potential user applies the preference curves created in this study (Figures 3 to 6), certain assumptions made in developing these curves should be understood. The assumption that available habitat was correctly assessed, both quantitatively and qualitatively, is probably the most questionable. While the strategy used, i.e., the representative reach concept borrowed from the IFIM, is generally accepted by state and federal agencies for instream flow protection, it is new to suitability curve development. The IFG found our strategy acceptable, and they are the originators of the IFIM which is the principal medium for application of these preference curves. I believe the representative reach approach is at once the most reasonable, in terms of field effort, and the least subjective approach to assessing available habitat.

Another assumption was that adult spring chinook were numerous enough to fill most or all preferred locations for holding. I believe that this was the case. The Wind River spring chinook run is a hatchery run, and the spawner return to CNFH during 1984 was only 25% smaller than average. In 1985, when most of the utilization data were collected, the return size exceeded the average by more than 50%.

I assumed that holding fish were not driven from their preferred holding microhabitat to other locations where they were observed and data were recorded. While fish could have been displaced on a few occasions, this was avoided. By rejecting a potential observation when there was any doubt, and by working instream with appropriate caution, fish displacement was minimized or eliminated.

I assumed that the presence of other fish had no effect on spring chinook selections of holding microhabitat. The only other large fish in the river were a few summer steelhead. Steelhead were so few in number and so passive that they appeared to have no effect on spring chinook behavior.

These preference curves are offered to potential users for application in most streams where spring chinook habitat needs protection or is to be enhanced. If the curves are to be applied to a stream that is colored with glacial flour during the period of concern, consideration should be given to their appropriateness. Ability of spring chinook to hide from view in one or two feet of opaque water might render these total depth and protective cover curves quite meaningless. Also, if the mean body size of a spring chinook run varies greatly from that of the Wind River run, then the potential user should question the appropriateness of these curves for that application.

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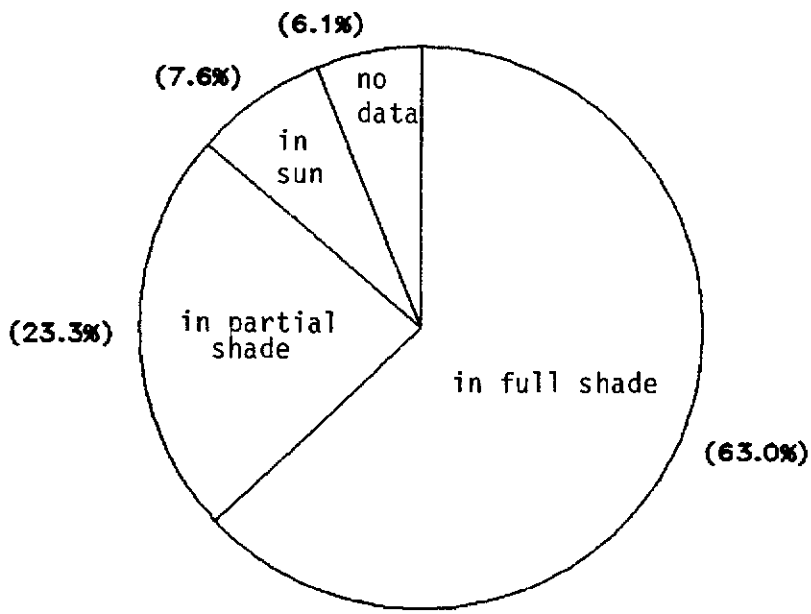
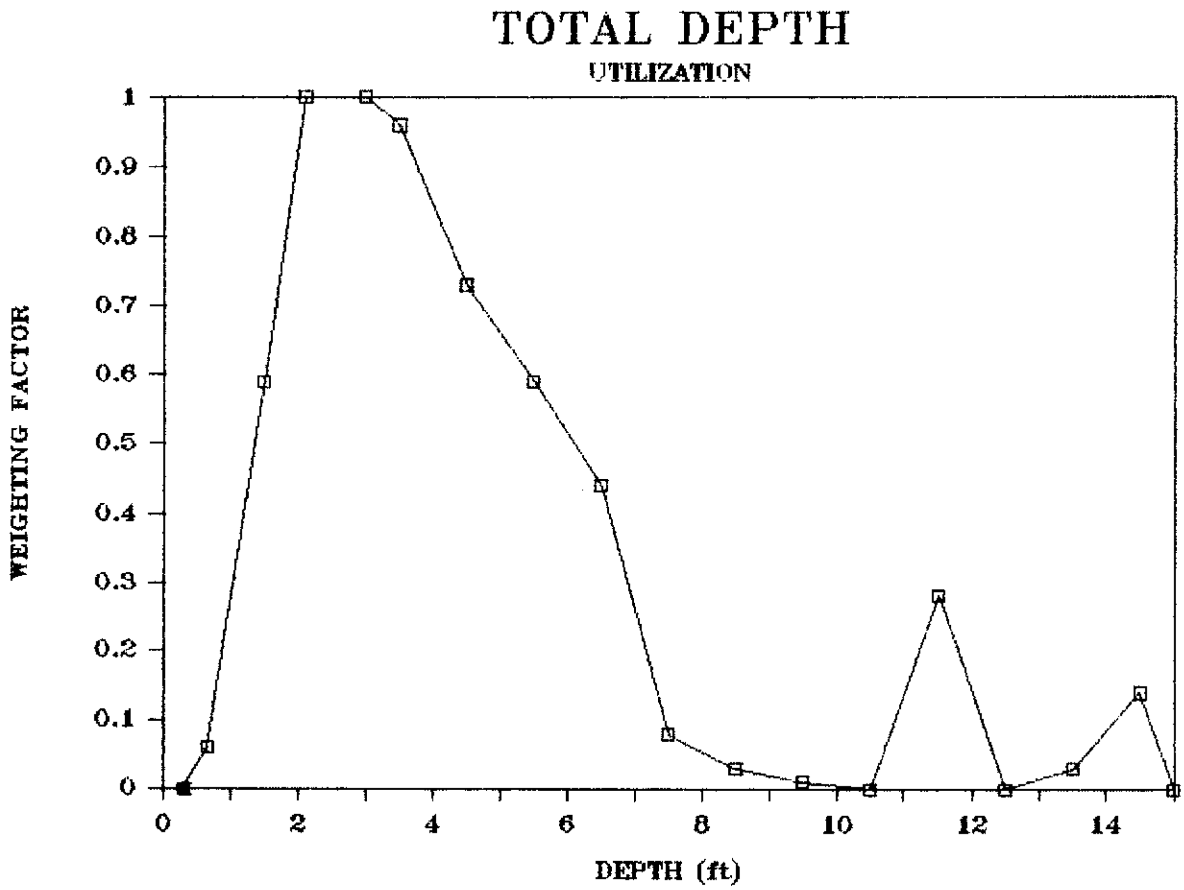
APPENDIX

