Thomas Creek Mainstem Assessment Completion Report

OWEB Project Number 200-089

Prepared for the South Santiam Watershed Council

By

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Description

This project expands upon a year 2000 project (OWEB 99-543) that was designed to examine riparian and water quality impacts on aquatic invertebrate assemblages and fish diet in Thomas Creek. The initial project design was to sample water quality, fish, and invertebrates at nine sites along 30 river kilometers (R kms) of the stream; three in conifer dominated, three in mixed forest, and three in hardwood dominated riparian forest. Preliminary results suggested water quality conditions were similar throughout the 30 R kms and riparian vegetation composition was not associated with fish diet or invertebrate assemblage composition. Longitudinal patterns were weak and appeared to be driven by three upstream sites. Therefore we proposed to expand the survey area to include the entire stream open to anadromous fish migration (51 R kms). The fish diet portion of the project was discontinued because we were denied a sampling permit for ESA listed salmonids during 2001. Instead, we focused on broad-scale fish distribution and habitat use. Additionally, we compared patterns for fish with invertebrates. The extent of fish, invertebrate, and water quality sampling locations increased to include all 51 R kms downstream of the waterfall. An extensive fish survey to examine fish distribution included 218 survey locations throughout the 51 R kms. Intensive snorkel surveys to examine fine-scale, habitat use by salmonids included four sample locations in the upstream 14 R kms. Invertebrate samples were collected from three habitat types at 27 sites to examine distribution and habitat use along the 51 R kms.

Material & methods

During six days in May 2001, two people in an inflatable kayak floated the entire 51 R kms. During the float, we noted general stream, riparian, and upslope characteristics, and surveyed riparian transects at every river kilometer using more precise techniques. We delineated reach types by using 28 stream and riparian variables collected at 51 riparian transects. Transects were 15 m *x* 50 m plots on the right and left stream banks at each river-kilometer 1 through 51. Stream and riparian variables measured in the transects included percent cover of seven vegetation types, dominant vegetation height, valley width, bank slope and height, terrace slope and height, and presence of roads in the riparian zone. Cluster analyses (by group average and Ward's method) of riparian transects in Thomas Creek failed to produce a logical pattern of reaches. Although, we expected adjacent transects to have similar characteristics and cluster together to form distinct reaches, groups were generally small and included transects from throughout the stream. Adjacent transects did not cluster at even the broadest scale (e.g. segment). Therefore, we separated the stream into nine reach types using general characteristics and distinct changes in stream, riparian, and upslope conditions (Table 2.1). Elevation, valley width, valley slope, stream order, and sinuosity were calculated using 7.5-minute USGS topographic maps. Sinuosity was calculated for each R km, reach, and segment by measuring the channel length between the two end points and dividing it by

Table 2.1. Riparian and stream characteristics at each reach.

		Dominant Substrate	Rkm	Sinuosity	Valley Width	Riparian Vegetation	Upslope Vegetation
Falls Segment	Reach 1	Boulder / Large Cobble	51-46.5	0.97	< 250m	Conifer	Conifer logged ~1985
	Reach 2	Bedrock / Cobble	46.5 - 45	0.94	< 100m	Conifer	Conifer
	Reach 3	Cobble	45 -42.5	0.96	< 250m	Old-growth conifer / some deciduous	Conifer logged ~1985
	Reach 4	Cobble / Gravel some Bedrock	42.5 - 38.5	0.90	250-1000m	Even mix Conifer and deciduous	Agriculture corn / grass seed
Middle Segment	Reach 5	Cobble / Gravel	38.5 - 30	0.95	500-1000m	Deciduous/ agriculture	Agriculture/ grass seed
	Reach 6	Cobble / Gravel	30 - 27	0.91	< 500m	Even mix Conifer and deciduous	Deciduous/ conifer
	Reach 7	Cobble / Gravel	27 - 7.5	0.96	> 1500m	Deciduous/ agriculture	Agriculture/ grass seed
Mouth Segment	Reach 8	Gravel	7.5 - 4.5	0.86	> 1500m	Deciduous/ occasional conifer	Agriculture/ grass seed corn
	Reach 9	Gravel	4.5 - 0	0.88	> 1500m	Deciduous/ agriculture	Agriculture/ grass seed, corn, grazing

the straight-line distance between the same two points. In addition to nine reaches, we identified three distinct stream segments that coincide with the end of conifer dominated upland and riparian forests (ca. R km 38) and after the stream flows through the town of Scio, Oregon (ca. R km 7.5) (Figure 2.1). I will refer to these as the Falls segment (waterfall through the region of conifer riparian dominance, ca. 13 R kms), Middle segment (from the region of conifer riparian dominance to Scio, ca. 30 R kms), and the Mouth segment (from Scio to the stream mouth, ca. 7.5 R kms) (Figures 2.1 & 2.2).

Survey units for fish and invertebrate surveys were classified as one of three habitat types, that were defined as riffles (broken water surface less than one meter deep), glides (non-broken water less than one meter deep), or pools (any water deeper than one meter). Survey units were delineated at the point where conditions clearly changed (e.g. water surface became broken, the bubble curtain ended, depth reached 1 m). Forty-four survey units that contained no fish were removed from the statistical analyses; no survey units sampled for invertebrates were empty. Although an argument could be made that units without fish provide valuable information, statistical methods we used for analyses were not compatible with empty units. Because no fish groups occurred in less than 5% of the units, we included all fish groups in the analysis.

Sites within reaches were not at identical locations for fish and invertebrates, but the same general criteria were required. Survey sites consisted of at least three adjacent survey units and included one riffle, glide, and pool. Because sites were not selected prior to the initial longitudinal fish survey, 27 fish sites were randomly selected from the original 218 survey units, empty units were excluded whenever possible. For the invertebrate survey, 27 sites (three per reach) were randomly selected from a pool of approximately 50 sites (limited by physical access and permission). Sites were generally between 100 and 300 meters in length.

Fish sampling

During summer 2000, electroshocking and seining for fish proved inefficient because of deep water and low conductivity in Thomas Creek. Therefore, we used snorkel surveys to count fish in 2001. Data were recorded with a waterproof handheld computer. Because juvenile cutthroat (*Oncorhyncous clarki*), and juvenile steelhead and resident rainbow trout (*O. mykiss*) are difficult to differentiate during snorkel surveys, these species were combined into one group called Trout. Based on frequency analysis of 300 trout captured for diet studies on Thomas Creek in the year 2000, trout age classes were defined as Age 0 (<75 mm fork length), Age 1-2 (100-125 mm fork length), Age 3 and greater Trout (>145 mm fork length).

We used an extensive downstream survey to enumerate fish at whole-stream, segment, reach, and site scales (Figure 2.2). During 12 sampling days between June 19 and July 10, 2001, we systematically surveyed 218 channel units in the study section of Thomas Creek. Depending on channel unit lengths and frequencies within a reach, survey units were systematically selected for

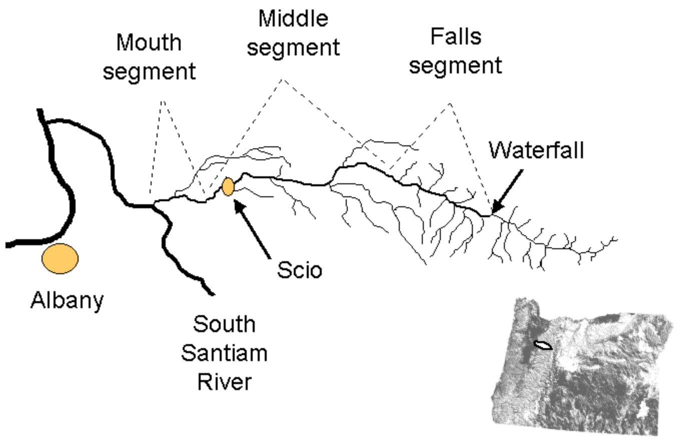

Figure 2.1. A stream outline of Thomas Creek, Oregon.

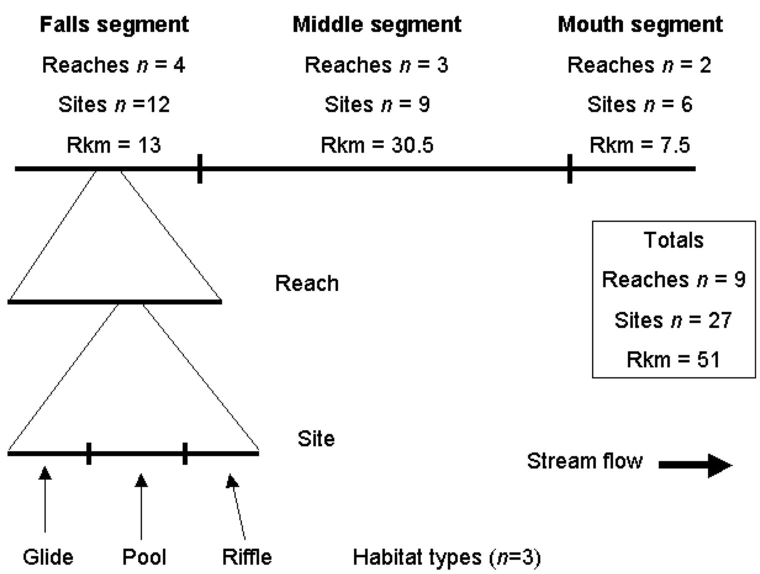

Figure 2.2. Scales of study. The number of Reaches, Sites, and Rkm's within each segment are listed.

every third, fourth, or fifth unit within habitat types. For example, we sampled every fifth riffle in reaches with short, frequently occurring riffles or every third riffle in reaches with long, infrequently occurring riffles. This approach maximized the number of units surveyed, minimized survey time, and kept the habitat type area surveyed generally equal across different reach types.

