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CHAPTER 3

Valley Segment Use by Juvenile Ocean-type Chinook Salmon (*Oncorhynchus tshawytscha*) in Tributaries of the Elk River, Oregon (1988-1994)

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ABSTRACT

Relationships between juvenile ocean-type chinook salmon (*Oncorhynchus tshawytscha*) and their freshwater habitats have been studied infrequently and usually at fine spatiotemporal scales. The among-valley segment distribution of juvenile ocean-type chinook salmon was examined annually (1988-1994) for tributaries of the Elk River, Oregon. Discriminant analysis indicated that level of use by juvenile chinook salmon could be explained by valley segment- and channel unit-scale characteristics in four of seven years. In each of these four years, both valley segment type and spatial position appeared important in determining use by juvenile chinook salmon. Unconstrained valleys and valley segments located near these were more highly used by chinook salmon than valley segments of other types or in other positions. More highly used valley segments were also those with deeper pools (1988 and 1991), larger volume pools (1994), and pools with greater densities of large wood (1989). These among-year differences probably stemmed from inter-annual variation in the salmonid assemblage and, to a lesser extent, in the channel units themselves. Discriminant models were also deemed useful for classifying new observations (i.e., data collected in Elk River tributaries but for other years). Each model typically classified new observations better than random assignment as determined by the significance of the Cohen's kappa statistic. This increased confidence in the models and indicated their applicability for other years in Elk River tributaries. Results emphasize the value of examining fish and habitat relationships over multiple years and suggest the relevance of unconstrained valleys and pool characteristics in conservation strategies for ocean-type chinook salmon.

INTRODUCTION

Prior to recent listings of chinook salmon (*Oncorhynchus tshawytscha*) under the federal Endangered Species Act, relatively little effort was directed at understanding this species' distribution and habitat use in rivers of the Pacific northwestern United States. Hicks et al. (1991) attributed an unintended bias in freshwater anadromous salmonid research toward coho salmon (*O. kisutch*), cutthroat trout (*O. clarki*), and steelhead (*O. mykiss*) to a traditional focus on small-watersheds from which chinook salmon are typically absent. This has been reinforced for ocean-type chinook salmon by the perception that freshwater habitat was of minor importance to them as juveniles (Myers et al. 1998). Juvenile ocean-type chinook salmon typically rear in streams only a few months instead of a year or more like many other salmonids, including stream-type chinook salmon (Taylor 1990; Healey 1991).

Knowledge of relationships between juveniles and their freshwater habitats may be particularly important for ocean-type chinook salmon in two situations: 1) rivers where the population exhibits diversity in the length of freshwater residency, and 2) rivers that lack a well developed estuary. Although most juvenile ocean-type chinook salmon emigrate in spring or summer after three to five months in coastal rivers, some emigrate in fall or winter (i.e., late-migrants), and others emigrate after spending up to a year in freshwater (i.e., yearlings) (Nicholas and Hankin 1988; Myers et al. 1998). Commonly, 1-13% of returning ocean-type adults emigrated from Oregon coastal rivers as yearlings (Nicholas and Hankin 1988; Myers et al. 1998). Relatively few juveniles leave freshwater after mid-summer, but these fish can be large (K.M. Burnett and G.H. Reeves, unpublished data). Thus, they may have higher smolt-to-adult survival rates than their smaller, earlier migrating counterparts due to increased marine survival as commonly found for anadromous salmonids (e.g., Henderson and Cass 1991), particularly when ocean conditions are unfavorable (Holtby et al. 1990). Later emigrating ocean-type chinook salmon tend to be older (i.e., 5-6 yrs), larger, and more fecund adults on returning to freshwater than earlier emigrating fish (Nicholas and Hankin 1988). Larger adults may have increased reproductive success under certain circumstances. For example, they may have higher likelihoods of laying eggs below the mean scour depth of bank-full flows (Montgomery et al. 1999), contributing disproportionately to recruitment in years with bed-mobilizing floods. They may also produce eggs of greater diameter and weight than smaller adults (Nicholas and Hankin 1988). Larger eggs develop into larger juveniles (Fowler 1972) that may have a competitive advantage in both fresh- and saltwater.

The condition of freshwater habitat may be critical also to ocean-type chinook salmon in rivers lacking well developed estuaries. Estuaries are key rearing areas for juvenile ocean-type chinook salmon because they may grow better here than in freshwater (Reimers 1973; Healey 1991). However, many rivers along the Pacific coast of the continental United States lack an extensive, permanent estuary or other near-shore rearing habitats for anadromous salmonids (Bottom et al. 1986; FEMAT 1993). Thus, juvenile ocean-type chinook salmon in these coastal rivers, even those that emigrate soon after hatching, must rely heavily, and in some years solely, on freshwater habitat for growth that is sufficient to support ocean entry.

Although a longer term, watershed perspective is increasingly recommended for strategies to conserve salmonid populations (Doppelt et al. 1993; FEMAT 1993), finer spatial and shorter temporal scales have usually been targeted when examining relationships between juvenile ocean-type chinook salmon and their freshwater habitats. This situation typifies most habitat research for salmonids (Platts and Nelson 1988; Folt et al. 1998). Habitat use by juvenile ocean-type chinook salmon has been best characterized at channel unit (100 m) and sub-unit scales (10^{-1} m) (Lister and Genoe 1970; Johnson et al. 1992; Scarnecchia and Roper 2000). Distributions of juvenile ocean-type chinook salmon within a watershed were documented and explained qualitatively (Stein et al. 1972; Murray and Rosenau 1989; Johnson et al. 1992; Scarnecchia and Roper 2000). However, empirically-derived statistical relationships have seldom been developed for juvenile ocean-type chinook salmon and their habitat at coarser spatial scales (Schwartz 1990). In some of these watershed studies (Schwartz 1990; Scarnecchia and Roper 2000), juveniles were likely a mixture of ocean- and stream-type fish. Only one study examining habitat use by juvenile ocean-type chinook salmon included data from more than two years (Stein et al. 1972). Given that abundances of stream fish can vary greatly from year to year (Platts and Nelson 1988; Grossman et al. 1990; Ham and Pearsons 2000), longer-term studies are necessary to understand inter-annual variability and to identify and protect habitat characteristics that are important to fish at each level of abundance.

