

AN ABSTRACT OF THE THESIS OF

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Title: The Influence of Riparian Habitat and Microhabitat Selection
on Fish Assemblage Structure in the Upper John Day Basin, Oregon

Abstract Approved: Signature redacted for privacy.
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Fish assemblage structure was determined along a longitudinal gradient for three drainages in the upper John Day basin: Middle Fork, South Fork, and upper Mainstem proper. One or two tributaries in each drainage were included. Where possible, sites were paired: those with good versus those with poor riparian habitat. Detrended correspondence analysis was used to determine how the assemblages were structured and to determine which environmental variables influenced that structure. Two assemblages resulted: a warmwater assemblage dominated by speckled dace (Rhinichthys osculus), redbelt shiners (Richardsonius balteatus), northern squawfish (Ptychocheilus oregonensis), and suckers (Catostomus spp.); and a coldwater assemblage dominated by juvenile steelhead (Oncorhynchus mykiss) and chinook salmon (Oncorhynchus tshawytscha), but also containing mountain whitefish (Prosopium williamsoni), piute sculpins (Cottus beldingi), and other salmonids. This coldwater assemblage had two distinct components: the chinook component and the steelhead component. The chinook component was concentrated in the mid-elevation reaches of the Mainstem and the Middle Fork, between the steelhead component and the warmwater assemblage. The primary physical gradient on which all assemblages aligned was an elevation/stream size gradient. A secondary gradient consisted of

various riparian habitat and bank condition variables. Generally, riparian habitat improved moving toward the headwaters.

Microhabitat use was compared for salmonids within a habitat type (i.e. pools, riffles, and runs) for mainstem and tributary streams. It was also compared for the same age classes and species between stream types (mainstem versus tributary). Finally, microhabitat selection (versus availability) was examined for significant differences between microhabitat available and that selected. Different age classes of steelhead and juvenile chinook salmon used different microhabitats in the same habitat type. These did not change significantly between habitats or stream type. All groups selected microhabitats that varied significantly from that available. The most important variables in all cases were focal point depth and focal point velocity, total depth and mean velocity.

The Influence of Riparian Habitat and Salmonid Microhabitat
Selection on Fish Assemblage Structure in the Upper John
Day Basin, Oregon.

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THE INFLUENCE OF RIPARIAN HABITAT AND SALMONID MICROHABITAT
SELECTION ON FISH ASSEMBLAGE STRUCTURE IN THE UPPER JOHN DAY BASIN,
OREGON

INTRODUCTION

There has been much discussion in the literature concerning the mechanisms responsible for structuring fish assemblages (Grossman 1982b; Grossman et al. 1982; Herbold 1984; Rahel et al. 1984; Yant et al. 1984; Grossman et al. 1985; Moyle and Vondracek 1985; Li et al. 1987; Whittier and Miller in press). The two hypotheses being discussed are the deterministic and the stochastic hypotheses. The deterministic hypothesis predicts that species assemblages are in equilibrium (or in succession) and therefore they will be relatively constant and predictable through time. Biotic factors (i.e. competition and predation) are the primary determinants of assemblage structure (Grossman et al. 1982). On the other hand, the stochastic hypothesis maintains that the physical and chemical environments are rarely stable enough to allow equilibrium and are thus very unpredictable. As a result, the assemblage structure is determined by environmental changes (i.e. floods and drought), not biotic interactions.

Some researchers have found both deterministic and stochastic processes acting together to determine fish assemblage structure. Baltz et al. (1982) found temperature mediated competition between dace and sculpins in a California stream, and Reeves et al. (1987) observed the same phenomenon between juvenile steelhead trout (Oncorhynchus mykiss) and redbreast shiners (Richardsonius balteatus) in Oregon.

Historically, snow-melt streams in the Western United States reach base flow in late summer (August and September). This can be a critical or limiting time for fish. With the low flows come the possibility of higher water temperatures, lower dissolved oxygen

levels, decreased habitat for some species, crowding of fish, increased chance of disease, competition, and predation, as well as decreased food supplies. This pattern is typical in the John Day basin. These low flows cause a shift or redistribution of the fishes throughout the basin (Errol Claire, Regional Biologist, Oregon Department of Fish and Wildlife, personal communication). Typically, the juvenile steelhead move out of the main forks and into the cooler tributaries, while juvenile chinook salmon (Oncorhynchus tshawytscha) may move farther upstream but remain in the main channels. Other species such as redbelt shiner, speckled dace (Rhinichthys osculus), and squawfish (Ptychocheilus oregonensis) also move upstream during this period. However, this pattern has not been adequately documented or quantified.

This low flow "crunch" period has been made considerably more acute throughout the west by man's activities. Irrigation withdrawal has significantly reduced late summer low flows, and has left some steelhead rearing streams in the John Day basin dry during some years (E. Claire personal communication). The loss of riparian vegetation due to livestock grazing, mining activity, channelization, and timber harvesting has resulted in a loss of salmonid habitat, lowering of the water table, and opening of the canopy. This opening has exposed streams to direct solar radiation, resulting in further water temperature increases.

These late summer low flows together with the quality and quantity of riparian habitat can work together to structure fish assemblages in the John Day basin. While these are physical aspects of the stream and thus fall into the stochastic school of thought, stream flow and riparian habitat condition may influence competition and predation. The general decline in salmonid habitat quantity and quality are at least partially responsible for the decline of the

steelhead and chinook runs in the John Day basin. Therefore, the following objectives were established:

- A) Develop a hierarchical classification of the basins and streams within the John Day basin.
- B) Determine how fish assemblage structure changes along longitudinal gradients in several John Day subbasins, and relate these changes to physical habitat features and riparian condition of the streams.
- C) Determine differences in microhabitat use by salmonids in different habitats and stream types.
- D) Determine if there is microhabitat selection by salmonids in different habitats and stream types.

The first objective would serve to statistically block out the study design, stratify different ecological settings, and to ensure that inappropriate comparisons were not made. The second objective serves to identify whether fish assemblages are discrete entities or change along a continuum (sensu stream continuum concept, Vannote et al. 1980) and to address the effects that changes in physical habitat have on the assemblages.

The microhabitat objectives seeks to provide some "inferential evidence of the organizational mechanism operating within an assemblage" and "furnish basic information necessary for experimental studies of inter and intraspecific competition." (Grossman and Freeman 1987). The following questions were addressed:

- 1) Were there any intra- or interspecific differences in microhabitat use by salmonids within a habitat (i.e. pools, riffles, and runs) or between stream types (i.e. mainstem versus tributary)?
- 2) Was there any microhabitat selection by salmonids?
- 3) If so, did it vary with size and species; between habitat types and/or stream types?

METHODS

STUDY AREA

The John Day basin was selected as the study area because it has one of the last major runs of wild spring chinook salmon and summer steelhead in the Columbia basin (ODFW unpublished report). It has no major impoundments to obstruct fish passage, and the influence of hatchery fish is likely to be very low (ODFW unpublished report; Bureau of Reclamation 1985). There has been considerable riparian rehabilitation work done in the basin. Over three million dollars has been spent to rehabilitate fish habitats as part of the Northwest Power Planning Council's fish and wildlife program. Also, the John Day is being developed as a model of water resource management by the Oregon Department of Fish and Wildlife (ODFW), the U. S. Forest Service, the Bureau of Land Management, and the Bonneville Power Administration (Li et al. 1985; 1986).

The John Day basin is located in north eastern Oregon (fig. 1). It ranges in elevation from 45.7 meters at the mouth to over 2,743 meters on Strawberry Mountain. It flows through a variety of vegetative and landform types including forested, range, and agricultural land, six mountain ranges to the east, west, and south and the Deschutes-Umatilla Plateau to the north. All totaled, the basin drains approximately 20,746 square kilometers.

Sampling was restricted to the upper basin where salmonids spawn and rear. The subbasins that were sampled were 1) the South Fork from the mouth to Izee Falls (a natural falls blocking anadromous salmonid migration located approximately two-thirds of the length of the stream from the mouth) 2) the upper mainstem from the John Day Fossil Beds National Monument to the headwaters and 3) the Middle Fork from its confluence with the North Fork to its headwaters.

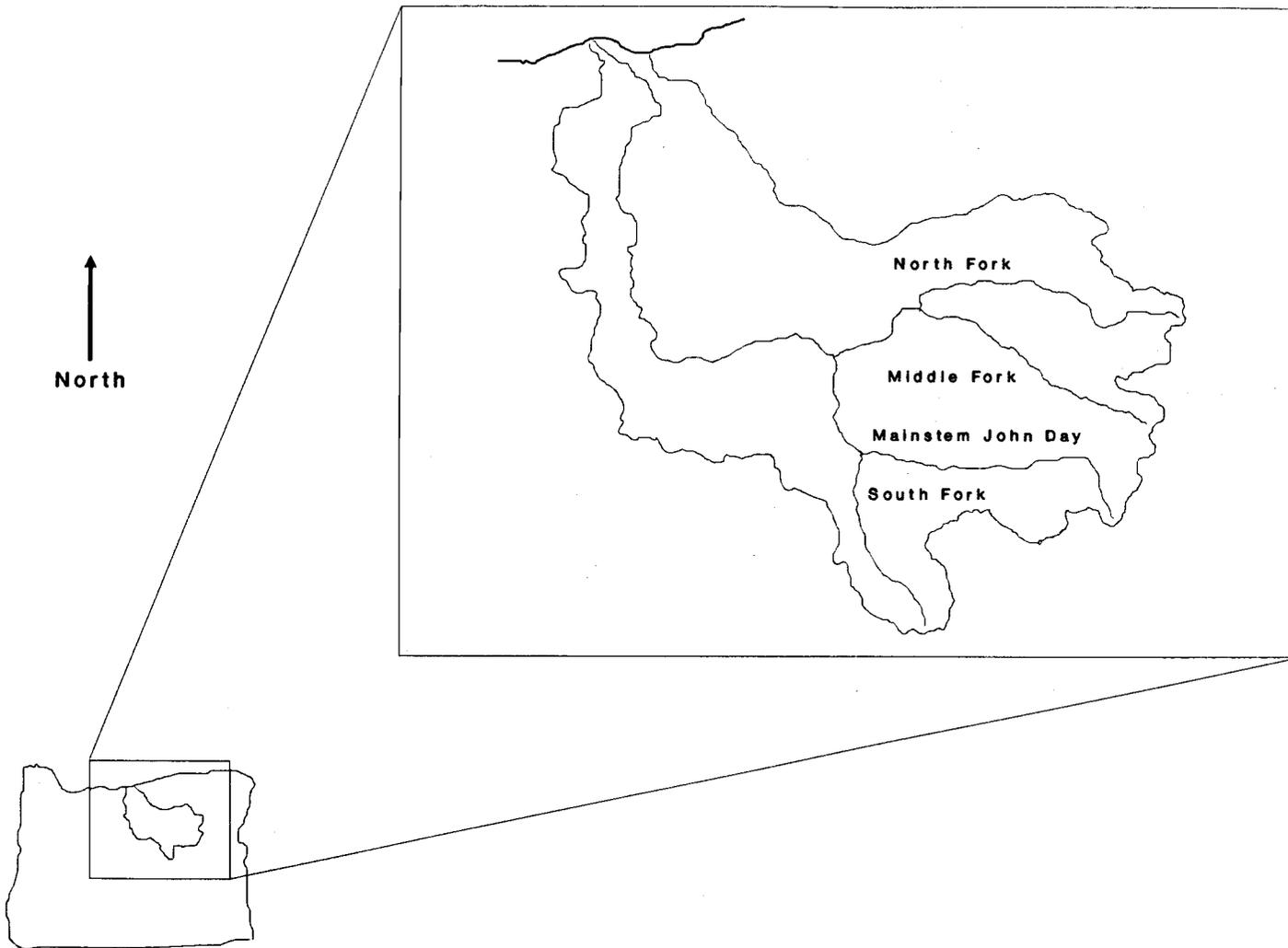


Figure 1. John Day basin study area.

CLASSIFICATION OF BASINS

The basins sampled were classified according to their similarities in physical and geomorphic features. Hierarchical agglomerative clustering with correlation as the dissimilarity measure was used to classify the drainages. Hierarchical clustering was used because it best shows the relationships between the groups, plus it arranges the groups in an easy to follow dendrogram (Gauch 1982). The following data was collected from USGS quadrangle maps: drainage length, stream gradient, compass aspect, and stream order. Data for watershed area, mean annual discharge and highest and lowest elevation were obtained from "A Resource Survey of River Energy and Low-Head Hydroelectric Power Potential in Oregon" (WRI, 1979: Appendix 6). Mean annual precipitation, and area geology, as expressed in water yield capacity, were obtained from maps published by the State of Oregon Water Resources Board.

The following subbasins within each basin of the John Day were clustered to ensure that inappropriate comparisons would be avoided: Murderer's Creek (South Fork drainage); Camp Creek (Middle Fork drainage); Reynolds Creek, Deardorff Creek, and Call Creek (upper mainstem drainage). Total length of all subbasin streams, drainage density, and watershed area were measured from USGS quadrangle maps. A digitizer was used to integrate proportional values based on area (e.g. precipitation within a subbasin, and water yield of a subbasin).

FIELD SAMPLING

Data was collected during the low-flow period for both 1985 and 1986. This period extends from approximately the middle of July until the third week of September. This was done for two reasons.

It is thought to be a critical time for salmonids in the Pacific Northwest (Platts, 1981) and it is the period during which there is little migratory activity by juvenile salmonids (E. Claire, ODFW, personal communication).

Whenever possible, reaches of a stream were paired at each elevation sampled: reaches with and without well developed riparian areas. Reaches were selected that appeared to be representative of the habitat along the longitudinal gradient from low elevation to headwater reaches. Habitat types were divided into pools, riffles, and runs. Where possible, all habitat types were sampled in a given reach.

Physical habitat surveys were performed at each sampling site, followed by a snorkeling survey to inventory fish populations. Physical habitat measurements followed the guidelines of Platts et al. (1983; 1987) and Hamilton and Bergersen (1984) with the following exceptions. Transects were measured for each habitat type (i.e. pool, riffle, run) rather than the stream reach per se. A minimum of one and a maximum of three transects were taken at each habitat type depending on its size. Measurements were taken at three to five grid points along the transects depending on the width of the stream. A light meter was used to measure incident light reaching the stream. Readings of the meter were averaged and the meter was never aimed at the sun. Measurements were taken at midstream along the transect lines, and in an area without shade. The difference between the two measures expressed the amount of light blocked by the riparian canopy or other shading structures. The light meter was later calibrated to a LiCor solar radiometer. Surface water turbulence was estimated using the following classes:

<u>class</u>	<u>criteria</u>
5	standing waves greater than 0.67m in height
4	standing waves between 0.33 and 0.67m in height
3	standing waves between 1.5cm and 0.33m in height
2	rippled waves up to 1.5cm in height
1	flat, glassy water

Water column turbulence was the fluctuation in water column velocity as measured by a Marsh-McBirney flow meter (+/- cm/sec). The physical habitat parameters measured are listed in table 1. Refer to Platts et al. (1983; 1987) or Hamilton and Bergersen (1984) for further details on these variables. Velocity was measured with a Marsh-McBirney model 201 flow meter according to Bovee and Milhous (1978). Substrate was measured visually with the aid of a viewing box with a plexiglass bottom and the percentages of seven substrate classes were recorded for each grid point and for each microhabitat location. The size categories were taken from a modified Wentworth scale (Cummins 1962). The size categories were then converted to a phi scale (-log base 2) based on the midpoint of the size range. The substrate categories, sizes, and corresponding phi values are summarized in table 2. The percentage of a particular substrate size present at a given transect point or microhabitat was then multiplied by the corresponding phi value for that size group. These values were added for all the size groups present to give a mean substrate score for that particular transect point or microhabitat. The mean substrate score for a particular habitat type or a microhabitat group (e.g. YOY steelhead in mainstem pools) was the average of all the substrate scores for that group. There was no bedrock seen during this study, therefore it was not used.

Table 1. Physical habitat variables measured.

site length	channel vegetation
site gradient	substrate size
bank full width	bank angles
habitat type	surface turbulence
habitat type length	water column turbulence
habitat type width	soil alteration
depth	vegetative stability
surface velocity	vegetative use
average velocity	stream shore depth
total discharge	embeddedness
maximum temperature	dissolved oxygen
minimum temperature	nitrate
percent canopy cover	alkalinity
total bank cover	hardness
light - stream	turbidity
light - open	pH
undercut banks	large woody debris

Table 2. Substrate size descriptions and associated phi values.

substrate category	diameter size range	phi value
large boulder	> 1000 mm.	-9.97
small boulder	300 - 1000 mm.	-8.23
rubble	150 - 300 mm.	-7.23
cobble	75 - 150 mm.	-6.23
large gravel	25 - 75 mm.	-4.64
small gravel	2 - 25 mm.	-1.00
sand, silt, and clay	0 - 2 mm.	8.97

Note that the larger the substrate, the smaller the phi value.

After the physical measurements were taken, the reaches were snorkeled in a manner similar to those described by Rodnick (1983) and Helfman (1983) to get a visual estimate of the number of fish of each species present. Fish were counted while moving upstream and each reach was snorkeled twice to ensure the reliability of the counts. A minimum of two divers censused fish populations. The technique differed slightly for each habitat type. In riffles, two or more divers moved upstream in lanes, the width was determined by visibility. In runs and pools, at least one diver was stationed at the upper end of the habitat to assess the degree to which fish were moving ahead of the divers doing the counting. Substrate was disturbed to aid in the counting of benthic species such as longnose dace (Rhinichthys cataractae), piute sculpin (Cottus beldingi) and torrent sculpin (C. rotheus).

During the 1986 field season various microhabitat measures were taken on juvenile salmonids. These included focal point depth, depth of the water column at the fishes location, focal point velocity, mean velocity of the water column at the fishes location, substrate composition immediately below the fish, embeddedness of the substrate, surface turbulence, and focal point turbulence. Only undisturbed fish were sampled. Individual fish were observed for one to three minutes to be certain they were undisturbed before taking the microhabitat measurements. All age classes of juvenile steelhead and age zero chinook were sampled in all habitat types (i.e. pools, riffles, and runs).

Several reaches within each subdrainage sampled in 1985 were resampled in 1986. These served as index sites to monitor yearly changes in physical habitat quality and species abundances. There were six such sites within the South Fork drainage, four on the South Fork and two on Murderer's Creek. Two reaches were resampled on the upper mainstem both above Prairie City. Four reaches were

resampled in the Middle Fork drainage, two on the upper Middle Fork and two on Camp Creek.

Many new reaches were sampled in 1986. The purpose of this was to increase the amount of data collected on juvenile salmonid rearing habitats. Analysis of the 1985 data showed the importance of these habitats (see Li et al. 1986). The 1986 sampling was concentrated in these areas in order to more accurately describe and determine the importance of these areas, to better quantify the availability of these habitats, and to increase the diversity of stream reaches sampled. Reaches were added on upper Murderer's Creek (above the Murderer's Creek Ranch, near the mouth of Tex Creek), lower Camp Creek in the Middle Fork drainage, and Deardorff and Reynolds Creeks, mainstem tributaries above Prairie City. Call Creek, an upper mainstem tributary sampled in 1985 was not sampled in 1986 because it was deemed not to be representative of upper mainstem tributaries. Reynolds and Deardorff Creeks were added because they are more typical tributaries, and they are larger (fourth and third orders respectively) and therefore more directly comparable to Camp and Murderer's Creeks (both fourth order tributaries). Two reaches on the lower Middle Fork and two on the lower mainstem were planned for the 1986 field season but could not be sampled due to inclement weather and turbid water.

Four of the index sites in the South Fork drainage were sampled twice in 1986. The first was in mid-July when flows were on the declining limb of the hydrograph. The second was in mid-August after the flows had dropped to base flow. This was done to assess the effects changes in flow would have on the physical habitat and the fish assemblage. Because changes were very minor, only the first, more detailed sampling of those sites was used.

STATISTICAL ANALYSIS

FISH ASSEMBLAGE STRUCTURE

Fish density data were analyzed using detrended correspondence analysis (DCA) to fully analyze assemblage structure. DCA is an ordination technique similar to reciprocal averaging (RA). It is considered an improvement on RA because it avoids the two major problems associated with it, namely the "arch effect", and the compression of the endpoints (Hill, 1979; Gauch, 1982). Ordination arranges species and samples in a low dimensional space with similar entities together and dissimilar entities far apart (Gauch, 1982). The basic goal of ordination is to derive ecological space (space with environmental gradients as axes) from the species data. Two steps are involved. First, community patterns are summarized with ordination. Second, the "community patterns are compared with environmental information in order to produce an environmental interpretation of the ordination (community) results" (Gauch, 1982).

DCA generated species scores, and then site scores (weighted averages of the species scores). Environmental interpretation of the axes was a separate step. Site scores were correlated with the physical habitat variables. Those that had significant correlations were assumed to be the physical habitat variables that influenced the fish assemblage structure. DCA has problems dealing with rare species (Hill, 1979; Hill and Gauch, 1980), therefore they were down weighted for this analysis.

DCA was run on the fish density data for each drainage (Middle Fork, South Fork, and upper mainstem) and each year separately. The years were then combined but the drainages were kept separate.

MICROHABITAT

The microhabitat data was divided into 20 groups based on age class, species, habitat type (pool, riffle, run), and stream type (mainstem versus tributary). Due to sample size problems, the streams could not be broken down according to drainage. These groups are listed in table 3.

A Kruskal-Wallis test was performed to test for interspecific or age group differences in microhabitat use. If there was a significant difference, a Tukey-Kramer multiple comparison test was used on the ranked data to identify pairwise differences.

Habitat availability was determined by averaging the values of the appropriate physical habitat variables measured along transects from the physical habitat survey. To test for selection, a chi-squared goodness of fit test was performed to test for significant differences between observed values (those of the individual fish) and expected values (the mean values for that particular habitat type).

Table 3. Definitions and sample sizes (n) of the microhabitat groups.

Group Number	n	Definition
1	12	YOY steelhead trout in mainstem pools
2	105	YOY steelhead trout in tributary pools
3	37	Age 1+ steelhead trout in mainstem pools
4	63	Age 1+ steelhead trout in tributary pools
5	28	Age 2+/3+ steelhead trout in mainstem pools
6	38	Age 2+/3+ steelhead trout in tributary pools
7	93	Juvenile chinook salmon in mainstem pools
8	36	YOY steelhead trout in mainstem riffles
9	42	YOY steelhead trout in tributary riffles
10	21	Age 1+ steelhead trout in mainstem riffles
11	16	Age 1+ steelhead trout in tributary riffles
12	10	Age 2+/3+ steelhead trout in mainstem riffles
13	13	Age 2+/3+ steelhead trout in tributary riffles
14	20	Juvenile chinook salmon in mainstem riffles
15	12	YOY steelhead trout in mainstem runs
16	23	YOY steelhead trout in tributary runs
17	24	Age 1+ steelhead trout in mainstem runs
18	7	Age 1+ steelhead trout in tributary runs
19	17	Age 2+/3+ steelhead in mainstem runs
20	4	Juvenile chinook salmon in mainstem runs

RESULTS AND DISCUSSION

CLASSIFICATION

The results of the classification are shown in figures 2 and 3 and in tables 4 and 5. The South Fork is drier and smaller than the upper Mainstem and Middle Fork drainages (table 4). The tributary subbasins formed two clusters: 1) the upper Mainstem tributaries (Call, Reynolds, and Deardorff Creeks) and 2) Camp Creek (Middle Fork drainage) and Murderer's Creek (South Fork drainage). The factors that separate the groups are gradient and geology. The upper Mainstem tributaries are steeper and have geologies that yield more water. Call Creek is distinct from Reynolds and Deardorff Creeks in watershed size, gradient, drainage density, and stream length (table 5).

DCA PLOT INTERPRETATION

Proper interpretation of the plots (figs. 4 to 21) requires examining the site score and the species score plots simultaneously in addition to the physical habitat variables that were significantly correlated with the DCA site scores (tables 6-8). In all cases only two interpretable axes resulted from the DCA. A key to aid in the interpretation of the physical habitat variables is shown in the appendix.

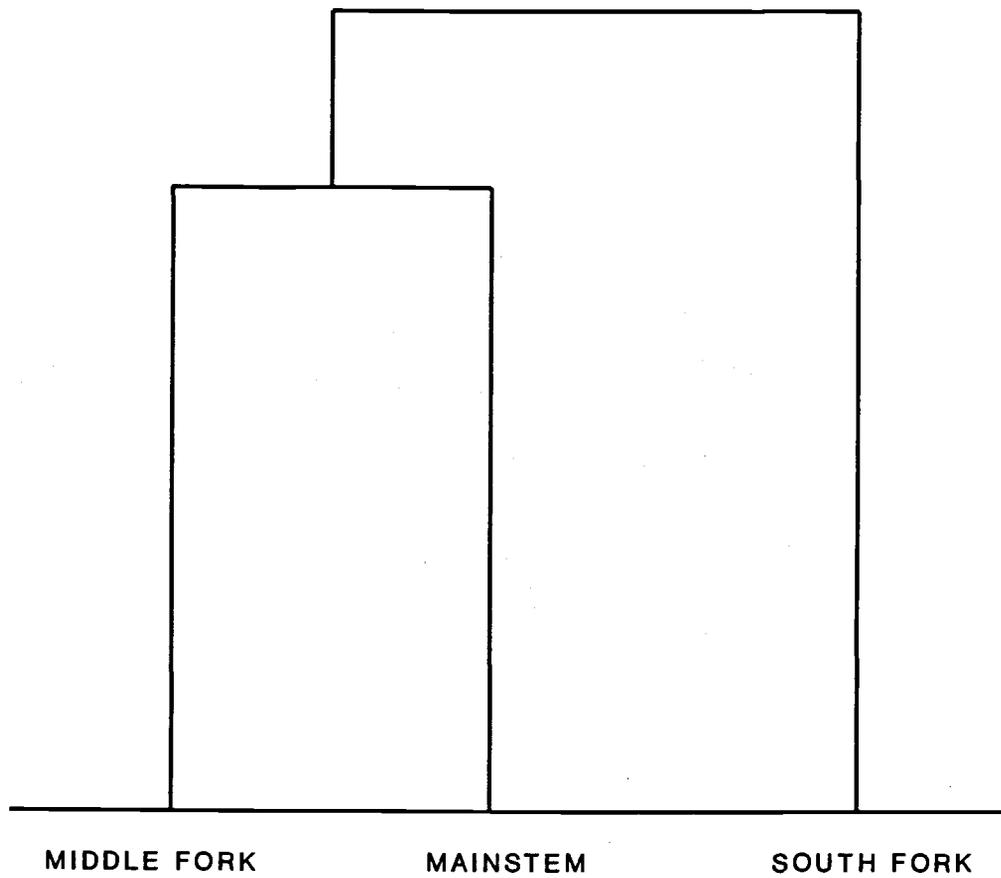


Figure 2. Cluster analysis of the South Fork, Middle Fork, and upper Mainstem of the John Day River drainages based on geomorphological characteristics.

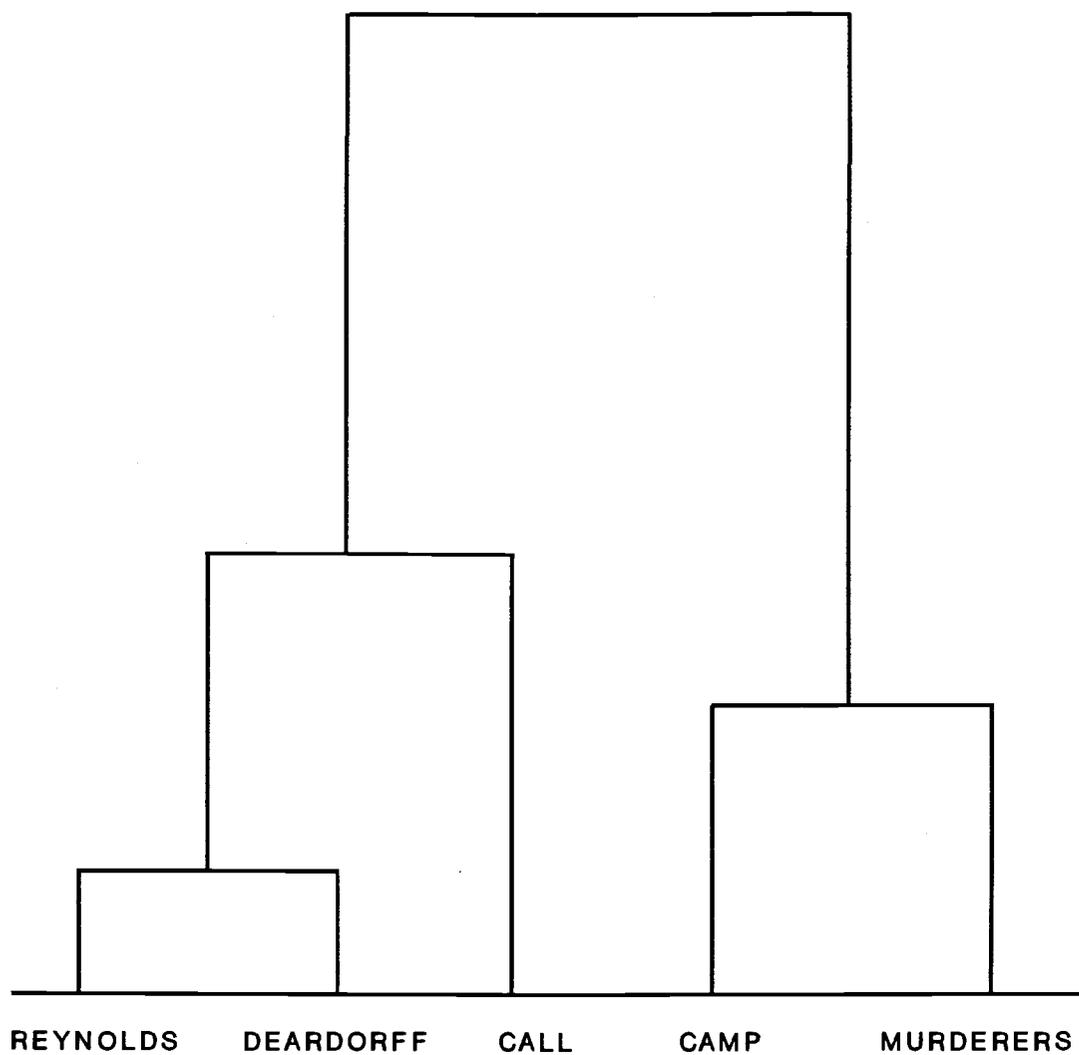


Figure 3. Cluster analysis of the South Fork, Middle Fork, and upper Mainstem tributary drainages of the John Day River based on geomorphological characteristics.

Table 4. Characteristics of the major drainages of the upper John Day Basin.

Character	Middle Fork	South Fork	Upper Mainstem
mean annual precipitation (cm)	55.20	44.10	54.30
geology*	406.00	293.00	387.00
watershed area (km. ²)	2006.90	1637.70	3921.10
drainage length (km.)	122.30	98.20	159.30
gradient (%)	0.87	0.95	0.91
compass aspect**	2.00	1.00	3.00
order	5.00	5.00	6.00
highest elevation (m)	1725.00	1646.00	2012.00
lowest elevation (m)	668.00	710.00	561.00
mean annual discharge (m ³ /sec.)	7.99	3.79	18.24

* geology value based on water yield = the sum of (% area of a geological type in a drainage) x (code for that geological type)

type	water yield capacity	code
alluvium	medium	6
Columbia R. basalt	medium-low	5
undifferentiated rock	mostly low	4
lava, ash, tuff	very low	3
sandstone, shale	very low	2
intrusive rock	negligible	1
data not available		0

** direction of flow: 1= N to S, 2=NW,NE,SW,SE, 3= E to W

Table 5. Characteristics of the subdrainages of the John Day Drainage.