Within each survey unit, a team of two snorkelers swam downstream (side-by-side) and recorded abundances (specific counts whenever possible, and estimates of small numerous fish) of all non-benthic fish species or size classes observed. Fish groups included Age 0 Trout, Age 1-2 Trout, Age 3 and greater Trout, juvenile chinook salmon (*O. tshawytscha*), mountain whitefish (*Prosopium williamsoni*), adult largescale suckers (*Catostomus macrocheilus*), juvenile largescale suckers, northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), and redside shiners (*Richardsonius balteatus*). Channel unit characteristics were described concurrently and included unit length, width, and estimated minimum, maximum, and mean thalweg, and large wood volume. Concentrations of each fish group within their distribution range were determined by plotting within group relative densities.

To examine the influence of water temperature on fish distribution, counts for all fish species were combined into thermal tolerance groups. All salmonid species were considered cold-water species and all other fish species were considered cool-water species (Zaroban et al. 1999). To clarify fish density trends, moving averages were calculated by averaging density values from the fifteen adjacent survey units. Moving averages were calculated from total densities and relative densities within each survey unit, for cold and cool-water species. Redside shiner densities from three survey units in the Mouth segment were especially influential to density trends and were removed.

To assess salmonid habitat use at finer scales (e.g. habitat unit and subunit), intensive upstream snorkel surveys were performed in the four farthest upstream reaches during July and September 2001. We selected one location within each reach. At each location, we required a minimum of three survey units for each habitat type, resulting in at least nine survey units per reach. The length of the surveyed area depended on the number and length of habitat types and ranged between 350-700m. Each unit was separated into habitat sub-units, which were defined as a unit head (upstream 25% of the unit), unit body (middle 50%), and unit tail (downstream 25% of the unit). Prior to snorkel surveys, boundaries were marked on the stream bottom using colored flagging to maintain consistency during repeated trails. During each survey, two snorkelers (side-by-side) moved slowly upstream recording abundances for each fish group in each habitat sub-unit. Care was taken to avoid double counting fish. Each site was snorkeled on three consecutive days. During July, each site was snorkeled once in the morning (at approximately 9 am) and once in the afternoon (at approximately 3 pm). After repeated measures ANOVA suggested no significant difference between morning and afternoon surveys, counts for the final analyses were averaged from all passes. Twice-a-day surveys were continued during September, until it was determined that there was no significant difference between morning and afternoon surveys, after which only morning surveys were performed.

Channel characteristics measured in each habitat sub-unit included unit length, wetted width, mean depth, and substrate sizes. Unit lengths and widths were measured at a line perpendicular to the stream channel; the line was estimated as an average if the end of the unit was not perpendicular to the channel. Characteristics were measured at seven transects (two in the head and tail and three in the body) perpendicular to the stream channel (Figure 2.3). Each transect consisted of seven points where depth was measured and substrate was classified. Substrates were estimated as bedrock, large boulder, small boulder, large cobble, small cobble, course gravel, fine gravel, sand, and silt, based on a modified Wentworth scale (Wentworth 1922). The measurement points were approximately equidistant from each other including one in the thalweg. Categorical stream flow was recorded for the entire subunit by estimating whether a majority of the flow was: very slow (no visible water movement), slow (slight visible water movement), moderate (currents visible on the water surface but surface not broken), fast (broken water surface), and very fast (broken water surface with bubbles visible under water). Volume was estimated for large wood (>10 cm in diameter and > 1 m in length) with categories defined as: none (no large pieces), low (1-3 large pieces), med (4-5 large pieces), and high (> 5 pieces).

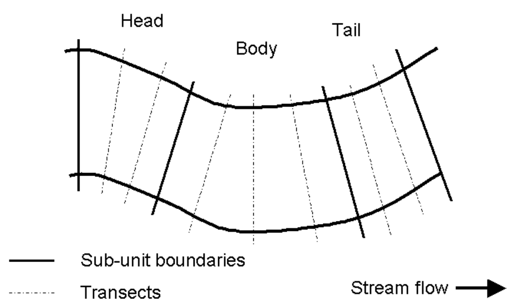

Figure 2.3. Example habitat unit for the upstream intensive snorkel survey. Channel characteristics are measured at each transect.

Manly's Index (MI) (Chesson 1978; Manly et al. 1972) was used to assess fish habitat electivity. Manly values range from zero to one, with zero indicating no use and one indicating exclusive use of that particular habitat. Within each reach, this index indicates the proportion of fish (0-100%) found in a particular habitat type in relation to its availability. A Manly value was calculated for each fish group in each habitat (*m*=4) and sub-habitat (*m*=9) type in each reach.

Manly's Formula:

$$\alpha_i = \frac{r_i / n_i}{\sum_{j=1}^{m} r_j / n_j} \qquad i = 1, 2, \ldots, m$$

α_i = preference for an *i*-th sub-unit type

r_i = proportion of the *i*-th sub-unit type in cells used by fish

n_i = proportion of the *i*-th sub-unit type in cells available

Within habitat types, habitats can be further divided by stream velocity (Inoue and Nunokawa 2002). Because we did not measure current velocity, we attempted to differentiate pools by the habitat type directly upstream. Pools that were directly downstream of riffles or glides were defined as Riffle/pools and Glide/pools respectively. Mann-Whitney U tests were used to test for electivity differences between Riffle/pools and Glide/pools, as well as between habitat sub-units within habitats (e.g. head, body, and tail within Riffle/pools). Density data were log transformed to provide for homogeneity of variances.

Invertebrate sampling

Invertebrate samples were collected from 27 sites during May 2001, with a surber sampler modified for deep water with 0.135 m^2 enclosed sample area (500 micron net). The surber was placed randomly (longitudinally and laterally within each survey unit) on the stream bottom and the substrates within the surber area were disturbed to approximately 10 cm depth for one minute. At each site, two samples were collected within each habitat type (e.g. riffle), transferred to 95% ethanol, and transported back to the laboratory for sorting and microscope identification. Invertebrates were identified to the lowest reasonable taxonomic resolution: genus in most cases, occasionally family or species, and tribe for the family Chironomidae (Merritt and Cummins 1996). Invertebrate taxa were classified by functional feeding group (FFG), if feeding characteristics are known (Merritt and Cummins 1996). Taxa tolerance values were assigned to each family or genera (Mandaville 2002). Because tolerance can vary for species within a genus, we assigned the most conservative value listed for each genus or family. Values of 0 indicate the least tolerance for organic pollution and values of 10 indicate the most tolerance. After identification, the two samples from the same habitat within a site were combined to make one sample per habitat type per site.

At the point of each surber sample, depth was measured, and dominant and sub-dominant substrates were recorded. Estimates were done using the same substrate size and velocity classifications as for the fish survey.

Statistical Analyses

Outlier analysis was performed by examining a frequency distribution of average Sørensen distances between assemblages from each survey unit and all other survey units in fish or invertebrate species space. All survey units with greater than three standard deviations from the mean distance, frequency distribution were removed from analyses (McCune et al. 2002). Outlier analysis was performed at each scale with outliers removed for subsequent analyses at that scale. Three, two, and eight survey units were outliers for fish assemblages the Falls, Middle, and Mouth segments, respectively. The standard deviations of removed units ranged from 3.0 to 5.8 from the mean distance frequency distribution. Invertebrate outliers were not greater than 2.7 standard deviations from the grand mean and were not removed.

Data were analyzed as hierarchically averaged composite samples, which were samples averaged within habitat types at each scale. For example, a reach-scale riffle composite sample was an average of all individual riffle samples within that reach. This was done to reduce variability of notoriously patchy invertebrate data (Li et al. 2001) and clarify ordination patterns.

Non-metric Multi-response Randomized Block Permutation Procedures (MRBP, PC-ORD version 4.20), were used to examine differences in assemblage structure between habitat types. MRBP is similar to Non-metric Multi-response Randomized Block Permutation Procedures (MRPP;(Mielke 1984), except it is modified for blocked sampling designs to reduce location effects. In non-metric MRBP the distance matrix is converted to ranks before the test statistic is calculated. (See (Zimmerman et al. 1985) for a description of MRPP). Assemblages consisted of abundances (for invertebrates) or density (for fish) values for each taxon in each sample (individual or hierarchically averaged). Tests for differences between habitat types were conducted at the stream segment scale (7.5-30.5 R km), stream reach scale (1.5-7 R km), and stream site scale (100-300 m). MRBP was also used to test for differences in assemblage structure between stream segments and reaches. *P*-values less than 0.05 suggest a significant difference between groups or treatments. *A*-values express within-group agreement and values of 1.0 indicate all samples within a group (e.g. riffles from the Falls, Middle, and Mouth segments) were identical. Values greater than zero indicate groups were more similar than expected from random chance, and values less than zero indicate groups were less similar than would be expected by random chance. *A*-values less than 0.1 are common; values greater than 0.3 are rare in ecological research and are considered to be exceptionally similar (McCune et al. 2002). However, low numbers of taxa types can inflate *A*-values, which may have occurred in my fish analyses. Because there is only one sample per habitat type, MRBP cannot be performed to test for differences between sites. However, *A*-values for tests between habitat types indicate similarities between site samples within habitat types.

Non-metric Multidimensional Scaling (Kruskal 1964; Mather 1976) (NMS, PC-ORD version 4.20) was used to describe assemblage differences between habitat types and survey locations at all scales. NMS is one of the most robust and defendable ordination techniques currently available for community data. It is robust to non-normal distributions and relieves zero-truncation problems commonly found in heterogeneous community data (McCune et al. 2002). Additionally, it can be consistently applied to data sets that vary in the number of attributes across sample units (i.e. 205 invertebrate taxa versus 10 fish groups) (Faith and Norris 1989).

Data were analyzed using the "slow and thorough" autopilot settings of PC-ORD (version 4.20) and Sørensen's distance measure. Sørensen's distance measure was used because it is one of the most effective techniques available for measuring similarity between samples (McCune et al. 2002) and is robust to long environmental gradients (Beals 1984). Final configurations were limited to three dimensions. Stress of ordination solutions is an inverse measure of how well the data fits the solution, and it was used to determine dimensionality of the solution. A significant decrease in the amount of stress when solution dimensions are increased indicates a significant increase in variation explained by the solution (Faith and Norris 1989). In order to compare ordinations, each was rotated so that longitudinal position was along axis 1. Individual r^2 was calculated for each axis to determine the amount of variation in the data explained by that particular axis. Pearson's correlation coefficients were calculated (bi-plots) for quantitative environmental variables and taxa types with each axis. Significant relationships and categorical environmental variables were used to characterize patterns of biological assemblages in each ordination.