Figure 1. Percentages of holding adult spring chinook found in sunlight, partial shade, or in full shade. From combined 1985 utilization data (408 observations).

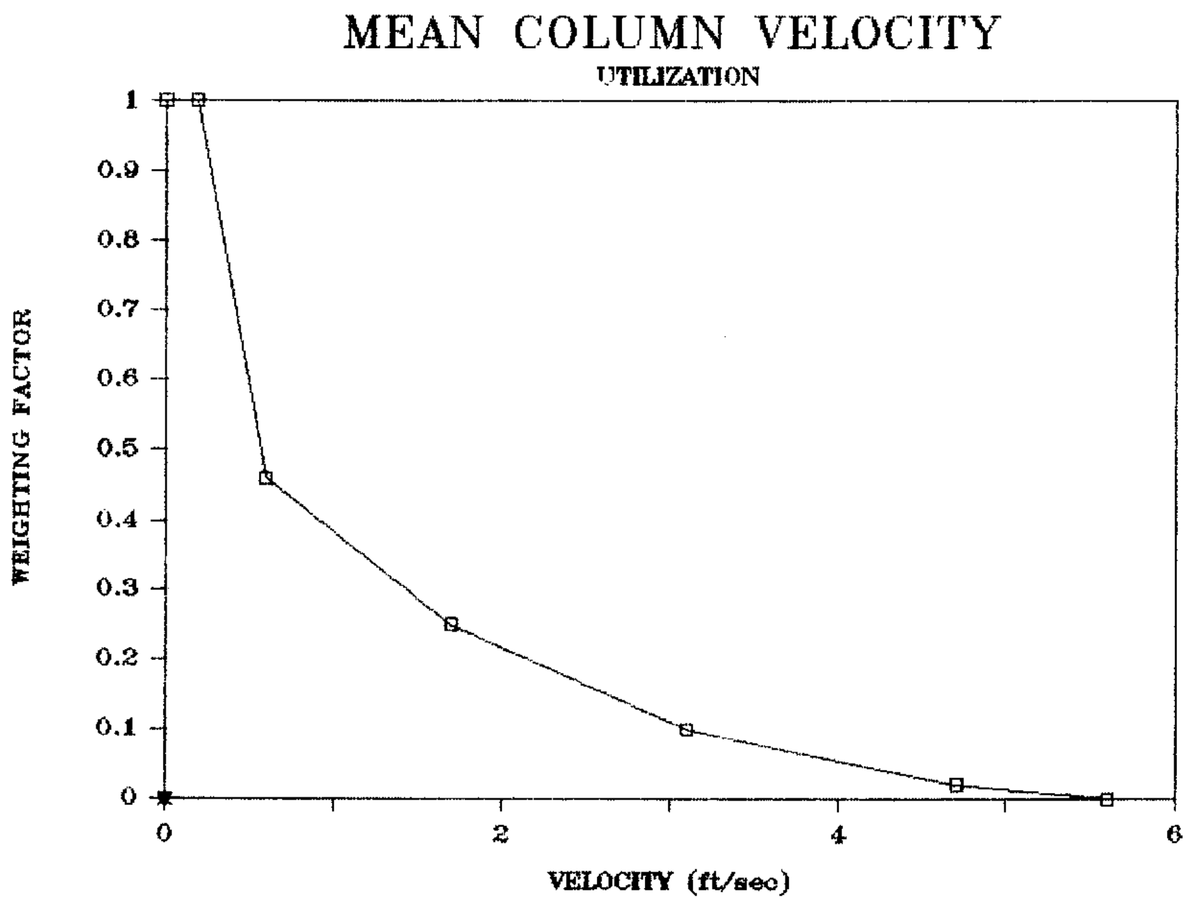




Coordinates

X	.3	.65	1.5	2.1	3.0	3.5	4.5	5.5	6.5