Character	Camp Creek	Murderer's Creek	Reynolds Creek	Deardorff Creek	Call Creek
mean annual precipitation (cm)	63.50	38.10	63.50	69.90	76.20
geology*	367.00	331.00	500.00	500.00	500.00
watershed area (km. ²)	167.50	335.00	81.90	53.00	34.70
drainage length (km.)	25.60	42.80	16.20	16.10	6.30
total stream length (km.)	131.50	388.90	66.70	51.90	6.30
drainage density	0.79	1.16	0.81	0.98	0.18
gradient (%)	2.60	2.40	5.70	5.10	12.06
compass aspect*	2.00	3.00	3.00	3.00	2.00
stream order	4.00	4.00	4.00	3.00	2.00
highest elevation (m.)	1719.00	1963.00	2097.00	2030.00	2158.00
lowest elevation (m.)	1055.00	902.00	1180.00	1213.00	1408.00

* geology value based on water yield = the sum of (% area of a geological type in a drainage) x (code for that geological type). Refer to table 3 for codes.

** Direction of flow: 1 = N to S, 2 = NW, NE, SW, SE, 3 = E to W.

1985

SOUTH FORK

The eigenvalue for axis 1 was 0.540 and 0.087 for axis 2. Eigenvalues represent the correspondence between the site and species scores along a particular axis. In other words, Gauch (1982) states that these values are "the variance accounted for by that axis. The axes are ranked by their eigenvalues, the first axis having the greatest eigenvalue." Eigenvalues that are much lower than the first are deemed to have little significance (Hill, 1979). Because the value for the second axis is much lower than that for the first, it is at best a weak axis.

The primary gradient is an elevation/stream size/bank condition gradient along DCA axis 1 for both site and species scores. The significantly correlated physical habitat variables are listed in table 6 and the species and site scores are shown in figures 4 and 5 respectively. High DCA site scores on axis 1 represent low elevation sites with lower bank ratings (i.e. greater bank angles, fewer undercuts, and shallower stream shores) where nongame fish (e.g. redbreast shiners, suckers, and speckled dace) dominate the assemblage. It is important to note that as bank angles decrease, their score increases. Therefore a negative correlation with the DCA axis 1 score indicates an increasing bank angle which reflects lower quality fish habitat, less stable and more altered banks. Also, axis 1 brings out the sites where rare species were found such as unidentified young-of-the-year (YOY) nongame fish (one site). The opposite end of the axis contains those sites where steelhead reached their highest densities in the drainage (eg. Murderer's Creek and the upper South Fork). Only one lamprey ammocete was seen in the entire study so it was removed from the analysis (in the South Fork - 1985).

Figure Legends. Descriptions of the abbreviated sample site codes for figures 4, 6, 8, 10, 12, 14, 16, 18, 20.

Upper Mainstem Drainage - 1985

PGPO = Mainstem at Picture Gorge, lowest elevation, pool habitat.
 HPRU = Mainstem at Holiday Park State Park, near Mt. Vernon, run habitat.
 ACRU = Mainstem on Al Coombs' property (Prairie City), run habitat.
 ACRI = Mainstem on Al Coombs' property (Prairie City), riffle habitat.
 ACPO = Mainstem on Al Coombs' property (Prairie City), pool habitat.
 HFRI = Mainstem on Harvey Fields' property (Prairie City), riffle habitat.
 HFP1 = Mainstem on Harvey Fields' property (Prairie City), upper pool habitat.
 HFP2 = Mainstem on Harvey Fields' property (Prairie City), lower pool habitat.
 ACPA = Mainstem at Call Creek, pool habitat above the confluence.
 ACPB = Mainstem at Call Creek, pool habitat below the confluence.
 RUAC = Mainstem at Call Creek, run habitat below the confluence.
 LMPO = Mainstem at Little Meadow (USFS), pool habitat.
 SIDE = Mainstem at Little Meadow (USFS), side channel.
 CCAS = Call Creek cascade, run habitat.

Middle Fork Drainage - 1985

1RUN = Site #1 on the Middle Fork, lowest elevation, run habitat.
 2RUN = Site #2 on the Middle Fork, run habitat.
 3RUN = Site #3 on the Middle Fork, run habitat.
 4POL = Site #4 on the Middle Fork, pool habitat.
 5POU = Site #5 on the Middle Fork (Phipps Meadow), upper pool habitat.
 5POL = Site #5 on the Middle Fork (Phipps Meadow), lower pool habitat.
 5RIF = Site #5 on the Middle Fork (Phipps Meadow), riffle habitat.
 5RUN = Site #5 on the Middle Fork (Phipps Meadow), run habitat.
 CRP1 = Upper Camp Creek riparian area, upper pool habitat.
 CRRU = Upper Camp Creek riparian area, run habitat.
 CRP2 = Upper Camp Creek riparian area, middle pool habitat.
 CRR2 = Upper Camp Creek riparian area, lower riffle habitat.
 CRP3 = Upper Camp Creek riparian area, lower pool habitat.
 CRRR = Upper Camp Creek riparian area, riffle/run habitat.
 CNR1 = Upper Camp Creek nonriparian area, upper run habitat.
 CNRI = Upper Camp Creek nonriparian area, riffle habitat.
 CNL1 = Upper Camp Creek nonriparian area, upper log weir habitat.
 CNL2 = Upper Camp Creek nonriparian area, middle log weir habitat.
 CNR2 = Upper Camp Creek nonriparian area, lower run habitat.
 CNL3 = Upper Camp Creek nonriparian area, lower log weir habitat.
 CNNP = Upper Camp Creek nonriparian area, natural pool habitat.

South Fork Drainage - 1985

CFRI = South Fork on Cliff Fine's property (Dayville), riffle habitat.
 ORIF = South Fork open canopy riffle habitat at the lower end of the Murderer's Creek Wildlife Area.
 OPOL = South Fork open canopy, pool habitat.
 CAPO = South Fork closed canopy, pool habitat.
 CARU = South Fork closed canopy, run habitat.
 CARI = South Fork closed canopy, riffle habitat.

CORI = South Fork at Murderer's Creek, riffle habitat.
 CORU = South Fork at Murderer's Creek, run habitat.
 COPO = South Fork at Murderer's Creek, pool habitat.
 CSRU = South Fork near campsite between Deer and Murderer's Creeks,
 run habitat.
 WFRU = South Fork below waterfalls, run habitat.
 MORI = Murderer's Creek open canopy riffle habitat.
 MLRI = Murderer's Creek lower canopy, riffle habitat.
 MURI = Murderer's Creek upper canopy, riffle habitat.

Upper Mainstem Drainage - 1986

ACUR = Mainstem on Al Coombs' property (Prairie City), upper run
 habitat (was a pool in 1985).
 ACRI = Mainstem on Al Coombs' property (Prairie City), riffle
 habitat.
 ACLR = Mainstem on Al Coombs' property (Prairie City), lower run
 habitat.
 HFRI = Mainstem on Harvey Fields' property (Prairie City), riffle
 habitat.
 HFP1 = Mainstem on Harvey Fields' property (Prairie City), upper
 pool habitat.
 HFP2 = Mainstem on Harvey Fields' property (Prairie City), lower
 pool habitat.
 LRRU = Lower Reynolds Creek, run habitat.
 LRLP = Lower Reynolds Creek, lower pool habitat.
 LRSR = Lower Reynolds Creek, side channel riffle habitat.
 LRUP = Lower Reynolds Creek, upper pool habitat.
 URLR = Upper Reynolds Creek, lower riffle habitat.
 URLP = Upper Reynolds Creek, lower pool habitat.
 URMP = Upper Reynolds Creek, middle pool habitat.
 URUR = Upper Reynolds Creek, upper riffle habitat.
 URSP = Upper Reynolds Creek, side channel pool habitat.
 NRL1 = North Fork Reynolds Creek, upper log weir habitat.
 NRL2 = North Fork Reynolds Creek, lower log weir habitat.
 LDNP = Lower Deardorff Creek, natural pool habitat.
 LDLL = Lower Deardorff Creek, lower log weir habitat.
 LDUL = Lower Deardorff Creek, upper log weir habitat.
 UDLR = Upper Deardorff Creek, lower riffle habitat.
 UDMR = Upper Deardorff Creek, middle riffle habitat.
 UDUR = Upper Deardorff Creek, upper riffle habitat.
 UDLP = Upper Deardorff Creek, lower pool habitat.
 UDUP = Upper Deardorff Creek, upper pool habitat.

Middle Fork Drainage - 1986

4POL = Site #4 on the Middle Fork, pool habitat.
 4RIF = Site #4 on the Middle Fork, riffle habitat.
 4RUN = Site #4 on the Middle Fork, run habitat.
 5POU = Site #5 on the Middle Fork (Phipps' Meadow), upper pool
 habitat.
 5RIU = Site #5 on the Middle Fork (Phipps' Meadow), upper riffle
 habitat.
 5RIL = Site #5 on the Middle Fork (Phipps' Meadow), lower riffle
 habitat (was a run in 1985).
 5POL = Site #5 on the Middle Fork (Phipps' Meadow), lower pool
 habitat.
 CRP1 = Upper Camp Creek riparian area, upper pool habitat.
 CRR1 = Upper Camp Creek riparian area, riffle habitat.
 CRP2 = Upper Camp Creek riparian area, lower pool habitat.
 CNL1 = Upper Camp Creek nonriparian area, upper log weir habitat.

CNL2 = Upper Camp Creek nonriparian area, lower log weir habitat.
 CNRI = Upper Camp Creek nonriparian area, riffle habitat.
 CNNP = Upper Camp Creek nonriparian area, natural pool habitat.
 CLL1 = Lower Camp Creek nonriparian area, upper log weir habitat.
 CLL2 = Lower Camp Creek nonriparian area, lower log weir habitat.
 CLP1 = Lower Camp Creek riparian area, upper pool habitat.
 CLR1 = Lower Camp Creek riparian area, upper riffle habitat.
 CLP2 = Lower Camp Creek riparian area, lower pool habitat.
 CLR2 = Lower Camp Creek riparian area, lower riffle habitat.

South Fork Drainage - 1986

OPOL = South Fork open canopy, pool habitat.
 ORIF = South Fork open canopy, riffle habitat.
 ORUN = South Fork open canopy, run habitat.
 CAPO = South Fork closed canopy, pool habitat.
 CARU = South Fork closed canopy, run habitat.
 CARI = South Fork closed canopy, riffle habitat.
 CSPO = South Fork near campsite between Deer and Murderer's Creeks,
 pool habitat.
 CSRI = South Fork near campsite between Deer and Murderer's Creeks,
 riffle habitat.
 CSRU = South Fork near campsite between Deer and Murderer's Creeks,
 run habitat.
 CSSR = South Fork near campsite between Deer and Murderer's Creeks,
 side channel riffle habitat.
 WFPO = South Fork below waterfalls, pool habitat.
 WFRI = South Fork below waterfalls, riffle habitat.
 WFLW = South Fork below waterfalls, natural log weir habitat.
 WFRU = South Fork below waterfalls, run habitat.
 MORU = Murderer's Creek open canopy, run habitat.
 MORI = Murderer's Creek open canopy, riffle habitat.
 MORR = Murderer's Creek open canopy, riffle/run habitat.
 MOSI = Murderer's Creek open canopy, side channel riffle habitat.
 MURU = Murderer's Creek upper canopy, run habitat.
 MURI = Murderer's Creek upper canopy, riffle habitat.
 MUR2 = Murderer's Creek upper canopy, lower run habitat.
 MUPO = Murderer's Creek upper canopy, pool habitat.
 MNPO = Murderer's Creek upper nonriparian (near Tex Creek), pool
 habitat.
 MNRI = Murderer's Creek upper nonriparian (near Tex Creek), riffle
 habitat.
 MNRU = Murderer's Creek upper nonriparian (near Tex Creek), run
 habitat.
 MRPO = Murderer's Creek upper riparian (near Tex Creek), pool
 habitat.
 MRRI = Murderer's Creek upper riparian (near Tex Creek), riffle
 habitat.
 MRRU = Murderer's Creek upper riparian (near Tex Creek), run
 habitat.

Combined Years Site Codes

Upper Mainstem Drainage - 1985

PGPO = Mainstem at Picture Gorge, lowest elevation, pool habitat.
 HPRU = Mainstem at Holiday Park State Park, near Mt. Vernon, run
 habitat.
 ACRU5 = Mainstem on Al Coombs' property (Prairie City), run habitat.

ACRI5 = Mainstem on Al Coombs' property (Prairie City), riffle habitat.
 ACPO5 = Mainstem on Al Coombs' property (Prairie City), pool habitat.
 HFRI5 = Mainstem on Harvey Fields' property (Prairie City), riffle habitat.
 HFP15 = Mainstem on Harvey Fields' property (Prairie City), upper pool habitat.
 HFP25 = Mainstem on Harvey Fields' property (Prairie City), lower pool habitat.
 ACPA = Mainstem at Call Creek, pool habitat above the confluence.
 ACPB = Mainstem at Call Creek, pool habitat below the confluence.
 RUAC = Mainstem at Call Creek, run habitat below the confluence.
 LMPO = Mainstem at Little Meadow (USFS), pool habitat.
 SIDE = Mainstem at Little Meadow (USFS), side channel.
 CCAS = Call Creek cascade, run habitat.

Upper Mainstem Drainage - 1986

All codes were the same as the 1986 data alone.

Middle Fork Drainage - 1985

1RUN = Site #1 on the Middle Fork, lowest elevation, run habitat.
 2RUN = Site #2 on the Middle Fork, run habitat.
 3RUN = Site #3 on the Middle Fork, run habitat.
 4PO5 = Site #4 on the Middle Fork, pool habitat.
 5UP5 = Site #5 on the Middle Fork (Phipps Meadow), upper pool habitat.
 5LP5 = Site #5 on the Middle Fork (Phipps Meadow), lower pool habitat.
 5RI5 = Site #5 on the Middle Fork (Phipps Meadow), riffle habitat.
 5RU5 = Site #5 on the Middle Fork (Phipps Meadow), run habitat.
 CRP15 = Upper Camp Creek riparian area, upper pool habitat.
 CRRU5 = Upper Camp Creek riparian area, run habitat.
 CRP25 = Upper Camp Creek riparian area, middle pool habitat.
 CRR25 = Upper Camp Creek riparian area, lower riffle habitat.
 CRP35 = Upper Camp Creek riparian area, lower pool habitat.
 CRRR5 = Upper Camp Creek riparian area, riffle/run habitat.
 CNR15 = Upper Camp Creek nonriparian area, upper run habitat.
 CNRI5 = Upper Camp Creek nonriparian area, riffle habitat.
 CNL15 = Upper Camp Creek nonriparian area, upper log weir habitat.
 CNL25 = Upper Camp Creek nonriparian area, middle log weir habitat.
 CNR25 = Upper Camp Creek nonriparian area, lower run habitat.
 CNL35 = Upper Camp Creek nonriparian area, lower log weir habitat.
 CNNP5 = Upper Camp Creek nonriparian area, natural pool habitat.

Middle Fork Drainage - 1986

All codes were the same as the 1986 data alone.

South Fork Drainage - 1985

CFRI = South Fork on Cliff Fine's property (Dayville), riffle habitat.
 ORIF5 = South Fork open canopy riffle habitat at the lower end of the Murderer's Creek Wildlife Area.
 OPOL5 = South Fork open canopy, pool habitat.
 CAPO5 = South Fork closed canopy, pool habitat.
 CARU5 = South Fork closed canopy, run habitat.
 CARI5 = South Fork closed canopy, riffle habitat.

CORI = South Fork at Murderer's Creek, riffle habitat.
CORU = South Fork at Murderer's Creek, run habitat.
COPO = South Fork at Murderer's Creek, pool habitat.
CSRU5 = South Fork near campsite between Deer and Murderer's Creeks,
run habitat.
WFRU5 = South Fork below waterfalls, run habitat.
MORI5 = Murderer's Creek open canopy riffle habitat.
MLRI = Murderer's Creek lower canopy, riffle habitat.
MURI5 = Murderer's Creek upper canopy, riffle habitat.

South Fork Drainage - 1986

All codes were the same as the 1986 data alone.

Figure legend. Species abbreviations for figures 5, 7, 9, 11, 13, 15, 17, 19, and 21.

0+ RBT	= Young-of-the-year steelhead.
1+ RBT	= Age 1+ (or yearling) steelhead.
2+ RBT	= Age 2+ steelhead.
3+ RBT	= Age 3+ steelhead.
TRBT	= Total steelhead (all age classes combined).
CTT	= Cutthroat trout.
BULL	= Bull trout.
CHS	= Juvenile chinook salmon.
MWF	= Mountain whitefish.
RSS	= Redside shiners.
SPD	= Speckled dace.
LND	= Longnose dace.
SQF	= Squawfish.
SUCKER	= Various sucker species (<u>Catostomus</u> spp.).
TSC	= Torrent sculpin.
PSC	= Piute sculpin.
MSC	= Mottled sculpin (<u>Cottus bairdi</u>).
SSC	= Slimy sculpin (<u>Cottus cognatus</u>).
USC	= Unidentified sculpin (<u>Cottus</u> spp.).
YOY	= Unidentified young-of-the-year nongame fish.
LAMP	= Lamprey ammocoetes (<u>Lampetra</u> spp.).

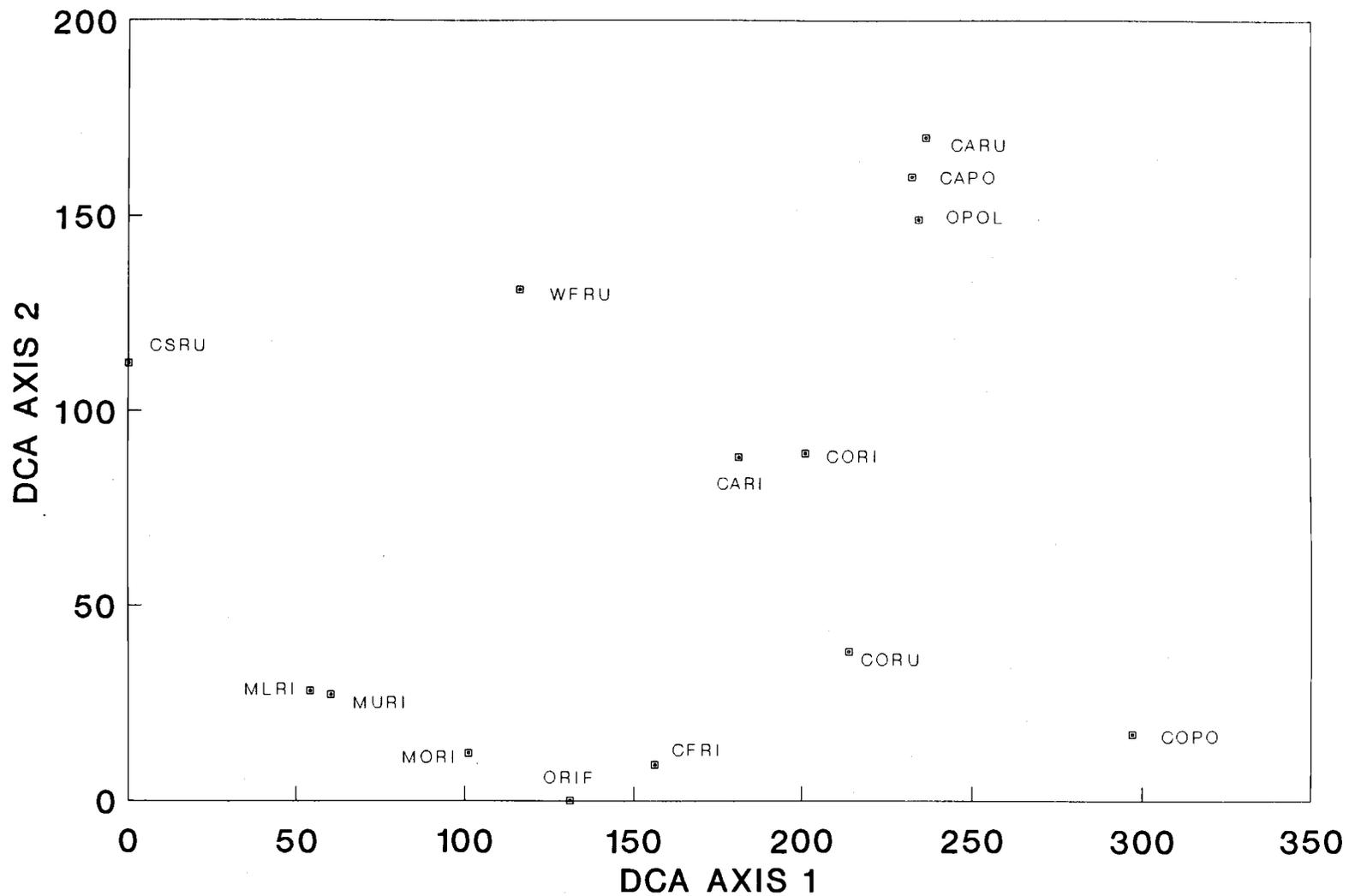


Figure 4. 1985 South Fork DCA site scores. DCA axis 1 vs. axis 2.

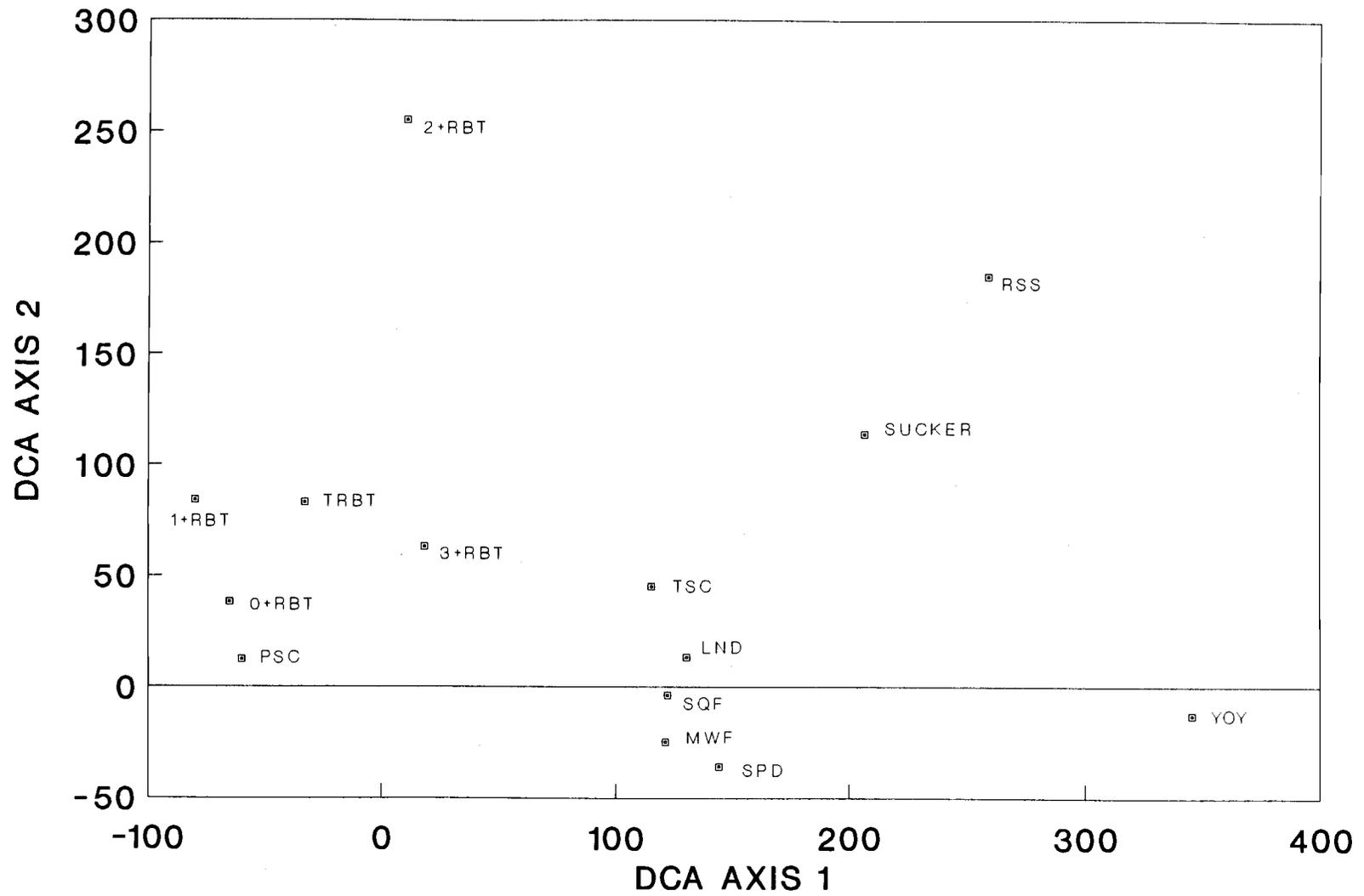


Figure 5. 1985 South Fork DCA species scores. DCA axis 1 vs. axis 2.

Table 6. Physical habitat variables significantly correlated ($\alpha = 0.05$) with the South Fork of the John Day River DCA site scores, and the associated r - values and significance levels.

1985		
AXIS 1		
Variable	R value	Sign. Level
width	0.7123	0.0043
bank angles	-0.6982	0.0055
bank undercut	-0.6982	0.0055
streamshore depth	-0.6982	0.0055
minimum temp.	0.6258	0.0167
elevation	-0.5404	0.0461
AXIS 2		
Variable	R value	Sign. Level
light	-0.8151	0.0004
mean depth	0.8045	0.0005
maximum temp.	-0.6788	0.0076
% canopy	0.5766	0.0309
bank cover	0.5542	0.0397

1986		
AXIS 1		
Variable	R value	Sign. Level
hardness	-0.7863	0.0000
alkalinity	-0.7447	0.0000
elevation	-0.6946	0.0000
mean depth	0.5876	0.0010
vegetative use	0.5347	0.0034
discharge	0.5143	0.0000
soil alteration	0.5047	0.0062
maximum temp.	0.4969	0.0072
pH	0.4952	0.0074
veg. stability	0.4743	0.0108
% canopy	0.4742	0.0108
area	0.4633	0.0130
substrate	-0.4023	0.0338
AXIS 2		
Variable	R value	Sign. Level
embeddedness	-0.7623	0.0000
turbidity	0.6320	0.0003
channel veg.	0.5932	0.0009
width	0.5494	0.0025
discharge	0.5070	0.0059
bank full width	0.5039	0.0063
hardness	0.4458	0.0174
mean vel. turb.	0.4368	0.0201
mean depth	0.3919	0.0392

Table 6. continued

COMBINED YEARS		
AXIS 1		
Variable	R value	Sign. Level
elevation	-0.7643	0.0000
width	0.7071	0.0000
discharge	0.6599	0.0000
alkalinity	-0.5834	0.0001
channel vegetation	0.5800	0.0001
mean depth	0.5640	0.0001
area	0.5378	0.0002
hardness	-0.4184	0.0058
bank angle	-0.3844	0.0120
streamshore depth	-0.3844	0.0120
embeddedness	-0.3698	0.0159
bank-full width	0.3293	0.0332
light	-0.3133	0.0433
AXIS 2		
Variable	R value	Sign. Level
hardness	0.6843	0.0000
elevation	0.6520	0.0000
alkalinity	0.5799	0.0001
mean depth	-0.4693	0.0017
discharge	-0.4502	0.0028
% canopy	-0.4144	0.0064
light	0.3844	0.0120
substrate	0.3198	0.0390
veg. stability	-0.3192	0.0394
maximum temp. = maximum temperature		
minimum temp. = minimum temperature		
channel veg. = channel vegetation		
mean vel. turb. = mean velocity turbulence		
veg. stability = vegetative stability		

The second gradient is a riparian/instream habitat gradient. Higher scores were given to those sites with much greater canopy development, more stable banks, lower maximum temperature, and deeper water. These were sites in the middle and upper reaches of the South Fork where the larger juvenile steelhead reared. These also had relatively high redbreast shiner densities.

MAINSTEM

The eigenvalue for axis 1 was 0.880 and 0.175 for axis 2. This also suggests one strong and one weak axis.

This plot has a similar axis 1 physical gradient as the South Fork. The only difference is that bank condition variables were replaced with riparian condition variables (table 7). Again, the "warmwater" fish assemblage dominates those sites with high DCA axis 1 site scores (Figs. 6 and 7). The opposite end of the axis represents the higher elevation sites dominated by age 0+ and 1+ rainbow trout. It also brings out those sites where brook trout (Salvelinus fontinalis) were found. The sites that contained juvenile chinook salmon and larger rainbow trout as well as some rarely observed sculpins are located in the middle of this axis. The significantly correlated variables are listed in table 7.

DCA axis 2 is a riparian habitat gradient. The highest scores are mainstem sites with the highest chinook densities, best riparian habitat in terms of the quantity of riparian vegetation, and a very low level of use. They also contained the species of sculpins not seen elsewhere. All of the sites along the mainstem had moderate to excellent riparian habitat. The failure to sample any sites with poor riparian habitat along the mainstem John Day helped weaken this gradient.

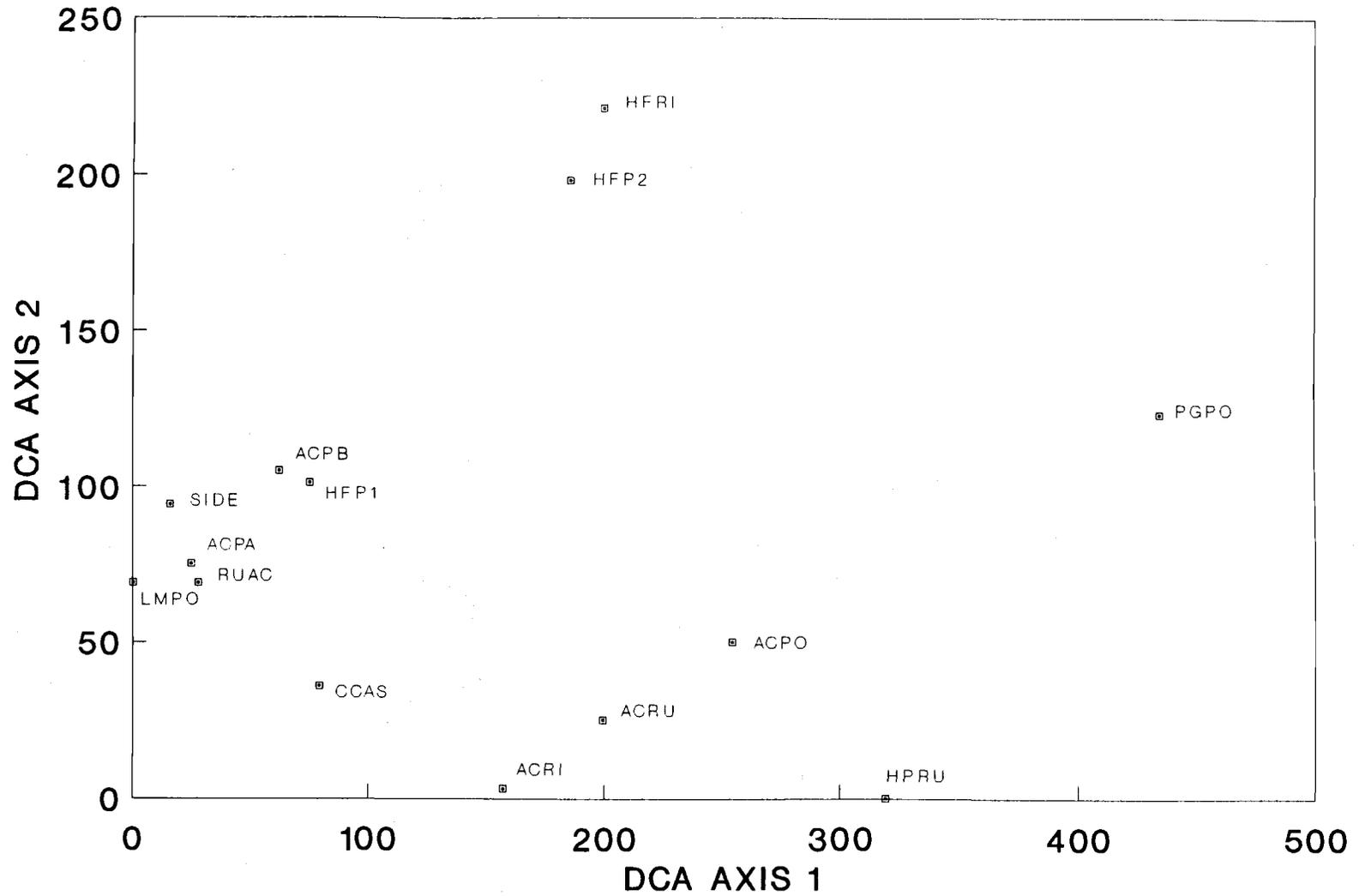


Figure 6. 1985 Mainstem DCA site scores. DCA axis 1 vs. axis 2.