Data were analyzed as individual sites and as hierarchical averages. Analyses at each scale were performed with one sample from each habitat type at each location for a total of 81, 27, and 9 samples for sites, reaches, and segments, respectively. For example, Site 1 consisted of one pool sample, one glide sample and one riffle sample. Within Reach 1, Sites 1, 2, and 3 were hierarchically averaged so that Reach 1 assemblages consisted of one pool sample, one glide sample and one riffle sample. A total of 205 identified invertebrate taxa and 10 fish groups were used in the analyses. Hierarchically averaged fish assemblages produced poor results and were generally uninformative. NMS produced 1-dimensional and 2-dimensional distorted ordinations at the segment and reach scales respectively. Because one-dimensional or distorted solutions are uninformative and/or unreliable in NMS, these ordinations will not be included (McCune et al. 2002). However an ordination of fish densities averaged across habitat types within each site was informative and included in the results.

Indicator Species Analysis (ISA) (Dufrene and Legendre 1997), PC-ORD version 4.20) was used to describe compositional differences between stream segments, reaches, and habitat types for both fish and invertebrates. Indicator values are calculated by combining abundance for each taxon in a particular group with the faithfulness of that taxon to occur in that group. For each taxon, the indicator value is tested for statistical significance with a Monte Carlo randomization technique. We used density data with 1000 Monte Carlo randomizations in each trial to find indicator taxa for fish and invertebrates at each scale and habitat types.

Results

Water temperatures peaked in early August at 15.5°C near the falls and 29.5°C near the mouth. During the September surveys, water temperatures ranged between 12 and 16°C, with the coolest temperatures in the upstream reaches (Figure 2.3). The elevation profile of Thomas Creek is gradual with an average elevation increase of 12.9 m, 4.2 m, and 1.5 m per river kilometer in the Falls, Middle, and Mouth Segments respectively (Figure 2.4).

Based on data from the longitudinal fish survey, a plot of relative fish densities clearly illustrates an upstream salmonid assemblage and downstream non-game fish dominated assemblage (Figure 2.5). During the study period, 74 percent of the salmonid population in the study section were observed in the Falls segment (R kms 51-35). When we grouped fish according to thermal tolerances (Zaroban et al. 1999), total densities reveal a strong

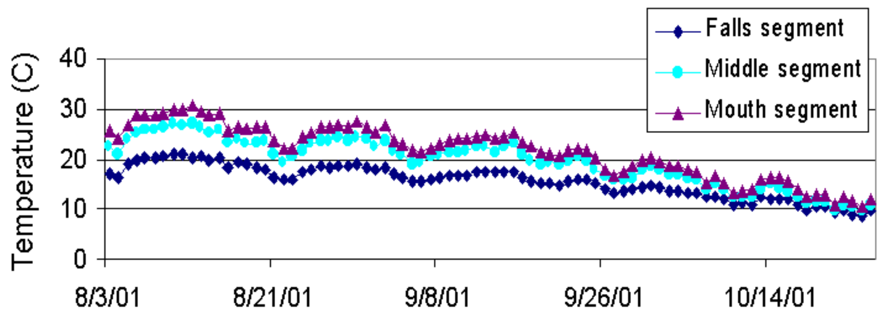

Figure 2.3. Maximum daily stream temperatures at one site in each segment. Temperatures were recorded between August 3 and October 25, 2001. These dates captured the annual maximum temperature and temperature profiles from other loggers in the stream during the same time period followed similar patterns

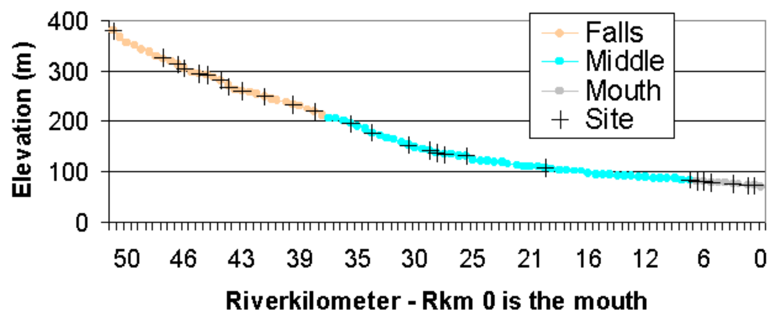

Figure 2.4. Elevation profile of Thomas Creek within the study section. Segments are denoted by color and sites locations are indicated by the addition symbol (+).

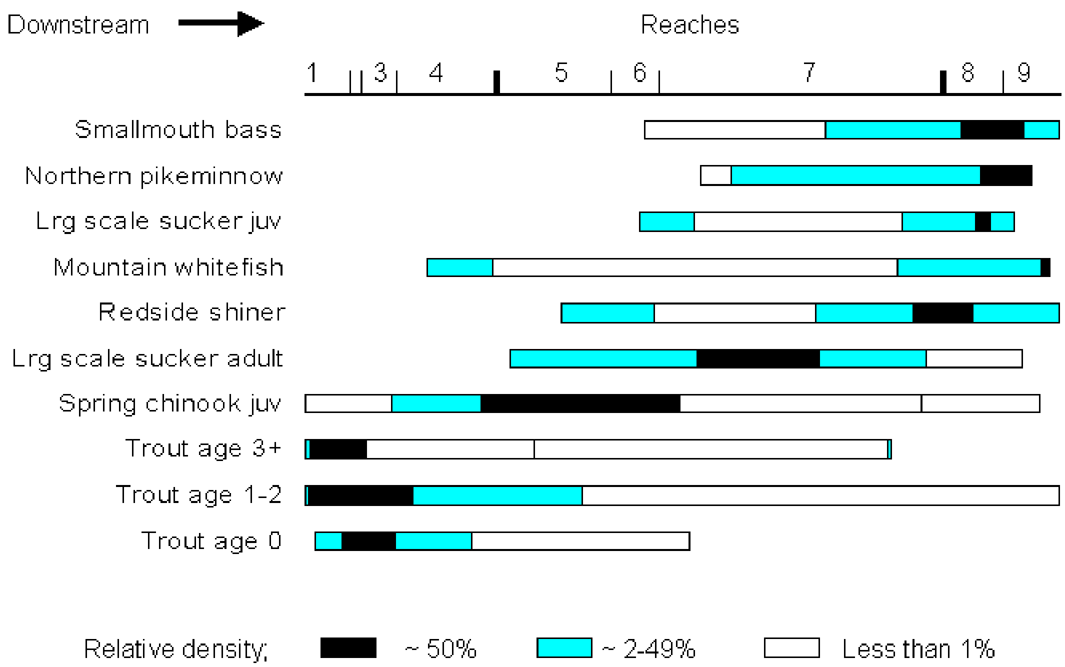

Figure 2.5. Thomas Creek fish distribution based on relative densities. The entire study section is 51 Rkms and reach numbers are listed on top of the figure. Breaks between segments are indicated by wider lines between reach numbers.

upstream/downstream pattern with a depauperate zone in-between (Figure 2.6). A breeched dam is at R km 31 and we observed a fish density increase (relative to surrounding survey units) associated with this structure. The Middle segment, described as depauperate, had the greatest number of empty units (Table 2.2) and the lowest fish densities and richness (Tables 2.3 & 2.4). Channel characteristics in the Middle segment appeared to be intermediate to Falls and Mouth segments. Pool lengths were shortest and riffles were longest in the Falls segment, while pools were longest and riffles were shortest in the Mouth segment (Table 2.4a). However, comparisons of survey units with and without fish revealed significant differences ($p<0.05$) between unit lengths and widths (Table 2.5). Empty riffles were shorter in the Middle segment and empty glides were wider than their counterparts with fish in the Falls and Mouth segments.

During upstream intensive surveys of the four Falls segment reaches, Age 0 Trout were the only fish group to exhibit a longitudinal pattern. The downstream decrease in density in this group correlated with R km (Pearson's r = 0.79) and elevation (r = 0.87) (Figure 2.7). During July and September, Manly Index values indicate that within reaches, all fish groups strongly selected for the same habitat types during both seasons. Therefore, we present average values among fish groups within reaches by habitat type and subunit type. The Manly Index values, at the habitat unit scale, indicate all salmonid groups selected for pool habitats with riffles directly upstream (Riffle/pools) in Reaches 1-3 and select for riffles and pools with glides directly upstream (Glide/pools) in Reach 4 (Table 2.6). At the sub-unit scale, all salmonid groups most strongly select for pool heads in Reaches 1-3 and 4, followed by Riffle/pool bodies in Reaches 1-3 and riffle tails in Reach 4 (Table 2.7). Age 1-2 Trout, Age 3 and greater Trout, and juvenile chinook selected for Riffle/pool heads and Age 0 Trout, Age 1-2 Trout, and juvenile chinook selected for Riffle/pool bodies significantly more than Glide/pool heads and bodies ($P<0.05$)(Table 2.8). There was no significant difference in selectivity between Riffle/pool and Glide/pool tails (Table 2.8). Although Reach 4 habitat selectivity differed from Reaches 1-3, as a whole Riffle/pools were selected for significantly more than Glide/pools for all fish groups (Mann-Whitney U, $P<0.05$)(Table 2.8).

Between July and September, we observed increased numbers of chinook and lower numbers of Age 0 Trout in all reaches. During this interval, total and pool survey area decreased for all reaches with the greatest changes occurring in Reaches 2 and 3 (Table 2.9). The least decrease in abundance for Age 0 Trout was in Reach 1; for all other fish groups the greatest increases were in Reach 2 (a 1.5 R km gorge) (Table 2.9).

When blocked by site to reduce location effects, fish assemblages were significantly different between habitat types in the Falls segment (Table 2.10) and in all reaches (Table 2.11)(MRBP, $p<0.05$). A-values averaged 0.06 for segments (Table 2.10) and 0.956 for reaches (Table 2.11).