Y	.00	.06	.59	1.00	1.00	.96	.73	.59	.44
X	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.0
Y	.08	.03	.01	.00	.28	.00	.03	.14	.00

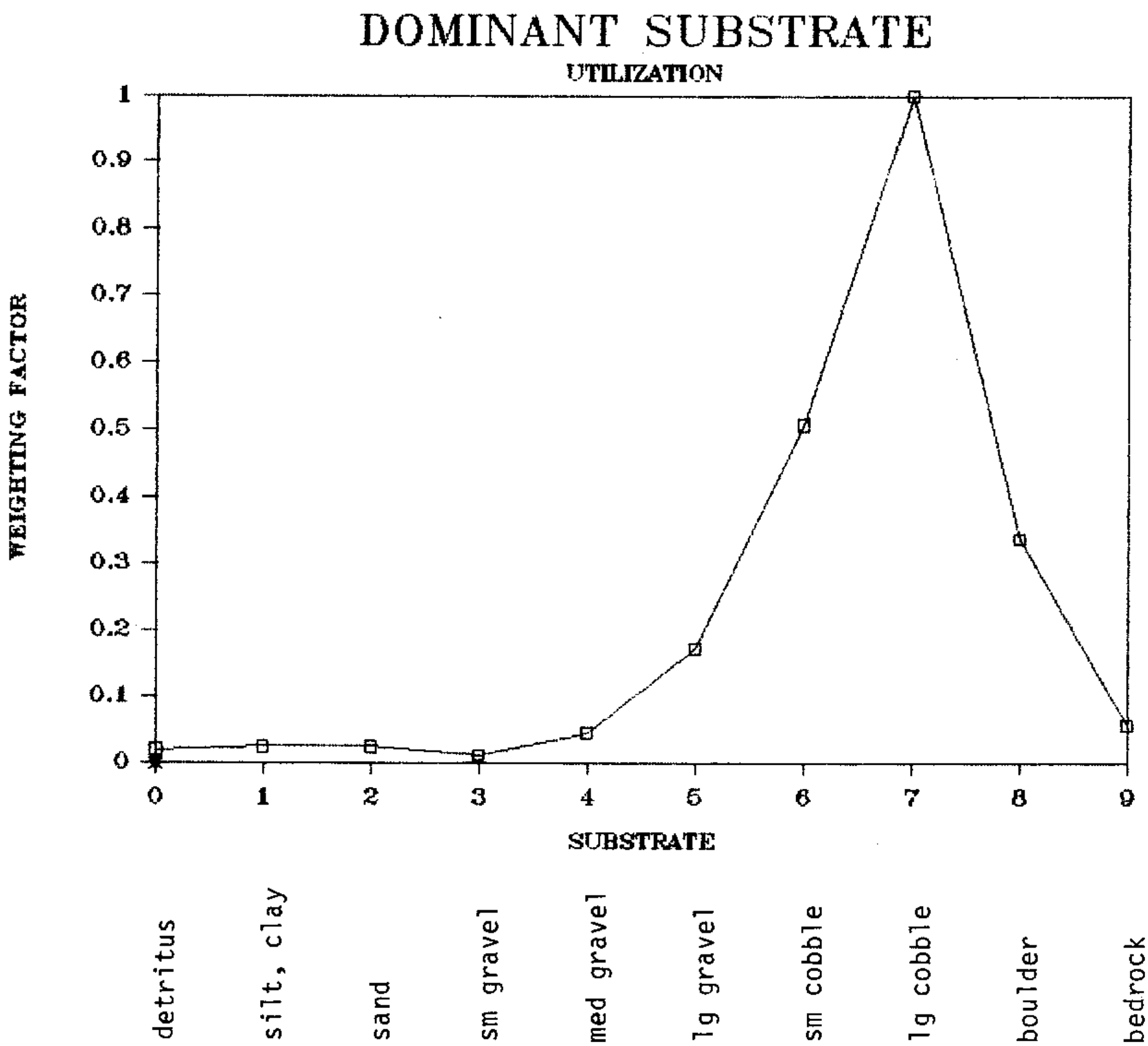
Figure 2. Utilization curve for total depth, and respective curve coordinates.