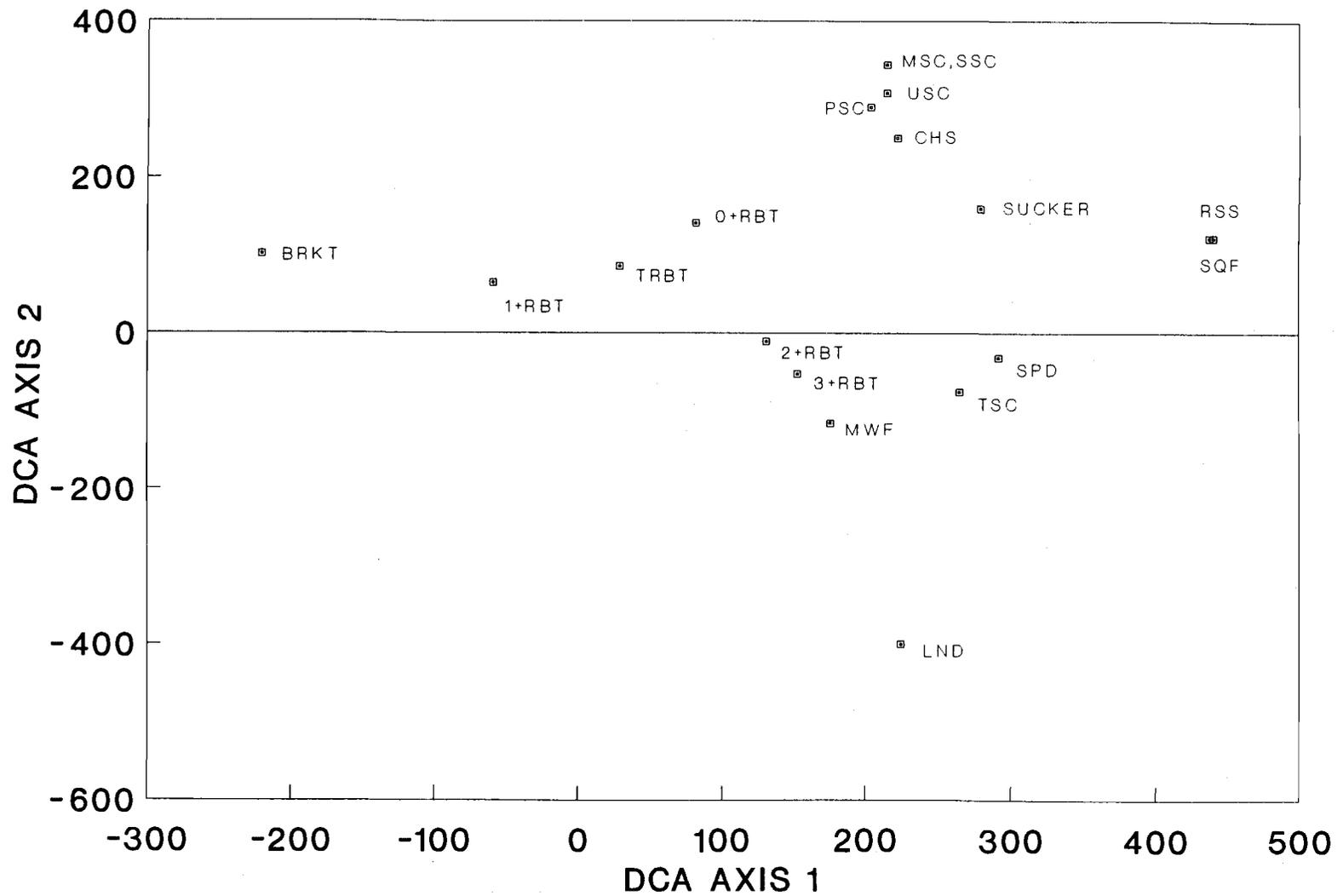


Figure 7. 1985 Mainstem DCA species scores. DCA axis 1 vs. axis 2.

Table 7. Physical habitat variables significantly correlated ($\alpha = 0.05$) with the upper mainstem of the John Day River DCA site scores, and the associated r - values and significance levels.

1985		
AXIS 1		
Variable	R value	Sign. Level
elevation	-0.9502	0.0000
pH	0.8926	0.0000
turbidity	0.8718	0.0000
discharge	0.8549	0.0000
minimum temp.	0.8269	0.0001
hardness	0.8129	0.0001
maximum temp.	0.8082	0.0002
area	0.7955	0.0002
alkalinity	0.7767	0.0004
width	0.7393	0.0011
bank-full width	0.7006	0.0025
vegetative use	0.5862	0.0170
soil alteration	0.5312	0.0342
veg. stability	0.5129	0.0422
AXIS 2		
Variable	R value	Sign. Level
vegetative use	0.6045	0.0131
soil alteration	0.5819	0.0180
veg. stability	0.5557	0.0254
dissolved oxygen	0.5514	0.0268

1986		
AXIS 1		
Variable	R value	Sign. Level
minimum temp.	0.7714	0.0000
turbidity	0.7603	0.0000
maximum temp.	0.7247	0.0000
elevation	-0.7012	0.0000
area	0.6498	0.0002
width	0.6468	0.0002
alkalinity	0.6461	0.0002
hardness	0.6275	0.0004
bank-full width	0.6151	0.0005
pH	0.5613	0.0019
discharge	0.5348	0.0034
soil alteration	0.5248	0.0041
vegetative use	0.5180	0.0048
mean depth	0.4808	0.0096
embeddedness	0.4094	0.0305
AXIS 2		
Variable	R value	Sign. Level
soil alteration	0.5117	0.0054
gradient	-0.3970	0.0365
mean depth	0.3529	0.0654
substrate	0.3415	0.0753

Table 7. continued.

COMBINED YEARS		
AXIS 1		
<u>Variable</u>	<u>R value</u>	<u>Sign. Level</u>
elevation	-0.8457	0.0000
turbidity	0.7396	0.0000
pH	0.7228	0.0000
discharge	0.7216	0.0000
hardness	0.7209	0.0000
minimum temp.	0.7208	0.0000
area	0.7180	0.0000
width	0.6998	0.0000
bank-full width	0.6500	0.0000
maximum temp.	0.6034	0.0000
vegetative use	0.5523	0.0001
mean depth	0.4801	0.0010
soil alteration	0.4664	0.0014
veg. stability	0.4342	0.0032
alkalinity	0.3088	0.0414
AXIS 2		
<u>Variable</u>	<u>R value</u>	<u>Sign. Level</u>
soil alteration	0.5893	0.0000
veg. stability	0.4196	0.0046
vegetative use	0.3772	0.0116
mean depth	0.3307	0.0283
maximum temp.	0.3146	0.0375

MIDDLE FORK

The eigenvalues were 0.571 and 0.178 for axes 1 and 2 respectively. Again, there is one strong and one weak axis.

DCA axis 1 has the same general physical and fish assemblage gradients as the South Fork and mainstem (Figs. 8 and 9). Table 8 lists the significantly correlated physical habitat variables. An anomaly in the data is the negative correlation between DCA axis 1 and hardness and alkalinity. One would expect that these would increase moving along a longitudinal gradient from headwaters to the mouth (as axis 1 score increased). The exact reason for this is unknown, but it could be due to nutrient loading in the upper reaches of the basin (i.e. Phipps Meadow area) or due to differing geologies. Although the majority of the Middle Fork drainage is Columbia River basalt, there are sizeable areas of lava, ash, and tuff, as well as sandstone and shale in the upper half of the drainage. A difference in the species scores is that age 3+ steelhead were seen lower in the drainage and therefore, in closer association with the "warmwater" fishes. The middle of this axis contains those mainstem Middle Fork sites that had juvenile chinook and the highest densities of age 1+ and 2+ steelhead. The lower end of this axis (i.e. small site scores) is comprised of the Camp Creek sites. Camp Creek is a major steelhead producing tributary of the Middle Fork (ODFW unpublished report). It rears primarily YOY steelhead (older fish rear in lower Camp Creek and/or in the Middle Fork).

The second axis is different. It is a combination bank condition, stream size gradient. Smaller, colder streams with poorer bank development (i.e. have fewer undercuts and shallower shores etc.) have lower scores while larger, warmer sites with better bank development have higher scores. This is primarily one

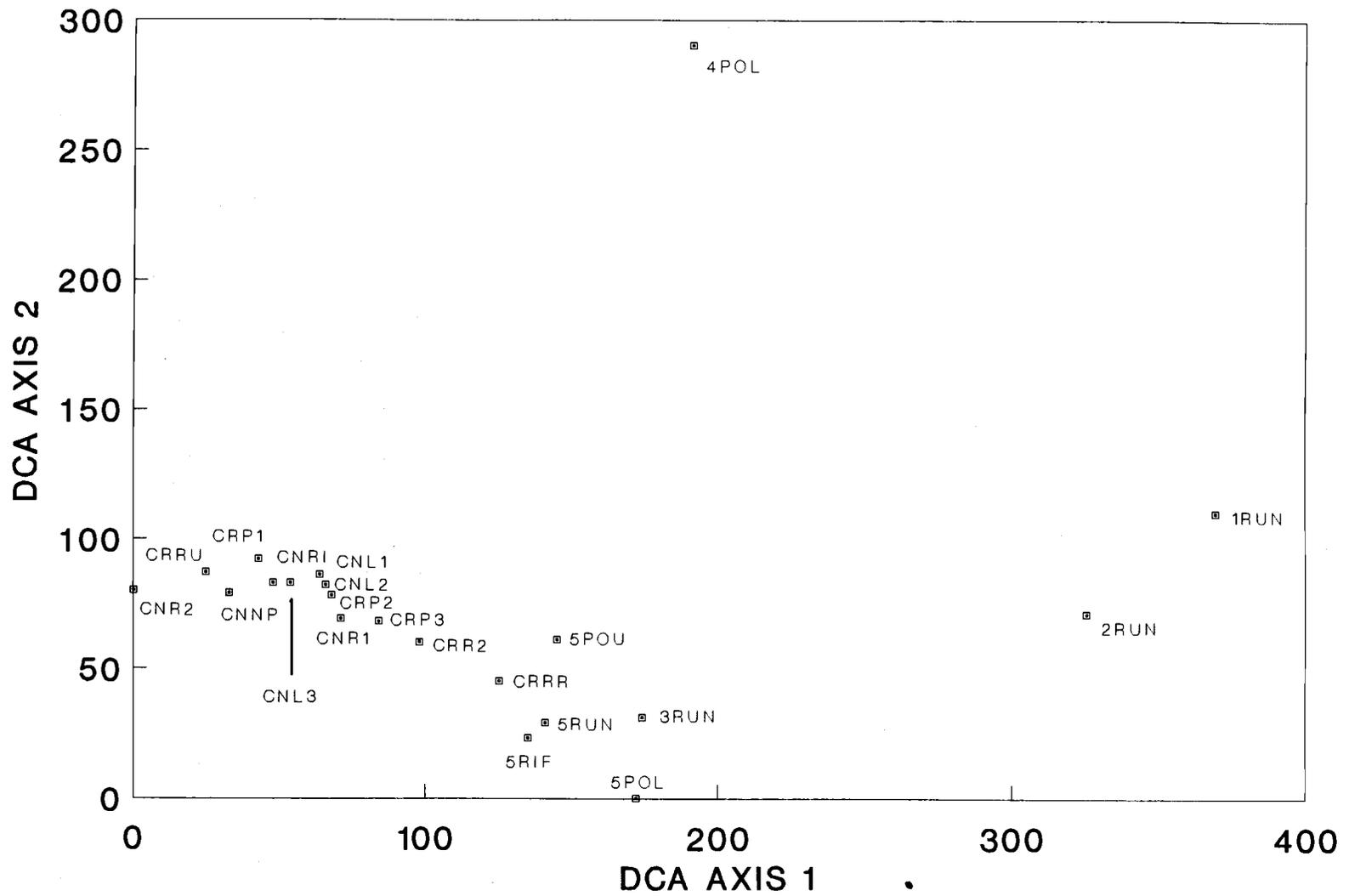


Figure 8. 1985 Middle Fork DCA site scores. DCA axis 1 vs. axis 2.

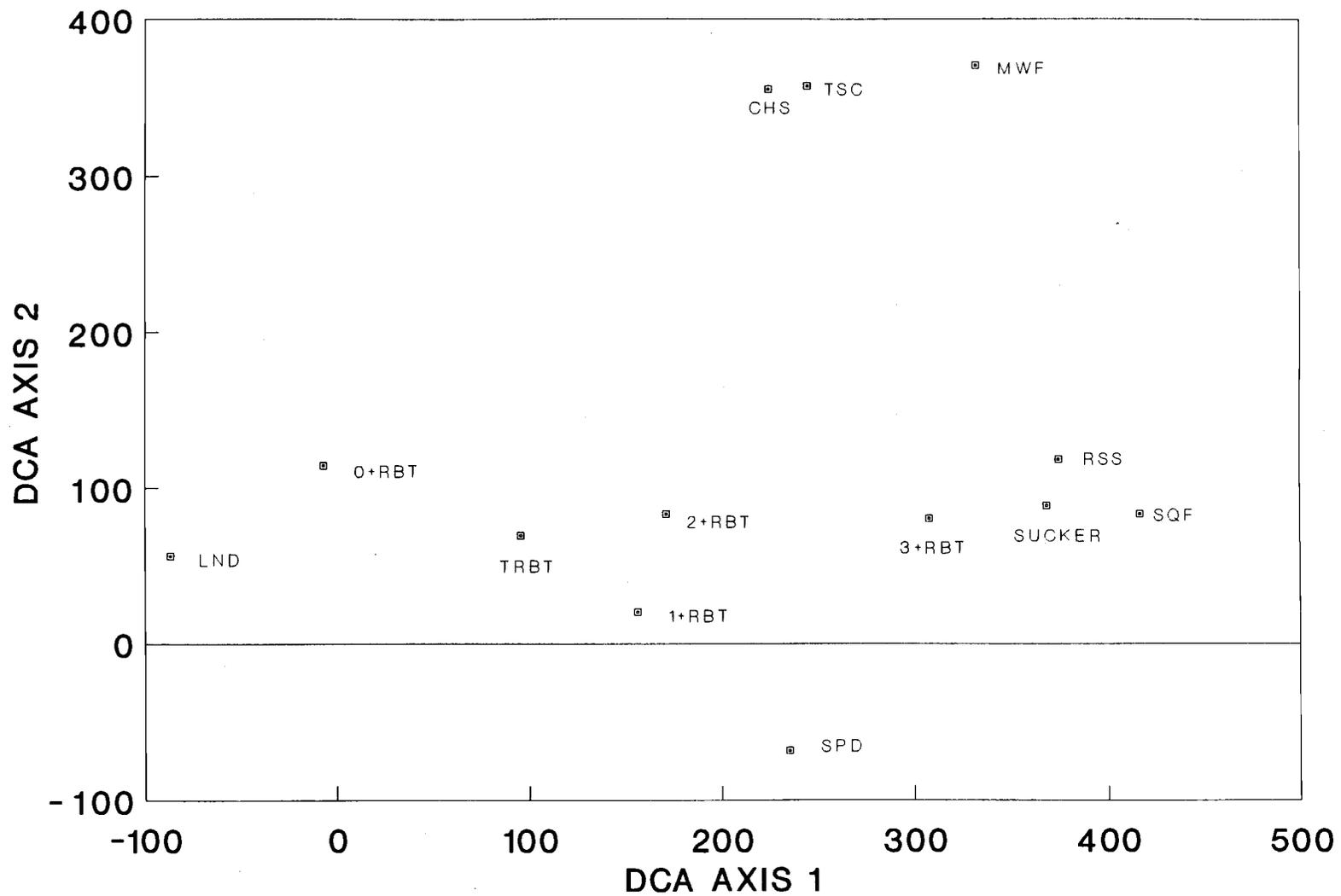


Figure 9. 1985 Middle Fork DCA species scores. DCA axis 1 vs. axis 2.

Table 8. Physical habitat variables significantly correlated ($\alpha = 0.05$) with the Middle Fork of the John Day River DCA site scores, and the associated r - values and significance levels.

1985		
AXIS 1		
Variable	R value	Sign. Level
elevation	-0.8885	0.0000
bank-full width	0.8647	0.0000
area	0.8452	0.0000
discharge	0.8275	0.0000
width	0.8243	0.0000
gradient	-0.7608	0.0000
mean vel. turb.	0.7337	0.0001
bank angle	0.6324	0.0016
streamshore depth	0.6324	0.0016
embeddedness	0.6221	0.0020
mean depth	0.5842	0.0043
alkalinity	-0.5754	0.0051
maximum temp.	0.5593	0.0068
hardness	-0.4892	0.0208
mean velocity	0.4651	0.0292
dissolved oxygen	0.4418	0.0395
minimum temp.	0.4357	0.0427
AXIS 2		
Variable	R value	Sign. Level
bank undercut	0.4568	0.0326
bank angle	0.4498	0.0357
streamshore depth	0.4498	0.0357
width	0.4474	0.0368
maximum temp.	-0.4425	0.0392
dissolved oxygen	0.4380	0.0415
minimum temp.	-0.4241	0.0492
1986		
AXIS 1		
Variable	R value	Sign. Level
area	0.7868	0.0000
mean depth	0.7304	0.0003
width	0.6697	0.0012
elevation	-0.6359	0.0026
mean vel. turb.	0.6320	0.0028
bank-full width	0.5734	0.0082
hardness	-0.5602	0.0102
discharge	0.5100	0.0216
nitrogen	0.4867	0.0295

Table 8. continued.

AXIS 2		
Variable	R value	Sign. Level
alkalinity	0.9124	0.0000
maximum temp.	-0.9032	0.0000
minimum temp.	-0.8423	0.0000
dissolved oxygen	0.8143	0.0000
pH	-0.7403	0.0002
embeddedness	-0.5876	0.0064
hardness	0.5725	0.0083
substrate	0.5285	0.0166
elevation	0.5215	0.0184
COMBINED YEARS		
AXIS 1		
Variable	R value	Sign. Level
elevation	-0.7892	0.0000
bank-full width	0.7859	0.0000
width	0.7073	0.0000
area	0.7068	0.0000
mean vel. turb.	0.6426	0.0000
discharge	0.6283	0.0000
embeddedness	0.6205	0.0000
hardness	-0.5845	0.0000
mean depth	0.5659	0.0001
minimum temp.	0.5555	0.0001
maximum temp.	0.5087	0.0006
gradient	-0.3966	0.0093
substrate	-0.3548	0.0211
bank angle	0.3426	0.0263
streamshore depth	0.3426	0.0263
AXIS 2		
Variable	R value	Sign. Level
maximum temp.	-0.6420	0.0000
minimum temp.	-0.4550	0.0025
bank undercut	0.4129	0.0066
dissolved oxygen	0.3542	0.0214
bank angle	0.3483	0.0238
streamshore depth	0.3483	0.0238
substrate	0.3280	0.0340

outlier that makes this axis (4POL). All other sites had similar axis two site scores (fig. 9). This shows that the second axis is extremely weak at best. This site is unique because it is a deep pool, and has a well developed riparian area. It has extensive canopy cover, undercut banks (and thus deeper streamshore depths), and cooler water temperatures. The species scores from low to high represent a trout/warmwater assemblage changing to a chinook assemblage. The trout and warmwater fishes were separated into distinct assemblages based on their axis one scores. Again, the age 3+ steelhead were found lower in the drainage and thus more closely associated with the warmwater assemblage. As with the site scores, the species second axis is also quite weak. The influence of the outlier (4POL) is what created the gradient and separated it from the rest. The site was dominated by juvenile chinook salmon and mountain whitefish.

1986

SOUTH FORK

The eigenvalues are similar to those from 1985. There is a strong and a weak axis. Axis 1 has an eigenvalue of 0.724 and axis 2 an eigenvalue of 0.147.

DCA axis 1 site scores (Fig. 10) was a combination elevation/stream size and riparian habitat gradient. Table 6 lists the significantly correlated physical habitat variables. The sites with the highest scores were the lowest elevation sites, and the fish assemblage was dominated by nongame "warmwater" fish (Fig. 11). The lower Murderer's Creek sites are next along the axis. Here, YOY steelhead and sculpins dominate the assemblage. The sites with the lowest axis 1 scores are the upper Murderer's Creek sites and the

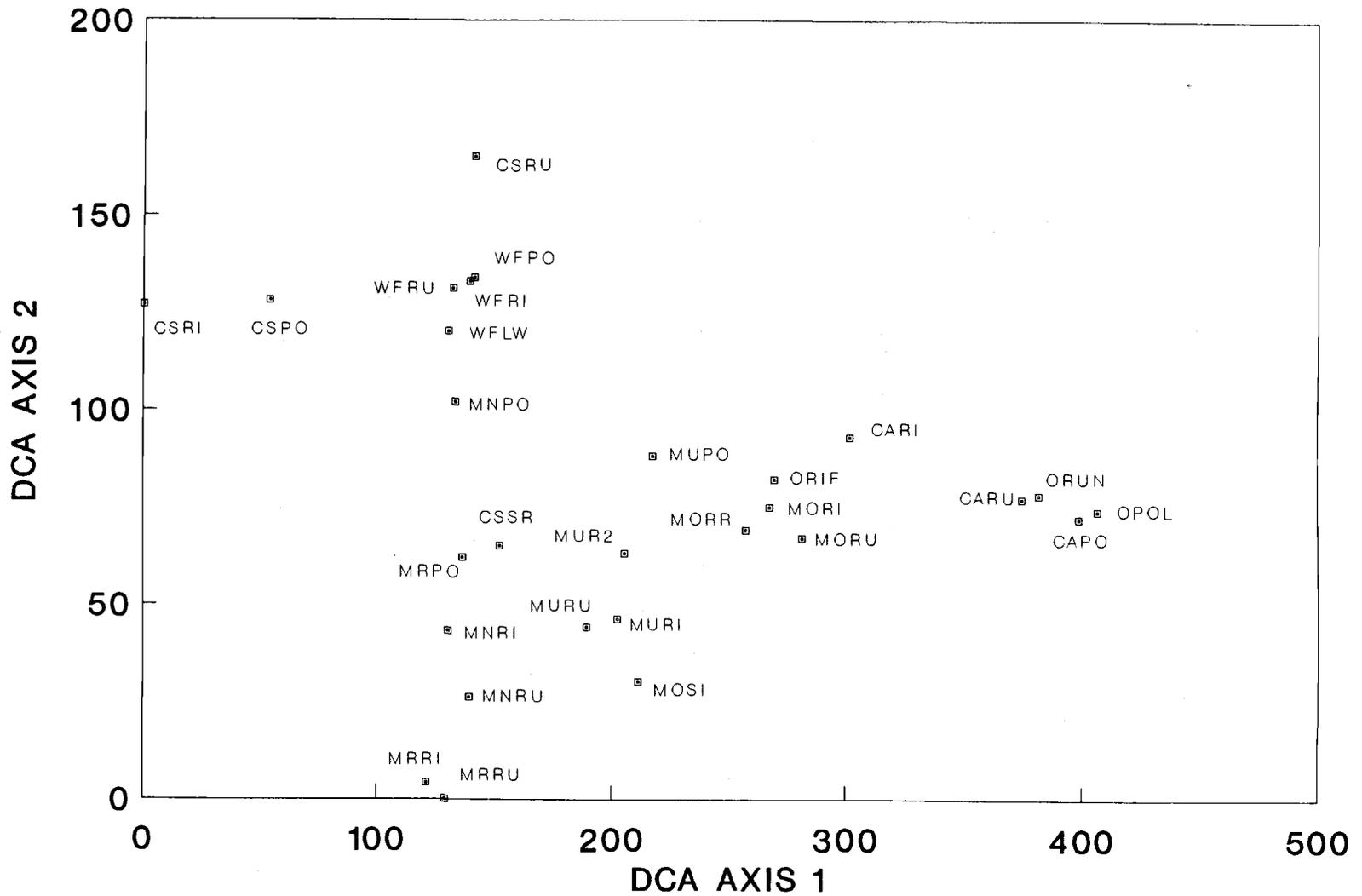


Figure 10. 1986 South Fork DCA site scores. DCA axis 1 vs. axis 2.

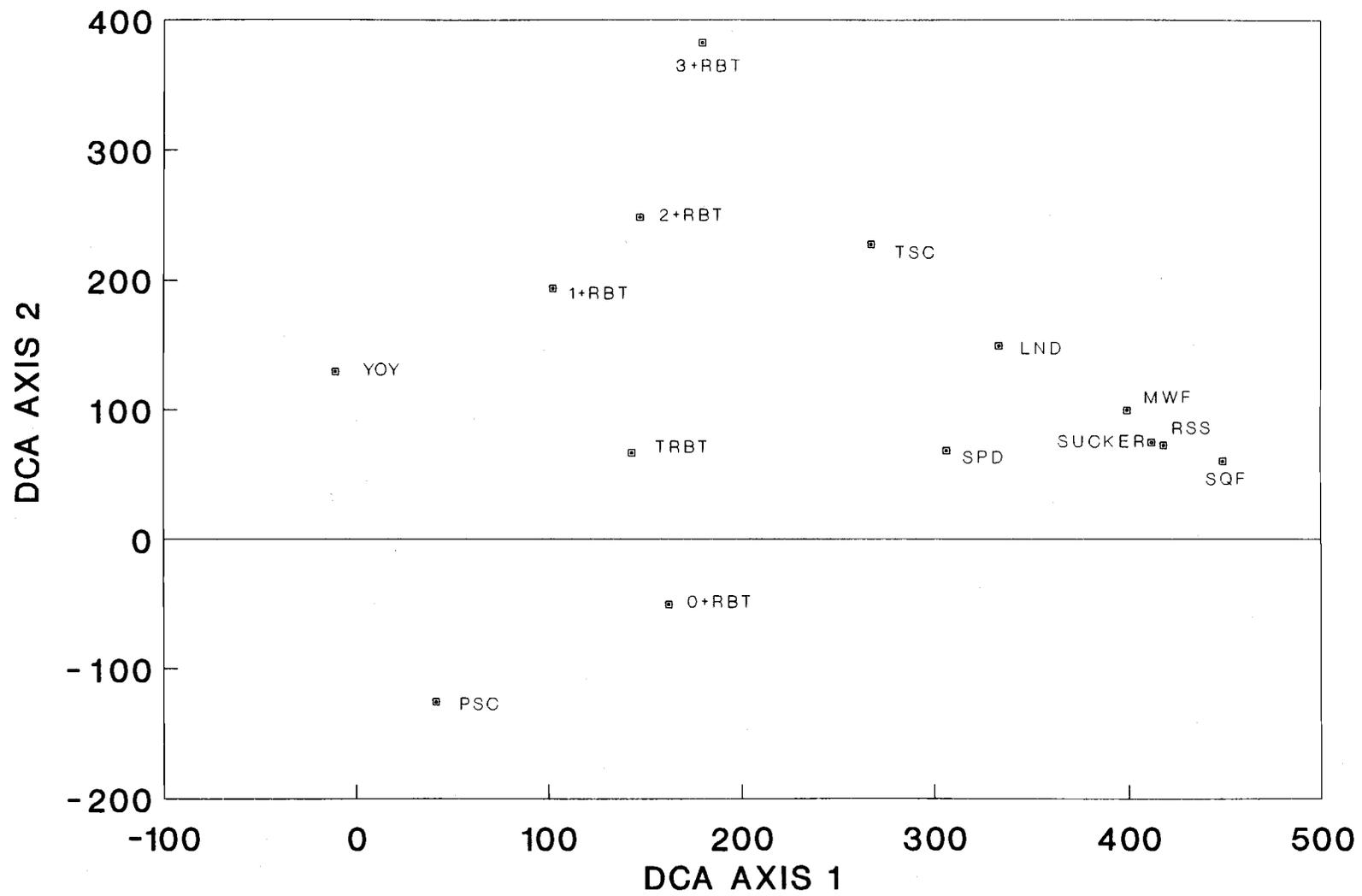


Figure 11. 1986 South Fork DCA species scores. DCA axis 1 vs. axis 2.

upper South Fork sites. The upper South Fork sites were separate from the others due to the presence of unidentified YOY nongame fish and age 1+ - 3+ steelhead (Figs. 10 and 11).

The general physical habitat gradient from small to large axis 1 scores is from smaller, high elevation sites with excellent riparian habitat to larger, lower elevation sites with much more streambank use and alteration (Fig. 11). In other words, there is a general decrease in streambank condition moving along a longitudinal gradient from headwater reaches to larger, low elevation reaches. However, there was also an increase in canopy cover along this gradient. This apparent contradiction is explained by the fact that many of the upper sites (that are in good to excellent condition) are found in meadows. Here, the stream banks are stabilized by grasses and shrubs (namely willows) which do not shade the entire stream. Lower in the drainage, on the South Fork proper, much of the stream shading results from large trees that offer complete canopy cover. Another point that needs to be mentioned is the negative correlation between axis 1 score and hardness and alkalinity (as with the Middle Fork 1985 data). Possible explanations for this are that sampling was limited to the mid and lower elevation reaches (i.e. the upper portion of the drainage was not sampled because it was above a barrier to anadromous fish). There may have been nutrient loading in the upper basin. The area above the barrier has different geology than the lower area. The upper area is primarily sandstone and shale with some Columbia River basalt, while the lower area is mainly Columbia River basalt. Plus, sample size is low, so it may be difficult to get an accurate picture of water quality indices without a larger sample and a greater range of elevations and habitat types in both mainstem and tributary reaches. All stream sites (including Murderer's Creek) were low to mid elevation sites. There was no obvious trend in pH,

alkalinity, or hardness in the South Fork sites. pH ranged from 5 - 7, with 10 sites having a pH of 7, one with 8 and three with 5. Alkalinity ranged from 190 - 290 ppm. calcium carbonate. Hardness ranged from 100 - 330 ppm. calcium carbonate but 11 out of 14 sites were between 150 and 190 ppm.

Axis 2 is a stream size/depth gradient. Smaller, shallower sites (YOY steelhead rearing areas) are lower on the axis while deeper, larger sites have higher scores. This also represents a salmonid age class gradient. YOY steelhead have their highest densities at the lower end of the axis (highest elevation sites). Moving up the axis, YOY steelhead decline in density and age 1+ and 2+ steelhead reach their highest densities in the middle of the axis (lower Murderer's Creek and lower South Fork sites). At the upper end of the axis are sites where age 2+ and 3+ steelhead dominate (upper South Fork sites).

MAINSTEM

Again, there is a strong axis (axis 1, eigenvalue = 0.674) and a weak axis (axis 2, eigenvalue = 0.176).