Though ordinations of individual survey units were unreliable, densities of fish averaged among survey units within each site produced a two-dimensional ordination that explained 76 percent of the variation in fish assemblages (Figure 2.8). Longitudinal position and channel unit width were associated with axis 1

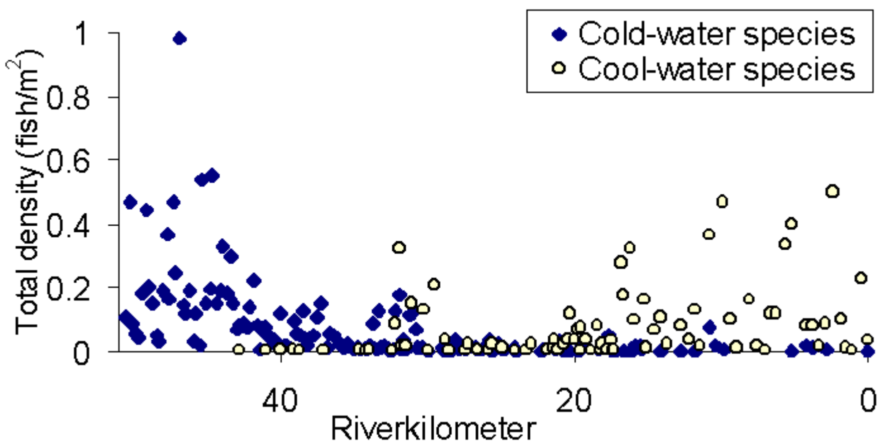

Figure 2.6. Total densities of cold and cool-water species. The dam remnants are at Rkm 31. Total density outliers for the cool-water group were 1.48, 2.03, and 3.0 fish/m^2 at Rkms 15.7, 15.6, and 10.3, respectively.

Table 2.2. Number of survey units within each segment and the number that were unoccupied by fish.

	Number of pools	Number of glides	Number of riffles	Total
Falls	22	26	26	74
Middle	28	44	41	113
Mouth	12	12	7	31

	Number of empty pools	Number of empty glides	Number of empty riffles	Total
Falls	0	5	0	5
Middle	6	21	9	36
Mouth	0	3	0	3

Table 2.3. Total densities of fish within segments. Densities are total numbers of fish counted per total area surveyed.

Segment	Pool Density	Glide Density	Riffle Density	Total Density
Falls	0.073	0.084	0.049	0.062
Middle	0.064	0.036	0.020	0.037
Mouth	0.104	0.041	0.187	0.081

Table 2.4. Average invertebrate and fish richness (taxa or fish group per sample) by habitat type and abundance or density within segments.

		Invertebrates Richness		
Segment	Pool	Glide	Riffle	Abundance
Falls	22.2	32.6	24.9	219.2
Middle	25.4	31.2	40.2	245.8
Mouth	28.6	34.1	37.1	269.7

		Fish Richness		
Segment	Pool	Glide	Riffle	Density
Falls	2.8	2.3	2.5	0.062
Middle	2.7	2.1	2.3	0.037
Mouth	3.5	2.3	2.7	0.081

Table 2.4a. Channel characteristics in Thomas Creek. All values are averages from the extensive snorkel survey in May 2001.

		Unit length (m)	Unit width (m)	Minimum depth (m)	Maximum depth (m)	Average depth (m)	Number of units with greater than 5 pieces of large wood (#/R km)
Falls Segment	Reach 1	37.8	8.5	0.1	2.5	0.6	0
	Reach 2	37.3	8.9	0.1	3.5	0.9	0
	Reach 3	54.2	10.3	0.1	3.8	0.8	0
	Reach 4	64.4	13.7	0.1	3.0	0.7	0.75
Middle Segment	Reach 5	51.8	12.7	0.1	5.0	0.6	0.71
	Reach 6	61.2	16.4	0.1	3.1	0.7	0
	Reach 7	58.5	13.9	0.1	4.0	0.6	0.41
Mouth Segment	Reach 8	75.2	15.0	0.1	4.0	0.9	3.7
	Reach 9	55.2	13.3	0.1	2.0	0.4	0.4

Table 2.5. Average stream characteristics of survey units occupied and unoccupied by fish. Characteristics with significant differences (*P*<0.05, Mann-Whitney U) between occupied and unoccupied survey units within segments are in bold. Significant differences between segments are marked by letters; identical letters are significantly different from each other. Distances and depths are in meters.

Pools

	Occupied			Unoccupied		
Segment	Thalweg	Length	Width	Thalweg	Length	Width
Falls	1.6	45a	10	-	-	-
Middle	1.4	60	12	1.7	70	11
Mouth	1.4	105a	13	-	-	-

Glides

	Occupied			Unoccupied		
Segment	Thalweg	Length	Width	Thalweg	Length	Width
Falls	0.4	38bc	**11**	0.3	27	**17**
Middle	0.4	70c	16	0.4	52	15
Mouth	0.4	66b	**16**	0.3	43	**24**

Riffles

	Occupied			Unoccupied		
Segment	Thalweg	Length	Width	Thalweg	Length	Width
Falls	0.3	76d	11	-	-	-
Middle	0.3	**53**e	13	0.2	**32**	12
Mouth	0.2	19de	11	-	-	-

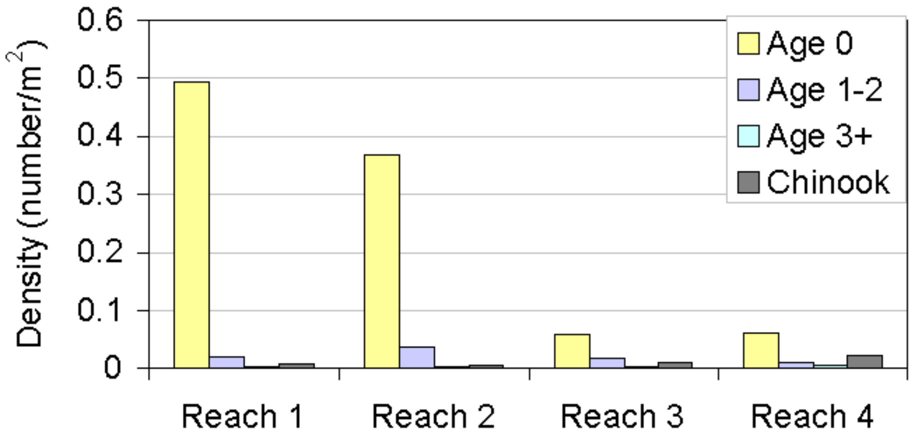

Figure 2.7. Total densities for each fish group during the upstream intensive survey. Densities are an average of July and September surveys at each reach. Only Age 0 Trout had a significant correlation (Pearson's *r*) between density and riverkilometer (*r* = 0.79) or elevation (*r* = 0.87).

Table 2.6. Unit scale habitat selection by salmonids based on upstream intensive surveys (Manly Index). The two highest values in each reach (bolded) indicate strongest selection. Values are averages for all salmonid groups during both seasons. Reach 4 is calculated for September only.

Habitat type	Reach 1	Reach 2	Reach 3	Reach 4
Riffle	**0.15**	**0.19**	**0.13**	**0.47**
Glide	0.14	0.08	0.07	0.09
Riffle/pool	**0.63**	**0.56**	**0.63**	0.03
Glide/pool	0.08	0.05	0.11	**0.39**

Table 2.7. Subunit scale habitat selection by salmonids based on results from the upstream intensive surveys (Manly Index). Two highest values in each reach (bolded) indicate strongest selection in that reach. Values are averages for all salmonid groups during both seasons; Reach 4 calculated for September only.

Habitat type	Reach 1	Reach 2	Reach 3	Reach 4
Riffle Head	0.03	0.07	0.05	0.11
Riffle Body	0.03	0.05	0.04	0.10
Riffle Tail	0.10	0.07	0.03	**0.25**
Glide Head	0.05	0.04	0.02	0.06
Glide Body	0.05	0.01	0.02	0.01
Glide Tail	0.04	0.04	0.03	0.02
Riffle/pool Head	**0.28**	**0.44**	**0.57**	0.02
Riffle/pool Body	**0.21**	**0.10**	**0.08**	0.01
Riffle/pool Tail	0.06	0.07	0.02	0
Glide/pool Head	0.04	0.05	0.08	**0.36**
Glide/pool Body	0.03	0	0.03	0.05
Glide/pool Tail	0.05	0	0	0

Table 2.8. Differences in habitat selectivity between Riffle/pools and Glide/pools at habitat unit and subunit scales. *P*-values < 0.05 indicate greater selection for Riffle/pool habitats (Mann-Whitney U).

Unit	Age 0	Age 1-2	Age 3+	Chinook
Riffle/pool greater than Glide/pool	$p<0.05$	$p<0.025$	$p<0.025$	$p<0.025$

Subunit	Age 0	Age 1-2	Age 3+	Chinook
Head		$p<0.01$	$p<0.01$	$p<0.05$
Body	$p<0.025$	$p<0.025$		$p<0.025$
Tail				

Table 2.9. Percent change in total fish counts and pool area from July to September in Reaches 1-3. The greatest increase (or smallest decrease) in fish counts and the greatest decrease in area are bolded. Reach 2 is the gorge reach. Counts are averages of three to six passes during three consecutive days.

	Reach 1 (Rkm 48)			Reach 2 (Rkm 45)			Reach 3 (Rkm 43)		
	July	Sept	total	July	Sept	total	July	Sept	total
Age 0 Trout	249.8	240.0	**-3.9**	327.5	257	-21.5	35.2	4.0	-88.6
Age 1-2 Trout	17.2	20.3	17.7	18.2	65.7	**261.5**	32.8	7.7	-76.6
Age 3+ Trout	3.8	3.3	-14.5	2.3	8.7	**271.4**	3	2.3	-22.2
Juvenile chinook	3.8	14.0	268.4	5.7	24.7	**335.3**	17.8	38.0	113.1
Pool area (M^2)	387	358	-7.4	987	565	-42.7	1033	579	**-43.9**
Total survey area (M^2)	3262	3083	-5.5	3683	2900	-21.3	8207	6261	**-23.7**

Table 2.10. Differences between habitat types for fish and invertebrate assemblages within each segment (MRBP). Samples are blocked by site; *P*-values indicate differences between habitat types (e.g. pool, glide, and riffle) and *A*-values indicate similarity between sites within each segment.