Coordinates

X	0.0	.19	.6	1.7	3.1	4.7	5.6
Y	1.00	1.00	.46	.25	.10	.02	.00

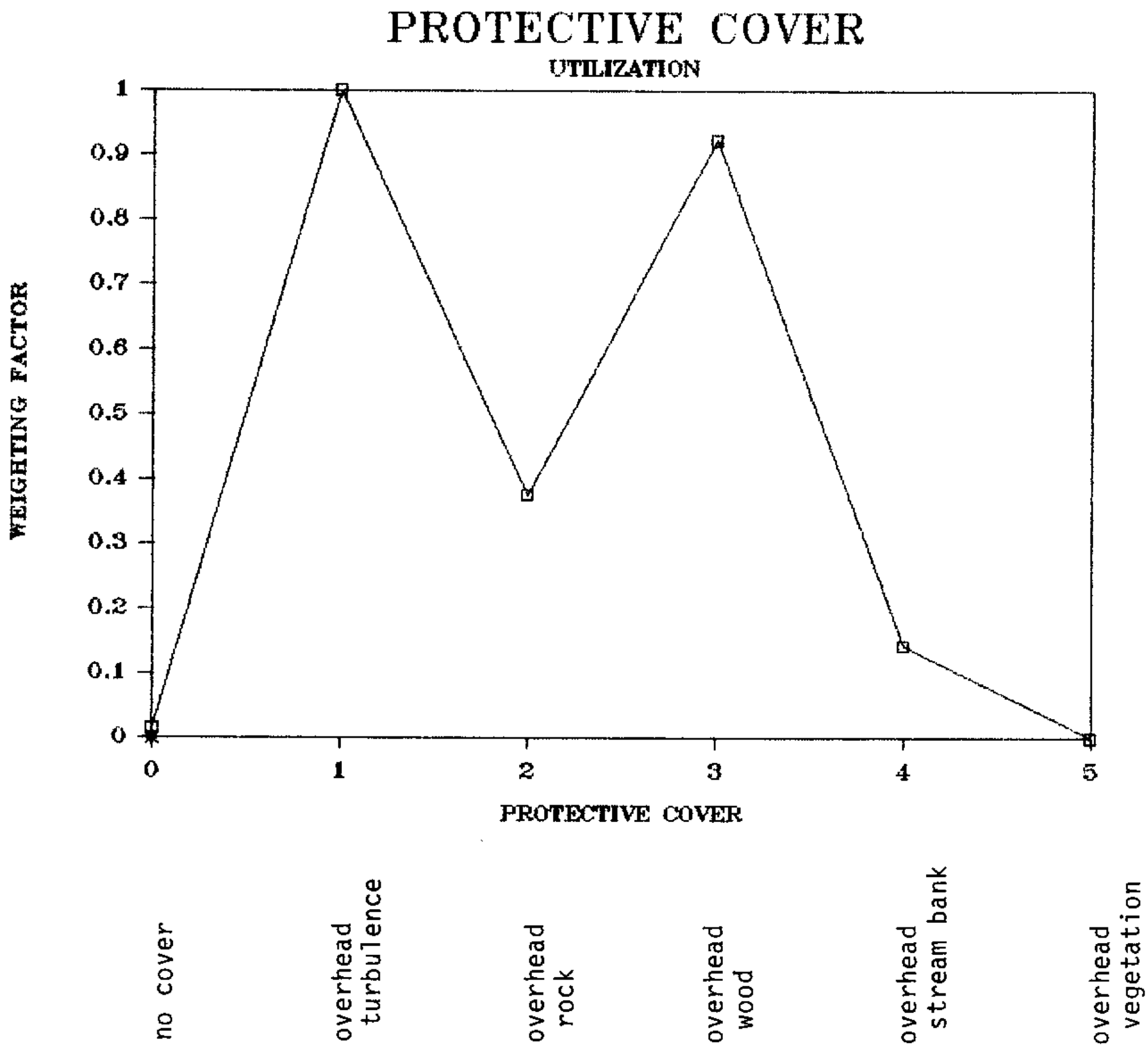
Figure 3. Utilization curve for mean column velocity, and respective curve coordinates.