The plots of species and site scores varied from the 1985 plots due to the different sites sampled in 1986 and the different species seen. In 1986, there were more tributary and fewer mainstem sites sampled (especially lower elevation sites). As a result, cutthroat (Oncorhynchus clarki) and bull trout (Salvelinus confluentus) were added while brook trout were not seen. They were only seen in the uppermost sites of the mainstem proper.

Despite this, DCA axis 1 is similar to that in 1985. It is an elevation/stream size gradient. The lowest elevation sites sampled in 1986 had the highest axis 1 scores and were the sites where the majority of nongame fish were seen in 1986 (Figs. 12 and 13). This

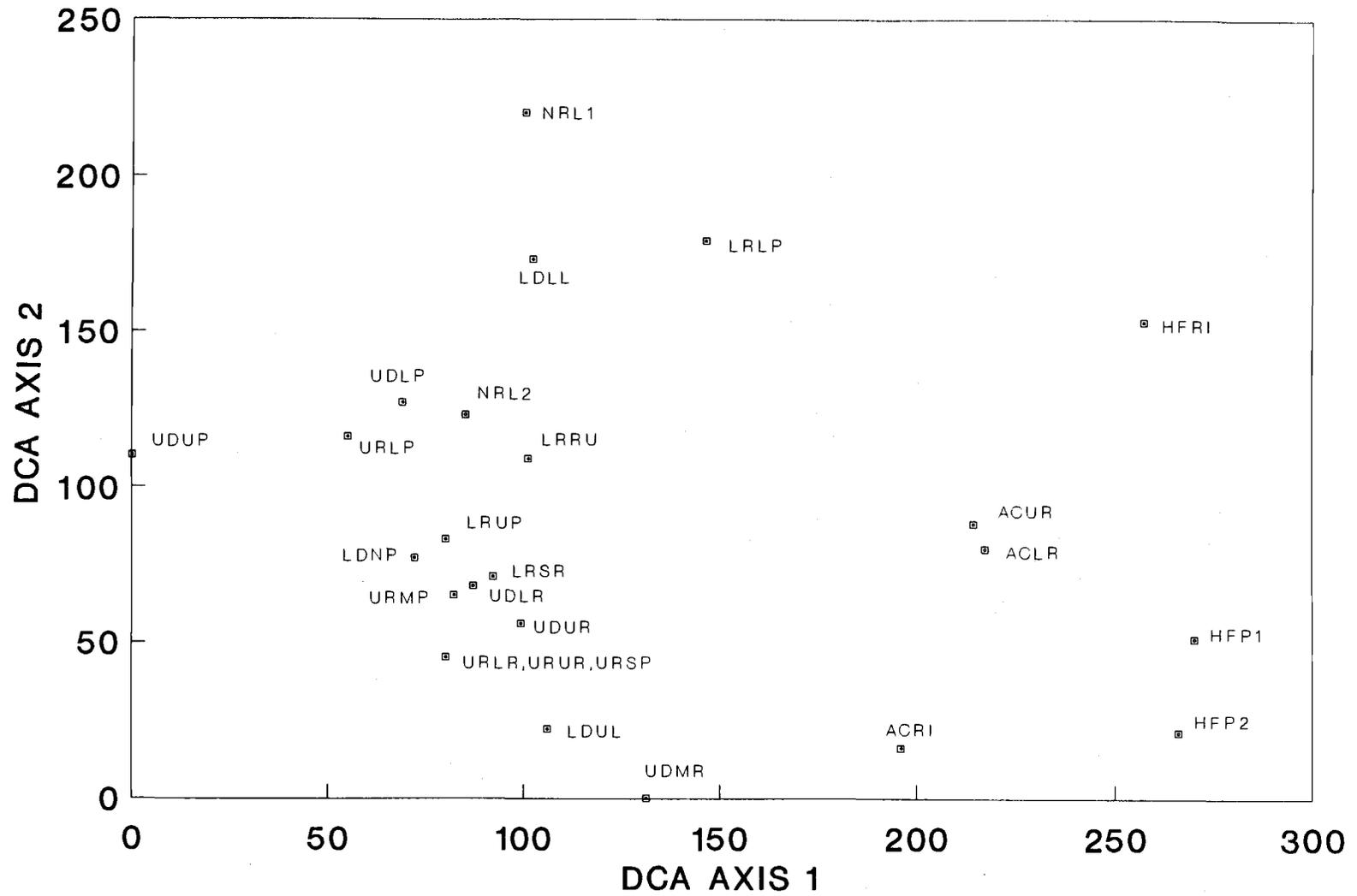


Figure 12. 1986 Mainstem DCA site scores. DCA axis 1 vs. axis 2.

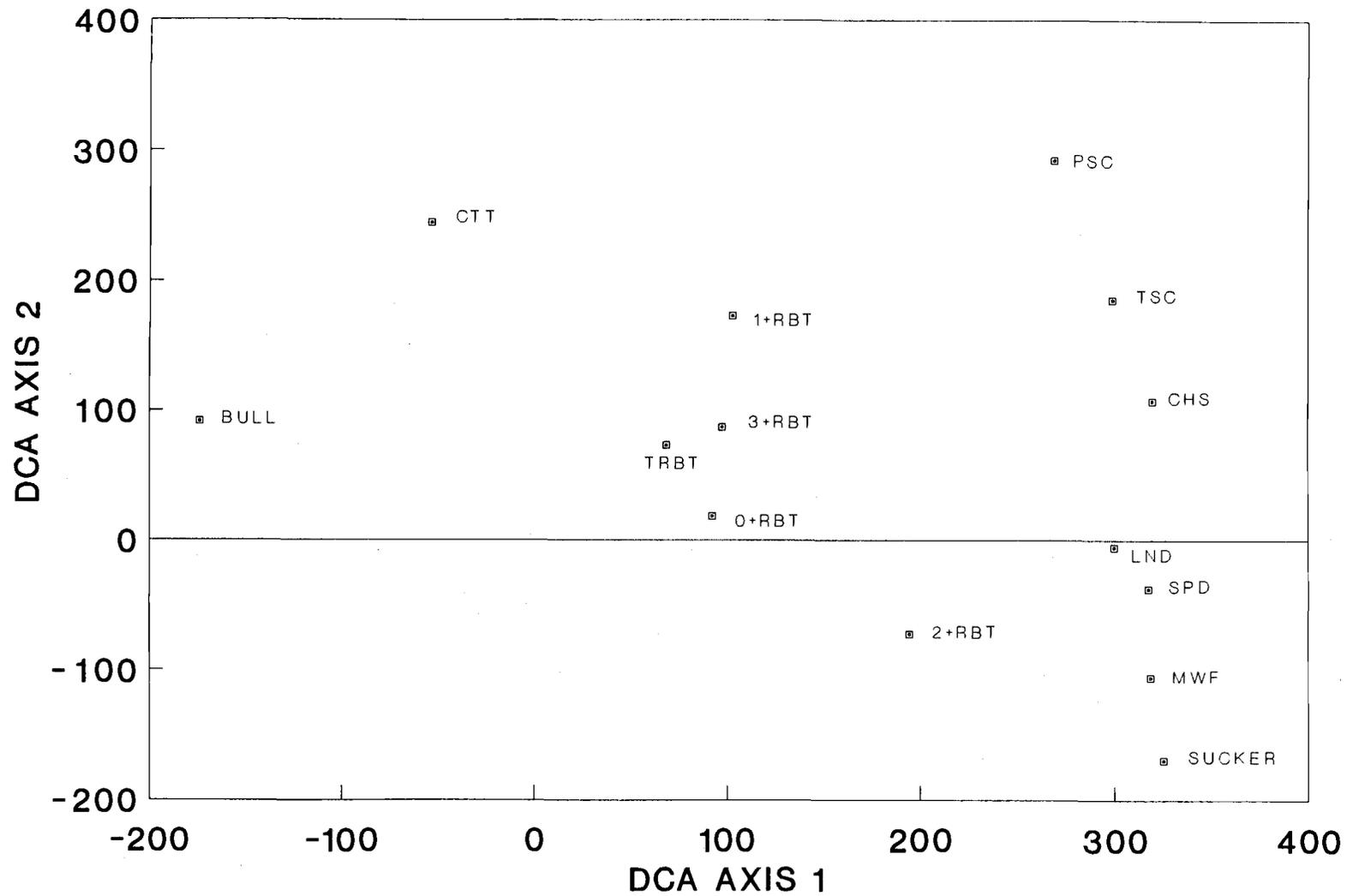


Figure 13. 1986 Mainstem DCA species scores. DCA axis 1 vs. axis 2.

is also where the juvenile chinook were seen. These sites correspond to the middle of the 1985 gradient. The 1985 sampling was more complete in that it covered a much wider range of habitats and elevations. The 1986 sampling concentrated on the tributaries which were missed in 1985 and the mid elevation reaches of the mainstem proper.

High axis one scores included those sites where juvenile chinook and the warmwater fishes dominated the assemblage. Intermediate scores contained those sites where steelhead dominated the assemblage (primarily in riffle sites in Deardorff and Reynolds Creeks) while the smallest scores include those sites where cutthroat and bull trout were seen. These are primarily the North Fork of Reynolds Creek and pools in both Deardorff and Reynolds Creeks.

The physical habitat variables that correlated with these site scores are very similar to 1985. Thirteen of the variables that correlated in 1985 also correlated in 1986 (Table 7). The only differences between years were the addition of mean depth and embeddedness and the removal of the vegetative stability rating as significantly correlated variables in 1986. It is important to note that hardness and alkalinity are positively correlated with axis 1, unlike the South Fork in 1986, and the Middle Fork in 1985 (hardness only in 1986). This was most likely due to sampling a much wider range of elevations and habitats both years in the mainstem compared to the South and Middle Forks. This also resulted in greater range of geologies. The lower end of the mainstem was comprised mostly of lava, ash, and tuff, while the headwaters and tributaries were made up of primarily Columbia River basalt.

Axis 2 is a weak habitat gradient comprised of the following habitat variables: streambank alteration rating, stream gradient, mean depth, and substrate (table 7). In general, moving from low to

high axis 2 site scores (Fig. 13) results in a shift from shallower, lower gradient, larger substrate (the larger the substrate, the lower the score), least altered sites to sites that are generally deeper (i.e. mostly pools), have higher gradients (e.g. tributaries), smaller substrate (perhaps indicating more sediment), and more altered streambanks. It should be noted that again all the sites had moderate to excellent riparian habitat development, and that the level of streambank alteration is relative and was not extreme in any of the sites sampled in this basin in 1986. Those sites with the most altered banks were sites where log weirs were placed in the stream and anchored into the banks. The fish assemblage shifts from a dominance of nongame fish (low axis 2 species scores) to steelhead and chinook then ends with those sites that have cutthroat trout and/or sculpins present (high axis 2 scores).

MIDDLE FORK

The eigenvalues were slightly different compared to the other basins. Axis 1 was still the strongest with an eigenvalue of 0.573, but axis 2 was stronger than the other plots. It had an eigenvalue of 0.229.

The changes in assemblage structure and the pattern shown from 1985 to 1986 was very similar to the mainstem. This was because (like on the mainstem) the lower elevation sites were not sampled in 1986. Again, effort was concentrated in the tributaries (i.e. Camp Creek). In a sense, the 1986 sampling can be considered a subset of the 1985 sampling because with the exception of the new sites on lower Camp Creek, all the sites sampled in 1986 were also sampled in 1985. Like the mainstem, the 1986 sampling concentrated on the middle and upper portions of the drainage, while the 1985 sampling

was more complete in terms of sampling along the longitudinal gradient.

The site and species plots (Figs. 14 and 15) reveal the same gradients as the 1985 Middle Fork and the 1986 mainstem plots. Like 1985, the lower elevation sites had the highest axis 1 scores and the highest densities and diversity of nongame fish. Like mainstem 1986, these index sites were also the sites where the juvenile chinook and older steelhead were observed, and correspond to the middle of the 1985 gradient. There are two distinct groups on the opposite end of the axis. One represents lower Camp Creek and most of the Phipps meadow sites where YOY steelhead and speckled dace dominated the assemblage. The other is primarily comprised of the upper Camp Creek sites. The presence of longnose dace separate these sites from the others.

Axis 2 is a water quality/substrate/elevation gradient. It was quite different from 1985. No stream bank ratings were significantly correlated in 1986. Elevation, substrate, and embeddedness as well as several water quality variables were added (table 8). In general, as the axis scores increases, the sites are higher in elevation, have a lower pH, are colder, have higher dissolved oxygen, alkalinity, and hardness but were more embedded and had a smaller mean substrate size. This may indicate increased sedimentation or it may reflect that the complex stream channel within the enclosure acts as a sediment trap, capturing runoff from logging and grazing activities upstream. Substrate was not a factor in 1985. This change may be the result of the destruction of the riparian enclosure, bank damage caused by the harvest of a single dead tree within the enclosure (which was felled across several meander bends in the stream causing obvious bank damage) and the introduction of cattle into the enclosure for the first time in 22 years. The fence was destroyed in order to harvest that one tree.

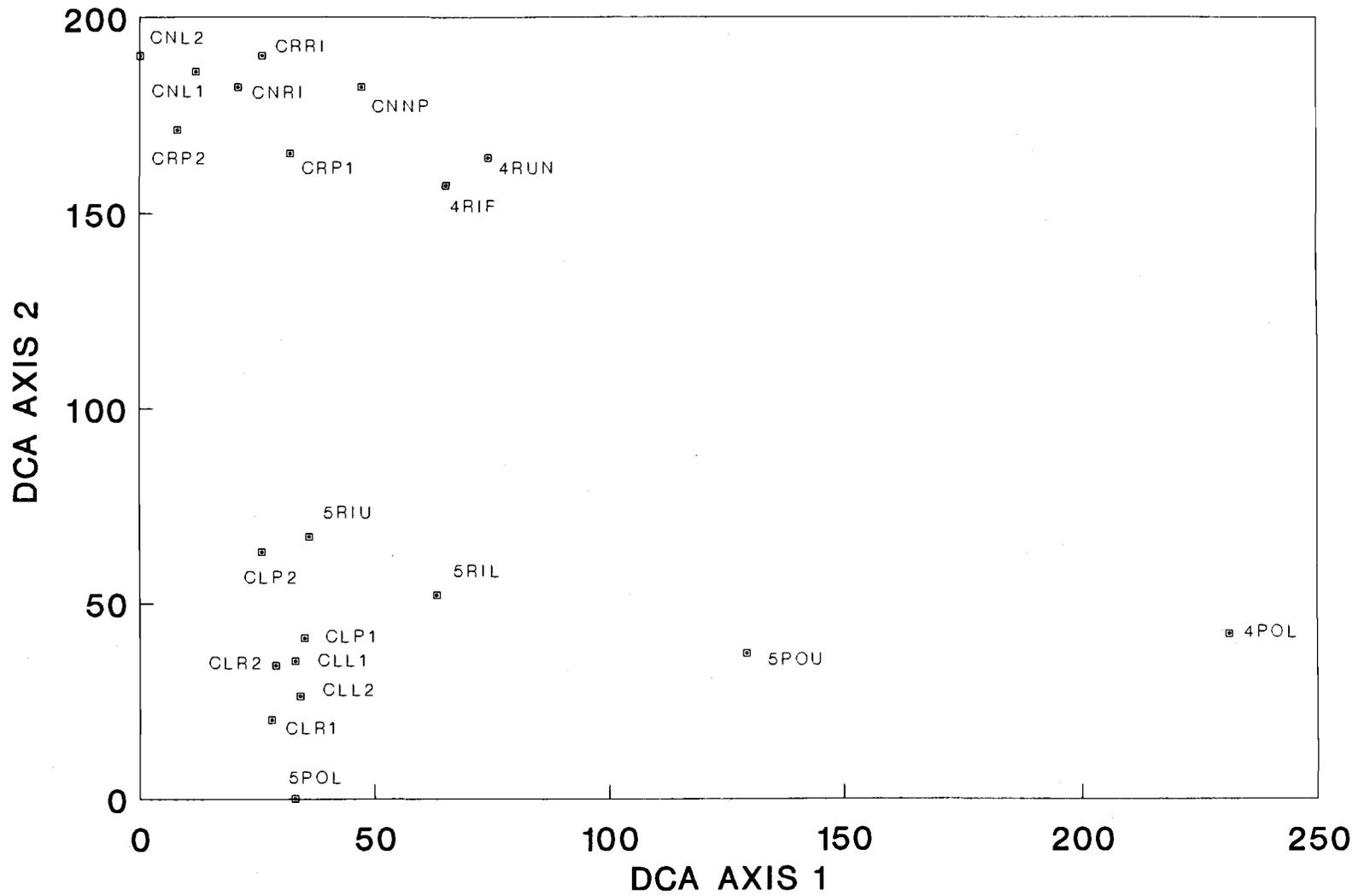


Figure 14. 1986 Middle Fork DCA site scores. DCA axis 1 vs. axis 2.

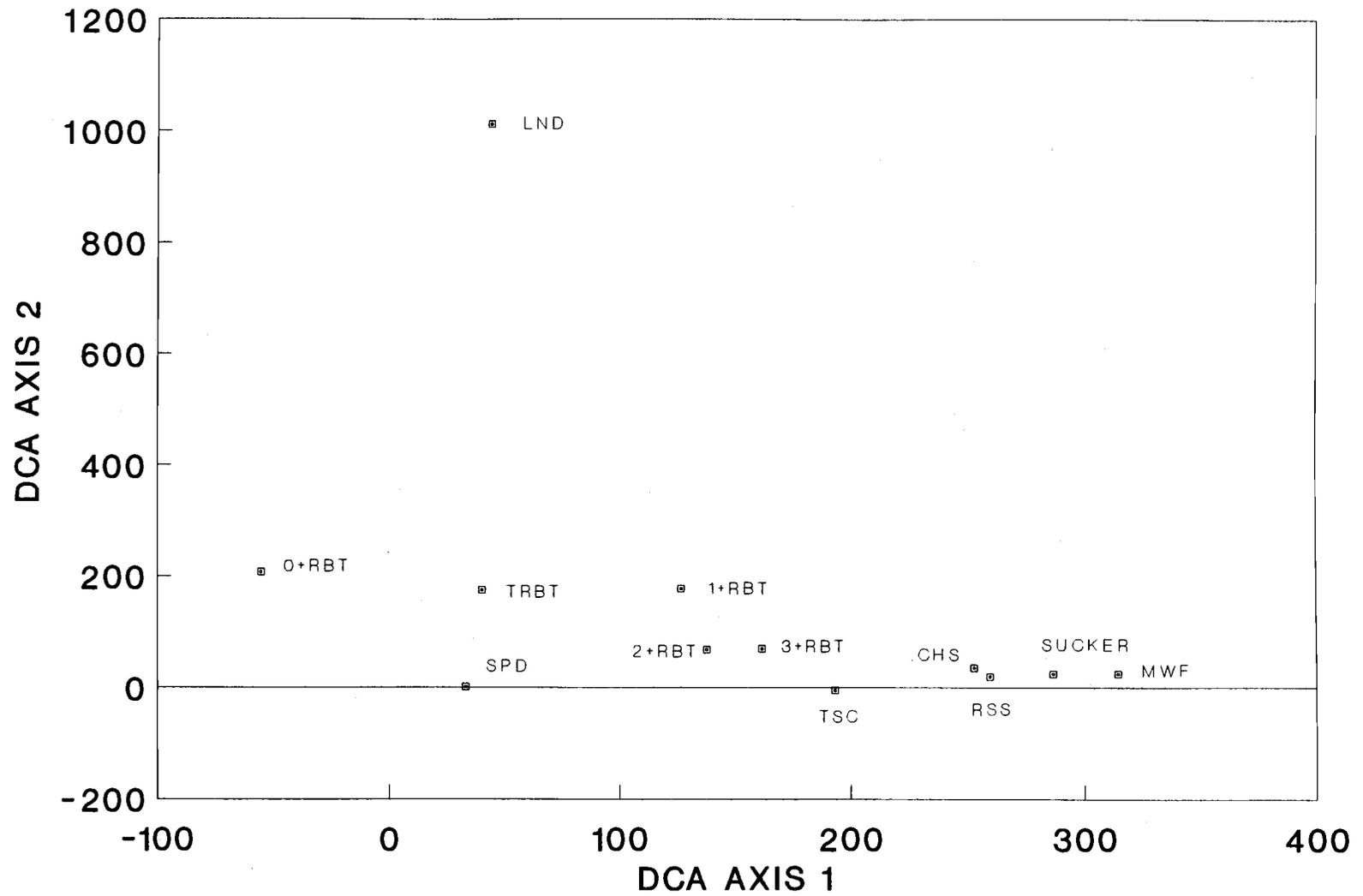


Figure 15. 1986 Middle Fork DCA species scores. DCA axis 1 vs. axis 2.

Livestock were to have been removed from the area, and the fence was to be repaired promptly, but neither happened (E. Claire, personal communication). This activity may have added sediment to the stream within the enclosure and immediately downstream. Another possibility is that for all practical purposes there was only one gradient in 1985. The addition of the lower Camp Creek sites in 1986 greatly strengthened the second axis.

The species all had low axis one scores with the exception of longnose dace (Rhinichthys cataractae). As in 1985, this shows a very weak second axis. For all practical purposes, there is only one meaningful species axis.

COMBINED YEARS

The years were combined to get the broadest possible spectrum of habitats and to see how assemblage structure varied between years. This was deemed feasible because there was no apparent major changes to the physical habitat between years, and because the flow regimes and the steelhead and chinook runs were similar between years.

SOUTH FORK

Combining years resulted in a much stronger second axis. Axis 1 has an eigenvalue of 0.707 while axis 2 has an eigenvalue of 0.538.

In general, the sites sampled both years aligned closely (Fig. 16). Again axis 1 was a stream size/elevation gradient. Table 6 lists the significantly correlated physical habitat variables. The warmwater fishes have the highest species scores along axis 1. Those sites where unidentified YOY nongame fish were observed also had high axis 1 scores but were separated from the others by also having high axis 2 scores (Fig. 17). Moving from high to low axis

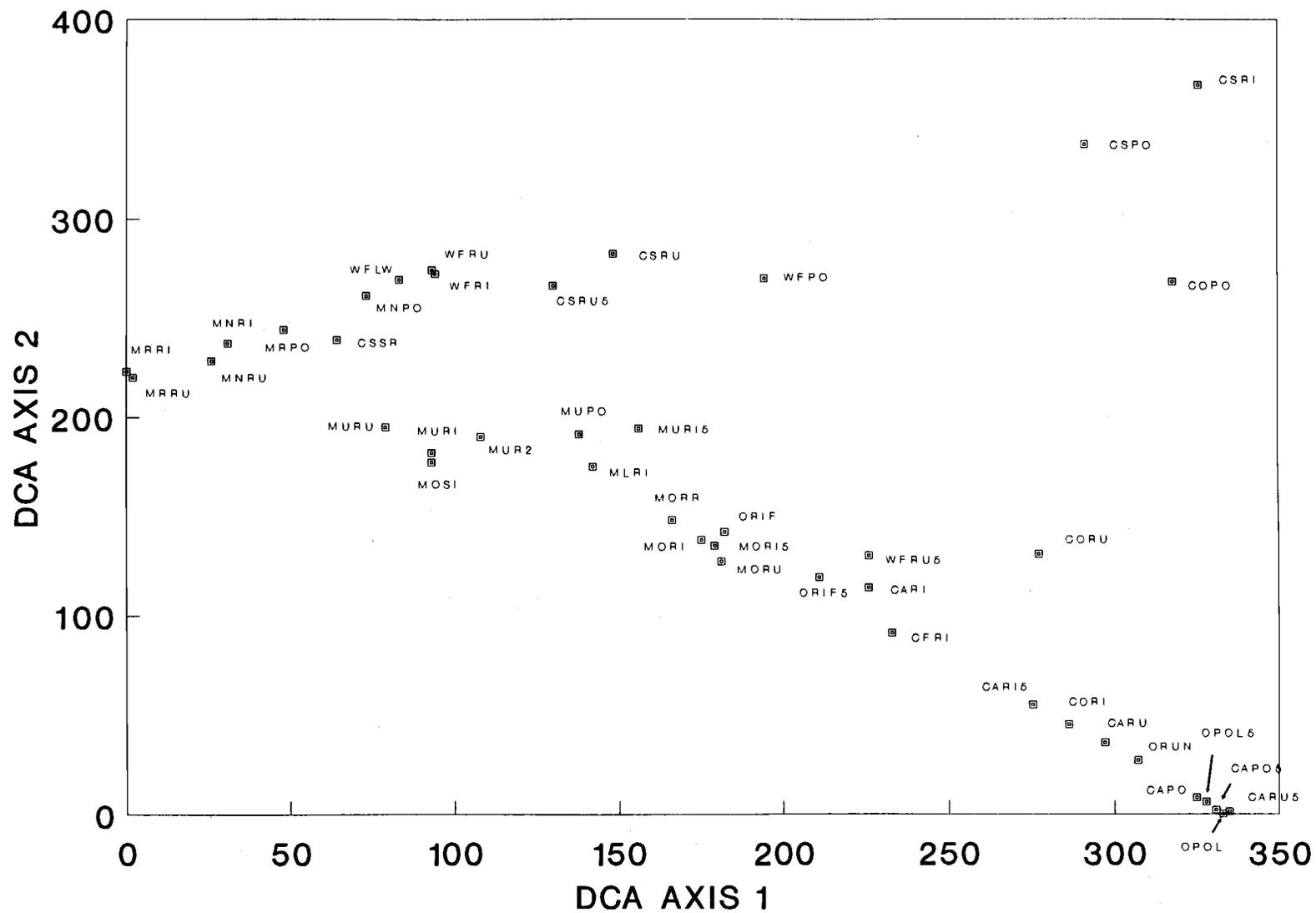


Figure 16. Combined years South Fork DCA site scores. DCA axis 1 vs. axis 2.

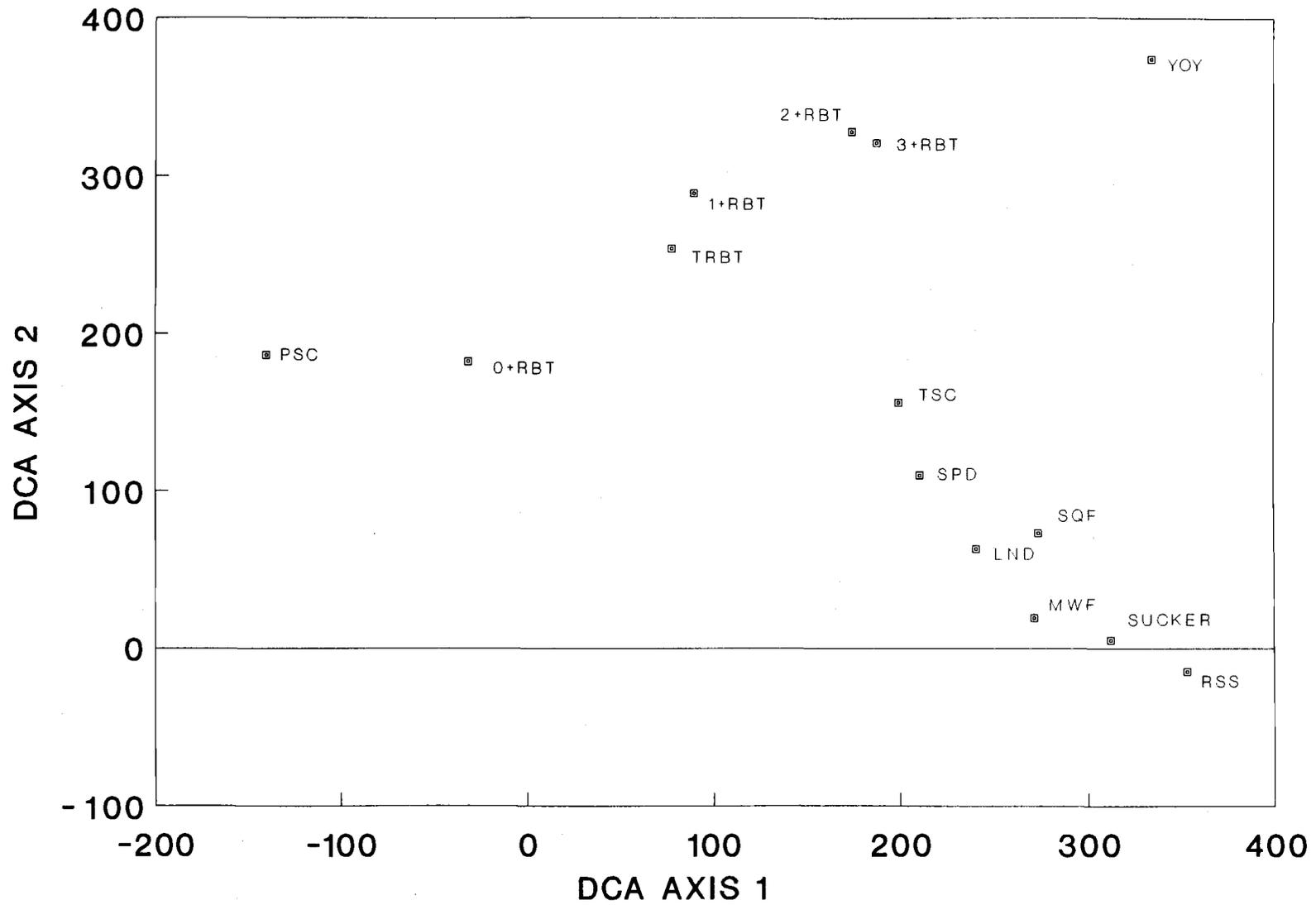


Figure 17. Combined years South Fork DCA species scores. DCA axis 1 vs. axis 2.

scores (i.e. from right to left), the assemblage changed from a warmwater assemblage to one where the older age classes of steelhead reached their highest densities to a simple piute sculpin/YOY steelhead assemblage. These changes correspond to changes in the site scores (Fig. 16) and represent an elevation gradient from low to high elevation (table 6).

Axis 2 is a weak riparian habitat/elevation/stream size gradient. Sites with low scores are lower in elevation, larger, deeper, more shaded, and the banks are more altered. High scores are generally represented by smaller, shallower, more stable sites with less canopy development. The fish assemblage changes from a warmwater assemblage (with low scores) to an assemblage dominated by steelhead (with high scores) (fig. 17).

MAINSTEM

Like the South Fork, combining the years resulted in a stronger second axis. The eigenvalues were 0.843 and 0.211 for axis 1 and 2 respectively.

The combined years site scores (Fig. 18) showed similar gradients as either year separately. The significantly correlated physical habitat variables are listed in table 7. Axis 1 is a stream size/elevation/riparian habitat gradient while axis 2 is primarily a riparian habitat gradient. Larger, lower elevation sites with lower riparian habitat quality have high axis 1 scores while the high elevation smaller mainstem and tributary sites with generally better riparian habitat have low axis 1 scores.

Low axis 2 scores represent better riparian habitat. Quality declines as score increases.