	Invertebrates		Fish	
Segment	*A*-value	*P*-value	*A*-value	*P*-value
Falls	0.157	0.000	0.092	0.002
Middle	0.160	0.000	0.013	0.286
Mouth	0.155	0.001	0.065	0.163

Table 2.11. Differences between habitat types for fish and invertebrate assemblages within each reach (MRBP). Samples are blocked by site; *P*-values indicate differences between habitat types (e.g. pool, glide, and riffle) and *A*-values indicate similarity between sites within each reach.

	Invertebrates		Fish	
Reaches	*A*-value	*P*-value	*A*-value	*P*-value
Reach 1	0.258	0.008	0.946	0.010
Reach 2	0.146	0.042	0.920	0.010
Reach 3	0.252	0.008	0.963	0.010
Reach 4	0.263	0.009	0.983	0.010
Reach 5	0.199	0.008	0.939	0.010
Reach 6	0.215	0.009	0.993	0.010
Reach 7	0.236	0.013	0.974	0.010
Reach 8	0.250	0.009	0.946	0.010
Reach 9	0.237	0.007	0.943	0.010

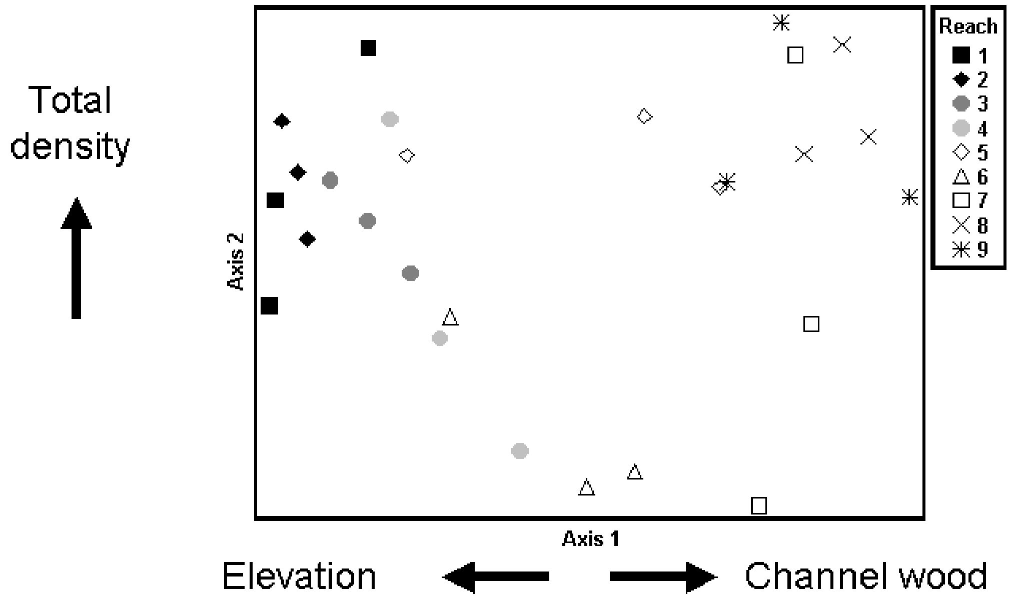

Figure 2.8. NMS ordination of fish assemblages from each site, averaged among habitat types. Reach numbers and segment types are overlaid. Full symbols indicate the Falls, open symbols indicate the Middle, and line symbols indicate the Mouth segment. r^2 = (axis 1 = 0.52; axis 2 = 0.24)

and total site density was associated with axis 2. Generally, this ordination delineates an upstream, high-density salmonid group, a low-density group (Middle segment), and a high-density non-game fish downstream group. Indicator species analysis identified fish species as distinctive segment, reach, and habitat type indicators. All trout groups were indicators for the Falls segment, adult largescale suckers for the Middle segment, and smallmouth bass, mountain whitefish, redside shiners, and northern pikeminnow were indicators for the Mouth segment. Only two reaches had indicator species, Age 0 and Age 1-2 Trout for Reach 2, and juvenile largescale suckers, smallmouth bass, and redside shiners for Reach 8. The only indicators for habitat types were Age 3 and greater trout and adult largescale suckers, that were indicators for pools (Figure 2.9).

Invertebrate Results

When blocked by site to reduce location effects, invertebrate assemblages were significantly different (MRBP, $p<0.05$) between habitat types within all segments and all reaches. *A*-values averaged 0.15 for segments and 0.228 for reaches (Tables 2.10 & 2.11).

Of the 205 available invertebrate taxa groups, 64 were indicator species at the segment-scale, 54 at the reach-scale, 24 at the site-scale, and 35 species were indicators for habitat type (26 were indicators for riffles) (Figure 2.10). For segments, true flies had the most indicator species (15) followed by caddisflies (13), mayflies (11), and stoneflies (8). Reach 9 had the most indicator species (15), followed by Reach 8 (10) and Reach 7 (7). Craneflies (Tipulidae) were indicators for the upstream segments and genera included: *Dicranota, Limnophila,* and *Hesperoconopa* in the Falls segment and *Antocha* in the Middle segment. There were Ephemerellidae mayfly and Brachycentridae caddisfly indicator taxa in each segment (E. *Ephemerella*, B. *Amiocentrus*, E. *Timpanoga*, B. *Micrasema*, E. *Attenella*, and B. *Brachycentrus*). See appendix A for a complete species list. Site indicators are likely rare species, and it is logical that the number of indicators decreases with increased area. As the longitudinal distance increases, the likelihood of individual taxa being contained within that sample area increases. Yet we observed 30 indicator species for the Mouth segment (only 7.5 R kms) including eight non-insects, seven caddisfly, and six mayfly indicator species. The high number of indicator species per R km (4.1) and the number of non-insects (80% of non-insect indicators were in the Mouth segment), suggests this segment was especially unique in Thomas Creek. Its proximity to the South Santiam River might explanation this phenomenon.

Tolerance values of 0 indicate the least tolerance for organic pollution and values of ten indicate the greatest tolerance. Tolerance values (Tv) for indicator taxa within segments and reaches varied. For example, a stonefly (Chloroperlidae) and a biting midge (Ceratopogonidae) were both indictor taxa for the falls segment with tolerance values of 0 and 6, respectively. A stonefly Pteronarcyidae (Tv = 0) and a true fly Psychodidae (Tv = 10) were two of the indicator taxa for the Middle segment and a caddisfly Glossosomatidae (Tv = 0) and a leech Hirudinoidea (Tv = 8) were two of the Mouth segment indicators.

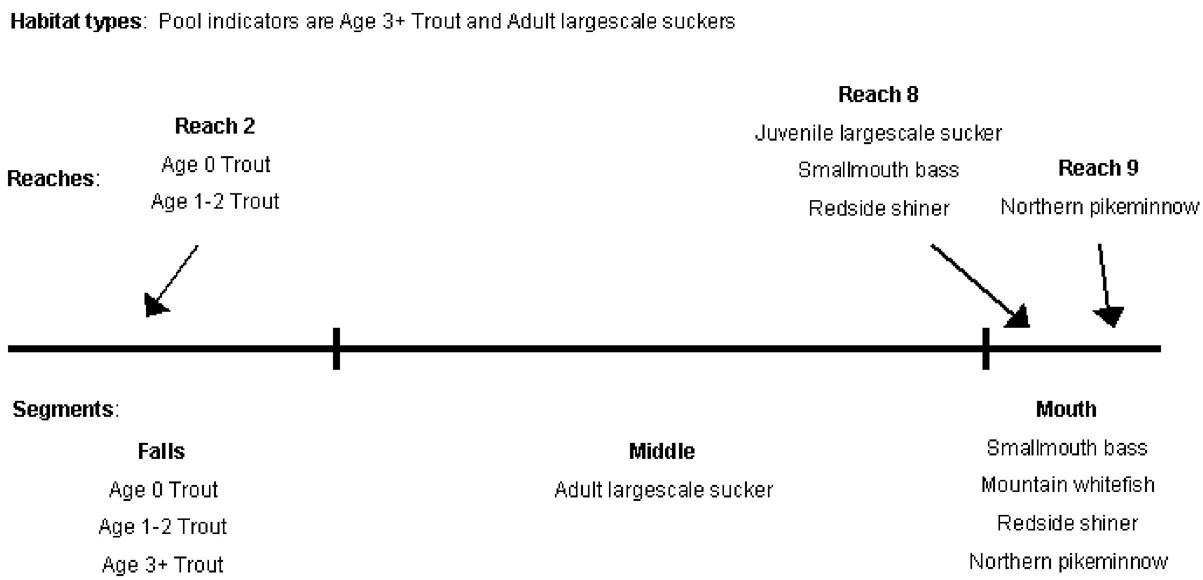

Figure 2.9. Indicator fish species and their location along the study section (ISA, $P<0.05$). Species or trout groups above the line are indicators for reaches and those below the line are indicators for segments. Segment delimiters are approximately equivalent to spatial distance along the 51 Rkms of Thomas Creek.