The goal of this study was to better understand the role of freshwater rearing habitat for juvenile ocean-type chinook salmon. The Elk River was chosen as the study site because it supports an ocean-type chinook salmon population averaging 3% (range 0-18%) of returning adults each year with a yearling life history (Nicholas and Hankin 1988; Myers et al. 1998) and it has a small, ephemeral estuary that does not form in many years. Specific objectives were to: 1) explain the annual distribution (1988-1994) of juvenile ocean-type chinook salmon in tributaries of the Elk River basin using valley segment and channel unit characteristics; 2) determine how consistently specific characteristics were related to fish distribution; and 3) evaluate the transferability of results among years.

METHODS

Study Area

Elk River is located in southwestern Oregon, USA (Fig. 3.1). The mainstem flows primarily east to west, entering the Pacific Ocean just south of Cape Blanco (42°5' N latitude and 124°3' W longitude). The Elk River basin (236 km^2) is in the Klamath Mountains physiographic province (Franklin and Dyrness 1988) and is similar to other Klamath Mountain coastal basins in climate, landform, vegetation, land use, and salmonid community (Chapter 4). The upper mainstem of Elk River (i.e., upstream of Anvil Creek) and its tributaries provide spawning and rearing habitat for native chinook salmon, coho salmon, coastal cutthroat trout, and winter-run steelhead. Chum salmon (*O. keta*) occurs with these species in the lower mainstem. All chinook salmon in Elk River are considered ocean-type fish, henceforth, they are referred to only as chinook salmon. The basin is highlighted in both state and federal strategies to protect and restore salmonids (USDA and USDI 1994; State of Oregon 1997). The study area was confined to tributaries in the upper basin (i.e., above and inclusive of Anvil Creek).

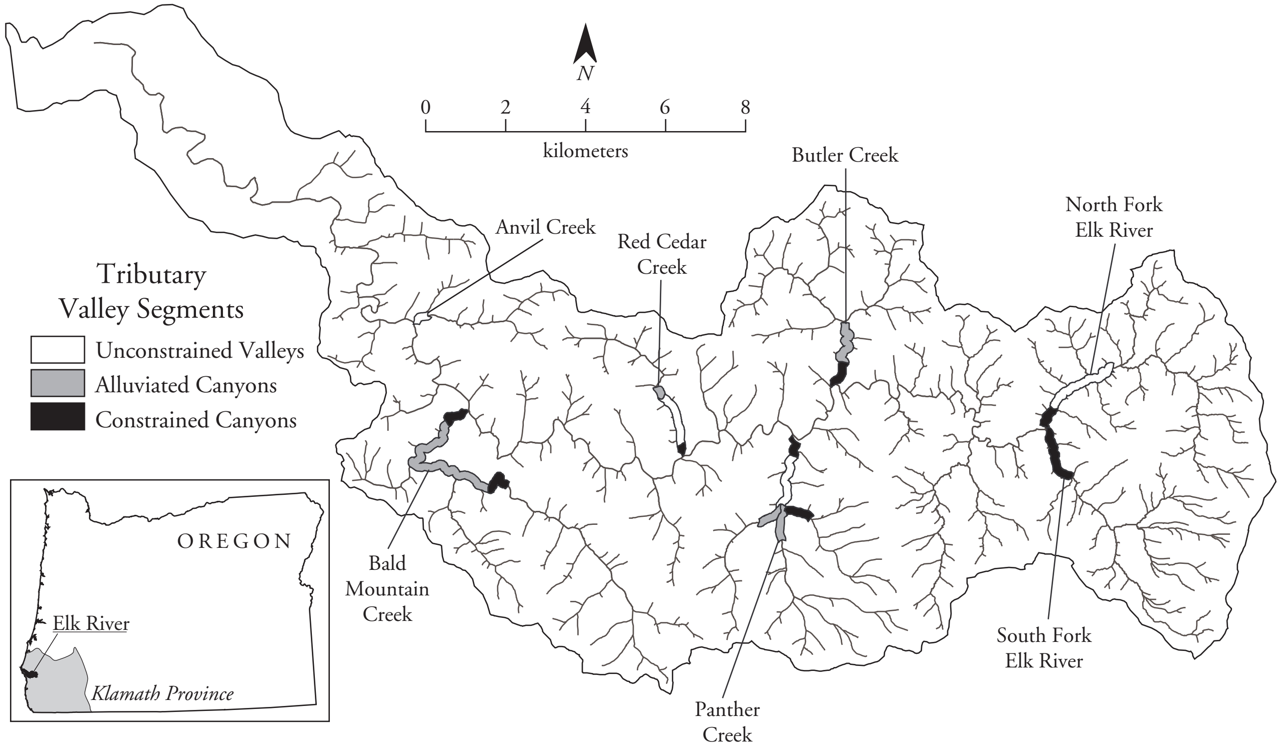


Figure 3.1. Location and map of the Elk River, Oregon with valley segments identified for anadromous fish-bearing sections of its tributaries.

Valley Segments

Valley segments encompass sections of tributaries accessible to anadromous salmonids. Accessibility was determined in the field based on the absence of physical features thought to be barriers for adult fish migrating upstream. Surveyed tributaries were either 3rd or 4th order channels (Strahler 1957) on the 1:24,000, centerlined, routed, vector-based, digital stream coverage obtained from the Siskiyou National Forest. The UTM projection, Zone 10, Datum NAD 27 was used for the stream coverage. The type and boundaries of each valley segment were determined through field reconnaissance. Valley segments were classified as one of three types (adapted from Frissell 1992) (Table 3.1 and Fig. 3.1). Unconstrained valleys (UV) contain stream channels that are relatively low gradient (mean ± SD; 1.5 ± 0.9%) and unconfined (i.e., valley floor width >2 x active channel width). Any confinement is imposed by channel-adjacent terraces. Constrained canyons (CC) contain stream channels that are relatively high gradient (mean ± SD; 3.1 ± 1.5%) and confined by valley walls (i.e., valley floor width - channel width). Alluviated canyons (AC) contain stream channels that are intermediate in gradient (mean ± SD; 2.3 ± 0.7%) and confinement to those in the former two valley segment types.