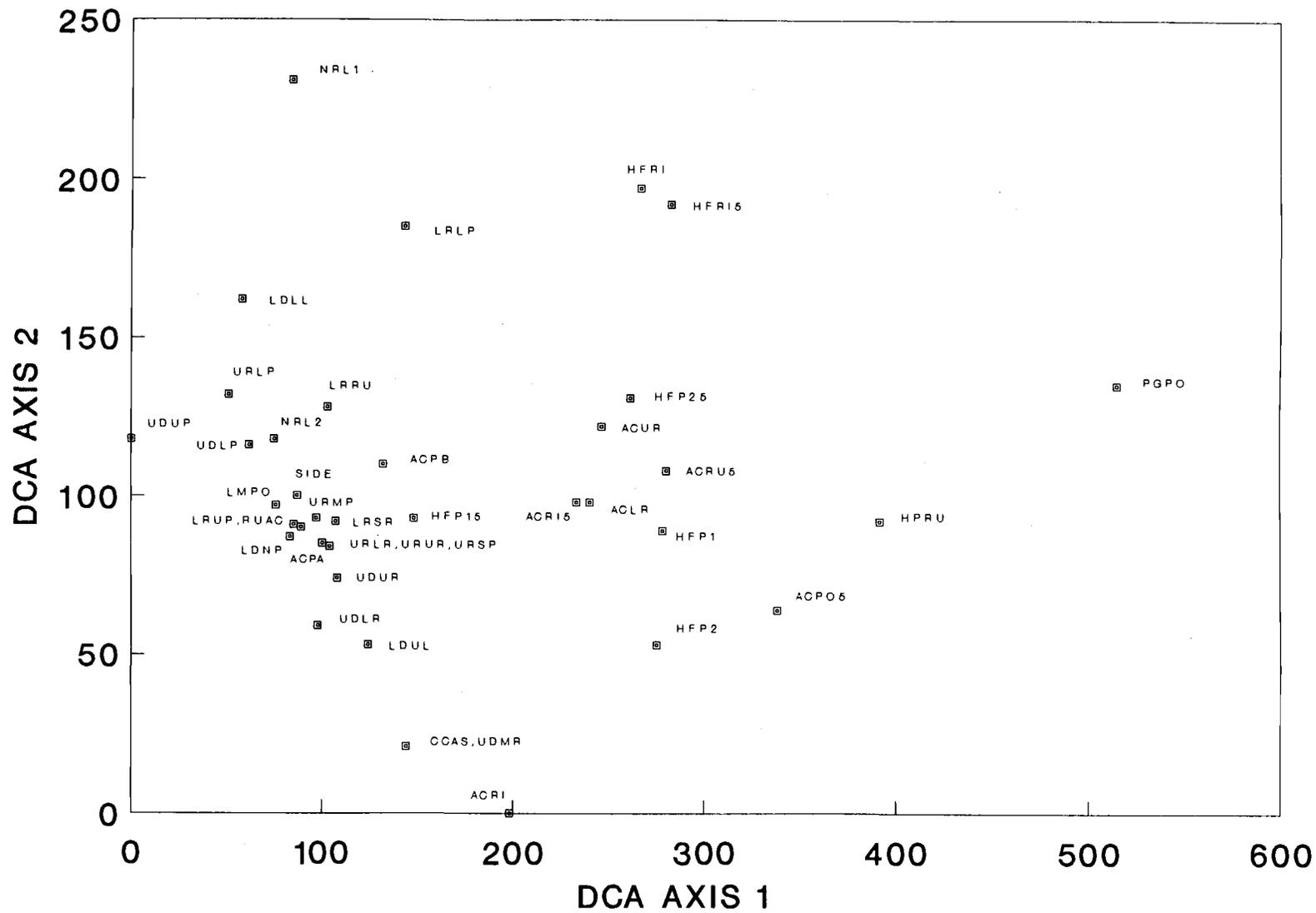


Figure 18. Combined years Mainstem DCA site scores. DCA axis 1. vs. axis 2.

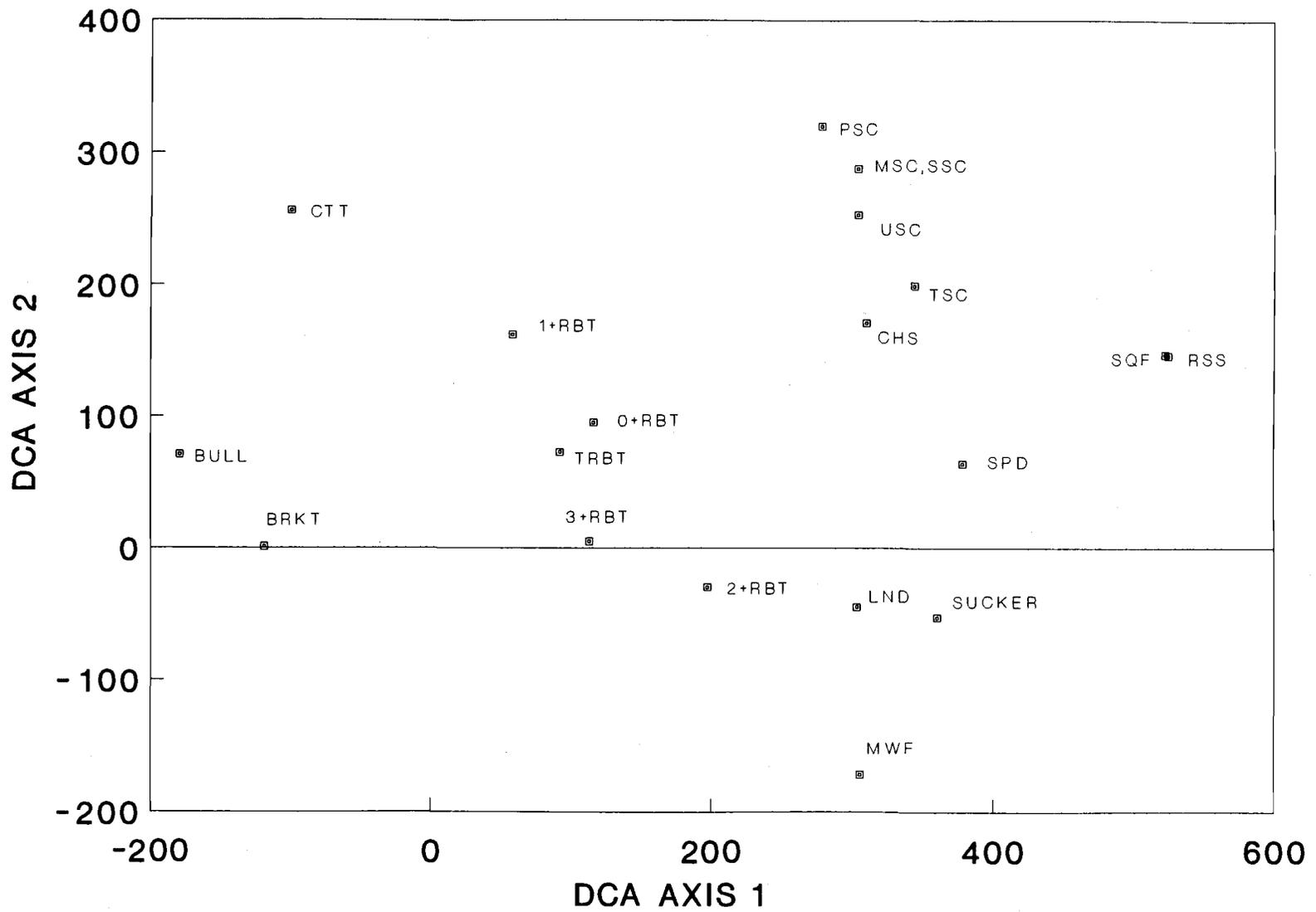


Figure 19. Combined years Mainstem DCA species scores. DCA axis 1 vs. axis 2.

The fish assemblage structure changes are similar to the years separately (fig. 19). Low axis 1 scores are indicative of the assemblage in the uppermost reaches of the basin where brook, cutthroat, and bull trout are found. As the species score increases, the assemblage changes to a steelhead assemblage, then a chinook assemblage, and finally a warmwater assemblage in the lowest sites sampled in the basin.

Axis 2 generally moves from warmwater fish with low axis 2 scores to coldwater fish (high axis 2 scores).

MIDDLE FORK

Unlike the South Fork and the mainstem, combining the years did not result in a more significant second axis. In fact, it appears to have had the opposite effect. The eigenvalues were 0.558 and 0.094 for axes 1 and 2 respectively.

The combined years plots (Figs. 20 and 21) showed no obvious changes compared to the years plotted separately. The same physical habitat and fish assemblage gradients were brought out. Most of the same physical habitat variables that were significantly correlated with the axis 1 site scores in 1985 and 1986 were also significantly correlated when the years were combined. There were four habitat variables that correlated in 1985 but not when the years were combined. These were gradient, alkalinity, mean velocity, and dissolved oxygen. Nitrogen was the only habitat variable from 1986 not represented when the years were combined. Substrate was not a factor in either year but became significant when the years were combined (table 8).

Axis 2 however, is a different matter. The position of the upper Camp Creek sites along this axis were quite different between years. In 1985, they had low axis 2 site scores while in 1986 they

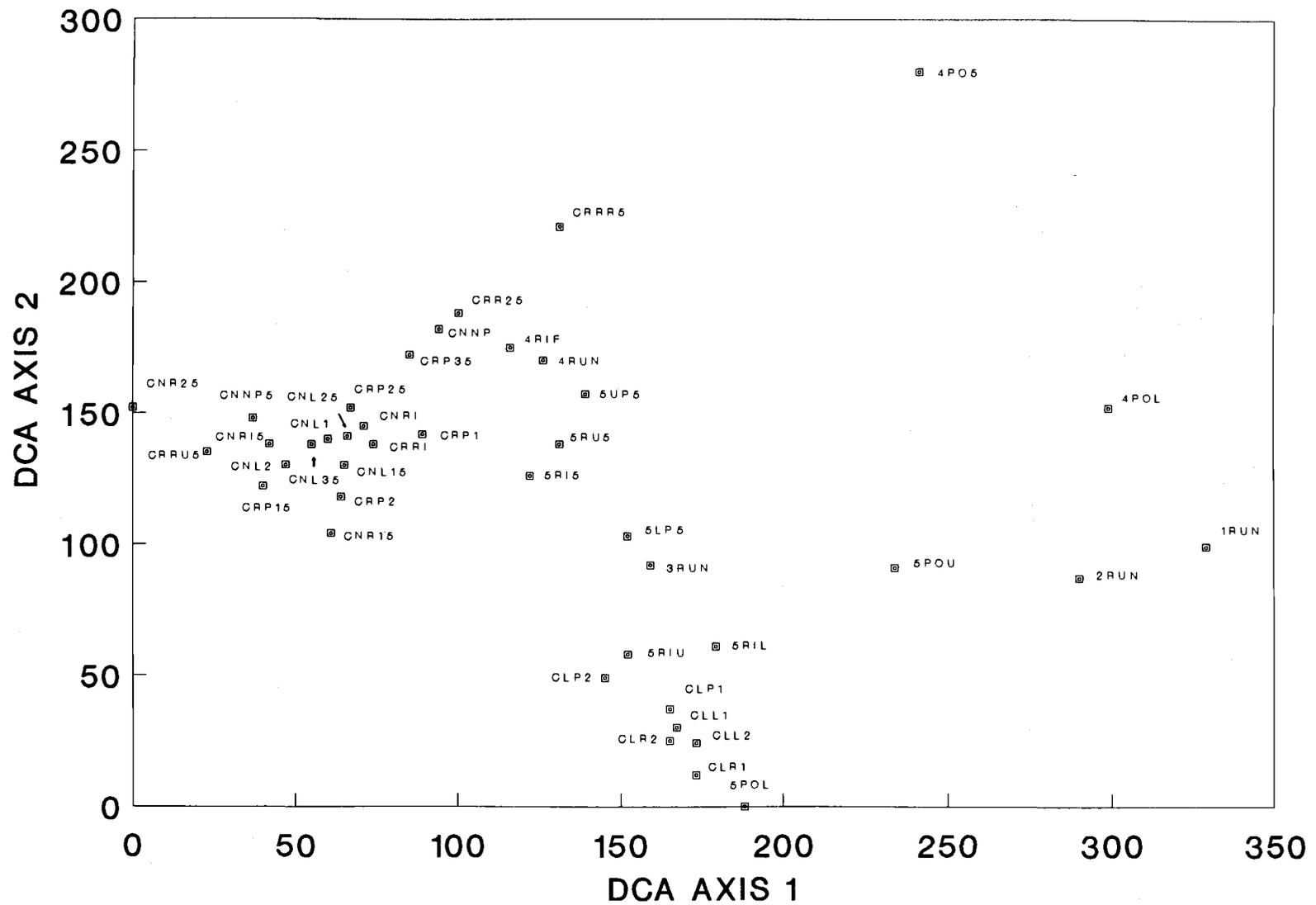


Figure 20. Combined years Middle Fork DCA site scores. DCA axis 1 vs. axis 2.

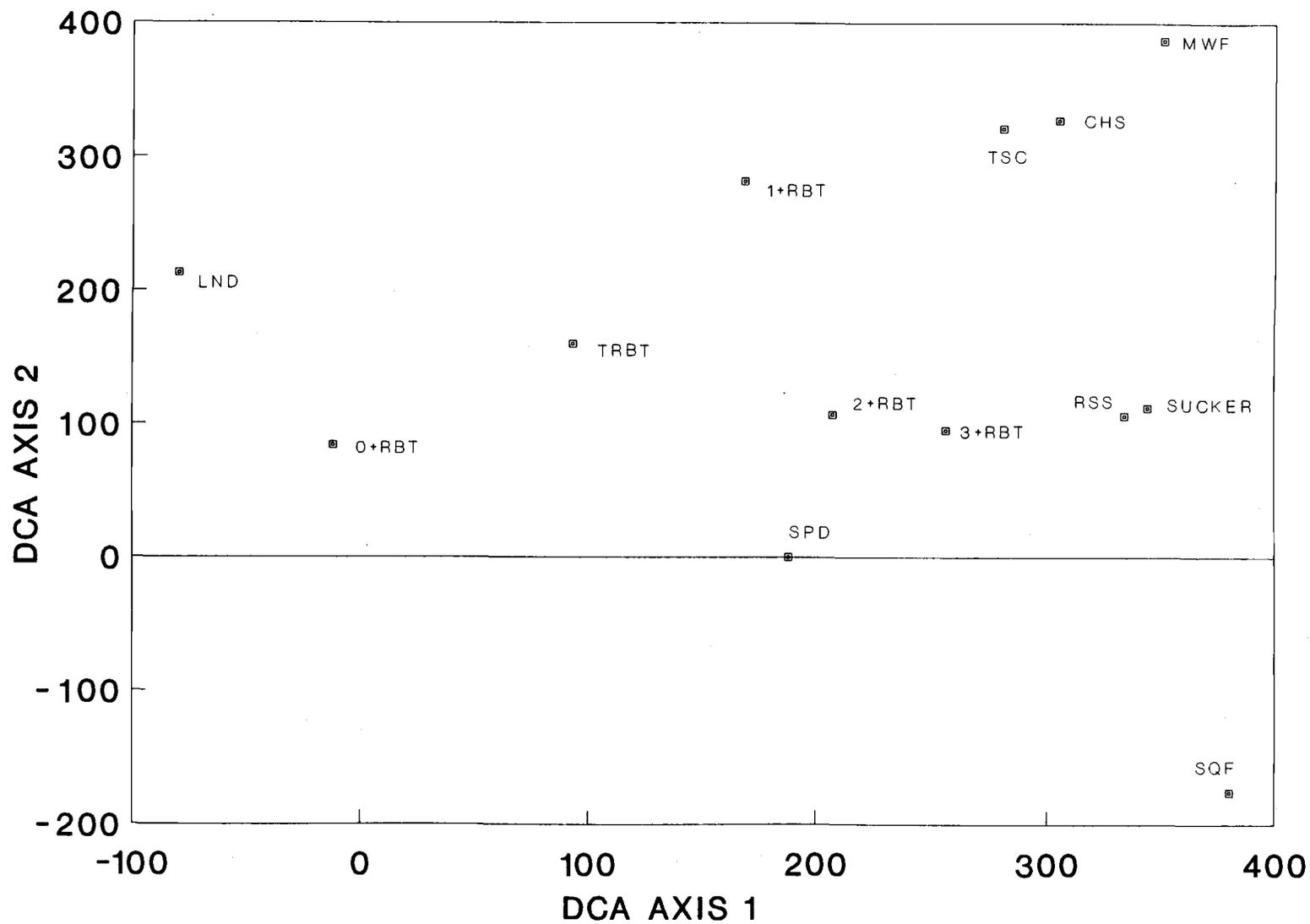


Figure 21. Combined years Middle Fork DCA species scores. DCA axis 1 vs. axis 2.

had high scores. When the years were combined, they had intermediate scores. The combined years axis 2 site score gradient represents an improving riparian habitat quality, increasing dissolved oxygen, and decreasing water temperatures and substrate size as site scores increase. The 1985 and 1986 upper Camp Creek sites generally grouped together indicating that the between years differences were minimal. The main difference between the 1985 and 1986 sites scores was the lack of a recognizable gradient along axis 2 in 1985. The addition of the lower Camp Creek sites greatly strengthened this axis.

Man has perhaps had the greatest impact on stream assemblages (Horwitz 1978; Gorman and Karr 1978). These influences on assemblage structure have not been adequately addressed. Man has affected all aspects of lotic communities including flow, habitat structure, fish distributions, richness and diversity (Horwitz 1978). It may be difficult to assess the extent of these alterations and to separate man-caused from natural changes. Human impacts to streams destabilize the entire lotic community. These communities may never again become stable as long as the underlying destabilizing influences remain on the streams (Gorman and Karr 1978).

The changes in stream habitats caused by human perturbations (e.g. logging, mining, livestock grazing, channelization, and irrigation withdrawal) have been well documented (Gorman and Karr 1978; Cross and Moss 1987; Li et al. 1987; Pflieger and Grace 1987). Increased water temperatures and structurally simple habitats have resulted in the expansion of the warmwater assemblage and a restriction of the coldwater assemblage in the John Day basin. This increases the probability of direct spatial and trophic competition between assemblages, especially if the increase in the range of the warmwater assemblage results in greater assemblage overlap. Whether

there is increased competition or just more restricted coldwater habitats, the result will be the same, namely decreased production of economically important salmonids such as chinook salmon and steelhead.

Within a given assemblage human disturbances that result in decreased summer low flows could further reduce the amount of edge habitat and side channel habitats critical to YOY steelhead and salmon (Chapman and Bjornn 1969; Everest and Chapman 1972; Annear and Conder 1984; Grossman and Freeman 1987; Chapman 1989; Moyle and Baltz 1991), thus increasing predation risk to these fish. This could also reduce the amount of microhabitat available for a given species, age class, or activity (e.g. spawning, feeding, or hiding). The net result in either case would be a change in assemblage structure (Stein et al. 1972). Jenkins (1969) showed that microhabitat selection is a result of flow conditions and Bjornn (1971) demonstrated that changes in flow can result in changes in population abundance.

Because of all the man caused changes in physical habitat it may appear that stochastic processes are the dominant force determining fish assemblage structure in streams. But, deterministic forces may also be operating in the Upper John Day basin. All three basins had similar fish assemblages (i.e. with a warmwater and a coldwater assemblage). The upper Mainstem and Middle Fork were the most similar, primarily due to the presence of chinook. This is also reflected in the physical characteristics of the three drainages (figure 2; table 2). The upper Mainstem and Middle Fork were most similar with respect to mean annual precipitation, geology, watershed area, elevation and mean annual discharge. This demonstrates that broad physical watershed characteristics are related to fish assemblage structure and possibly could be used to predict species presence or absence (sensu ecoregion concept Hughes

et al. 1990). The assemblages and the habitats were relatively stable between years. They changed in a predictable manner along longitudinal gradients (sensu stream continuum concept; Vannote et al. 1980). This also demonstrates that fish assemblages can be used to assess the degree of habitat deterioration similar to the Index of Biotic Integrity (IBI) (Karr 1981). The IBI was developed for species rich midwest streams. Thus, it would need modification for use in relatively depauperate streams of the Pacific Northwest. Hughes and Gammon (1987) successfully used a modified IBI in the Willamette River, Oregon to describe assemblage quality. Their results were similar to the results of this study in that they found fairly distinct assemblages with coldwater species in the upper reaches of the drainage and warmwater species in the lower reaches. Similar species were found in areas with degraded habitat. In this study, redbreast shiners, suckers, squawfish, and speckled dace were associated with deteriorated riparian habitats. These are primarily warmwater assemblage fishes. These species are all members of Hughes and Gammon's "middle river" assemblage, where habitat quality was declining. It should be noted that the lowest reaches sampled in this study were in the mid reaches of the basin. The lower John Day River was not sampled. This makes the results between studies even more comparable.

Juvenile chinook apparently avoid direct spatial competition and thus competitive exclusion (sensu competitive exclusion principle - Hardin 1960; Zaret and Rand 1971; Schoener 1974) with similar sized juvenile steelhead primarily by rearing in different habitats. This may reflect differences in spawning habitat. Chinook generally spawn in meandering mainstem channels, while steelhead spawn more in tributaries and higher elevation, higher gradient, smaller upper mainstem reaches. But, where they did overlap, they selected different microhabitats. Because of this, one might be inclined to

think that the system is stable and at equilibrium. However, Everest and Chapman (1972) observed similar habitat segregation between juvenile chinook salmon and steelhead trout in two Idaho streams. But each species selected similar microhabitats in allopatry and sympatry. They concluded that competition was not a factor determining habitat segregation and that the microhabitat selection was probably genetically determined.

Extreme caution is advised when considering the driving forces behind the observed assemblage structure. First, the study lasted only two years, and the streams were sampled at the same time each year. Although the study incorporated much of the upper John Day basin, it did not cover the entire basin, let alone the entire migratory range of the anadromous species present in the basin. Li et al. (1987) warns that in order to properly address the question of what mechanisms are responsible for the observed assemblage structure, one must first understand the history of the basin, how streams have evolved, and how they have been altered by man. Then one must incorporate long term basin-wide studies that take into account the migratory behavior of many Pacific Northwest fish and use "successional patterns of riparian habitat" as an appropriate time scale. Angermeier (1987) suggests that persistence of a species over proper spatio-temporal time scales is the key to assessing the degree to which stochastic and deterministic processes are operating to determine assemblage structure. The minimum time scale recommended is the generation time for the longest lived species in the assemblage, while the appropriate minimum spatial scale is the "the area that includes a breeding population of each community member."

It is overly simplistic to suggest that species are regulated entirely by deterministic or stochastic processes. Fish assemblage structure is most likely regulated by a combination of both (Moyle

and Li 1979; Li et al. 1987). There is a growing body of evidence that suggests fish assemblages are structured initially by zoogeographic factors (e.g. global climatic patterns) (Li et al. 1987; Herbold 1984). Then on a local scale, both deterministic and stochastic processes work together in varying degrees to determine the ultimate assemblage structure. The relative importance of these processes may depend on the severity and frequency of environmental disturbance (e.g. floods and drought). In extremely fluctuating streams, variations in the physical environment are most likely more important than biotic interactions. The opposite is likely true in relatively stable streams. This means that the species present in a particular environment are fairly predictable, but the actual numbers and biomass of the fish will vary considerably from year to year. This was the conclusion reached by Peckarsky (1983) in her analysis of invertebrate assemblages in Colorado and Wisconsin streams.

This variability can be attributed to unpredictable changes in the stream environment. Floods particularly affect spawning success while droughts primarily affect adult survival. Moyle and Li (1979) felt that predation and competition played a secondary role in determining assemblage structure. The results of Zaret (1982) support this. The accidental introduction of a predatory fish species into the stream had little impact on the assemblage structure in terms of stability or resilience. Zaret attributed this to the variability in the stream environment.

Matthews (1982) observed patterns in the distribution and relative abundance of minnows in Ozark streams that could have been due to interspecific competition. Species that were common in most of the streams were rare or absent in others and certain species pairs were mutually exclusive. But, when he compared the actual fish assemblages to a neutral model based on the random assembly of

species, the actual assemblages included no more randomly exclusive species than could be explained by chance. Despite this, he maintains that competition may be the reason some species pairs are mutually exclusive. It appears that both deterministic and stochastic forces could be operating here. Deterministic processes (i.e. competition) may limit the number of species present while stochastic forces (i.e. disturbance such as flood or drought) may determine the abundance and distribution of the complete fauna. The opposite is also possible. Environmental fluctuations could determine the species present while competition and predation could limit abundance of each species.

Li et al. (1987) describe fish assemblages in the Pacific Northwest as "adapted to invade and exploit new or recently disturbed environments." This would make it seem as though stochastic processes are the primary determinants of assemblage structure. But, they give evidence "that both stochastic and deterministic forces shape the stream assemblages of Pacific Northwest streams, but their relative roles are unknown." Also, they stress the importance of determining how the streams have been altered by man, as well as the migratory nature of many of the fishes in the Pacific Northwest when considering assemblage regulating mechanisms in this region.

On a local scale, the selection of microhabitats by a species or by age classes of a particular species can help structure fish assemblages (Shirvell and Dungey 1983; Werner and Gilliam 1984). Microhabitat requirements have been shown to vary for different activities such as spawning, feeding, and hiding (Shirvell and Dungey 1983), between day and night (Chapman 1989) as well as seasonally (Felley and Felley 1987; Grossman and Freeman 1987; Taylor 1988). If microhabitat requirements for a given activity are limiting for a particular species or age class, it could limit

density of that species and thus it's numerical dominance in a given assemblage. Human caused habitat alterations (e.g. reduced flow) could result in a shift of limiting microhabitats, thus altering assemblage structure and population abundance of certain species (Jenkins 1969; Bjorn 1971; Shirvell and Dungey 1983). Spatial segregation allows different age classes of steelhead to coexist (Grossman and Freeman 1987). Whether the observed microhabitats are the result of avoidance of competition and predation or the result of trophic requirements remain to be seen.

Biotic interactions could thus be determinants of assemblage structure within a mesohabitat, stream reach, or particular assemblage. This habitat segregation (or selection) may be critical in marginal habitats where warmwater and coldwater assemblages overlap or where closely related species are sympatric. This would serve to minimize competitive interactions and allow species to coexist. Other researchers have found microhabitat selection to be an important determinant of assemblage structure. Gorman (1987) found two assemblages in an Ozark stream based on microhabitat selection and fish size, an open water assemblage comprised of adult fish and a near shore or edge assemblage comprised of juvenile fish. Predation avoidance explained the differences between assemblages while within an assemblage, the species segregated vertically presumably to avoid competition. Stein et al. (1972) found that juvenile chinook and coho segregated spatially and Glova and Mason (1977) observed similar spatial segregation between coho and cutthroat trout. In both cases competition was cited as a probable reason for the observed segregation. Angermeier (1987) concluded that food preferences and predator avoidance determined microhabitats selected by fishes in an Illinois stream.

On the other hand, Cunjak and Green (1983) found no evidence of competition or predation between rainbow trout and brook trout and

surmised that stream morphology and habitat were responsible for observed spatial segregation. Grossman and Freeman (1987) found that trophic resources not competition was responsible for species segregation in a North Carolina stream assemblage. Shirvell and Dungey (1983) felt the observed differences in depth selected by brown trout (Salmo trutta) in streams with rainbow trout versus those without was due to geomorphological differences between streams, not competition.

Because juvenile chinook and steelhead appear to select the same microhabitats whether in sympatry or allopatry (suggesting a genetic component to microhabitat selection, Everest and Chapman 1972), competition at present probably is not an important factor in determining observed spatial segregation between these species. However, this does not preclude other deterministic factors (i.e. predation and food availability) or the "Ghost of Competition Past" (Connell 1980) from being important. Also, competition between other species may influence both microhabitat selection by these species as well as the overall assemblage structure.

In the John Day basin it appears that competition, probably mediated by physical features of the habitat (e.g. temperature, riparian habitat condition etc.) may be important in separating these assemblages along a longitudinal gradient. Chapman (1989) found evidence of direct competition between chinook salmon and redbreast shiners with chinook actively moving to avoid coexistence with the shiners. Reeves et al. (1987) found temperature mediated competition between redbreast shiners and rainbow trout while Baltz et al. (1982) observed the same phenomenon between riffle sculpin and speckled dace. But within the coldwater assemblage, the salmonids segregate spatially based primarily on depth and focal point velocity. This concurs with the findings of Chapman (1989), Everest and Chapman (1972), and Shirvell and Dungey (1983). Present day

competition between juvenile chinook and steelhead within this assemblage probably is not important. However, it may have been through the evolutionary history of the fish. It appears that competition (if it is operating) is most likely between assemblages (warmwater versus coldwater) rather than within an assemblage. Other biotic factors (e.g. predation on young salmonids by squawfish) could also help segregate assemblages along the longitudinal gradient.

It is also obvious that certain macro, meso and microhabitat features are important to assemblages and individual species within the assemblages. One can not definitively determine if this assemblage is regulated wholly by either deterministic or stochastic processes. In all likelihood, a combination of factors are operating to define assemblages regulate assemblage structure in the John Day basin. The many factors that determine and regulate assemblage structure vary between regions, streams, seasons, assemblages within a stream, and species within an assemblage. Therefore, it is important to assess assemblage structure on an individual case by case basis.

MICROHABITATS

Microhabitat values are summarized in table 9 and figures 22 to 36c. The inter and intraspecific as well as habitat type correlations are listed in table 10. All correlations were significant at the $P < 0.05$ level unless otherwise stated. The age 2+ and age 3+ steelhead were combined because of the similarity in microhabitat use and sample size considerations.

INTRA AND INTERSPECIFIC DIFFERENCES

WITHIN A HABITAT TYPE

The results of these analyses are summarized in figures 22 - 31 and in tables 9 and 10. The hypothesis tested was that there was no difference in microhabitat use between juvenile chinook salmon and the different age classes of steelhead within a given habitat type (i.e. mainstem pools, tributary riffles etc).

In general, there were trends of increasing total depth, focal point depth, water column velocity, focal point velocity, substrate size, and focal point turbulence as size of the fish increased for all habitats. Small sample sizes for some groups may have precluded finding significant differences (e.g. n = 4 for chinook salmon in mainstem runs and n = 7 for age 1+ steelhead in tributary runs).

This data suggests that there are differences in microhabitat use between the groups defined above within a particular habitat type. The differences are most pronounced between YOY steelhead and larger fish. This serves to point out the importance of shallow, slow moving edge habitats as rearing habitats for YOY salmonids. Chinook and age 1+ steelhead are similar in size and have similar microhabitats. But, they segregate vertically when in the same habitat possibly to avoid direct competition. Juvenile chinook salmon use the upper portions of the water column whereas juvenile steelhead are more benthically oriented when found together.

The results from the specific habitats are summarized below.

Pools

In mainstem pools YOY steelhead were found in the shallowest portions of the pools and were in closer association with the substrate than the other age classes of steelhead and chinook

Table 9. Mean values for the microhabitat variables.

Group*	Total Depth (cm)	Focal Point Depth (cm)	Mean Substrate size	Mean Velocity (cm/sec)	Focal Point Velocity (cm/sec)
1	47.75	7.00	+1.00	14.83	9.25
2	32.29	4.41	-1.23	5.40	4.21
3	68.84	10.65	-3.02	15.10	9.57
4	37.52	4.89	-1.33	13.41	8.55
5	70.18	11.92	-4.22	19.69	12.71
6	36.74	6.58	-2.02	16.40	7.74
7	67.85	15.32	-0.42	15.64	10.04
8	22.39	3.36	-2.52	26.39	19.47
9	18.29	3.62	-2.65	13.50	9.46
10	28.86	5.71	-2.96	24.29	15.86
11	20.06	3.63	-3.16	20.38	15.69
12	36.00	6.20	-3.10	32.50	19.30
13	26.85	6.00	-3.48	28.23	21.12
14	38.05	5.75	-0.08	24.05	16.05
15	39.00	8.33	-0.70	9.58	7.00
16	33.13	4.70	-0.86	9.70	4.78
17	45.21	7.63	-3.60	23.17	14.88
18	32.86	7.86	-3.02	29.57	19.29
19	48.53	8.35	-3.69	31.82	18.71
20	52.50	7.00	-3.83	18.25	14.25

* Refer to table 3 for group descriptions.

Table 9. continued.