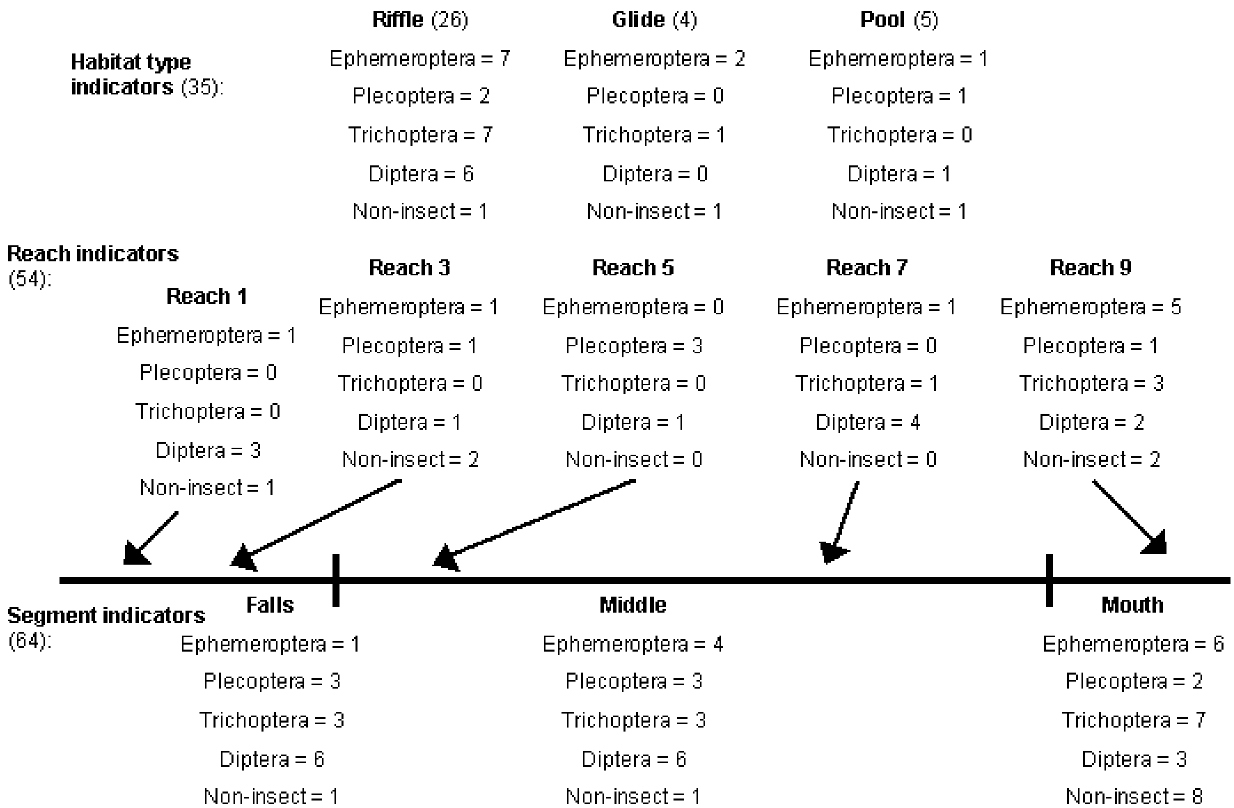

Figure 2.10. Summary major indicator invertebrate taxa and their location along the study section (ISA, P<0.05). Numbers represent the number of species or genera indicators within each order. Taxa above the line are indicators for reaches and those below the line are indicators for segments. The numbers in parentheses are the total number of indicator taxa within segments, reaches, and habitat types. Breaks between segments are scaled to the 51 rkm study section. The complete list of invertebrate indicators can be found in Appendix A.

The average tolerance values for indicator taxa were 3.3, 3.8, and 4.0 for the Falls, Middle, and Mouth segments, respectively.

Relative abundance of invertebrate within functional feeding groups were similar throughout the study section of Thomas Creek (Figure 2.11). Of the 38564 benthic invertebrates collected, ninety-seven percent were assigned to functional feeding groups. A majority of the unclassified invertebrates were individuals in poor condition that could not be identified at a resolution to confidently classify FFG. Proportionally by reach, gatherers were most abundant (average 53%); filterers, predators, and scrapers comprised from 14-17%. Seventy-eight percent of shredders were collected in the Falls segment and collectors were approximately twice as abundant in reaches within the Mouth segment as other reaches (Table 2.12). Comparable to other western Oregon streams (Li et al. 2001), invertebrate densities at each site ranged from 554 to 2988 and averaged 1773 individuals per square meter.

An NMS ordination of individual invertebrate samples produced a three-dimensional solution that explained 86 % of variation in invertebrate assemblages. Axis 1 explained 25 % of the total variation and was correlated with elevation. Axis 2 explained 28 % of the total variation and was not correlated with any of the variables that we measured. Axis 3 explained 33 % of the total variation and was associated with substrate size. There was a clear pattern of segments along axis 1 and a less clear pattern of habitat types along axis 3 (Figures 2.12 & 2.13). Though there was considerable overlap of pool, glide, and riffle samples, pool samples generally were in the upper half and riffles were in the lower half of the ordination.

Hierarchical Analyses

To test for differences between habitat types, hierarchically averaged samples were grouped by habitat type and blocked by scale category (e.g. stream segment). There was a significant difference (MRBP, $p<0.01$) between habitat types (e.g. pool vs. riffle vs. glide) for assemblages of invertebrates at all scales and for fish assemblages at site and reach scales (Table 2.13). To test for differences between locations, hierarchically averaged samples were grouped by scale category and blocked by habitat type. There were significant differences ($p<0.01$) between locations (e.g. Falls, Middle, and Mouth segments) at all scales for invertebrate and fish assemblages (Table 2.14).

In tests for differences between habitat types, within scale categories, invertebrate *A*-values were greater than fish *A*-values (Table 2.13). In contrast, tests for differences between locations, within scale categories, fish *A*-values were greater than invertebrate *A*-values (Table 2.14). Larger *A*-values suggest more similarity between blocks, therefore, invertebrate assemblages appear to be more similar across locations and fish assemblages appear to be more similar across habitat types.

Ordinations (NMS) of hierarchically averaged invertebrate assemblages produced surprisingly clear results. At segment (Figure 2.14) and reach (Figure 2.16) scales, NMS produced clear two-dimensional ordinations that explained

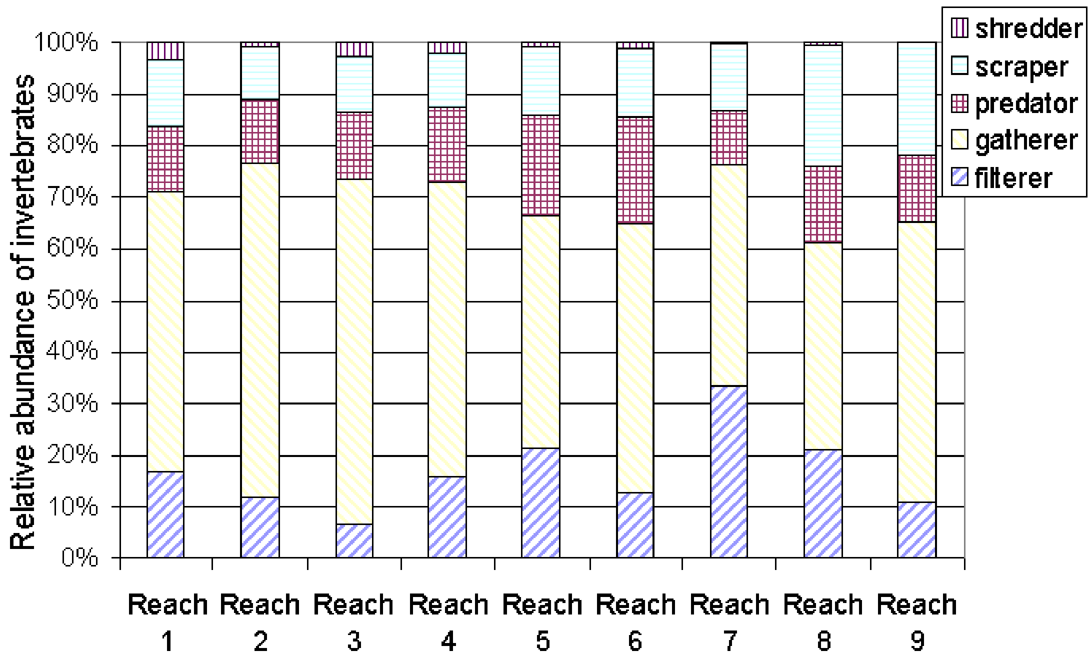

Figure 2.11. Reach-scale proportions of classified invertebrates in each Functional Feeding Group. Approximately 97% of all collected invertebrates were classified into FFG's. Reach 1 is upstream and Reach 9 is downstream.

Table 2.12. Relative abundance of invertebrate Functional Feeding Groups averaged by segment

Functional Feeding Group	Segment		
	Falls	Middle	Mouth
Shredder	0.20	0.06	0.02
Scraper	0.08	0.10	0.19
Predator	0.10	0.13	0.12
Gatherer	0.12	0.10	0.11
Filterer	0.08	0.16	0.11

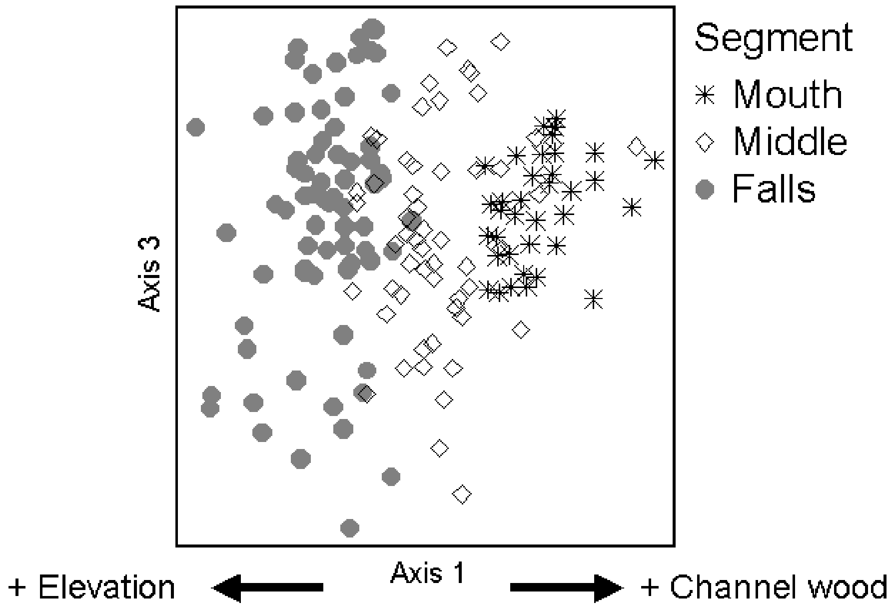

Figure 2.12. NMS ordination of invertebrate assemblages from individual samples, overlaid with segment. Each point is an individual sample overlaid with segment. Axis 1 r^2 = 0.25