The percent gradient of each valley segment was the mean percent gradient for 100 m sections comprising the segment (Table 3.1). The upstream and downstream boundaries of each valley segment were located on the digital stream layer. Distance between the boundaries was divided into 100 m sections, then the stream coverage was overlain onto the US Geological Survey (USGS) 30 m digital elevation model (DEM). The change in elevation over each 100 m section was determined and expressed as percent gradient. The mean and standard deviation of 100 m sections were calculated for each valley segment.

Suitability for, and use by, a terrestrial organism of a habitat patch may be affected by the patch type and by features surrounding the patch in the landscape (Weins et al. 1993). Following this rationale, we hypothesized that use of a valley segment by juvenile chinook salmon was related to the valley segment type and location relative to other valley segment types in the same tributary. Nearby valley segments may provide fish or resources (e.g., macroinvertebrate drift, dissolved nutrients, thermal buffering) or both to a particular valley segment, influencing the use of that valley segment by juvenile chinook salmon. To express the influence of valley segments of a particular type on each valley segment in a tributary, the variable, influence of valley segment type (I_t), was derived (Table 3.1 and Fig. 3.2):

$$(1) \qquad I_t = \sum_{n=1}^{N} \left(\left(L_{n_t} / \left(L_{n_t} + L_v + L_{b_1} + \ldots + L_{b_z} \right) \right) (1/c)(100) \right)$$

where t identified the type of influencing valley segment (i.e., unconstrained valley [UV], constrained canyon [CC], alluviated canyon [AC]); N was the number of valley segments of the influencing type in that tributary; ***n*** was the nth influencing valley segment of that type; L was the length of a valley segment; v identified the influenced valley segment; b_1 - b_Z were any valley segments between the influencing and influenced valley segments; **c** was a weighting factor that reflected the potential of the influencing valley segment to supply the influenced valley segment with inputs of juvenile fish and resources, c = 1 if the influencing valley segment had the potential to supply both classes of inputs (i.e., resources and fish), c = 2 if the influencing valley segment had the potential to supply only one class of inputs, and c = L_t / L_t + L_v if the influencing and influenced were the same valley segment.

Valley segment	Valley segment type	Length (m)	Drainage area (ha)	Mean (SD) % gradient		Influencing valley segment type[a] I_{UV}	I_{CC}	I_{AC}
Anvil Creek 1	UV	532	687	0.1	(0.1)	100	0	0
Bald Mountain Creek 1	CC	826	2715	3.1	(3.8)	0	100	42
Bald Mountain Creek 2[b]	AC	4251	2679	2.4	(2.7)	-	-	-
Butler Creek 1	CC	763	1752	3.3	(4.3)	0	100	68
Butler Creek 2	AC	1588	1724	1.2	(1.8)	0	16	100
North Fork Elk River 1	CC	648	2456	3.3	(4.9)	80	100	0
North Fork Elk River 2	UV	2511	2303	1.6	(2.9)	100	10	0
Panther Creek 1	CC	727	2347	0.6	(0.8)	70	100	58
Panther Creek 2	UV	1697	2275	2.3	(2.0)	100	49	73
Panther Creek 3	AC	1165	929	1.9	(1.9)	30	32	100
W. Fork Panther Creek 1	AC	806	575	2.8	(2.7)	33	37	100
E. Fork Panther Creek 1	CC	888	570	1.8	(3.2)	33	100	52
Red Cedar Creek 1	CC	344	743	4.7	(3.3)	80	100	19
Red Cedar Creek 2	UV	1418	737	2.1	(1.9)	100	10	23
Red Cedar Creek 3	AC	419	565	3.3	(3.4)	39	8	100
South Fork Elk River 1	CC	1544	1988	5.6	(6.2)	0	100	0

Table 3.1. Characteristics of tributary valley segments in the Elk River, Oregon. Valley segments are numbered starting downstream. Valley segment types are unconstrained valleys (UV), constrained canyons (CC), and alluviated canyons (AC) [adapted from Frissell et al. 1992]. Mean percent gradient and drainage area were derived from US Geological Survey (USGS) 30 m digigal elevation models (DEMs).

[a]See text and Figure 3.2 for description.
[b]A barrier prohibited access by adult chinook salmon, but this valley segment was accessible to other species of anadromous salmonids so had the potential to supply marine derived nutrients. Thus, its influence on Bald Mountain Creek 1 was calculated.

The influence of a valley segment type was assumed to be greatest when the influencing and influenced were the same valley segment. In such cases, I_t = 100. If the type of influencing valley segment did not occur in a tributary, then I_t = 0. Values of I_t between these extremes tended to be greater when an influencing valley segment was longer than and closer to the influenced valley segment. These values were generally greater also when an influencing valley segment was upstream of the influenced valley segment because both classes of inputs (i.e., resources and fish) could be supplied, so a value of 1 was assigned to c, the weighting factor. When the influencing valley segment had the potential to supply only one class of inputs, a value of 2 was assigned to c. This occurred if the influencing valley segment was downstream of the influenced valley segment or was upstream of the influenced valley segment but adult chinook salmon could not access it (e.g., Bald Mountain Creek 2). It was not calculated when two different valley segments were of the same type. Although we recognize mainstem valley segments may supply tributary valley segments with juvenile chinook salmon, tributaries were considered independent of mainstem influences for this analysis. Examination of the 30 m DEMs indicated that sections of stream immediately beyond the extent of anadromy in each tributary were similar to constrained canyons, but the influence of these stream sections on valley segments was not assessed.