Group*	Embeddedness	Surface Turbulence	Focal Point Turbulence
1	3.25	1.42	1.67
2	2.62	1.42	0.68
3	2.62	1.65	1.63
4	2.43	1.60	1.10
5	3.11	1.78	2.53
6	2.68	1.71	1.76
7	3.72	1.36	2.27
8	2.39	1.97	1.58
9	2.43	1.86	0.77
10	2.33	1.91	1.81
11	2.50	1.94	1.06
12	3.00	2.10	4.10
13	2.62	2.00	0.92
14	2.20	1.85	2.80
15	2.67	2.00	2.08
16	2.09	1.87	1.04
17	3.21	2.00	2.42
18	3.14	2.00	0.86
19	3.12	2.00	3.29
20	3.25	2.00	2.75

* Refer to table 3 for group descriptions.

Table 10. Size and interspecific differences in microhabitat use. The numbers represent groups significantly different at the 95% level.

Group*	Total Depth (cm)	Focal Point Depth (cm)	Mean Substrate size	Mean Velocity (cm/sec)
1	3,5,8,9,10,11 13,18,20	3,5	17	2,10,12,19
2	3,5,7,11,19,20	3,5,19	--	1,5,6,8,10,12,13 14,17,18,19
3	1,2,4,6,8,9 10-16,18,19	1,2,4,8,9 11,12,16	--	--
4	3,5,7,8,9,11,20	3,5,7,15,19,20	--	5,10,12,13,18,19
5	1,2,4,6,8-16,18	1,2,4,8-12 16,18	14	2,4,15,16
6	3,5,7,8,9,10 11,19,20	--	--	2,10,12,19
7	2,4,6,8-16,18	4,8,9,11	--	--
8	1,3-7,12,14,15 17-20	3,5,7,15 18,19,20	--	2,16
9	1,3-7,12,14,15 17-20	3,5,7,15 19,20	--	10,12,18,19
10	1,3,5,6,7,11,15 19,20	5	--	1,2,4,6,9,15,16
11	1-7,10,12,14-20	3,5,7,15 18,19,20	14	--
12	3,5,7,8,9,11,19 20	3,5	14	1,2,4,6,9,15,16
13	1,3,5,7,19,20	--	14	2,4,15,16
14	3,5,7,8,9,11,20	--	5,11,12 13,19,20	2,16
15	3,5,7-11,20	4,8,9,11	17	5,10,12,13,18,19
16	3,5,7,11,19,20	3,5	--	5,8,10,12,13,14,18,19
17	8,9,11	--	1,15	2
18	1,3,5,7,8,9,11 19,20	5,8,11	--	2,4,9,15,16
19	2,3,6,8-13,16,18	2,4,8,9,11	14	1,2,4,6,9,15,16
20	1,2,4,6,8-16,18	4,8,9,11	14	--

* Refer to table 3 for group descriptions.

Table 10. Continued

Group*	Focal Point Velocity	Embeddedness	Surface** Turbulence	Focal Point Turbulence
1	2,5,8,12 14,19	--	--	2,9,12,19
2	1,5,8,10-14, 17-20	--	--	1,5,7,8,10,12 14,15,17,19,20
3	--	--	--	--
4	5,8,12,14,19	--	--	12,19
5	1,2,4,6,9	--	--	2,9,11,13,16
6	5,8,12,14,19	--	--	12
7	--	--	--	2,9
8	1,2,4,6,9	--	--	2,12
9	5,8,12,14,19	20	--	1,5,7,12,14,15 17,19
10	2	--	--	2
11	2	--	--	5,12,15,17,19
12	1,2,4,6,9	--	--	1,2,4,6,8,9,11 13,16
13	2	--	--	5,12,15,17,19
14	1,2,4,6,9	--	--	2,9
15	--	--	--	2,9,11,13
16	--	20	--	5,12,19
17	2	--	--	2,9,11,13
18	2	--	--	--
19	1,2,4,6,9	--	--	1,2,4,9,11,13,16
20	2	9,16	--	2

* Refer to table 3 for group descriptions.

** One or more groups has no variance. Therefore, no test was performed.

salmon. The same trend was observed for YOY steelhead in tributary pools although the differences were not significant.

Chinook are more of a schooling, pelagic species residing throughout the water column in the deepest portions of pools, whereas steelhead are more closely associated with the substrate (thus the lower focal point depth values) and are more territorial. There was a trend of increasing substrate size with increasing fish size for both mainstem and tributary steelhead but the differences were not significant. This may be a reflection of the portion of the pools where the fish were observed. The deeper water is generally faster and has more scouring action especially during high flows. Whereas, the shallow edge water is where the sediment settles out. Chinook were observed over substrate intermediate in size between YOY and age 1+ steelhead.

There were no obvious trends in embeddedness of the substrate in either mainstem or tributary pools, and no significant differences between species or age classes. There were no significant differences in surface or focal point turbulence. However, there was a trend of increasing surface and focal point turbulence with the length of the fish.

Juvenile chinook salmon were associated with microhabitats having the lowest surface turbulence which may be due to the proximity to overhead cover or large instream cover (e.g. boulders and rootwads) that create deep pools where chinook were often found. Chinook also were found in microhabitats with high focal point turbulence values, second only to age 2+/3+ steelhead. It was expected that the largest fish would be associated with greatest turbulence ratings in the water column because they were observed in the deepest, fastest water. This may reflect that microhabitats used by juvenile chinook salmon are high in the water column but

close to boulder outcrops or woody debris where water column turbulence is often high.

As size of juvenile steelhead increased, microhabitats tended to increase in total depth, focal point depth, mean water column velocity, focal point velocity, substrate size, surface turbulence and focal point turbulence. This shows a size specific microhabitat selection for steelhead. As the fish got larger, they moved away from the edges toward mid channel microhabitats. This also emphasizes the importance of edge habitat for YOY steelhead.

Chinook generally were found occupying similar microhabitats as age 1+ steelhead. They used microhabitats with similar total depths, mean and focal point velocities, and focal point turbulence values. But, they segregated on the basis of focal point depth and substrate.

Riffles

Riffles are more uniform habitats (i.e., less diversity in microhabitats, and overall a less desirable habitat because of increased water velocities, shallower water, less cover etc). Despite this, microhabitat trends in mean velocity, focal point velocity, total depth, focal point depth, surface and focal point turbulence were the same as those in pools with the following exceptions.

YOY steelhead in mainstem riffles occupied greater focal point velocities than all other fishes inhabiting mainstem riffles and were associated with greater mean velocities than all groups except age 2+/3+ steelhead. One explanation for this is that these areas are not prime YOY rearing areas. The best YOY rearing habitat is in the tributaries (Li et al. 1985). It could be that these YOY steelhead were occupying these energetically expensive microhabitats

because they were forced out of other more favorable microhabitats by larger fish, or high densities of smaller fish in the tributaries. The other exception was that juvenile chinook were observed over much smaller substrate than the other fish (primarily pea gravel and sand, silt, and clay). This difference reflects the fact that juvenile chinook in riffles were most often observed in pockets behind boulders (or some other instream habitat) where fine material can settle out, and where the water is relatively calm, fairly deep, and had low velocities.

Runs

Few juvenile chinook salmon were found in mainstem run habitats (n = 4) and few age 1+ steelhead were found in tributary run habitats (n = 7). Therefore, the means for these groups may not be representative. More fish need to be sampled before meaningful analyses can be done.

The mean and focal point characteristics of microhabitats followed the same trends as found elsewhere. The same may be said for substrate quality with one exception. Juvenile chinook salmon were observed over much larger substrate particles (mean size approximates large gravel) than in pools and riffles. But, this value was similar to age 1+ and 2+/3+ steelhead in runs. This may be an artifact of small sample size or a reflection of availability (fig. 23).

No embeddedness or surface turbulence trends were evident. But, focal point turbulence was positively associated with size of fish for the mainstem groups, while YOY steelhead in the tributaries used slightly higher focal point turbulence than age 1+ tributary steelhead. Once again this may be an artifact of low sample size.

There were some odd results obtained from the run habitats. For example, YOY steelhead in mainstem runs had a mean substrate score of -0.70 (mean size slightly smaller than pea gravel) while 1+ steelhead, 2+/3+ steelhead, and juvenile chinook had substrate scores of -3.60, -3.69, and -3.83 respectively (mean size slightly less than large gravel) (table 8). But, the only significant difference was between the YOY and age 1+ steelhead (scores -0.70 and -3.60 respectively)! Clearly, microhabitat measurements need to be taken on more run dwelling fish before there can be much confidence in these results.

BETWEEN HABITATS - SAME STREAM, SAME AGE CLASS

Mainstem Habitats

The results are shown in figures 22 - 26 and tables 9 and 10. The null hypothesis was that there was no difference in microhabitat use for a given species and age class among habitats (pools, riffles, and runs) within the same stream type (mainstem or tributary). Many of the differences reflect physical habitat differences among habitat types. For example, total depth was significantly deeper in pools than riffles for all groups, and total depth in runs was also significantly deeper than that in riffles for all groups except age 1+ steelhead. In all cases, microhabitats in pools were deepest, riffles shallowest, and runs intermediate. There were few other significant differences. These habitats lie along a gradient from harsh to benign. Riffles are the harshest, because they are the fastest, shallowest, and most turbulent. Pools are the most benign and runs are intermediate.

There does not appear to be any major or consistent differences in microhabitat use by a given species and age class between habitats within a stream type. The trends indicate potential

differences in focal point velocity and focal point depth. This warrants further investigation. The differences may be real or just the an artifact of the differences between habitat types. The physical nature of riffles and runs may force fish to occupy microhabitats that are closer to the substrate (lower focal point depth) and thus lower focal point velocity. As water velocity decreases and depth increases, the need for close association with the substrate (in the form of protection from higher water velocities and providing cover) also declines, therefore the fish are able to maintain themselves higher off the substrate. Lack of significant differences may be the result of small sample sizes in some cases.

YOY Steelhead

Most differences reflect a difference in availability. Because pools are the deepest habitat type, one would expect fish found here to be in the deepest water and be observed farther from the substrate than fish of similar size in riffles and runs. YOY steelhead in riffles were observed in the shallowest water and closest to the substrate as expected. But, although the YOY steelhead seen in pools were found in deeper water than those in runs, they were closer to the substrate than their run dwelling counterparts. This may be due to low sample size ($n = 12$ for pools and runs). Likewise, one would expect them to be in areas with lower mean water column velocities, turbulence, and substrate values. Riffles had the highest mean and focal point velocities with pools intermediate and runs the lowest. But, the only significant difference was focal point velocity between pools and riffles. There was no significant differences for mean velocity.

Again, this is most likely due to the low sample size and large variance in the run data.

No differences were detected between riffle and pool microhabitats in either substrate size or degree of substrate embeddedness. Because pools have the smallest mean substrate size (and thus more fines) in addition to the fact that pools are depositional (during low flows) it was expected to be the most embedded. This was not the case. The scouring action of pools during high flows may flush much of the embedding fine material from the substrate. Riffles had little fine material on the surface of the substrate, but were quite embedded. Because there is little scouring action in riffles, there is a tendency for an armor layer to develop. This appears to be what happened in the upper John Day basin. The fines that are present act to cement the larger substrate particles together. This problem is confounded by land use practices that 1) cause more sediment to be added to the stream (such as livestock grazing and logging) and 2) reduce stream flow so as to minimize or eliminate any scouring action (e.g. irrigation withdrawal). Here, a visual estimate of embeddedness would lead to erroneous conclusions.

There were no obvious trends with the turbulence measures. The values reflect availability (fig 26).

Age 1+ Steelhead

The trends were as expected but the lack of significant differences suggest that this age group does not select different microhabitats depending on what habitat they are in. Total depth was significantly deeper in pools compared to riffles. This merely reflects availability and suggests that they will inhabit deeper water if it is available, but their focal point depths will not

change significantly. Focal point depth, velocity, and turbulence as well as substrate did not vary significantly among habitats (Figs 22 - 26; table 9). There was a trend towards increasing focal point depth from riffles to runs to pools, although it was not significant.

Age 2+/3+ Steelhead

The trends were similar to age 1+ steelhead. The only difference was that these fish occupied significantly higher focal point depths in pools compared to riffles (with runs being intermediate but not significantly different from either). This along with the significant differences in total depth values indicates that when available, the older fish will move into deeper water and hold farther off the bottom. Also, this suggests that the older age classes of steelhead select similar microhabitats based on mean and focal point velocity and turbulence, as well as substrate in all habitat types. The only variables that influenced microhabitat selection among habitats were total and focal point depths. There was a definite trend with focal point turbulence and a slight trend with surface turbulence declining from riffles to runs to pools but the differences were not significant. Embeddedness values were very similar for all habitats. There was the opposite trend with substrate. This age class was found over larger substrate in pools and smaller substrate in riffles (runs were intermediate). One explanation for this is that in riffles the fish were found in pockets behind boulders or other instream structure (like juvenile chinook) where the water is relatively calm thus allowing fines to settle out and lowering the mean substrate size. Whereas in pools, the fish are in the deepest, fastest areas

where the much of the fine material has been washed away, resulting in a higher mean substrate size.

Chinook Salmon

Chinook salmon microhabitats exhibited very similar patterns as microhabitats of age 1+ steelhead. This was expected because of the similarity in sizes. As already mentioned juvenile chinook and age 1+ steelhead select different microhabitats based on water column and focal point depths.

Figure legend. Definitions of abbreviations used to label the microhabitat figures.

AV = Mean value of available habitat for that particular habitat type, from the physical habitat survey.

0+ = Young-of-the-year steelhead.

1+ = Age 1+ (yearling) steelhead.

2+/3+ = Age 2+ and 3+ steelhead combined.

CHS = Juvenile chinook salmon.

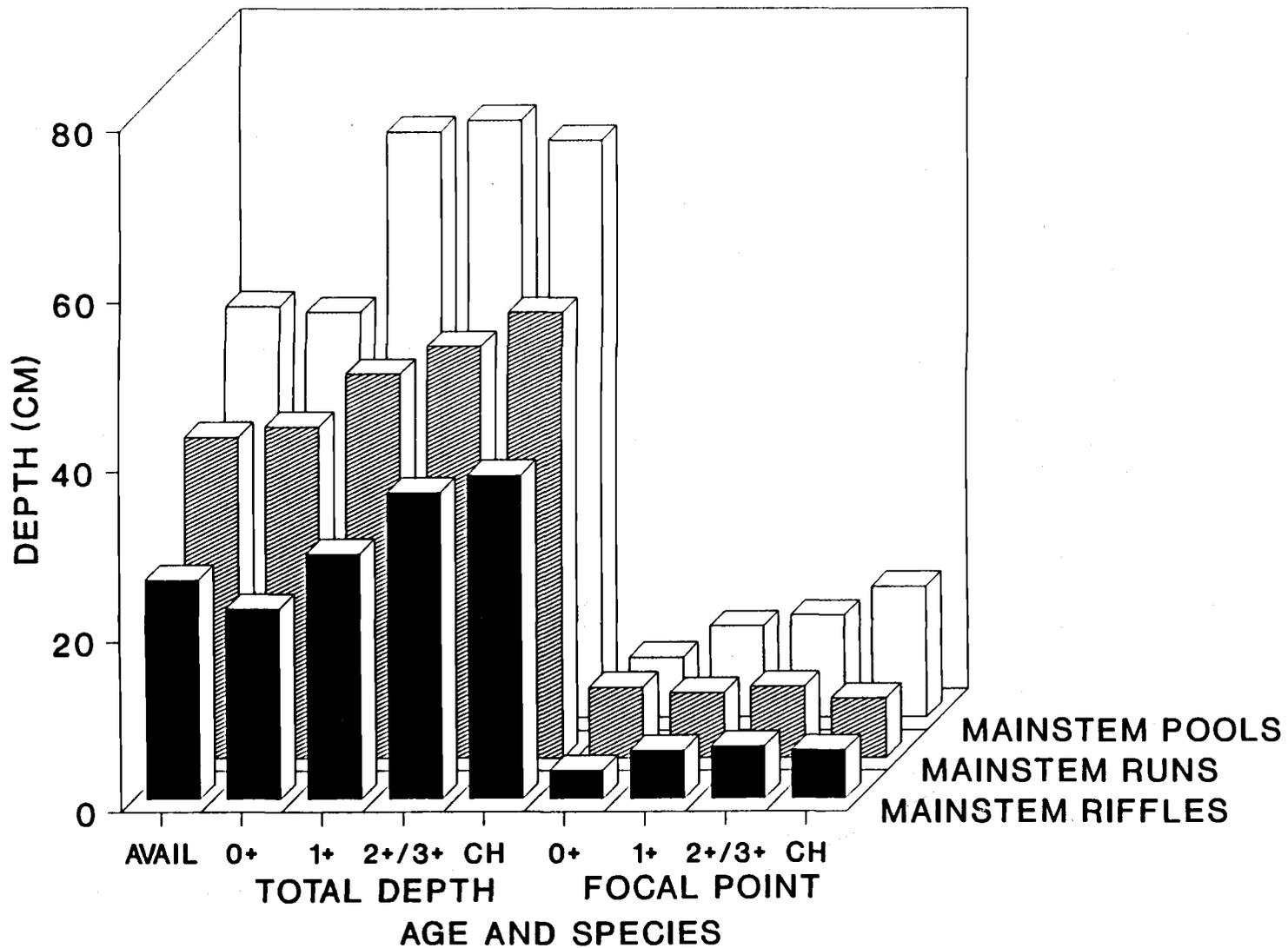


Figure 22. Total and focal point depths for juvenile chinook salmon and juvenile steelhead trout occupying mainstem pools, riffles, and runs.

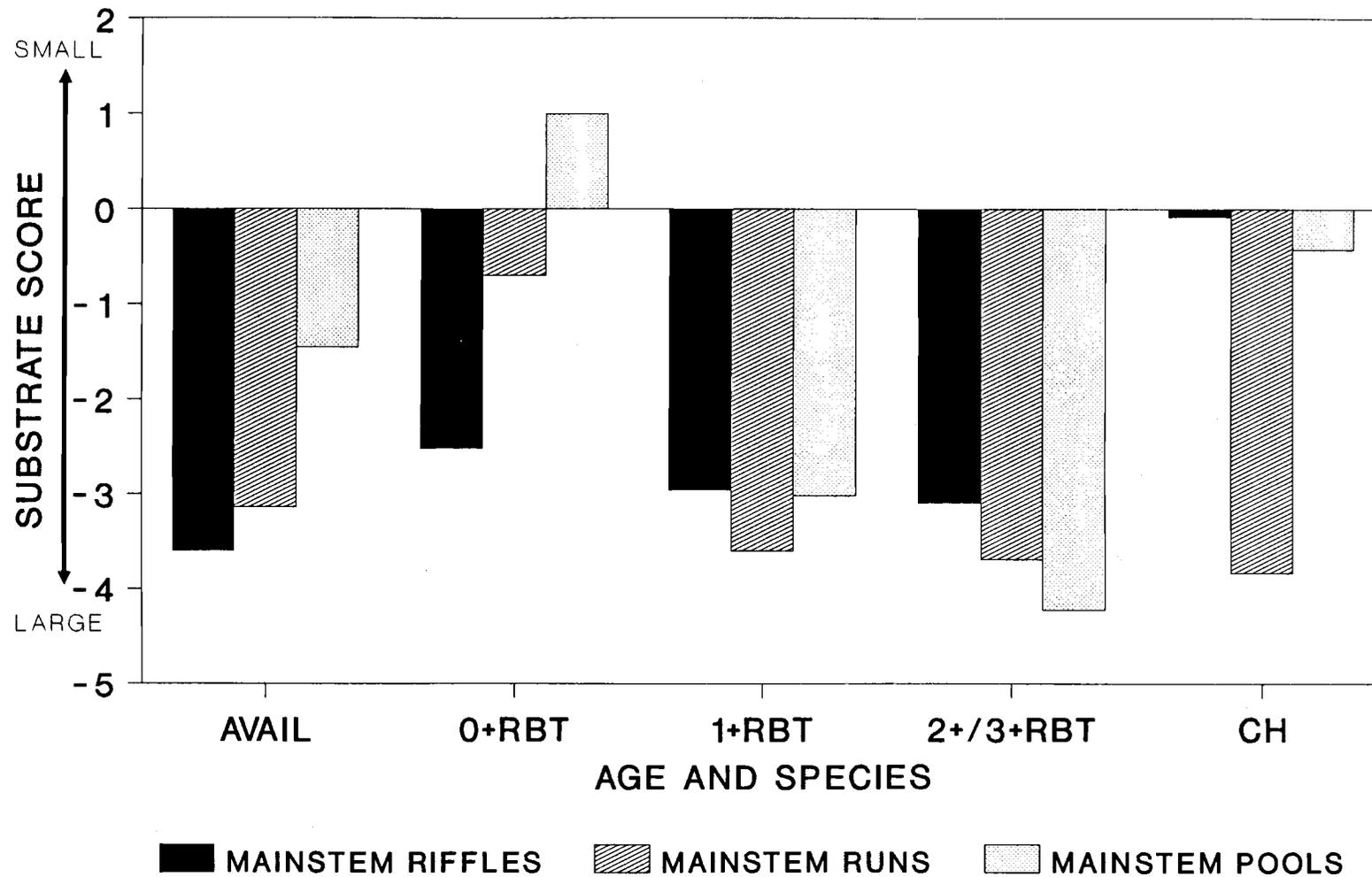


Figure 23. Mean substrate scores for microhabitats in mainstem pools, riffles, and runs.

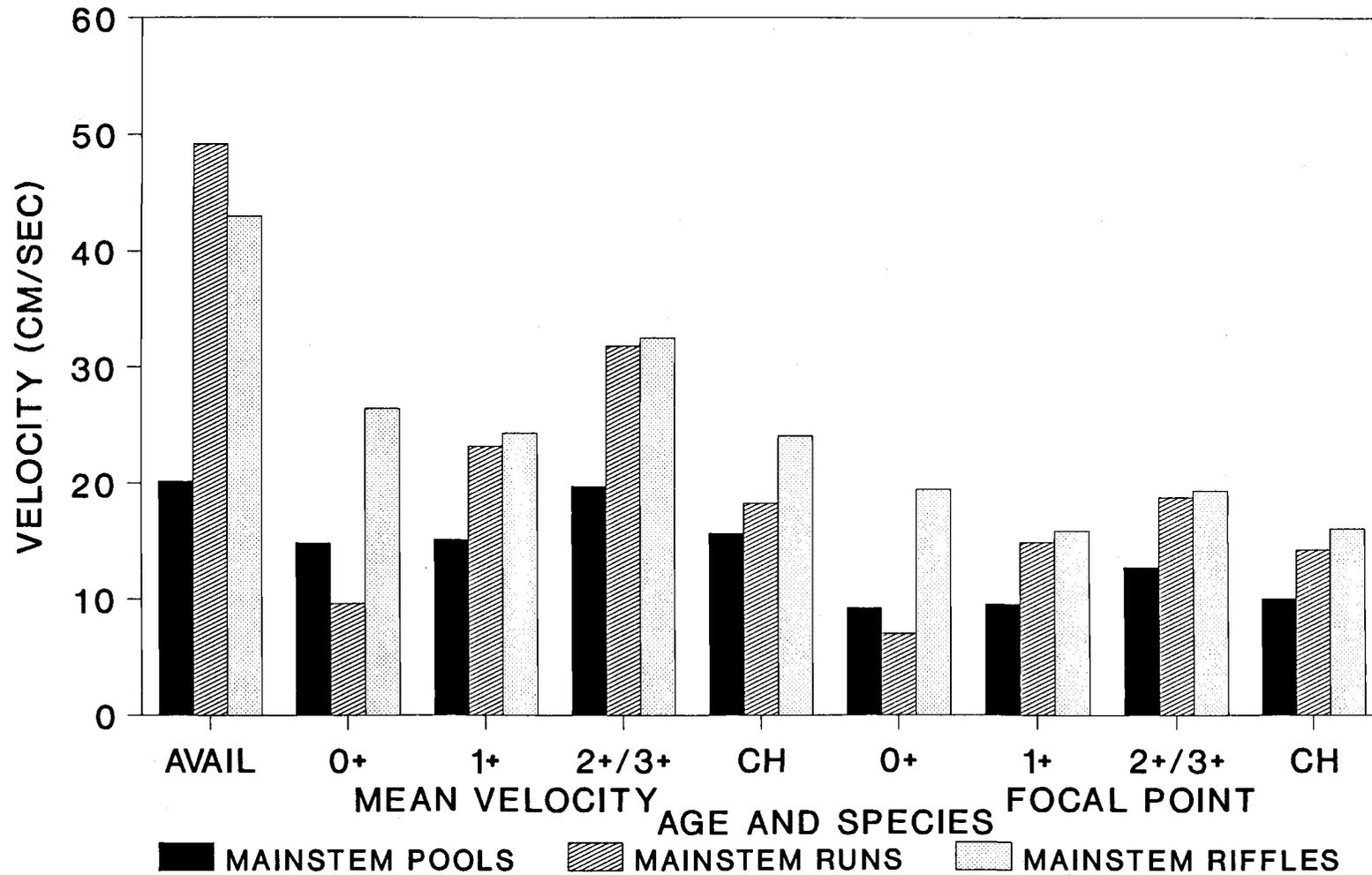


Figure 24. Focal point and mean velocities for microhabitats in mainstem pools, riffles, and runs.

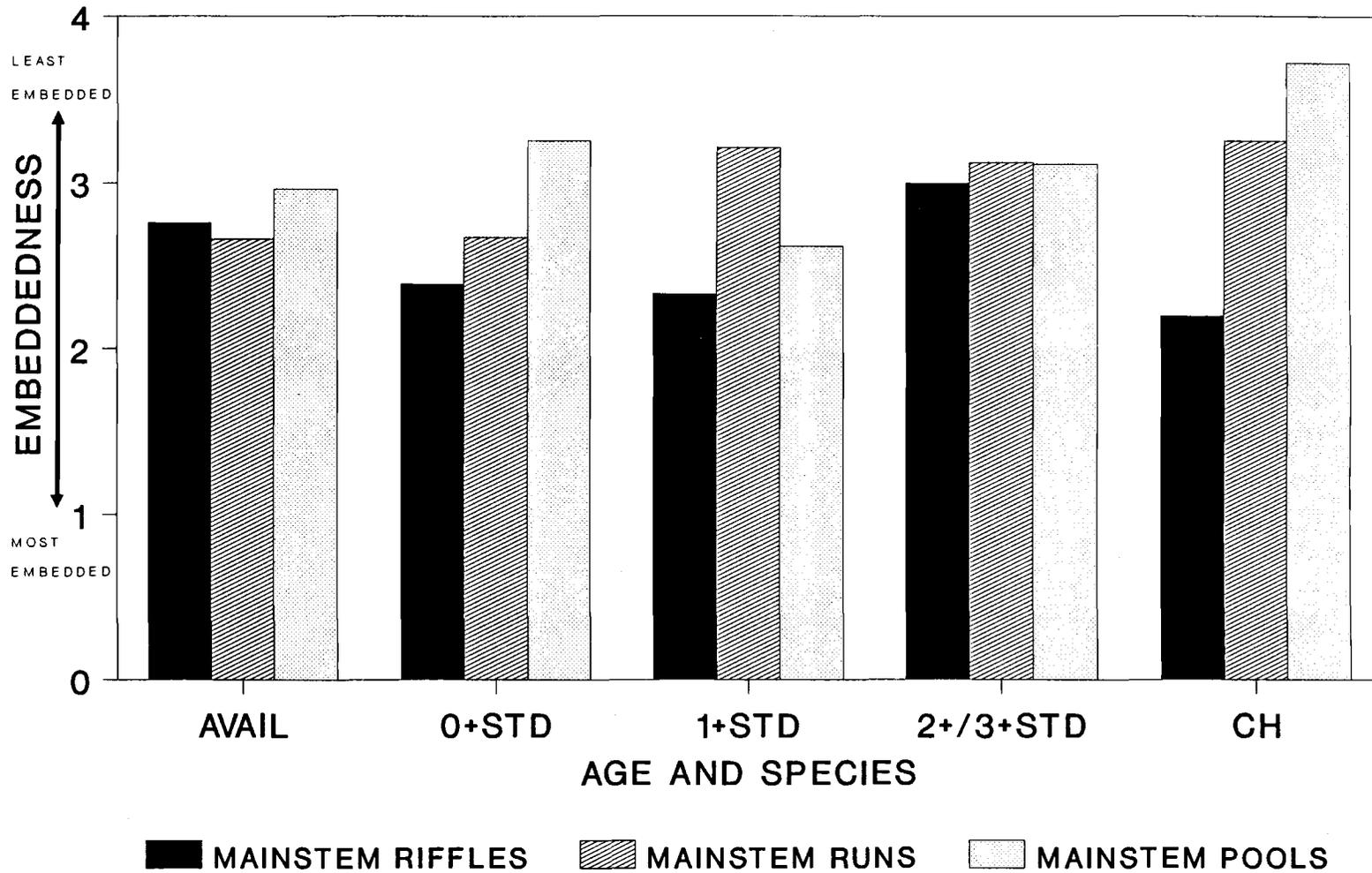


Figure 25. Mean embeddedness ratings for microhabitats in mainstem pools, riffles, and runs.

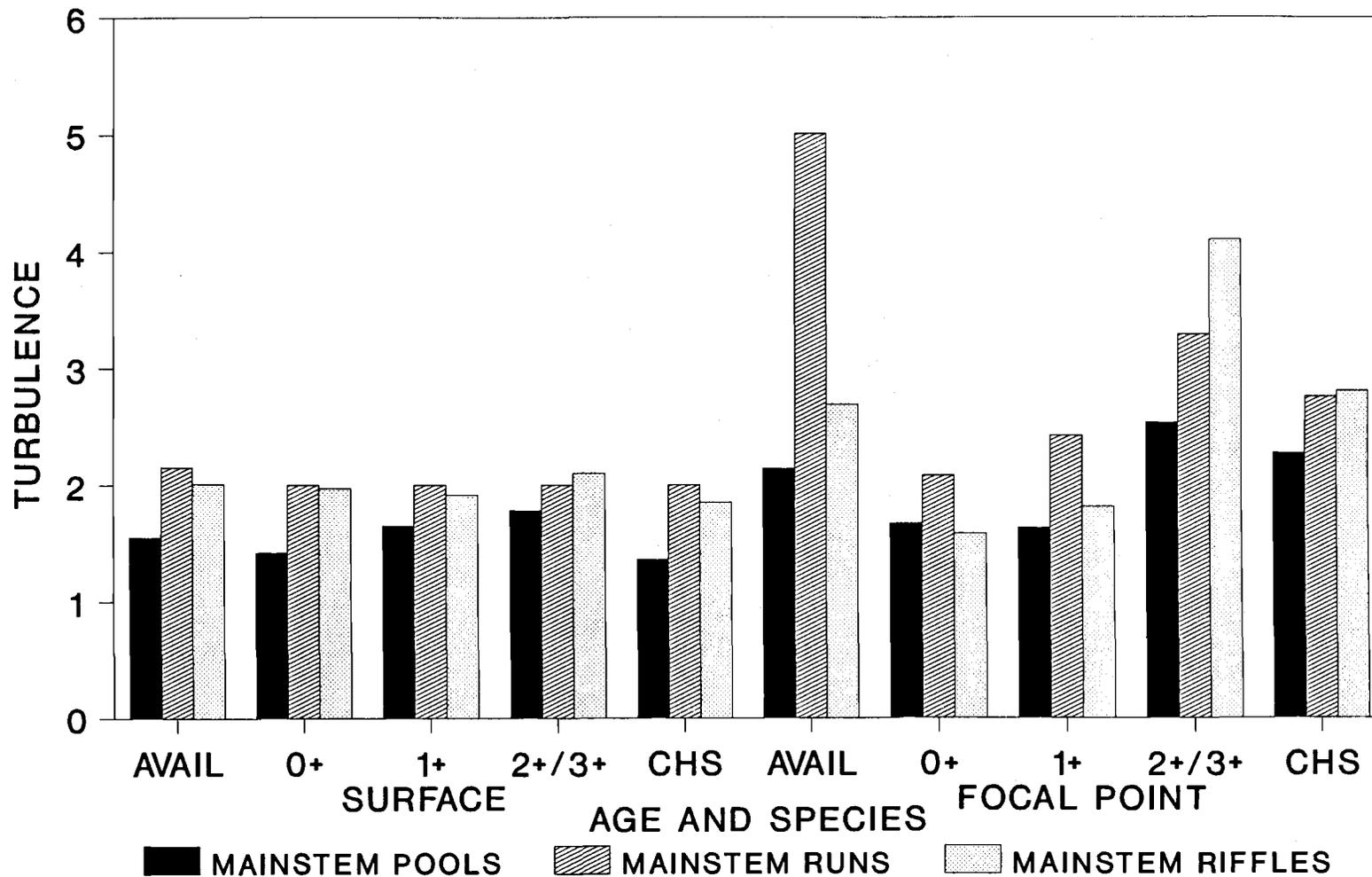


Figure 26. Mean turbulence ratings for microhabitats in mainstem pools, riffles, and runs.