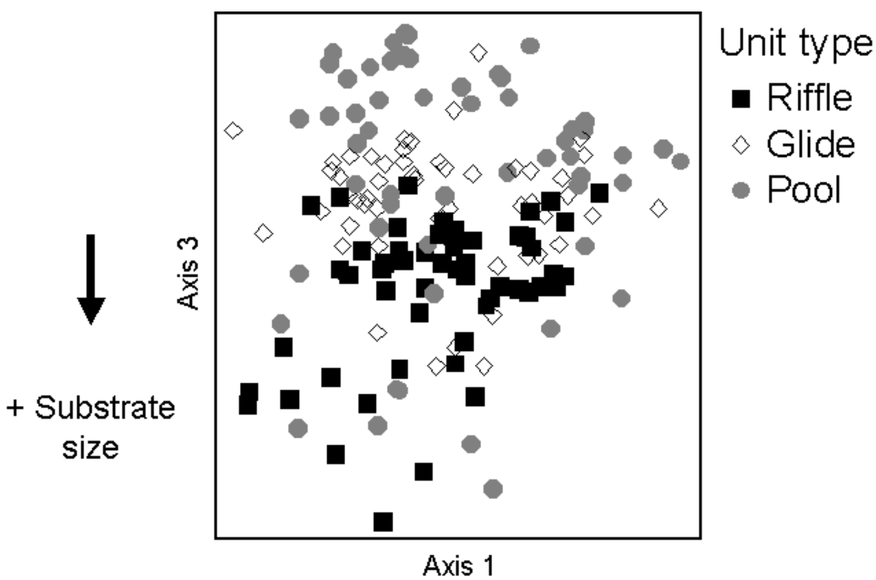

Figure 2.13. NMS ordination of invertebrate assemblages from individual samples, overlaid with habitat type. Each point is an individual sample overlaid with habitat type. Axis 3 r^2 = 0.33

Table 2.13. Differences between habitat types (e.g. pool, glide, and riffle) for fish and invertebrate assemblages at all scales (hierarchically averaged MRBP, *P* < 0.05 indicate a significant difference between habitat types). Samples were blocked by location; *A*-values indicate similarity between locations within a scale category (e.g. similarity between Falls, Middle and Mouth segment assemblages).

	Invertebrates		Fish	
Scale category	*A*-value	*P*-value	*A*-value	*P*-value
Segment	0.232	0.014	0.063	0.214
Reach	0.202	0.001	0.096	0.001
Site	0.110	0.000	0.025	0.015

Table 2.14. Differences between locations within a scale category (e.g. Falls, Middle and Mouth segments) for fish and invertebrate assemblages at all scales (hierarchically averaged MRBP, *P* < 0.05 indicates a significant difference between locations). Samples were blocked by habitat type; *A*-values indicate similarity of samples across habitat types (e.g. similarity of pools, glides, and riffles within the Falls segment).

	Invertebrates		Fish	
Scale category	*A*-value	*P*-value	*A*-value	*P*-value
Segment	0.322	0.009	0.451	0.012
Reach	0.270	0.000	0.432	0.000
Site	0.163	0.000	0.285	0.000

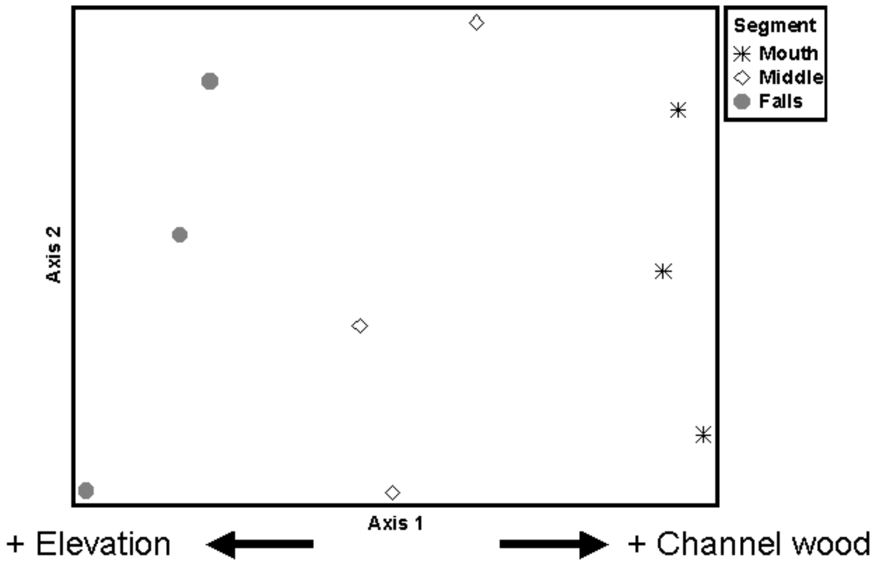

Figure 2.14. NMS ordination of invertebrate assemblages averaged by segment, overlaid with segment. Each point is an average of 18 samples within each segment. Habitat types are averaged separately. Axis 1 r^2 = 0.59

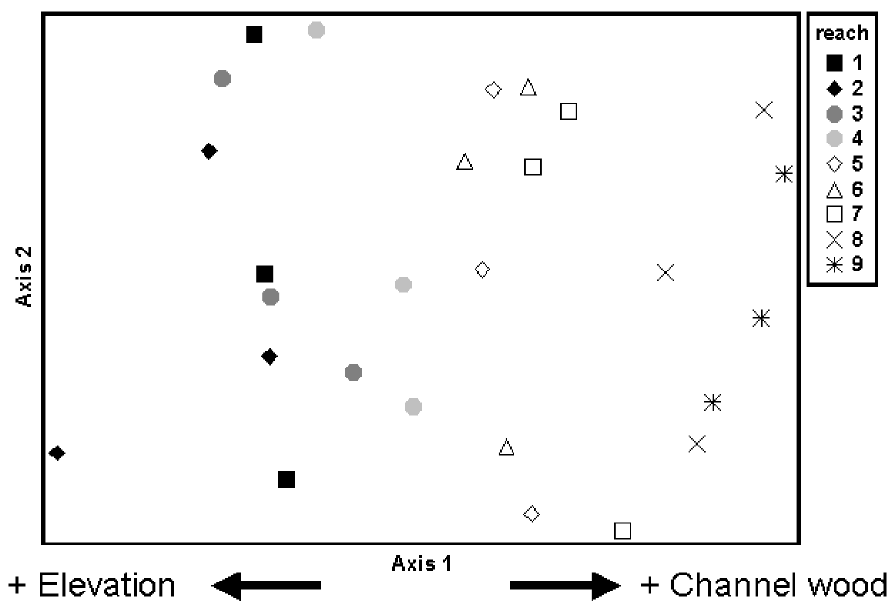

Figure 2.16. NMS ordination of invertebrate assemblages averaged by reach, overlaid with reach number. Each point is an average of six samples within each reach. Habitat types are averaged separately. Axis 1 r^2 = 0.66

97% and 91% of the variation in invertebrate assemblages, respectively. At both scales, longitudinal position explains axis 1 and habitat type explains the second axis with glide habitats intermediate to pool and riffle habitats (Figures 2.15 & 2.17). Hierarchically averaged ordinations result in more variation explained by longitudinal position than habitat type; elevation and R km were both highly correlated with axis 1, which explains 66% (segment scale) and 59% (reach scale) of variation in invertebrate samples (Figures 2.14 & 2.16). Longitudinal changes in assemblage structure (axis 1) appeared consistent across habitat types (axis 2). Within each habitat type the order of composite samples corresponded well with the longitudinal order or reaches.

The second axis was associated with velocity and substrate size increasing towards riffle habitats, and depth increasing towards pool habitats. Habitat type clearly characterizes axis 2, which explains 31% (at both scales) of variation in invertebrate samples. Correlations with each axis indicate that the midges *Orthocladiinae* and *Dasyhelea,* a riffle beetle larva *Zaitzevia,* a flatworm Turbellaria *spp.,* the snail *Lymnaeidae/Ancylidae spp.,* and many other invertebrates increased in abundance downstream, while only the stonefly *Calineuria* and small Oligochaeta *spp*. had strong upstream associations. Generally, invertebrate taxa associated with axis 2 (habitat type) had moderate abundances in glides and highest abundances in riffles (e.g. the caddisflies *Hydropsyche /Ceratopsychae,* the stonefly *Hesperoperla,* and the mayflies *Epeorus* and *Pseudocloeon*, etc). Only the midges *Tanypodinae* and the mayfly *Ameletus* increased in abundance towards the pool group on the ordination. Generally, invertebrate taxa associated with each axis were also indicator species. In this study, Indicator Species Analysis was more informative than correlations with ordination axes. Of the eighteen Middle segment indicator species, only the mayfly *Acentrella* was associated with the longitudinal axis. Among others, the caddisfly *Tricorythodes,* cranefly *Antocha,* mayfly *Cinygmula,* and stonefly *Cultus* were indicators for the Middle segment and were not associated with the longitudinal axis.