Channel Unit Features and Juvenile Chinook Salmon Densities

Data for channel units and juvenile chinook salmon abundance in tributaries of the Elk River basin were collected each year from 1988 to 1994. Annual data collection began in late July to mid-August and continued for approximately three weeks. Data were collected for 20 km of stream in fifteen valley segments in each year, for an additional 0.5 km in Anvil Creek in 1991-1994, and for an additional 0.9 km in the East Fork of Panther Creek in 1990 and 1992-1994.

Each channel unit was classified by type [i.e., pool, fastwater (Hawkins et al. 1993), or side channel (<10% flow)]. The length, mean wetted width, and mean depth of each channel unit was estimated using the method of Hankin and Reeves (1988). Channel units were at least as long as the estimated mean active channel width (10^0 -10^1 m). Dimensions were measured for approximately 15% of all channel units. A calibration ratio was derived from the subset of channel units with paired measured and estimated values. Separate calibration ratios were developed annually for each person estimating channel unit dimensions. All estimated dimensions were multiplied by the appropriate calibration ratio, and only calibrated estimates were analyzed. For each channel unit, the dominant substrate by percent area (i.e., fines <3 mm, small gravel 3-10 mm, large gravel 11-100 mm, cobble 101-299 mm, boulder >300 mm, and bedrock) was estimated visually and the number of wood pieces (≥3 m long and ≥0.3 m diameter) was counted. Maximum depth of each pool was measured if ≤1 m and was estimated otherwise.

A systematic sample of channel units was selected each year for estimating chinook salmon abundance. Every fourth pool, tenth fastwater habitat, and second side channel were chosen annually using an independent random start for each channel unit type in each tributary. Abundance estimates were derived from fish counted while snorkeling in these selected units (Hankin and Reeves 1988) between 1000 and 1600 hours. Snorkeling counts were not calibrated with electroshocking estimates of fish abundance in a departure from Hankin and Reeves (1988). Consequently, estimates from snorkeling counts were assumed to be negatively biased (Rodgers et al. 1992; Thompson and Lee 2000) but to provide measures of rela-

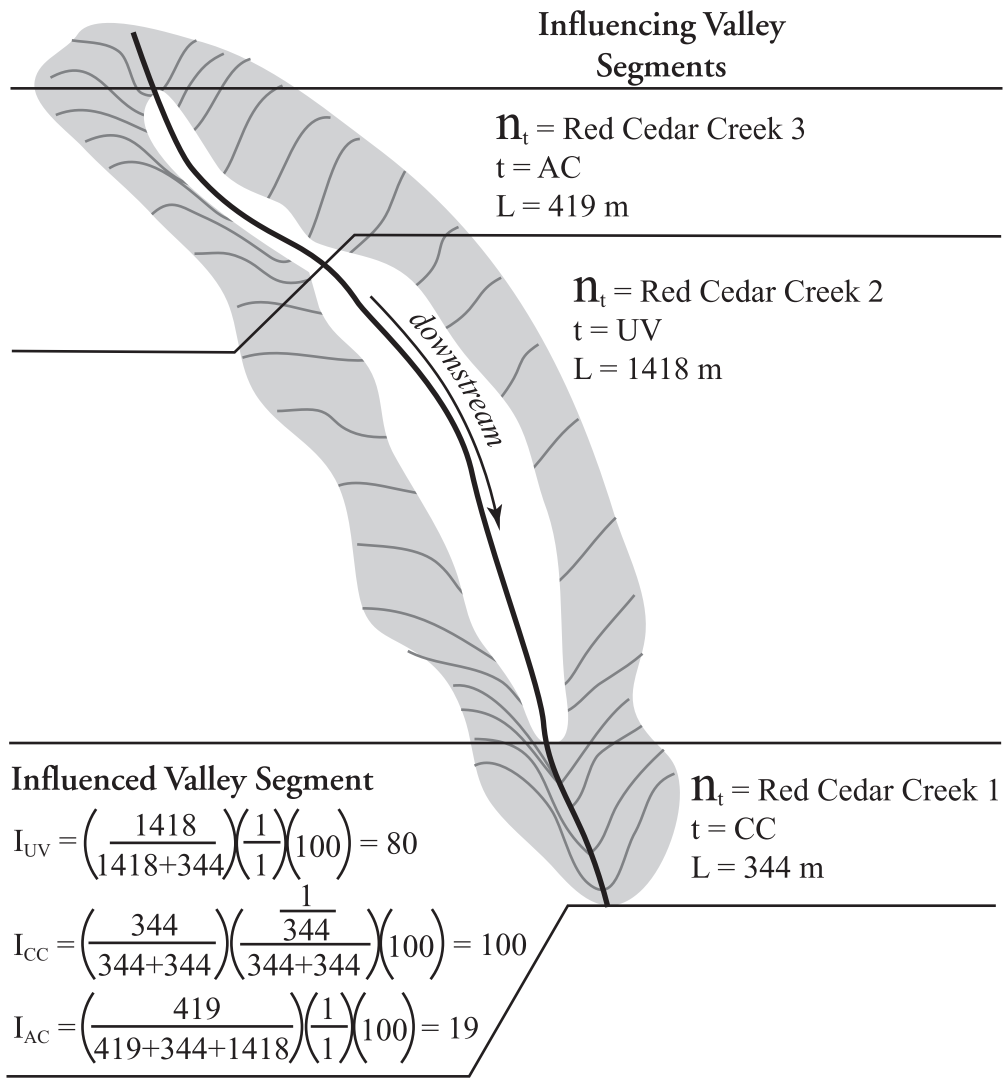


Figure 3.2. Example to calculate the influence of each valley segment type (It) in Red Cedar Creek on the influenced valley segment Red Cedar Creek 1. Where t identified the type of influencing valley segment (i.e., unconstrained valley [UV], constrained canyon [CC], alluviated canyon [AC]); L was the length of a valley segment; N was the number of valley segments of the influencing type in that tributary; n was the nth influencing valley segment of that type; v identified the influenced valley segment; b_1 - b_z were any valley segments between the influencing and the influenced valley segments; c was a weighting factor that reflected the potential of the influencing valley segment to supply the influenced valley segment with inputs of juvenile fish and resources, c = 1 if the influencing valley segment had the potential to supply both classes of inputs(i.e., fish and resources), c = 2 if the influencing valley segment had the potential to supply only one class of inputs, and c = L_t / L_t + L_v if the influencing and influenced were the same valley segment.