Coordinates

X	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
Y	.02	.025	.025	.012	.045	.172	.508	1.00	.336	.057

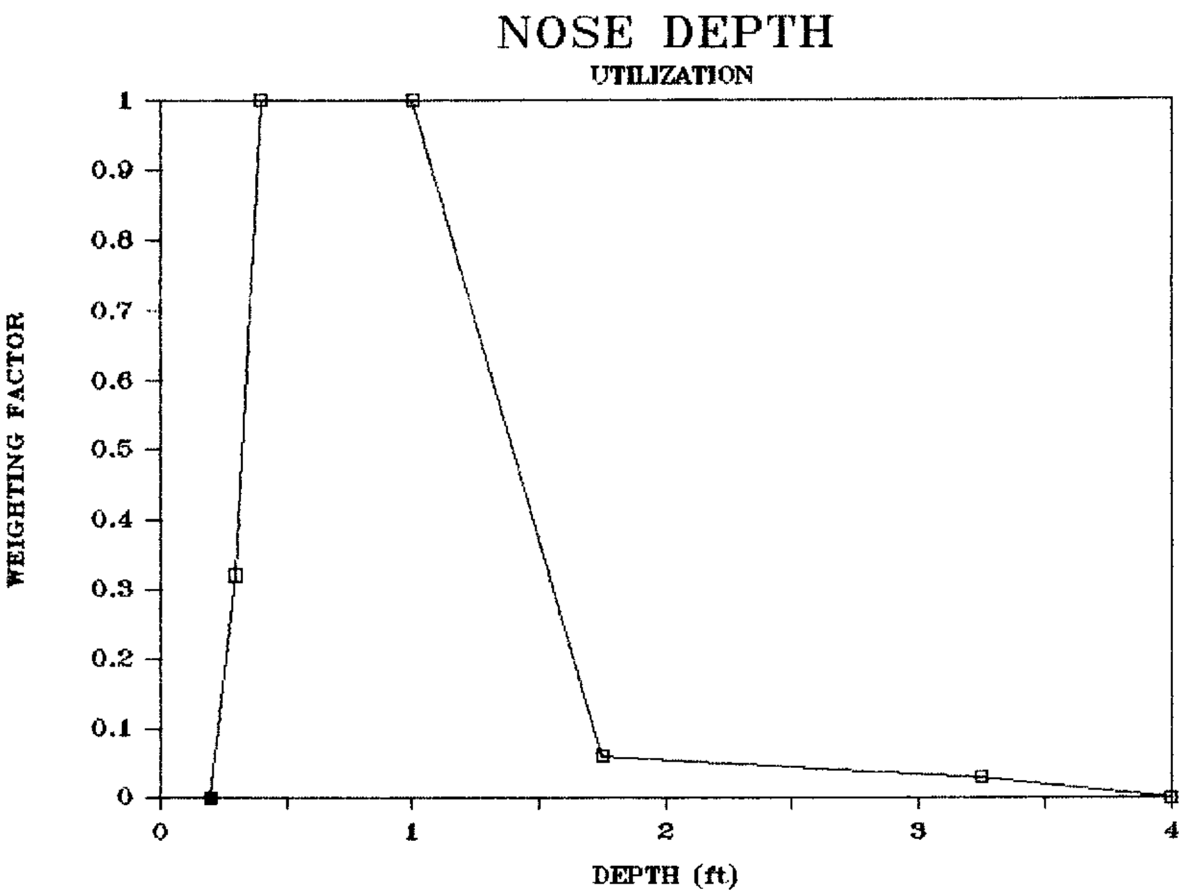
Figure 4. Utilization curve for dominant substrate, and respective curve coordinates.