Information to assist evaluating strengths & weaknesses

Although, we cannot directly determine agricultural land use practices influence on fish and invertebrate assemblages, their longitudinal patterns appeared to correspond with land use patterns in Thomas Creek. Densities of upstream salmonid assemblages quickly declined near where agricultural land use began. There were distinct invertebrate assemblages changes at the same location. Assemblages from these 12 R kms made-up approximately half of the longitudinal space (axis 1) in the invertebrate ordination (Figure 2.16). This suggests that as much change in assemblage composition occurred in the upstream 12 R kms as in the downstream 39 R kms. In Lapwai Creek, invertebrate assemblages appeared homogenized along an agricultural landscape (Delong and Brusven 1998). Although assemblages were not

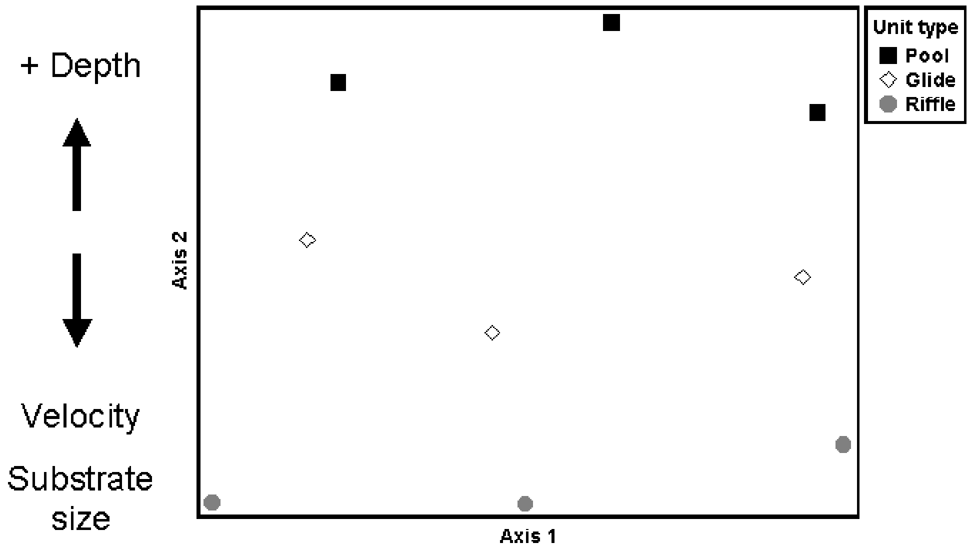

Figure 2.15. NMS ordination of invertebrate assemblages averaged by segment, overlaid with habitat type. Each point is an average of 18 samples within each segment. Axis 2 r^2 = 0.31

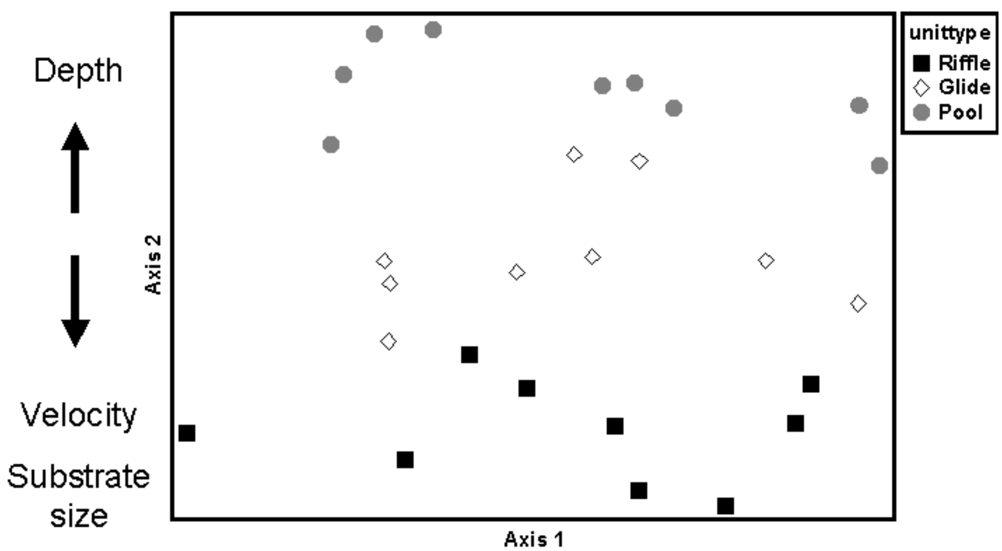

Figure 2.17. NMS ordination of invertebrate assemblages averaged by reach, overlaid with habitat type. Each point is an average of six samples within each reach. Axis 2 r^2 = 0.31

completely homogenized, downstream changes in assemblage composition occurred more gradually than upstream changes.

The scope of these results were restricted to Thomas Creek during summer. However, the different patterns of fish and invertebrate assemblages we observed may provide insight into other systems. Studies rarely incorporate more than one type of organism, especially at scales appropriate for investigating different responses of each organism to their surrounding environmental conditions. Management generally focuses on one or a few species (e.g. ESA listed fishes) within a region. To understand how ecological communities will respond to management and land-use, the distribution and behavior of multiple organisms and the appropriate scales of their responses must be considered. Ironically, the higher mobility of fish (presumably) allows them to explore and select better habitats, yet it may reduce our ability to detect patterns and scales at which fish are responding to environmental conditions.

By extending the length of stream surveyed in 2001 and modifying sampling design, patterns for fish and invertebrates became clearer than from year 2000 studies. Additionally, continuous snorkel surveys allowed us to identify unique features within Thomas Creek. For example, two mussel beds with approximately 100 and 300 native western pearl shell mussels (*Margaritifera falcata*) were identified. These mussels are relatively unstudied and can be valuable indicators of anthropogenic disturbance. They are especially sensitive to pollution (e.g. silting, temperature, pesticides, nutrients, etc.) and may be indicators of stream stability and disturbance as they are sedentary and require relatively stable substrates (Johnson and Brown 2000). Additionally, we documented an unusually large pool with multiple habitats (e.g. water > 3m deep, macrophyte beds, wood jams, etc.) that contained seven of the ten fish groups identified in the snorkel survey. Furthermore, we observed a section of stream that had approximately 30 car bodies imbedded in the stream banks. Without our extensive downstream snorkel survey, these anomalies would have been difficult if not impossible to identify.

Additionally, this study demonstrates that methods chosen for processing and analyzing invertebrate samples can have profound effects on research results. Composite samples emphasized strong longitudinal patterns while individual samples emphasized the effects of local conditions. Because identification and analysis of invertebrate samples can be time consuming, sample design is critical for studies and monitoring. If the objective is to monitor streams or detect large-scale patterns, combining samples within habitat types is likely adequate. Combining samples within habitat types comprises between maximizing (analyzing individual samples) and minimizing (combing all samples) information about local conditions. Potentially, because patterns I observed were consistent within habitat types, sampling from one habitat type may be an adequate, cost effective method for monitoring or detecting broad-scale patterns. If fine scale information is desired, combing samples will likely be inadequate. Combing samples from multiple habitat types may mask patterns because of variable local conditions. For example, combing riffle and pool samples will lose information from depths, substrates, and velocities.

In conclusion, patterns that we detected for fish and invertebrates would suggest that they were responding to conditions at different scales. Our simple definitions of habitat types appeared adequate to describe patterns of invertebrate assemblages. Especially intriguing is that several patterns were consistent for invertebrates across scales and along the longitudinal profile. Initially, we were curious about differences between longitudinal patterns within habitat types. For example, we thought assemblages in pools might have a less distinct longitudinal pattern than riffles. In Thomas Creek, riffles have distinct physical longitudinal differences; upstream, they were more variable, longer, deeper, and had higher gradients, larger substrates, and faster velocities. In contrast, pools did not exhibit strong longitudinal differences; substrates were generally fine throughout and depths were similar, but surface areas were generally larger downstream. Because the pattern of longitudinal assemblage changes were similar across habitat types, local conditions may drive assemblage differences between habitat types; but longitudinal changes in unit characteristics may not drive the longitudinal patterns. This suggests that some broad scale conditions were influencing the invertebrate assemblages as a whole.

Because shifts in land-use and stream conditions occur relatively slowly along Thomas Creek, we expected the biotic assemblages to change slowly as well. We observed a gradual transition of invertebrate assemblages, but not for fish. This brings up the question of whether fish may be more sensitive to land use than invertebrates. Invertebrates are often used as biotic indicators of disturbance or pollution (Cao et al. 1997; Loeb and Spacie 1994; Thorne and Williams 1997; Wallace et al. 1996) and in Thomas Creek they demonstrate consistent patterns and describe differences between locations. However, responses by fish appear to be more dramatic and are revealed by greatly reduced densities, shifts in assemblage composition, and empty habitat units. From my study, what fish were responding to beyond elevation and temperature was unclear. For example, unoccupied glides in the Falls and Mouth segments were significantly wider, and riffles in the Middle segments were significantly shorter than their occupied counterparts. However, we did not find a significant relationship between these characteristics and fish density or abundance and were unable to determine if these characteristics were influencing fish use. However, wider glides and shorter riffles may be associated with some unmeasured characteristic and its influence on presence or absence of fish (e.g. habitat complexity). These same characteristics influencing fish may or may not be influencing invertebrate assemblages. The next logical step would be to examine fish and invertebrates at the same sites to determine if conditions that were associated with occupancy and no occupancy by fish were associated with changes of invertebrate assemblages.

The fact that intolerant fish species dominated downstream fish assemblages and the Mouth segment had the most mayfly and caddisfly indicator species is encouraging. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (EPT) species are generally considered sensitive to anthropogenic disturbance (Lenat and Barbour 1994), yet the downstream reaches (presumably the most heavily impacted reaches) had the most EPT indicator species. Although tolerance values vary for EPT's (there are some tolerant species), tolerance values for these indicator taxa averaged 1.8, 1.8, and 2.2 in the Falls, Middle, and Mouth segments. This would suggest that Thomas Creek is in relatively good condition and likely a prime candidate for stream restoration/enhancement.

Volunteers

2 residents, 40 hours - assisted with fish sampling
6 OSU students, 350 hours - assisted with fish sampling and invertebrate collecting and processing

Participants

Caragwen Bracken, OSU Department of Microbiology
Lindsey Carlson, OSU Department of Fisheries and Wildlife
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William Gerth, OSU Department of Fisheries and Wildlife
Alan Herlihy, US EPA
Ken Kenniston, ODFW
Russell Langshaw, OSU Department of Fisheries and Wildlife
Judith Li, OSU Department of Fisheries and Wildlife
Various land owners including but not limited to: Ron Bentz, Francine & John Cereghino, Charlie & Jerry Faessler, Bob & Sherry Gaskey, Willis Koehn, Lori McKay, Dan Meyers, Tom & Pricilla Rogers, and Willamette Industries (now Weyerhaeuser)

A thesis was derived from this research and will be complete April, 2003.

Langshaw, R. B. 2003. The continuum of fish and invertebrate habitat use and distribution in Thomas Creek, Oregon; a transition from conifer uplands to agricultural lowlands. MS thesis. Oregon State University, Corvallis, Oregon.

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