$$\text{(1)} \qquad I_t = \sum_{n=1}^{N} \left(\left(L_{n_t} / \left(L_{n_t} + L_v + L_{b_1} + \ldots + L_{b_z} \right) \right) (1/c)(100) \right)$$

tive abundance.

Habitat and fish abundance data for each channel unit were geo-referenced to the digital stream network with Dynamic Segmentation in ARC/INFO[1] (Byrne 1996). A separate channel unit coverage was created for each year that data were collected. Geo-referenced channel unit data were summarized for each year to derive channel unit features and estimates of fish density for subsequent analyses. The mean relative density (number/100 m^2) and its standard error for each channel unit type in a valley segment and the total relative density (number/100 m^2) and its standard error across all channel unit types in a valley segment were estimated each year for juvenile chinook salmon using equations for stratified sampling (Cochran 1977).

Statistical Analysis

All statistical analyses were performed with SAS/STAT statistical software (Version 6.12, 1997, SAS Institute Inc., Cary, NC). Estimated relative densities of juvenile chinook salmon were not normally distributed because each year few or no fish were observed in many valley segments. Preliminary data analysis indicated that linear regression assumptions were unlikely to be met following any transfor-mation. Thus, modeling fish density as a categorical variable- High or Low use- seemed appropriate and has been recommended when using estimates from uncorrected snorkel counts (Thompson and Lee 2000). Linear discriminant analysis (e.g., Wood-Smith and Buffington 1996) and logistic regression (e.g., Rieman and McIntyre 1995) are common techniques for modeling categorical data and assigning group membership. Although logistic regression is considered more flexible (i.e., can easily accommodate categorical independent variables and has no distributional assumptions) (Tabachnick and Fidell 1996), discriminant analysis may be a more efficient strategy with continuous independent variables when its assumptions are met (James and McCulloch 1990). The two approaches should yield similar results with a dichotomous dependent variable. Discriminant analysis was applied for each year to test the null hypothesis that juvenile chinook salmon use of tributary valley segments was

[1]The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Year	Number of tributary valley segments	Number of valley segments with observed use High	Low	Threshold density between observed juvenile chinook salmon use groups (number/100 m^2)	Estimated mean density of juvenile chinook salmon in pools (number/100 m^2) mean±SD	(range)
1988	12	6	6	0.14	2.2±5.6	(0-20.0)
1989	13	7	6	1.48	3.8±5.4	(0-16.0)
1990	14	6	8	0	0.2±0.3	(0-0.7)
1991	14	7	7	0.14	0.8±1.4	(0-4.0)
1992	14	2	12	0	0.2±0.5	(0-2.0)
1993	15	7	8	0	0.2±0.4	(0-1.0)
1994	15	6	9	0.89	0.7±0.8	(0-3.0)

Table 3.2. Number of valley segments in the High and Low groups for observed use by juvenile chinook salmon in tributaries of the Elk River, Oregon (1988-1994). A valley segment was designated as either High or Low observed use for each year by comparing its estimated mean density of juvenile chinook salmon in pools to the threshold density for that year.

unrelated to valley segment and channel unit features. Resulting canonical functions were used to classify valley segments as new observations (i.e., based on data for valley segment and channel unit features collected in years other than those used to develop each canonical function). Valley segments excluded from analysis were: Bald Mountain Creek 1 for 1992 because wood data were not collected in this year; Bald Mountain Creek 2 for every year, Anvil Creek 1 for 1988-90, E. Fork Panther Creek 1 for 1988, 1989, and 1991, and Red Cedar Creek 3 for 1988 because fish data were not collected.

Developing the grouping variable

The grouping variable in discriminant analysis was juvenile chinook salmon use. Each valley segment was designated as either High or Low observed use in each year by comparing its estimated density of juvenile chinook salmon to a threshold density for that year (Tables 3.2 and 3.3). Annual threshold densities were selected to meet two objectives: 1) ensure the smallest density in the High use group was at least twice the largest density in the Low use group, and 2) produce approximately equal group sizes. The second objective was included because the effectiveness of discriminant analysis decreases as the difference between group size increases (Tabachnick and Fidell 1996). Zero was the threshold density in years that juvenile chinook salmon were observed in less than half of the valley segments (1990, 1992, and 1993). Varying the annual threshold density to reflect the range of fish densities estimated in each year, instead of using a single fixed threshold density for all years, reduced

Table 3.3. Group, High (H) and Low (L) observed use by juvenile chinook salmon, into which each valley segment was designated annually (1988-1994) for tributaries of the Elk River, Oregon. Valley segments not sampled for juvenile chinook salmon in a particular year are identified by --. Mean (standard deviation) estimated density of juvenile chinook salmon in pools for all years that the valley segment was sampled.