Coordinates

X	0.0	1.0	2.0	3.0	4.0	5.0
Y	.014	1.00	.374	.922	.142	.00

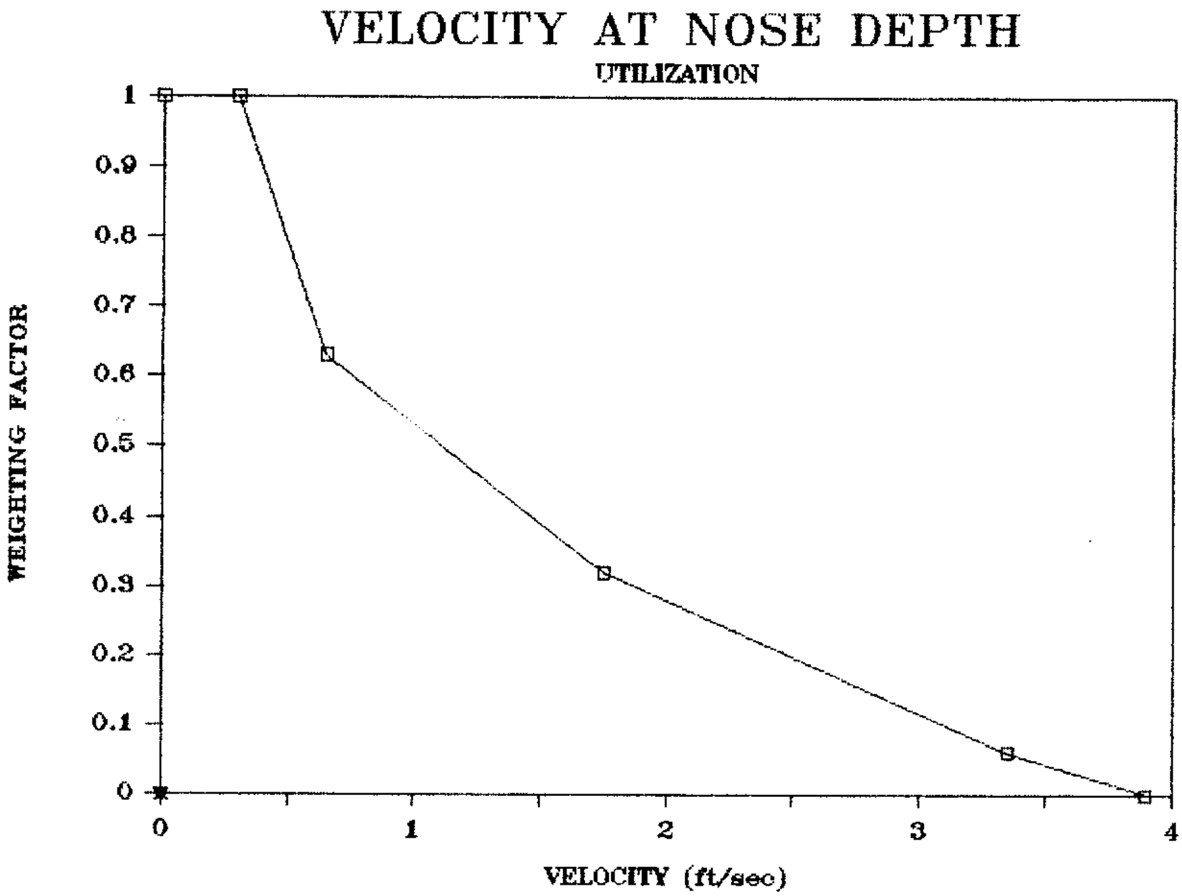
Figure 5. Utilization curve for protective cover, and respective curve coordinates.



Coordinates

X	.2	.3	.4	1.0	1.75	3.25	4.0
Y	.00	.32	1.00	1.00	.06	.03	.00

Figure 6. Utilization curve for nose depth, and respective curve coordinates.



Coordinates

X	0.0	.3	.65	1.75	3.35	3.9
Y	1.00	1.00	.63	.32	.06	.00

Figure 7. Utilization curve for velocity at nose depth, and respective curve coordinates.

Table 1a. Substrate particle size categories and their codes.[a]

Particle Description	Diameter	Code
organic detritus	(b)	0
silt, clay	<2 mm	1
sand	<2 mm	2
small gravel	2 mm - .5 in	3
medium gravel	.5 - 1.5 in	4
large gravel	1.5 - 3.0 in	5
small cobble	3.0 - 6.0 in	6
large cobble	6.0 - 12.0 in	7
boulder	12.0 in	8
bedrock		9

(a) Substrate categories and codes recommended by an interagency substrate committee and the Washington Department of Fisheries (1985).

(b) Material smaller than that which will provide protective cover.

Table 1b. Protective cover categories and their codes.

Cover Description	Code
no cover	0
turbulence overhead	1
rock overhead	2
wood object overhead	3
stream bank overhead	4
vegetation overhead	5

Table 2. Frequency analysis, standardization, and percent fish occurrence for measurements of total depth among combined utilization data. Horizontal lines separate weighted intervals of depth values.