Tributary Habitats

The results are summarized in figures 27 - 31 and tables 9 and 10.

YOY Steelhead

YOY steelhead microhabitats in tributaries exhibited similar patterns as microhabitats of YOY steelhead in the mainstem sites. There was no significant differences between the habitat types for any variable. But, there was the same trend for mean and focal point velocities as seen with the mainstem fish.

Age 1+ Steelhead

Once again, total depth at the locations used by the fish was significantly greater in pools than in riffles. Microhabitats in runs were of intermediate depth but were not significantly distinguishable from those in riffles or pools. This reflects availability. Depth values at the focal points did not exhibit the expected trend. Run microhabitats were significantly deeper than those of riffles (pools were intermediate). This is most likely a reflection of low sample size ($n = 7$) of 1+ steelhead in run habitats. The same type of pattern was observed for mean water column velocity. Runs were significantly greater than pools (with riffles intermediate). The same pattern existed for focal point velocity but the differences were not significant. Again, the most likely explanation for this is low run habitat sample size.

Age 2+/3+ Steelhead

The usual trends were present (i.e. increasing focal and water column depth and decreasing mean and focal point velocity from riffles to pools), but the differences were not significant, again suggesting that microhabitat selection did not vary between habitats.

WITHIN HABITATS - SAME AGE CLASS, DIFFERENT STREAM

YOY Steelhead

Unlike the previous comparisons there are differences in microhabitat selection between stream types. YOY steelhead occupying mainstem pools were observed in water of significantly greater mean water column and focal point velocities, and focal point turbulences (Figs 34a and 36a; table 10). Microhabitats for YOY steelhead did not differ significantly between mainstem and tributary pools for the following variables: total depth, focal point depth, surface turbulence, embeddedness, and substrate.

There were fewer differences in riffle microhabitats between mainstem and tributary sites. Focal point velocity was significantly higher in mainstem riffles (fig. 34b). Run habitats had no significant differences suggesting that there was no difference in selection between mainstem and tributary runs. Again, low sample size may come into play here.

Age 1+ Steelhead

While the YOY steelhead in pools were electing for different microhabitats on the basis of focal point velocity, age 1+ steelhead electivity appeared to be on the basis of depth and focal point

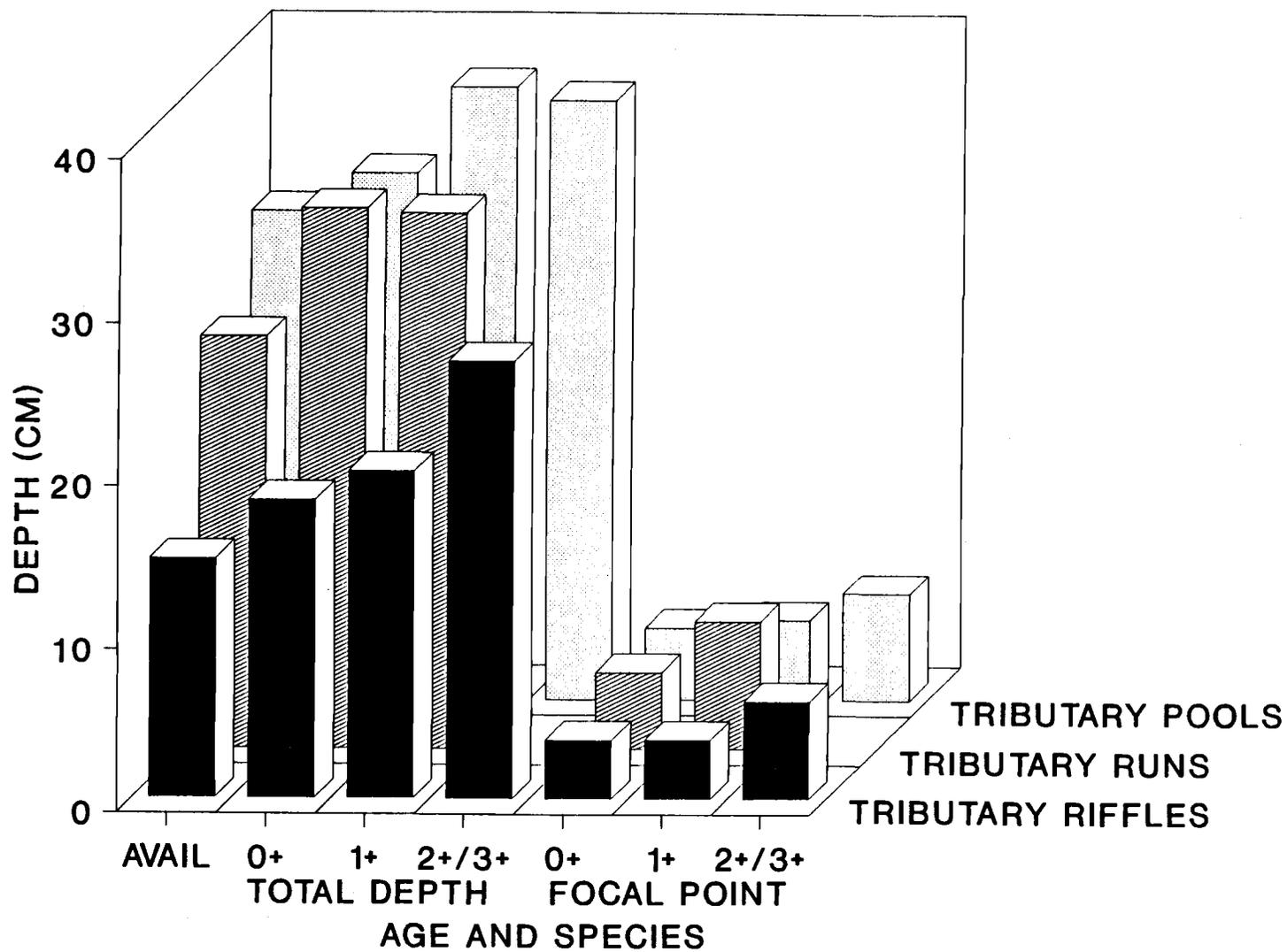


Figure 27. Total and focal point depths for microhabitats in tributary pools, riffles, and runs.

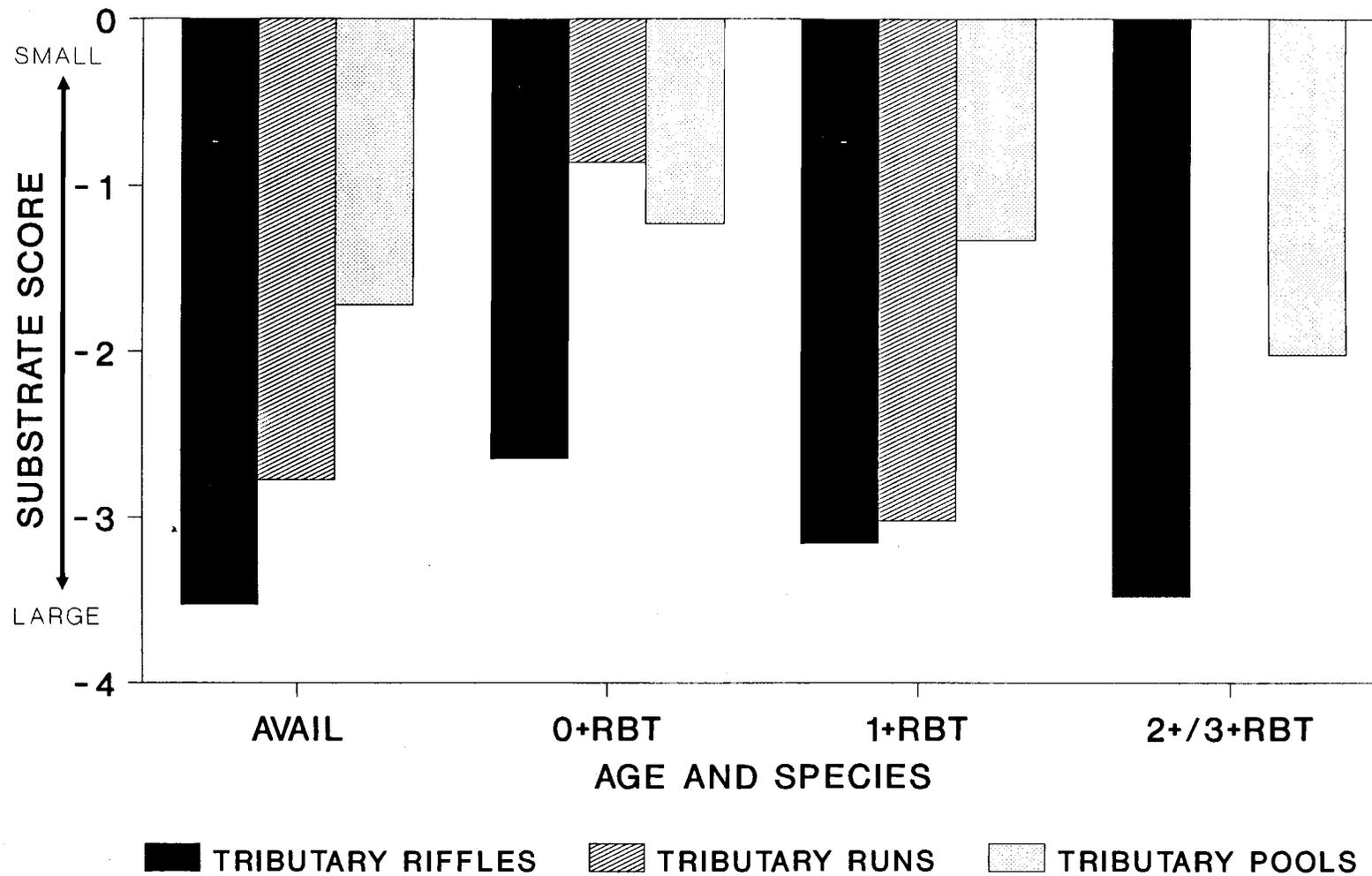


Figure 28. Mean substrate scores for microhabitats in tributary pools, riffles, and runs.

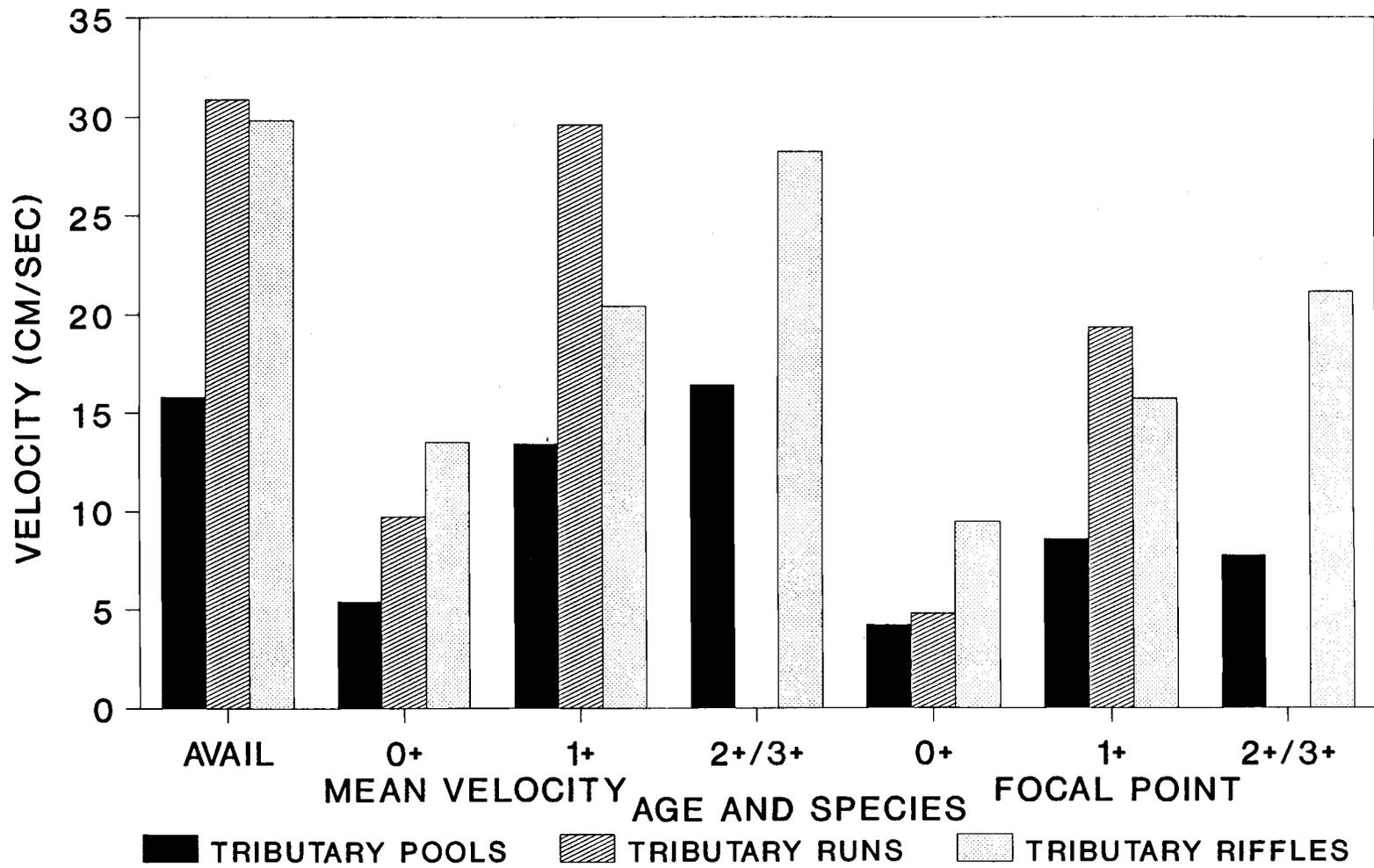


Figure 29. Focal point and mean velocities for microhabitats in tributary pools, riffles, and runs.

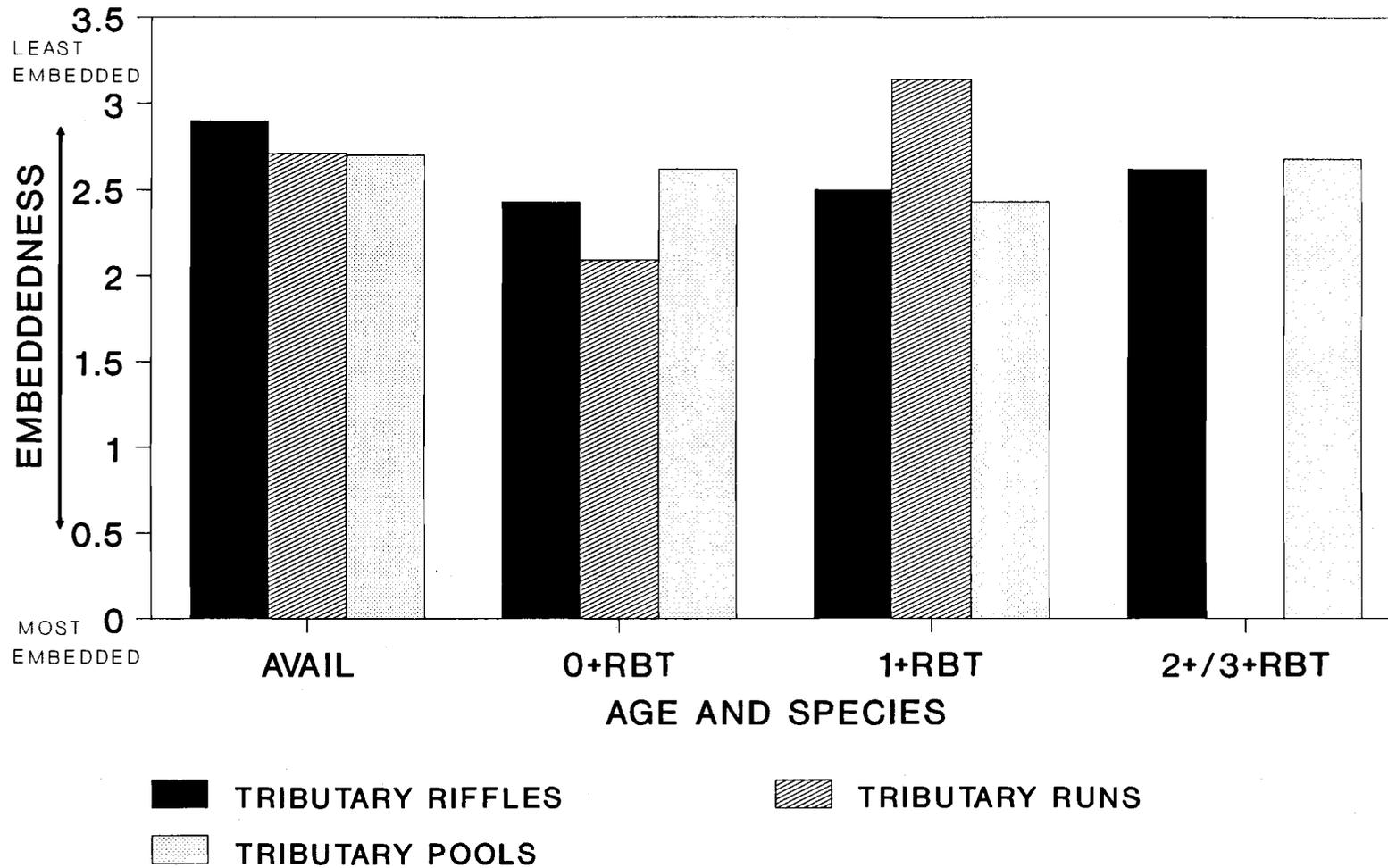


Figure 30. Mean embeddedness ratings for microhabitats in tributary pools, riffles, and runs.

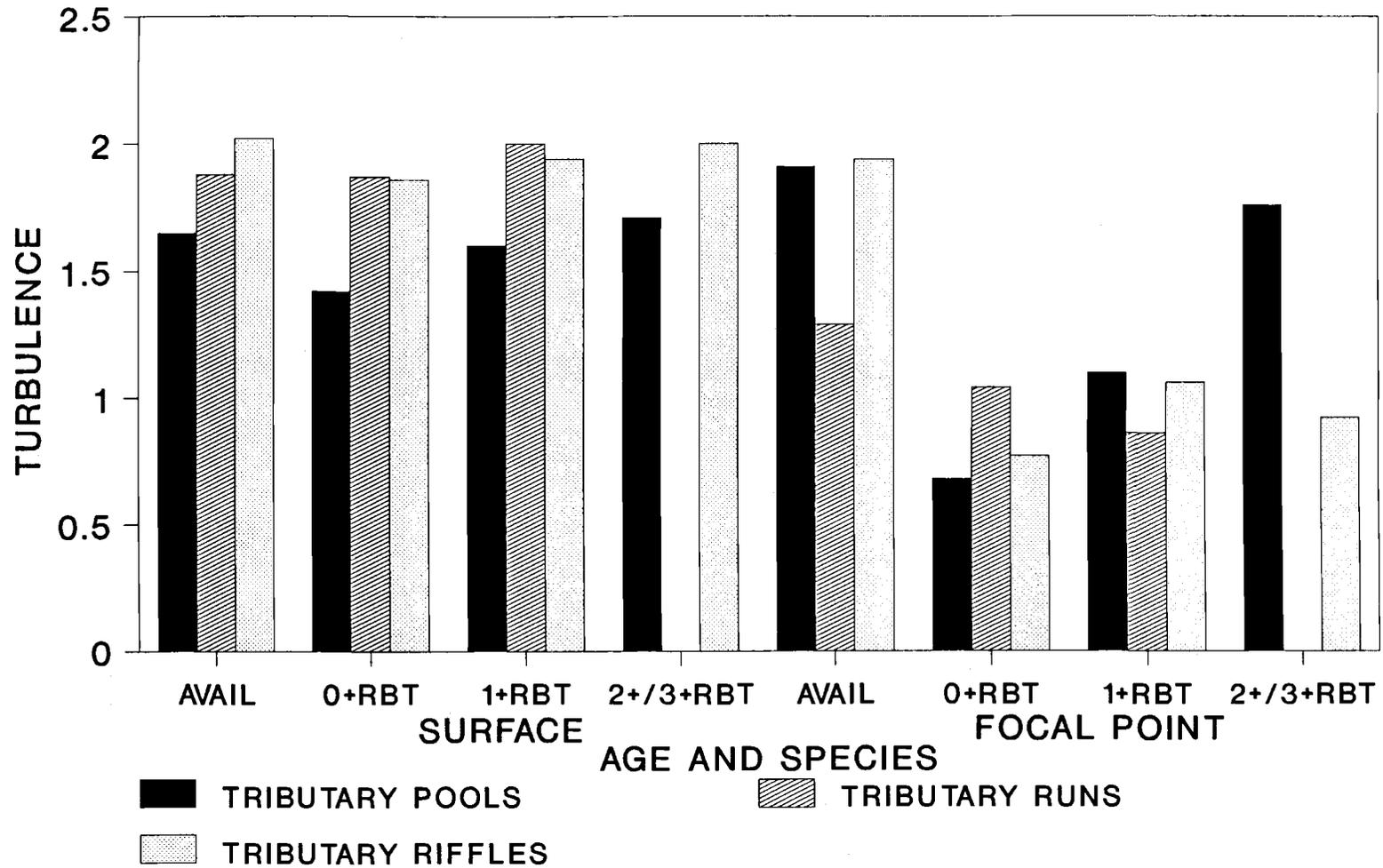


Figure 31. Mean turbulence ratings for microhabitats in tributary pools, riffles, and runs.

depth. Age 1+ steelhead in mainstem pools were found in significantly deeper water and used focal point depths significantly farther from the substrate than in tributary pools (fig. 32). The tributary microhabitats were shallower and had lower focal point velocities but these differences were insignificant (fig. 34a).

The mainstem fish were found in significantly deeper riffles than those in the tributaries (fig. 32). But, this difference appears to be more of a reflection of availability. There were no other significant differences in riffle habitat. Focal point depth and mean water column velocity were higher in mainstem sites but not significantly. Focal point velocity was almost equal (fig. 34b).

There were no significant differences between mainstem and tributary runs. But, this age class of fish was found in deeper water in mainstem habitats. Focal point depths were almost equal (fig. 32). The focal point and mean water column velocities were faster in the tributaries (fig. 34c).

Age 2+/3+ Steelhead

Fish in the mainstem habitats were found in significantly deeper pools and faster focal point velocities than in the tributaries. These fish also had higher focal depths and mean water column velocities but the differences were not significant (figs. 32 and 34a).

The only other significant difference was that the microhabitats in mainstem riffles had a higher focal point turbulence than those in tributaries. This, in all likelihood, is not something selected for but rather a consequence of selecting for some other variable. Total water column depth at the fish and mean water column velocity above the fish were greater (but not significantly) in mainstem

riffles. Focal point depths were almost equal while focal point velocity was greater in the tributaries (figs. 32 and 34b).

There appears to be very little if any difference in microhabitat selection between mainstem and tributary riffles and runs. What differences exist are more a reflection of the differences in availability among the habitats. There are differences in the availability of depth and velocity only in pools.

MICROHABITAT SELECTION VERSUS AVAILABILITY

Selection versus availability data is summarized in tables 11 and 12 as well as figures 32 - 36c.

Salmonids in the Upper John Day basin select specific microhabitats. Available habitat was defined as mean values for those variables measured across the transect lines (i.e. depth, substrate composition, embeddedness, velocity, and turbulence).

All groups except age 1+ steelhead in tributary runs (due to low sample size) selected lower focal point velocities than the mean velocity available for those habitats. This appears to be the primary microhabitat determining variable. Lotic dwelling salmonids were found in close association with the substrate.

Total depth is also an important variable, but primarily for the larger age classes. YOY steelhead did not exhibit positive selection for total depth in any habitat except tributary runs. Here, the relationship was weak ($p < 0.0793$). All other groups in pools selected areas of the pools that were deeper than the mean. Juvenile chinook were in deeper water than all groups in all habitats except age 1+ and 2+/3+ steelhead in mainstem pools. The differences were small and insignificant.

Focal point turbulence was a factor in tributary pools and riffles. All groups in these habitats selected areas with lower

focal point turbulence values than available, except age 2+/3+ steelhead in tributary pools and age 1+ steelhead in tributary riffles. This may be just a reflection of the lower velocities selected.

Like focal point turbulence, mean velocity of the water column was only a factor for certain groups. Generally, smaller fish in both mainstem and tributary riffles and runs selected microhabitats in which the water column velocities were less than the average for that habitat. Whereas larger fish and most pool dwelling fish (all except YOY steelhead in tributary pools) did not. The larger fish were found in mid-channel areas associated with faster mean velocities. For the most part, these mean velocities were very close to the mean velocities of those channel units.

The other variables, substrate, embeddedness, and surface turbulence do not appear to be important variables for most groups. Embeddedness was selected weakly for by only three groups (table 12; figs. 35a-35c). Here, the differences were most likely an artifact of the fish selecting for another variable such as velocity. When a fish selects a microhabitat with lower than average water column and focal point velocities, it would be expected that sediment would settle out, thus increasing visual embeddedness estimates in those microhabitats. This is what happened for two of the three groups (YOY and age 1+ steelhead in tributary riffles). The third group, chinook in mainstem pools had lower embeddedness. This was most likely due to them selecting microhabitats in the deeper portions of pools that are more apt to be scoured at high flows, thus removing much of the sediment. Five groups selected surface turbulence values significantly different from what was available. Four of the groups (YOY steelhead in tributary pools, YOY, age 1+, and 2+/3+ steelhead in mainstem runs) had lower values than available while age 2+/3+ steelhead in mainstem pools had a greater surface

Table 11. Availability data for mainstem and tributary pools, riffles, and runs.

Habitat	VARIABLE					
	Mean Depth (cm)	Mean Velocity (cm/sec)	Mean Substrate size	Embed.	Surface Turb.	Focal Point Turb.
Mainstem Pools	48.45	20.16	-1.455	2.96	1.55	2.14
Tributary Pools	29.89	15.80	-1.719	2.70	1.65	1.91
Mainstem Riffles	25.81	42.96	-3.600	2.76	2.01	2.69
Tributary Riffles	14.67	29.80	-3.527	2.90	2.02	1.94
Mainstem Runs	37.77	49.14	-3.142	2.66	2.15	5.01
Tributary Runs	25.25	30.85	-2.775	2.71	1.88	1.29

Table 12. Significance levels for microhabitat selection versus availability.

		VARIABLE			
Group*		Total Depth	Focal Point Depth	Substrate	Mean Velocity
<u>MAINSTEM POOLS</u>					
YOY	STHD	NS	3.53E-4	NS	NS
1+	STHD	0.033	2.77E-5	0.052*	NS
2+/3+	STHD	0.015	4.72E-5	4.36E-3	NS
CHS		5.05E-4	5.50E-5	NS	NS
<u>TRIBUTARY POOLS</u>					
YOY	STHD	NS	1.21E-13	NS	2.15E-4
1+	STHD	3.26E-3	1.71E-12	NS	NS
2+/3+	STHD	0.033	6.33E-10	NS	NS
<u>MAINSTEM RIFFLES</u>					
YOY	STHD	NS	8.21E-6	NS	0.019
1+	STHD	NS	5.41E-5	NS	7.01E-3
2+/3+	STHD	NS	6.98E-4	NS	NS
CHS		6.37E-4	3.75E-5	0.032	2.17E-3
<u>TRIBUTARY RIFFLES</u>					
YOY	STHD	NS	1.17E-7	NS	6.91E-4
1+	STHD	9.13E-3	7.06E-6	NS	0.041
2+/3+	STHD	3.33E-4	3.58E-4	NS	NS
<u>MAINSTEM RUNS</u>					
YOY	STHD	NS	2.05E-3	NS	2.91E-3
1+	STHD	NS	4.93E-4	NS	0.018
2+/3+	STHD	0.065*	8.26E-4	NS	NS
CHS		0.050	0.014	NS	0.050
<u>TRIBUTARY RUNS</u>					
YOY	STHD	0.079*	3.46E-4	0.057*	5.16E-3
1+	STHD	0.087*	5.60E-3	NS	NS

* = Significant at the 10% level of confidence

STHD = Juvenile steelhead

CHS = Juvenile chinook salmon

NS = Not significant

Table 12. Continued.

		VARIABLE			
Group*		Focal Point Velocity	Embeddedness	Surface Turbulence	Focal Point Turbulence
<u>MAINSTEM POOLS</u>					
YOY	STHD	0.014	NS	NS	NS
1+	STHD	2.36E-3	NS	NS	NS
2+/3+	STHD	0.020	NS	0.039	NS
CHS		2.12E-3	0.095*	NS	NS
<u>TRIBUTARY POOLS</u>					
YOY	STHD	2.80E-7	NS	5.98E-3	2.18E-5
1+	STHD	0.012	NS	NS	0.023
2+/3+	STHD	0.021	NS	NS	NS
<u>MAINSTEM RIFFLES</u>					
YOY	STHD	4.62E-4	NS	NS	NS
1+	STHD	6.17E-4	NS	NS	NS
2+/3+	STHD	1.37E-3	NS	NS	NS
CHS		1.58E-4	NS	NS	NS
<u>TRIBUTARY RIFFLES</u>					
YOY	STHD	1.11E-5	0.049	NS	1.04E-3
1+	STHD	0.012	0.089*	NS	0.069*
2+/3+	STHD	0.022	NS	NS	0.035
<u>MAINSTEM RUNS</u>					
YOY	STHD	2.03E-3	NS	0.024	0.049
1+	STHD	3.21E-3	NS	1.62E-3	0.067*
2+/3+	STHD	0.011	NS	7.61E-3	NS
CHS		0.028	NS	NS	NS
<u>TRIBUTARY RUNS</u>					
YOY	STHD	4.97E-4	NS	NS	NS
1+	STHD	NS	NS	NS	NS

* = Significant at the 10% level of confidence.

STHD = Juvenile Steelhead

CHS = Juvenile chinook salmon

NS = Not significant

turbulence value than what was available. But, the significant result for the three mainstem run groups was due to the fact that there was no variation in surface turbulence for the fish in those groups. Therefore, the result was an artifact of the data. The actual differences were quite small (table 9). For the remaining two groups, the significance is a result of selecting for other variables, namely velocity. The higher the velocity, the higher the surface turbulence will be. Age 2+/3+ steelhead in mainstem pools selected microhabitats with the highest mean and focal point velocities for that habitat. As a result, they also had the highest surface turbulence. On the other hand, the YOY steelhead in tributary pools selected the lowest mean and focal point velocities in that habitat and thus had the lowest surface turbulence values.