Valley segment	Valley segment type	1988	1989	1990	1991	1992	1993	1994	Mean (SD) estimated density of chinook salmon in pools (number/100 m^2)
Anvil 1	UV	--	--	--	H	H	H	H	1.43 (0.44)
Bald Mountain 1	CC	H	L	L	H	--	L	L	0.74 (1.48)
Butler 1	CC	L	L	H	L	L	H	L	0.05 (0.09)
Butler 2	AC	L	L	H	L	L	L	L	0.07 (0.10)
N. F. Elk River 1	CC	H	H	H	H	L	H	H	2.42 (4.09)
N. F. Elk River 2	UV	H	H	H	H	L	H	H	2.68 (6.10)
Panther 1	CC	L	H	L	L	L	H	H	0.73 (1.51)
Panther 2	UV	H	H	L	H	L	H	H	1.09 (1.08)
Panther 3	AC	L	L	L	L	H	H	L	0.22 (0.44)
W. F. Panther 1	AC	L	H	L	L	L	L	L	0.36 (0.83)
E. F. Panther 2	CC	--	--	L	--	L	L	L	0.00 (0.00)
Red Cedar 1	CC	H	H	H	H	L	L	L	4.48 (7.74)
Red Cedar 2	UV	H	H	H	H	L	L	H	2.04 (1.77)
Red Cedar 3	AC	--	L	L	L	L	L	L	0.06 (0.15)
S. F. Elk River 1	CC	L	L	L	L	L	L	L	0.00 (0.00)

the influence of adult spawner abundance on the observed use group into which a valley segment was designated.

Valley segments were initially designated into observed use groups by two measures - total relative density and the mean relative density in pools. These estimates were highly correlated for each year ($R^2 \geq 0.90$) because juvenile chinook salmon selected for and used pools in the tributaries almost exclusively (Chapter 2). Identical observed use groups resulted from the two density measures, so only the mean relative density of juvenile chinook salmon in pools was reported (Table 3.2). The observed use groups were applied in two ways: 1) developing canonical functions from valley segment and channel unit features; and 2) evaluating canonical functions by supplying the basis to calculate correct classification rates.

Developing canonical functions

Overfitting a discriminant model is of concern when the number of observations in the smallest group does not exceed the number of discriminating variables (Tabachnick and Fidell 1996). To avoid this, Williams and Titus (1988) suggested the number of observations in each group should equal or exceed three times the number of discriminating variables. Whereas at least six valley segments were designated into each observed use group in all years but 1992 (Tables 3.2 and 3.3), models containing no more than two variables were considered appropriate. Canonical function development was attempted for all years except 1992.

Discriminating variables were chosen from among four valley segment features and nine channel unit features: mean percent gradient; influence of unconstrained valleys (I_{UV}), constrained canyons (I_{CC}), and alluviated canyons (I_{AC}); mean maximum depth of pools (m); mean volume of pools (m^3); mean density of wood in pools (number of pieces/100 m); percent area of pools; frequency of pools (number/km); percent area of pools with boulders as dominant substrate; percent area of pools with bedrock as dominant substrate; percent area of fastwater units with large gravel as dominant substrate, and percent area of fastwater units with cobble as dominant substrate (Table 3.4 and Appendix 3.1). These variables were screened for univariate outliers by standardizing to mean=0 and SD=1 within each use group for each year, then comparing the annual Z scores for the High and Low use groups to a standard ($Z>2.575$, two-tailed $P \leq 0.01$) (Tabachnick and Fidell 1996). However, no data point was suspected as an outlier in any year.

Other valley segment and channel unit features were not considered in discriminant analyses for three reasons: 1) they were consistently highly correlated with variables used in stepwise discriminant analyses (e.g., mean maximum depth of pools and mean depth of pools; $r>0.8$ in six of seven years), 2) they varied little among valley segments (e.g., percent area of fastwater units with fine sediment as dominant substrate; seven-year range across all valley segments 0-5%), or 3) they were thought to be of minor importance to chinook salmon (e.g., percent area of fastwater units with small gravel as dominant substrate).

To develop canonical functions, valley segment and channel unit features were selected objectively by stepwise procedures with a tolerance level of 0.001, the SAS defaults for the partial F tests (i.e., F-to-enter and F-to-remove, P=0.15), and the Wilks' Lambda statistic as the selection criterion. Stepwise methods may find an adequate

Table 3.4. Seven-year mean (standard deviation) of channel tributary valley segments in the Elk River, Oregon (1988-1994).

		Pools:							Fastwater:	
Valley segment	Valley segment type	Mean maximum depth (m)	Mean volume (m^3)	Mean density of wood (no./100m)	%Area	Number per km	%Area with boulders as dominant substrate	%Area with bedrock as dominant substrate	% Area with large gravel as dominant substrate	% Area with cobble as dominant substrate
Anvil 1	UV	0.84 (0.09)	21.2 (2.2)	10 (3)	41 (6)	33 (6)	21 (12)	0.0 (0.0)	40 (7)	45 (10)
Bald Mountain 1	CC	1.51 (0.43)	75.0 (26.8)	11 (6)	41 (9)	23 (6)	9 (7)	1.8 (0.9)	16 (12)	53 (27)
Butler 1	CC	1.06 (0.23)	70.6 (21.4)	9 (6)	58 (5)	23 (2)	8 (10)	10.2 (10.1)	14 (12)	64 (18)
Butler 2	AC	1.06 (0.21)	67.6 (15.0)	2 (1)	56 (5)	19 (3)	1 (1)	19.7 (14.8)	23 (16)	57 (18)
N. F. Elk River 1	CC	1.04 (0.17)	56.4 (16.2)	9 (3)	35 (13)	19 (7)	40 (30)	13.5 (24.3)	15 (21)	31 (26)
N. F. Elk River 2	UV	1.07 (0.06)	87.5 (18.4)	22 (11)	40 (7)	14 (2)	21 (15)	1.1 (2.6)	18 (17)	48 (18)
Panther 1	CC	0.95 (0.25)	66.1 (21.4)	6 (3)	51 (9)	21 (6)	8 (16)	26.7 (12.8)	13 (13)	52 (15)
Panther 2	UV	1.01 (0.22)	74.0 (22.5)	4 (3)	36 (6)	13 (3)	8 (10)	3.0 (4.0)	19 (15)	60 (18)
Panther 3	AC	0.75 (0.10)	32.7 (7.6)	9 (2)	24 (6)	14 (5)	5 (11)	0.0 (0.0)	22 (24)	52 (27)
W. F. Panther	AC	0.55 (0.10)	10.3 (3.9)	32 (16)	19 (5)	18 (4)	12 (13)	0.7 (1.4)	17 (13)	73 (10)
E. F. Panther	CC	0.61 (0.11)	11.8 (3.7)	20 (9)	37 (4)	39 (13)	29 (23)	1.5 (1.5)	12 (13)	50 (25)
Red Cedar 1	CC	0.77 (0.11)	14.5 (3.7)	13 (5)	29 (13)	24 (11)	1 (4)	1.1 (1.9)	29 (13)	65 (13)
Red Cedar 2	UV	0.75 (0.05)	18.2 (1.7)	23 (7)	32 (6)	21 (4)	6 (10)	1.9 (1.9)	40 (25)	49 (27)
Red Cedar 3	AC	0.90 (0.09)	21.8 (2.8)	13 (10)	58 (12)	35 (7)	7 (8)	13.6 (12.3)	11 (7)	64 (21)
S. F. Elk River 1	CC	0.99 (0.11)	36.8 (13.1)	11 (4)	30 (7)	21 (7)	48 (16)	1.8 (2.3)	8 (11)	21 (15)