Depth (ft.)	Fish Frequency (Grouped)	Standardization Weighting Factor	Percent Fish Occurrence
.3 - 1.0	6	.06	1.1
1.1 - 2.0	64	.59	11.9
2.1 - 3.0	109	1.00	20.3
3.1 - 4.0	105	.96	19.6
4.1 - 5.0	80	.73	14.9
5.1 - 6.0	64	.59	11.9
6.1 - 7.0	48	.44	8.9
7.1 - 8.0	9	.08	1.7
8.1 - 9.0	3	.03	0.6
9.1 - 10.0	1	.01	0.2
10.1 - 11.0	0	.00	0.0
11.1 - 12.0	30	.28	5.6
12.1 - 13.0	0	.00	0.0
13.1 - 14.0	3	.03	0.03
14.1 - 15.0	15	.14	2.8
15.1	0	.00	0.0

Table 3. Frequency analysis, standardization and percent fish occurrence for measurements of mean column velocity among combined utilization data. Horizontal lines separate weighted intervals of velocity values.

Velocity (ft/sec)	Fish Frequency (Grouped)	Standardization Weighting Factor	Percent Fish Occurrence
0.0 - .19	98	1.00	18.2
.2 - .39	52		9.7
.4 - .59	30	.46	5.6
.6 - .79	49		9.1
.8 - .99	48		8.9
1.0 - 1.19	18		3.4
1.2 - 1.39	16		3.0
1.4 - 1.59	21		3.9
1.6 - 1.79	11	.25	2.0
1.8 - 1.99	39		7.3
2.0 - 2.19	38		7.1
2.2 - 2.39	33		6.1
2.4 - 2.59	14		2.6
2.6 - 2.79	13		2.4
2.8 - 2.99	7		1.3
3.0 - 3.19	5	.10	0.9
3.2 - 3.39	4		0.7
3.4 - 3.59	15		2.8
3.6 - 3.79	10		1.9
3.8 - 3.99	2		0.4
4.0 - 4.19	0		0.0
4.2 - 4.39	0		0.0
4.4 - 4.59	0		0.0
4.6 - 4.79	5	.02	0.9
4.8 - 4.99	0		0.0
5.0 - 5.19	0		0.0
5.2 - 5.39	8		1.5
5.4 - 5.59	1		0.2
5.60	0	.00	0.0

Table 4. Frequency analysis, standardization, and percent fish occurrence for measurements of dominant substrate among combined utilization data.

Substrate Category Description	Code	Fish Frequency	Standardization Weighting Factor	Percent Fish Occurrence
organic detritus	0	5	.020	0.93
silt, clay	1	6	.025	1.12
sand	2	6	.025	1.12
small gravel	3	3	.012	0.56
medium gravel	4	11	.045	2.05
large gravel	5	42	.172	7.82
small cobble	6	124	.508	23.09
large cobble	7	244	1.000	45.44
boulder	8	82	.336	15.27
bedrock	9	14	.057	2.61

Table 5. Frequency analysis, standardization, and percent fish occurrence for observations of protective cover among combined utilization data.

Cover Category Description	Code	Fish Frequency	Standardization Weighting Factor	Percent Fish Occurrence
no cover	0	3	.014	0.56
turbulence overhead	1	219	1.00	40.78
rock overhead	2	82	.374	15.27
wood object overhead	3	202	.922	37.62
streambank overhead	4	31	.142	5.77
vegetation overhead	5	0	.000	0

Table 6. Frequency analysis and standardization for measurements of fish nose depth among combined utilization data.*

Fish Depth (ft.)	Fish Frequency	Standardization Weighting Factor
.3	20	.32
.4	62	
.5	80	
.6	56	
.7	55	1.00
.8	71	
.9	22	
1.0	90	
1.1	6	
1.2	3	
1.3	2	
1.4	4	
1.5	7	
1.6	1	
1.7	4	.06
1.8	2	
1.9	1	
2.0	10	
2.1	1	
2.2	2	
2.3	3	
2.4	1	
2.5	7	

Table 6. (con't)

Fish Depth (ft.)	Fish Frequency	Standardization Weighting Factor
2.6	2	
2.7	4	
2.8	2	
2.9	3	
3.0	2	
3.1	2	
3.2	2	
3.3	2	.03
3.4	2	
3.5	2	
3.6	1	
3.7	1	
3.8	0	
3.9	0	
4.0	2	
4.1	0	.00

*Nose depth was the measured or observed depth of adult spring chinook relative to the stream bed immediately under fish.