Substrate was selected for by only four groups of fishes. There were two pool groups (Age 1+ and 2+/3+ steelhead in mainstem pools) which selected larger substrate. This is a reflection of the fact that these habitats are generally depositional in the summer, resulting in a lower mean substrate size (thus availability) and because these fish were found in the deeper, faster portions of the pools where less sediment settles out. They are also scoured during high flows. The other two groups (chinook in mainstem riffles and YOY steelhead in tributary runs) selected smaller substrate. Chinook in riffles were generally found in pockets behind boulders. These were not only the deepest portions of the riffles, but were also some of the few areas where sediment and pea gravel could settle out, thereby lowering the mean substrate size. The same reasoning is applicable for the YOY steelhead in tributary runs. They were also found in the slower portions of runs (often behind boulders and debris or near the shore) where sediment could settle out.

Salmonids in the upper John Day basin show distinct intra and

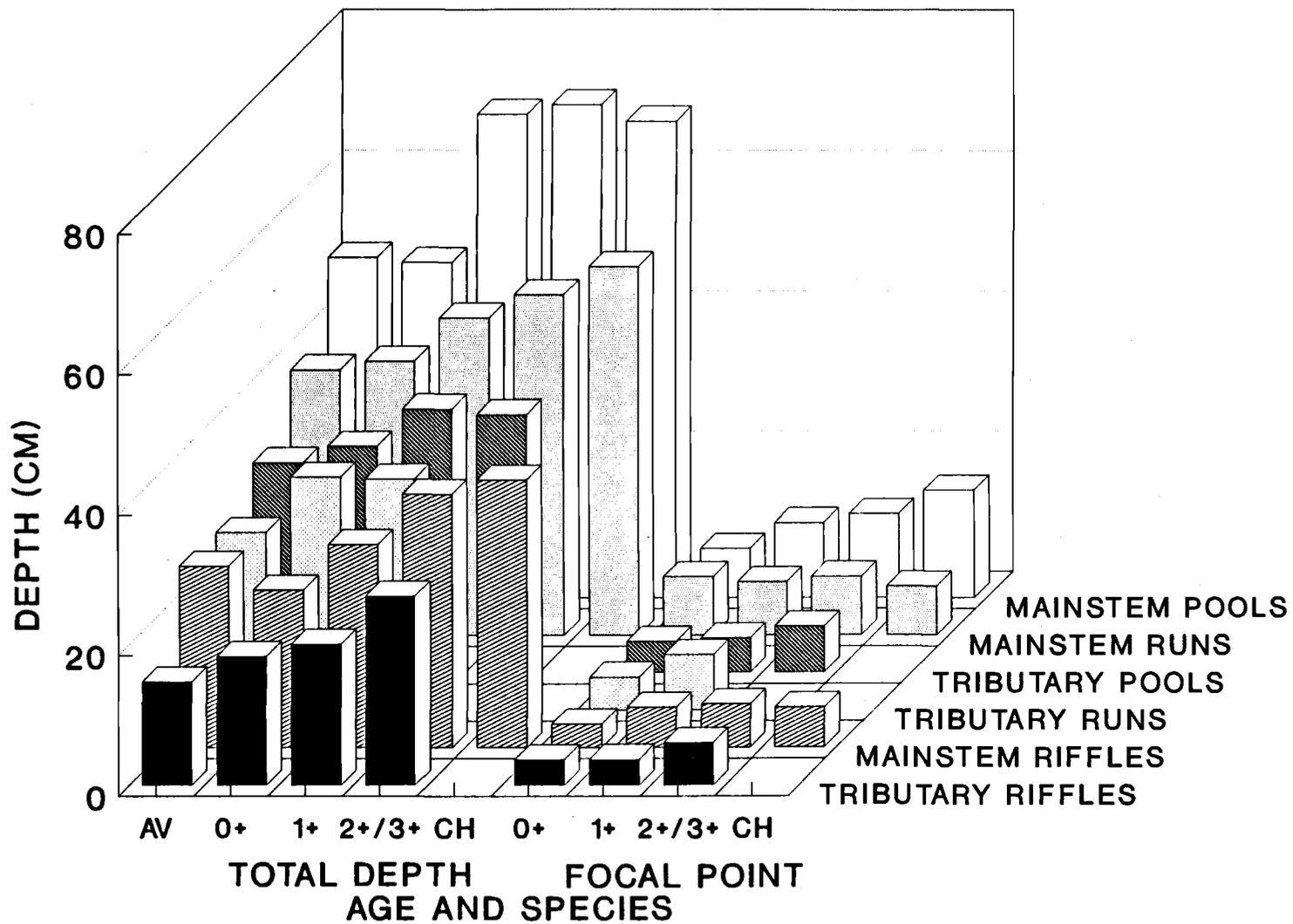


Figure 32. Total and focal point depths for all habitats. Selection vs. availability.

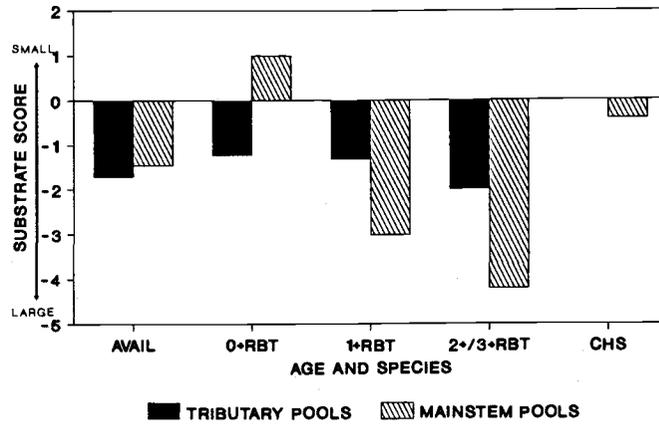


Figure 33a. Mean substrate scores for pools. Selection vs. availability.

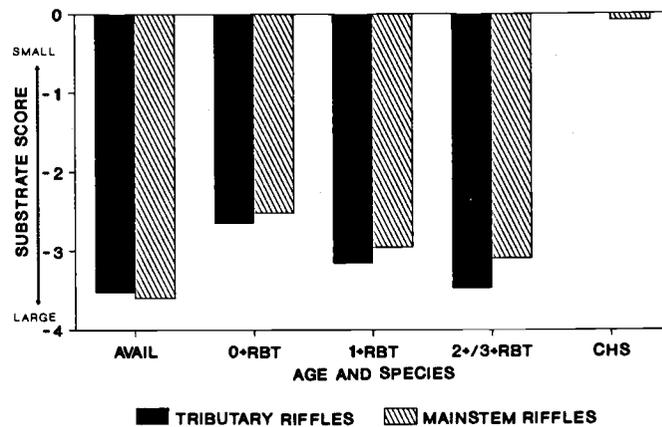


Figure 33b. Mean substrate scores for riffles. Selection vs. availability.

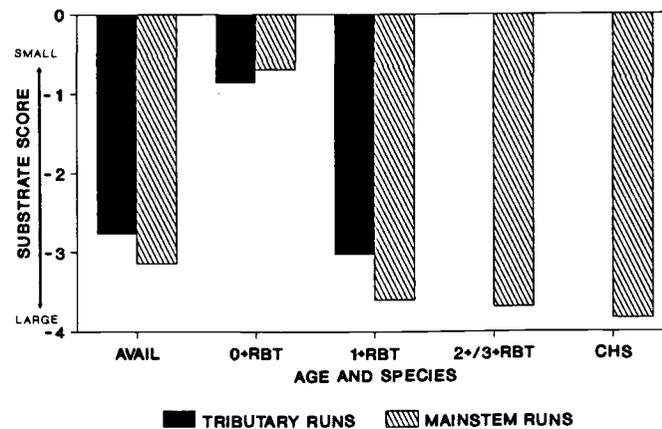


Figure 33c. Mean substrate scores for runs. selection vs. availability.

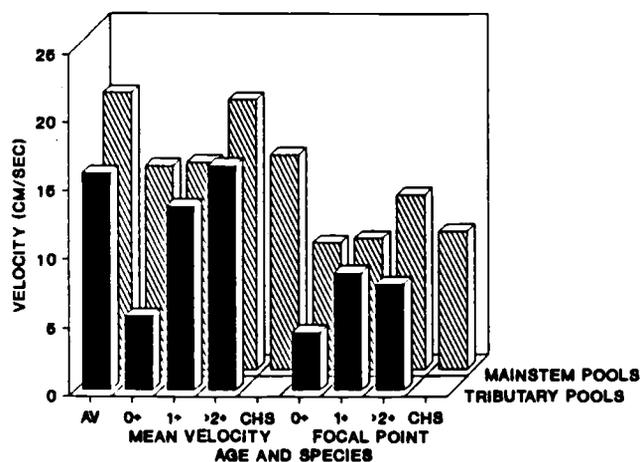


Figure 34a. Mean and focal point velocities for pools. Selection vs. availability.

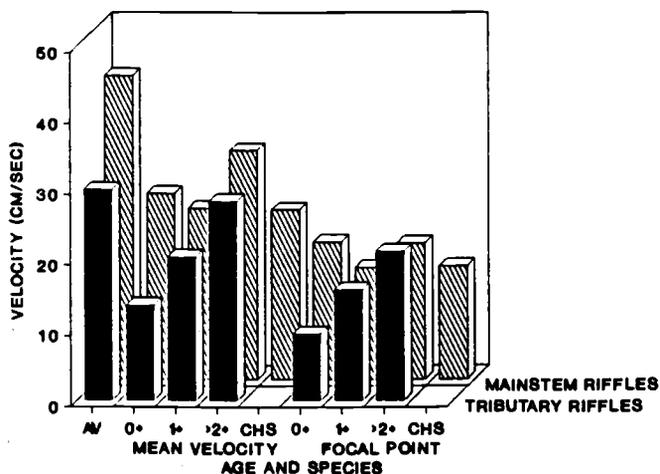


Figure 34b. Mean and focal point velocities for riffles. Selection vs. availability.

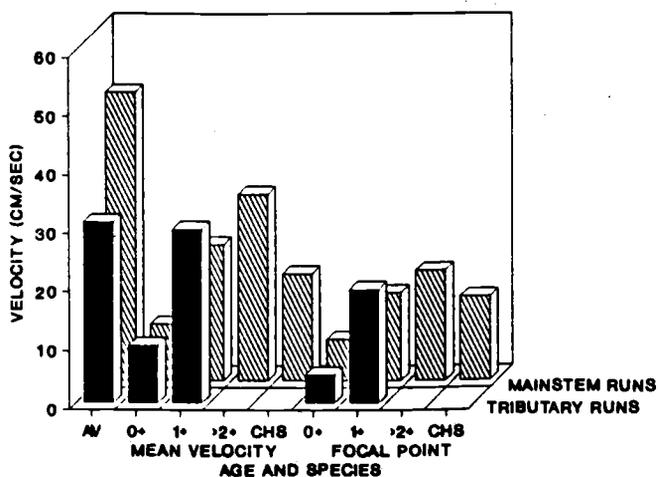


Figure 34c. Mean and focal point velocities for runs. Selection vs. availability.

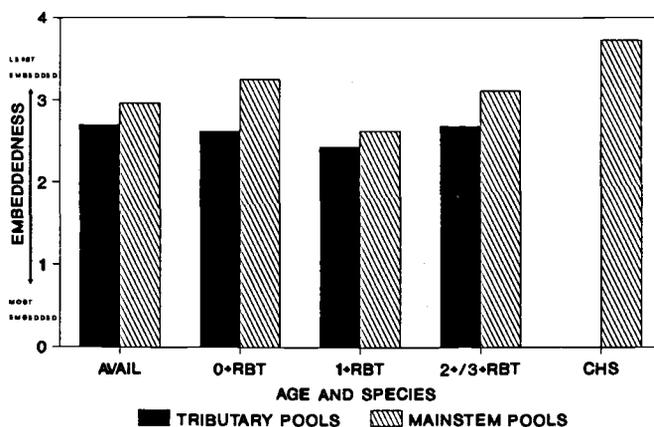


Figure 35a. Mean embeddedness ratings for pools. Selection vs. availability.

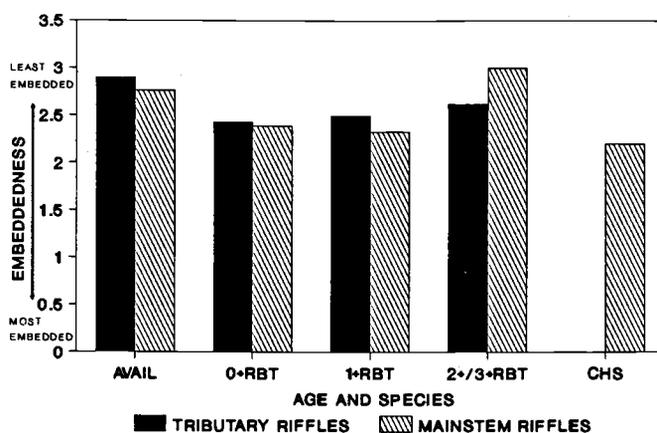


Figure 35b. Mean embeddedness ratings for riffles. Selection vs. availability.

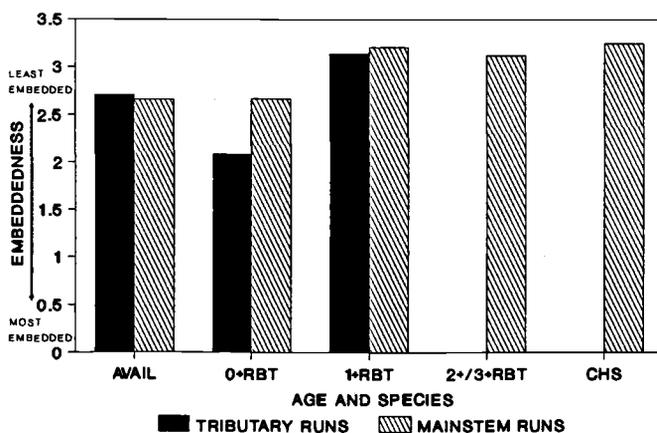


Figure 35c. Mean embeddedness ratings for runs. Selection vs. availability.

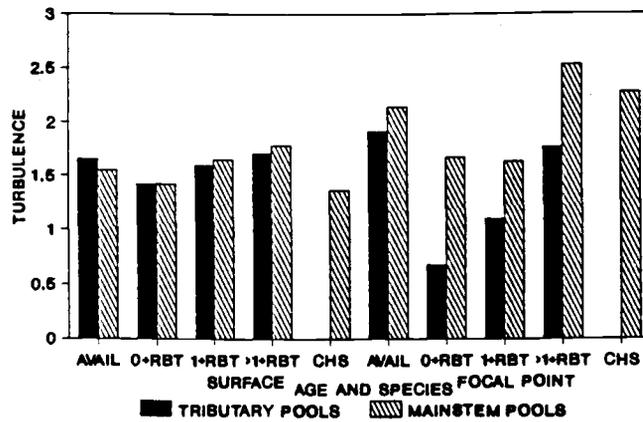


Figure 36a. Mean turbulence ratings for pools. availability.

Selection vs.

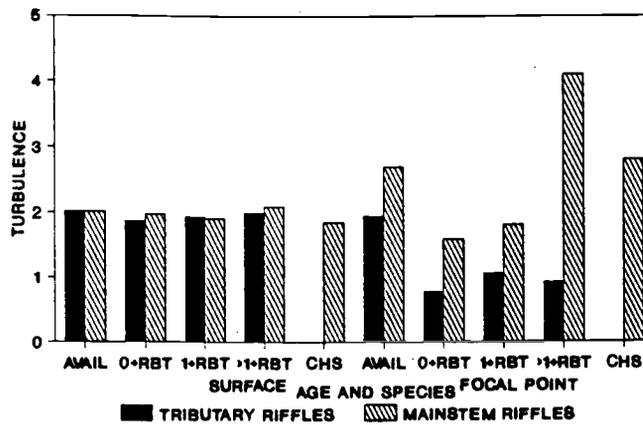


Figure 36b. Mean turbulence ratings for riffles. availability.

Selection vs.

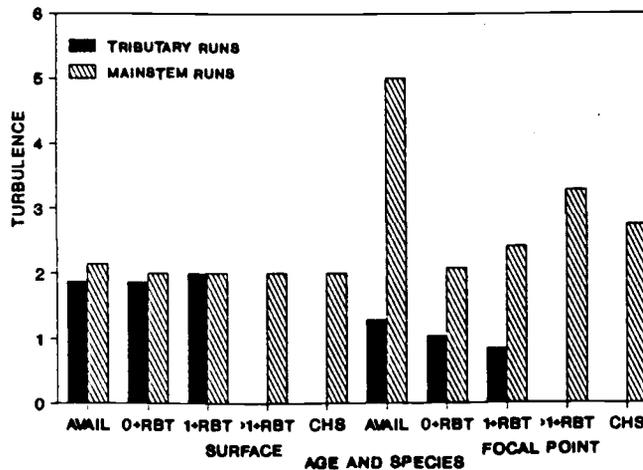


Figure 36c. Mean turbulence ratings for runs. availability.

Selection vs.

interspecific differences in microhabitat selection within a habitat type. These are similar to those shown by others (Everest and Chapman 1972; Chapman 1989). Microhabitat use was size dependent within a given habitat type (Moyle and Baltz 1985; Grossman and Freeman 1987). The mean and focal point depths and velocities increased as the size of the fish increased. There were also trends of increasing substrate size, surface and focal point turbulence with fish size but these differences were not significant.

Different species of similar size segregated vertically. The causal mechanisms for the observed differences are not easily explained. Present day competition between juvenile chinook and steelhead does not appear to be a factor (Everest and Chapman 1972). Grossman and Freeman (1987) also found that rainbow trout selected deeper water with size. They found no evidence of competition between two guilds of fish or within a guild, despite "high microhabitat overlap" within guilds. They concluded that this was most likely "a result of repeated adaptation to a common selective pressure . . . coupled with phylogenetic constraints on adaptive responses." Availability of food (Glova and Mason 1977; Fausch 1984; Grossman and Freeman 1987), predation (Angermeier 1987; Gorman 1987), and the structural diversity of the habitat (Cunjak and Green 1983) have been shown to be important microhabitat regulators. Also, one can not preclude competition between other species or competition between chinook and steelhead during their evolutionary history as possible reasons for the observed patterns. Smaller fish tended to stay in shallower water near shore where they could avoid larger fish predators and at a velocity that was conducive to finding food and allowing growth. As fish size increased, the fish move into deeper, faster water. This water probably offers protection from terrestrial predators (Everest and Chapman 1972; Gorman 1987; Chapman 1989).

Distance to nearby cover has been shown to be an important factor influencing microhabitat selection (Cunjak and Green 1983; Dolloff 1983; Angermeier 1987; Taylor 1988; Chapman 1989). This was not measured in this study. But snorkeling observations left the author with the impression that juvenile chinook salmon (especially in pools) were often in close association with some type of cover other than the substrate (e.g. undercut banks, woody debris, overhead cover). Steelhead were in close association with the substrate and no doubt used that as a form of cover. Chinook were not as close to the substrate as steelhead. Thus, that source of cover was not available to them, so they used whatever other cover was nearby. Despite being more of an "open water", schooling fish, cover was usually less than a meter away. Often, when snorkeling in the morning when water temperatures were cold, juvenile chinook were observed in very tight clusters in and around cover. Later in the day after water temperatures had increased, they had moved farther from cover and were actively feeding. When both chinook and steelhead were frightened, they darted to a very specific spot in cover, suggesting there are identified "safe zones" where the fish feel protected. The microhabitat variables for these zones may very well be different than at their daytime feeding locations.

These microhabitat differences were consistent between habitat types within streams and between stream types. Depth and velocity were the most important variables in most cases. The differences between mainstem and tributary habitats are mostly a reflection of the difference in availability of microhabitats between the streams. The main difference observed for YOY steelhead was between tributary and mainstem pools. They consistently selected shallower, slower water in the tributaries. This is most likely a reflection of increased reliance on edge and side channel habitats. These habitats were more abundant in the tributary streams and were

preferred by smaller fish. It may be these habitats are limiting in mainstem habitats and thus could limit YOY steelhead production in the major forks of the John Day River. Thus, these tributaries represent critical rearing areas for YOY salmonids (except chinook). The opposite is true for depth. The larger age classes selected shallower water and lower focal point depths in tributary habitats versus mainstem habitats. This reflects the fact that tributary habitats are shallower than the mainstem habitats, and suggests that if deeper water was available, it would have been selected.

The main variable selected for was focal point velocity. Velocity has been an important variable in most microhabitat evaluations (Shirvell and Dungey 1983; Fisher and Pearson 1987; Gorman 1987; Grossman and Freeman 1987; Ross et al. 1987). In all groups (except one due to low sample size), focal point velocity was lower than the mean velocity for that habitat type. This raises the question of the relevance of instream flow models such as the instream flow incremental methodology (IFIM). IFIM assumes that substrate, depth, and velocity are the most important determinants of habitat selection for fish. It also assumes that fish respond to these variables independently (i.e. that depth, velocity, and substrate are not correlated) and that the populations are unexploited and at carrying capacity (Orth and Maughan 1982; Mathur et al. 1985). This situation is very rare. These variables are used to calculate useable area for a given life stage in a given stream. Flow recommendations are made based on useable area (Bovee and Milhous 1978). IFIM was developed for small coldwater streams. Biotic factors (predation, competition etc.) are not considered (Mathur et al. 1985).

Substrate is assumed to be an important with IFIM. This was not the case in this study. Substrate was a significant variable in only four of 20 groups analyzed. The steelhead in this study were

found over substrate whose average size ranged from sand/silt/clay to large gravel and for the most part reflected availability, whereas Moyle and Baltz (1985) found rainbow trout selecting for predominately cobbles. This apparent lack of affinity for the substrate may be due to the averaging of the substrate scores to get a single score (thus masking any relationship), or it may reflect a lack of substrate diversity within these habitats. It is not clear at this time what the underlying reasons are, but I suspect the former because the substrate scores for the 1986 sites throughout the sampling area range from sand/silt/clay to cobble. On the other hand, the substrate scores for the microhabitat groups were all in the sand/silt/clay to large gravel sizes.

Fisher and Pearson (1987) and Gorman (1987) have found depth and velocity to be the most important variables. Substrate did not influence microhabitat selection. However, substrate was an important variable in other studies, usually in concert with depth and velocity (Gorman and Karr 1978; Finger 1982; Shirvell and Dungey 1983; Moyle and Baltz 1985; Grossman and Freeman 1987; Ross et al. 1987). Substrate may not be an appropriate measure for all streams and all species.

Depth and velocity have been shown to be correlated (Orth and Maughan 1982; Shirvell and Dungey 1983; Annear and Conder 1984; Mathur et al. 1985). This violates a major assumption of IFIM and results in "biased" minimum flow estimates. This study points out another erroneous assumption of IFIM. IFIM uses mean water column velocity as a variable fish select for. When in fact, fish select for a focal point velocity that is significantly lower than the mean water column velocity. This can also lead to erroneous flow recommendations. For instance, Annear and Conder (1984) state "In large streams (average flow greater than 100 cfs), boundary layer velocities (stream sides and bottom) may be a more important habitat

component for trout than mean column velocities. IFG-4 results in these streams show that higher flows are detrimental due to higher mean column velocities while in fact, boundary layer velocities may be within a preferred range. The model shows increased WUA at lower flows based on preferred mean column velocities and 'acceptable' depths. In all likelihood, this flow may result in either a reduction in cover (e.g. water depth, stream banks, overhead vegetation), reduction in water quality, or elevated water temperatures."

Other studies have shown reported that cover and food availability are important factors in microhabitat selection (Dolloff 1983; Angermeier 1987; Fausch 1984; Fisher and Pearson 1987; Grossman and Freeman 1987). These variables are not part of IFIM. But, a cover component is presently being investigated (Ted Bjornn, University of Idaho, personal communication). Temperature is another important factor for some species (Matthews and Hill 1979) that is not considered in IFIM. Temperature mediated competition has been shown between riffle sculpin (Cottus gulosus) and speckled dace (Baltz et al. 1982); redbreast shiners and rainbow trout (Reeves et al. 1987); redbreast shiners and chinook salmon (Chapman 1989).

Because microhabitat selection and the causal mechanisms responsible for that selection vary between species, different size classes of a species, between seasons, time of day, activity, streams, and may vary depending on other species present, food supply, temperature and flow regimes, I do not feel that IFIM can be used to accurately predict available habitat and thus minimum or optimal flows based on three physical habitat variables.

Microhabitat analysis may be an improvement on IFIM because it is based on a fishes preferences in a particular habitat, not on mean physical habitat measurements for a stream section. It also takes

into account the possibility that biotic factors (competition and predation) may be operating. Moyle and Baltz (1985) also feel habitat suitability curves for instream flow recommendations should be based on microhabitat data provided that:

- 1) "Suitability curves for habitat use should not be constructed from use data alone; they must be tempered with availability data, producing selectivity curves."
- 2) "Each instream flow study should use selectivity curves developed on site or in comparable sites nearby, to reduce variability caused by temperature differences, competitive interactions, and other factors."
- 3) "Suitability curves developed using standard methods (Bovee and Cochnauer 1977) should be used in conjunction with population data, so that curves can be evaluated in relation to the probable carrying capacity of the stream... Weighted useable area predictions may have no relation to population size for some species."
- 4) "Selectivity curves should not be limited to game species because interspecific interactions can have a strong influence on habitat selection." Changes in physical habitat characteristics "particularly temperature, may cause unexpected shifts in community composition."

Overall, the results obtained in this study concur with those of other researchers. Moyle and Baltz (1985) found that larger trout selected faster, deeper water than smaller trout. But, focal point depths were found to be similar within a species regardless of size. I found focal point depths varied with the size of the fish. In almost all cases, focal point depth increased with the size of the fish. However, these differences were rarely statistically significant. Only YOY steelhead in mainstem pools had a significantly lower focal point depth than all other steelhead in

the same pools. Each of the seven species Moyle and Baltz (1985) studied selected different microhabitats on the basis of depth, velocity, and substrate. But, there was a lot of similarity in the microhabitats as well. They made the observation that "microhabitat use by each species and size class may be quite different in years of low abundance from years of high abundance due to the effects of interspecific and intraspecific competition." They go on to state that "microhabitat use may vary within a species from one stream to the next reflecting not only availability, but also such factors as temperature regime, food supply, and presence of other species." On several occasions I observed acts of aggression between juvenile steelhead and speckled dace, and predation attempts by torrent sculpins on speckled dace.

Other researchers have found microhabitat analysis to be of limited use. Bozek and Rahel (1991) found that microhabitat analysis was useful for determining the specific locations in the stream channel (based on depth and velocity) where young cutthroat trout will be found. But, it did not guarantee that fish would be present or predict how many would be there. They found no relationship between density of young-of-the-year cutthroat trout and the amount of microhabitat. Their analysis at the macrohabitat level (i.e. pool, riffle, and run; which I have termed mesohabitats) did reveal that young cutthroat trout densities were positively correlated with the amount of spawning gravel and negatively correlated with depth. They concluded that the abundance of macrohabitat not microhabitat is more important in regulating young cutthroat trout densities. Bayley and Li (in press) feel that larger environmental units (e.g. mesohabitats such as pools, riffles, and runs) limit the quantity and quality of the smaller units (e.g. microhabitats). Microhabitats are the smallest habitat units and thus are less stable and occupied for the least amount of

time. Because of this, they feel that larger more stable habitat units (e.g. pools, riffles, and runs) may be a more appropriate scale for assessing habitat requirements, evaluating assemblage structure or densities etc. of a particular species.

Several problems with my research were that the microhabitat data were collected one summer, and although data were collected on a variety of streams and habitat types, there was insufficient data to analyze microhabitat use for each species and age class by individual stream and habitat type. Therefore, the data were combined into mainstem and tributary groups. This might mask between stream differences. However, a cursory examination of the data did not reveal any major differences in microhabitat use between tributary streams or between mainstem rivers.

The limitations of this study are that:

- 1) Microhabitats were measured in only one year in a limited number of streams and habitat types.
- 2) Microhabitats for all the species in the assemblage were not measured.
- 3) Cover and diets were not determined.
- 4) Measurements were taken only during daylight hours when the fish were actively feeding. They were not taken at night, during any other season or during any other activity.

It seems clear that there was active resource partitioning among these fish. Whether this was due to the ghost of competition past (Connell 1980), "adaptation to common selective pressure coupled with phylogenetic constraints on adaptive responses" (Grossman and Freeman 1987), genetic (Everest and Chapman 1972), or a response to local food supplies (Werner and Hall 1979; Fausch 1984) has not been determined and was beyond the scope of this study.

CONCLUSIONS

Fish assemblages in the upper John Day basin were aligned primarily along a stream size/elevation gradient, and secondarily by a riparian habitat/bank condition gradient. A "warmwater" assemblage dominated the lower portions of the drainages while a "coldwater" assemblage dominated the upper reaches. The coldwater assemblage had two components: the chinook component, and the steelhead component. The chinook component was concentrated in the mid elevation reaches of the Middle Fork and the upper mainstem of the John Day River. The steelhead component was concentrated in the tributaries and headwaters of all three drainages. Often, the larger age classes of steelhead were in closer association with the chinook component or the warmwater assemblage.

In general, the riparian habitat/bank condition improved as one moved up the drainages toward the headwaters. This suggests that if the riparian areas were improved farther downstream, the coldwater assemblage may also enlarge.

Although it may appear as though deterministic factors were responsible for the observed assemblage structure, it is premature to conclude this. In order to accurately determine the factors responsible for structuring fish assemblages one needs long term basin wide studies that include a wide variety of environmental conditions, and take into account the migratory behavior of the fish, the history of the basin, human impacts, and a riparian habitat successional time scale (Li et al. 1987). This study was only for two years, did not take into account the migratory range of the fish, did not look at all the human factors that could affect the observed structure (e.g. commercial and sport harvest of salmonids, irrigation withdrawal, mortality of juveniles and adults at the downstream dams etc), and did not look at all the seasons of

the year. The observed assemblages and the microhabitats used by the salmonids is most likely the result of both deterministic and stochastic factors. Because the two years of this study had similar flows (both were low but not catastrophic), adult steelhead and chinook run sizes and the habitat was stable between years, one would expect the assemblage structure to be similar between years.

There were differences in microhabitat use between the various groups of juvenile steelhead trout and chinook salmon within a habitat type. The most common significant variables were mean and focal point depths and velocities. But, there was very little difference in microhabitat use for a particular age class or species between habitat types. There was usually a trend of increasing total and focal point depth, and decreasing mean and focal point velocities from riffles to runs to pools in both mainstem and tributary streams. There were few differences in microhabitat use between stream types. YOY steelhead were in faster water in mainstem habitats, age 1+ steelhead were in deeper water, and age 2+/3+ steelhead were in deeper and faster water in mainstem habitats. The differences observed between habitats and stream types were most likely a reflection of availability, and not a real difference in microhabitat use (with the exception of focal point depth and focal point velocity).

There was definite microhabitat selection by all groups. But, not all groups selected for the same variables. The most important microhabitat variables were focal point depth (selected for by all 20 groups), focal point velocity (selected for by 19 groups), total depth (selected for by 12 groups), and mean velocity (selected for by 10 groups). The other variables were selected by just a few groups. These were likely to be artifacts of selecting for other factors. Generally, a particular salmonid age group selected similar microhabitats based on depth and velocity, regardless of

stream size or habitat type. The different groups did orient differently to those variables (e.g. YOY steelhead selected shallower and slower water than age 2+/3+ steelhead).

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APPENDIX

Appendix. Key to the interpretation of the values of various riparian habitat variables.

Streambank Soil Alteration Rating:	Level of alteration increases with the value.
Vegetative Stability:	Stability increases with the value.
Vegetative Use:	Use increases with the value.
Bank Cover:	Cover improves with the value.
Embeddedness:	Embeddedness decreases as the value increases.
Substrate:	Substrate size increases as the value decreases.
Bank Angle:	Bank angle decreases (i.e. more undercuts) as the value increases.
Streamshore Depth:	Depth increases as the value increases.
Bank Undercut:	The amount of undercut increases with the value.