model but cannot guarantee the best fitting or most relevant model (James and McCulloch 1990). Thus, we also examined numerous two-variable combinations in an attempt to identify a better fitting (i.e., based on direct criteria discussed below) or more biologically meaningful model. Objective and subjective approaches lead to the same models for each year.Relationships between a variable and a canonical function were gauged with two measures: 1) the total canonical structure matrix to determine the strength and direction of correlations, and 2) the partial F-ratio (i.e., F-to-remove) to test the significance of the decrease in discrimination if that variable was removed from the model. Each retained canonical function was evaluated directly by testing the hypothesis that group means were equal [i.e., F-statistic for the Wilks' lambda likelihood ratio ($P \leq 0.1$)] and by the squared canonical correlation (i.e., the percentage of the variation in a canonical function that was accounted for by differences in group means). Canonical functions were also evaluated indirectly by comparing results from direct and jackknife classification when data used to develop each canonical function were classified; if outcomes differed substantially (>15%), the canonical function was considered unreliable for classifying new observations. The linear classification criterion assigned each valley segment to the group in which the generalized squared distance between it and the group centroid was the smallest. Prior probabilities were set equal to the observed use group sizes for each year. The Cohen's kappa statistic (κ) (i.e., chance-adjusted correct classification rates) (Liebetrau 1983; Titus et al. 1984) and results from testing the null hypothesis that classification by a canonical function was no better than chance assignment (Ho: $\kappa \leq 0$; Ha: $\kappa > 0$; $P > Z$; $\alpha = 0.1$) (Liebetrau 1983) were reported.

Homogeneity of group dispersions was assessed (chi-square (X^2), $P > 0.1$) to determine appropriateness of deriving a canonical function with a pooled covariance matrix, thus permitting a linear canonical function to be used in subsequent classification. Multivariate outliers and normality of canonical scores for the High and Low use groups were evaluated by inspecting box and normal probability plots. All retained models appeared to meet assumptions for linear discriminant analysis, so results were presented for significance tests. Because our sample sizes were small, valley segments were not randomly selected, and variables describing influence of valley segment type emphasized dependence among valley segments, a randomization procedure was used also to determine significance when testing the null hypothesis that group means were equal (Manly 1998). For each year that a canonical function was developed, data on valley segment use were randomly reordered 1000 times. Discriminant analysis was repeated for each permutation of the randomized data to obtain the F-statistic for the Wilks' lambda. The test statistic derived from the original data was compared to the distribution of F-values arising from the 1000 random allocations to determine the proportion of values that were greater. If assumptions are met, then significance levels from classical statistical tests and from randomization procedures should be similar (Manly 1998).

Among-year differences in channel unit features comprising canonical functions

To better understand how juvenile chinook salmon relate to their habitat, among-year differences were assessed for any channel unit feature that significantly discriminated between juvenile chinook salmon use groups. Year was the independent variable and channel unit feature was the dependent variable in one-way analysis of variance with post-hoc comparisons conducted using the Ryan-Einot-Gabriel-Welsch multiple range test (REGWQ), controlling overall type I error rate at $\alpha=0.1$. Means were compared for years in which canonical functions deemed useable for classifying new observations were developed. Homogeneity of variance was evaluated with Levene's test (Snedecor and Cochran 1980). The assumption of normality was assessed by examining normal probability and box plots.

Applying models to classify new observations

To validate the canonical functions, the utility for classifying new observations and consistency of results among years were assessed. Each canonical function classified valley segments into juvenile chinook salmon use groups based on valley segment and channel unit data collected in each of the other six surveyed years. For example, the canonical function developed from 1988 data was used to classify valley segments based on valley segment and channel unit data collected in each year from 1989 to 1994. Because the observed juvenile chinook salmon use group was known for each valley segment in each year, the correct classification rate, the Cohen's kappa statistic, and the significance of the kappa statistic could be obtained and were reported.

Canonical functions were compared among and within years. For each canonical function, kappa values were averaged over the six years that new observations were classified, then the differences in mean kappa values were determined with one-way analysis of variance. Each canonical function was judged for each classified year by its kappa values, direction of misclassifications, and identity of misclassified valley segments.