Table 7. Frequency analysis and standardization for measurements of velocity at nose depth among combined utilization data.*

Velocity (ft/sec)	Fish Frequency	Standardization Weighting Factor
0.0 - 0.1	73	1.00
.2 - .3	76	
.4 - .5	57	
.6 - .7	36	.63
.8 - .9	48	
1.0 - 1.1	13	
1.2 - 1.3	31	
1.4 - 1.5	35	
1.6 - 1.7	31	
1.8 - 1.9	24	.32
2.0 - 2.1	10	
2.2 - 2.3	34	
2.4 - 2.5	8	
2.6 - 2.7	30	
2.8 - 2.9	5	
3.0 - 3.1	8	
3.2 - 3.3	1	.06
3.4 - 3.5	3	
3.6 - 3.7	0	
3.8 - 3.9	12	
4.0	0	.00

*Velocities at nose depth were measured at the depth and the exact nose position of respective adult spring chinook.

Table 8. Percent occurrence of values for total depth among combined availability measurements, during August 7-8, 1984, July 2, 1985, and July 15, 1985.

Total Depth (ft.)	Combined Surface Area (sq. ft.)	Percent of Combined Available Habitat (151,181*sq. ft.)
0.3 - 1.0	34,095	22.6
1.1 - 2.0	59,111	39.1
2.1 - 3.0	19,443	12.9
3.1 - 4.0	16,961	11.2
4.1 - 5.0	7,822	5.2
5.1 - 6.0	4,233	2.8
6.1 - 7.0	1,905	1.3
7.1 - 8.0	1,693	1.1
8.1 - 9.0	1,482	1.0
9.1 - 10.0	1,270	0.8
10.1 - 11.0	1,058	0.7
11.1 - 12.0	847	0.6
12.1 - 13.0	635	0.4
13.1 - 14.0	423	0.3
14.1 - 15.0	212	0.14

* This total includes an additional 21,165 sq. ft. estimated to represent surface area in the utilization reach having depths greater than 4.0 ft.

Table 9. Percent occurrence of values for mean column velocity among combined availability measurements, during August 7-8, 1984, July 2, 1985, and July 15, 1985.

Mean Column Velocity (ft/sec)	Combined Surface Area (sq. ft.)	Percent of Combined Available Habitat (132,672 sq. ft.)
0.0 - .19	19,797	14.92
.2 - .39	10,828	8.16
.4 - .59	11,436	8.62
.6 - .79	15,242	11.49
.8 - .99	11,903	8.97
1.0 - 1.19	16,743	12.62
1.2 - 1.39	7,607	5.73
1.4 - 1.59	4,640	3.50
1.6 - 1.79	7,643	5.76
1.8 - 1.99	3,076	2.32
2.0 - 2.19	4,284	3.23
2.2 - 2.39	5,628	4.24
2.4 - 2.59	2,643	1.99
2.6 - 2.79	1,257	0.95
2.8 - 2.99	3,147	2.37
3.0 - 3.19	1,907	1.44
3.2 - 3.39	1,121	0.84
3.4 - 3.59	665	0.50
3.6 - 3.79	418	0.32
3.8 - 3.99	0	0.00

Table 9. (con't)

Mean Column Velocity (ft/sec)	Combined Surface Area (sq. ft.)	Percent of Combined Available Habitat (132,672 sq. ft.)
4.0 - 4.19	859	0.65
4.2 - 4.39	342	0.26
4.4 - 4.59	460	0.35
4.6 - 4.79	0	0.00
4.8 - 4.99	342	0.26
5.0 - 5.19	0	0.00
5.2 - 5.39	342	0.26
5.4 - 5.59	0	0.00
5.6 - 5.79	342	0.26

Table 10. Percent occurrence of dominant substrate categories among combined availability measurements, during August 7-8, 1984, July 2, 1985, and July 15, 1985.

Substrate Category Description	Code	Combined Surface Area (sq. ft.)	Percent of Combined Available Habitat (132,672 sq. ft.)
organic detritus	0	0	0
silt, clay	1	2,712	2.04
sand	2	2,578	1.94
small gravel	3	1,085	0.82
medium gravel	4	2,286	1.72
large gravel	5	12,832	9.67
small cobble	6	18,809	14.18
large cobble	7	60,387	45.52
boulder	8	31,983	24.11
bedrock	9	0	0

Table 11. Percent occurrence of protective cover categories among combined availability measurements, during August 7-8, 1984, July 2, 1985, and July 15, 1985.

Cover Category Description	Code	Combined Surface Area (sq. ft.)	Percent of Combined Available Habitat (132,672 sq. ft.)
no cover	0	51,706	38.97
turbulence overhead	1	45,053	33.96
rock overhead	2	20,536	15.48
wood object overhead	3	6,770	5.10
streambank overhead	4	8,607	6.49
vegetation overhead	5	0	0