RESULTS

Valley Segment Use by Juvenile Ocean-type Chinook Salmon

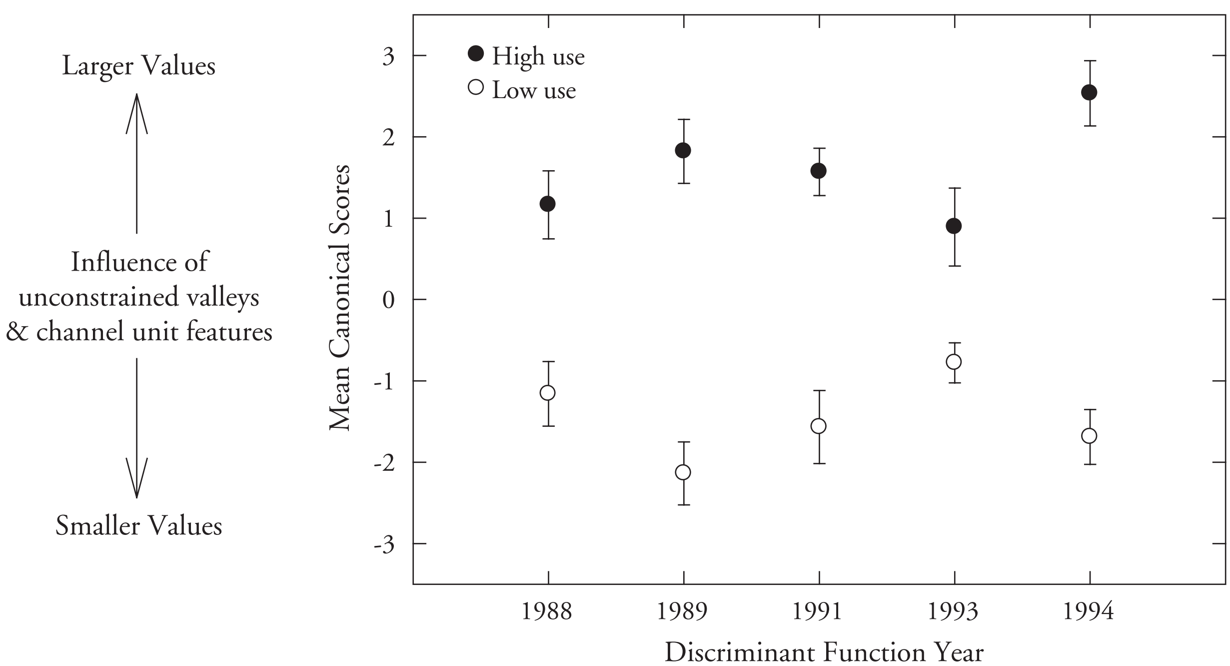
Models with two variables and that discriminated (Pr>F for Wilks' λ; $P \leq 0.03$) between the High and Low use groups for juvenile chinook salmon in tributary valley segments were developed for five of six years attempted (Table 3.5). The squared canonical correlation for these models ranged from 44 to 83%. Means of the canonical scores for the High use group were positive in every year (Fig. 3.3). The valley segment variable, influence of unconstrained valleys (I_{UV}), and one of three channel unit features, mean maximum depth of pools, mean density of wood in pools, or mean volume of pools, contributed significantly to group discrimination and were positively correlated with each canonical function and with the High use group (Table 3.5). Based on the significance of partial F-ratios and magnitude of total canonical structure coefficients, channel unit features were less significant discriminators and less correlated with the canonical function than the valley segment variable in all years except 1993. [[Table 3.5 and Figure 3.3 here]]

Correct classification rates for the initial five canonical functions when classifying data used in the development of each ranged from 83 to 100% (Table 3.6). Four canonical functions yielded correct classification rates from direct classification of valley segments that exceeded those from the jackknife resampling procedure, indicating

Table 3.5. Results of discriminant analysis to distinguish between valley segments that were highly used by juvenile chinook salmon and those that were not in tributaries of the Elk River, Oregon (1988-1994). A discriminant model that met the variable selection criteria could not be derived from 1990 data. Model development was not attempted with 1992 data. Model Wilks' λ P>F were determined from a single discriminant analysis and from a randomization procedure. Standardized canonical scores (SC) were calculated as SC = $c_1z_1 + c_2z_2$ where c was the standardized canonical coefficent, and z was the standardized score on each discriminating variable.

Year	Discriminating variables	Wilks' λ Partial F-ratio P>F	Total canonical structure coefficient	% Squared canonical correlation	Model Wilks' λ P>F (df) [randomization P>F]	Standardized canonical coefficients
1988	Influence of unconstrained valleys	0.01	+0.86	62	0.01 (2,9) [0.01]	1.33
	Mean maximum depth of pools	0.08	+0.51			0.79
1989	Influence of unconstrained valleys	0.0001	+0.93	82	0.01 (2,9) [0.01]	2.06
	Mean density of wood in pools	0.03	+0.42			0.85
1991	Influence of unconstrained valleys	0.0003	+0.81	74	0.01 (2,9) [0.01]	1.80
	Mean maximum depth of pools	0.007	+0.38			1.15
1993	Influence of unconstrained valleys	0.10	+0.66	44	0.01 (2,9) [0.01]	0.74
	Mean volume of pools	0.04	+0.82			0.98
1994	Influence of unconstrained valleys	0.0001	+0.94	83	0.01 (2,9) [0.01]	2.13
	Mean volume of pools	0.02	+0.42			0.83

Figure 3.3. Mean and 95% confidence intervals for canonical scores when valley segments were classified into juvenile chinook salmon use groups for tributaries of the Elk River, Oregon. Canonical functions used to classify valley segments were developed with data on valley segment and channel unit features obtained in 1988, 1989, 1991, 1993, and 1994



Year	n	Kappa (SE)	Kappa P>Z	Jackknifed correct classification rate	Jackknifed kappa (SE)	Jackknifed kappa P>Z
1988	12	67 (22)	0.01	75	50 (25)	0.02
1989	13	100 (0)	0.0000	92	85 (15)	<0.0001
1991	14	86 (14)	0.0007	86	71 (19)	<0.0001
1993	15	73 (18)	0.003	67	32 (25)	0.09
1994	15	87 (13)	0.0005	93	86 (13)	<0.0001

Table 3.6. Results from direct and jackknifed classification of valley segments from tributaries of the Elk River, Oregon. Canonical functions classified valley segments with the same data on valley segment and channel unit features that were used to develop each canonical function. The number of valley segments classified is n. Cohen's kappa statistic is the chance-adjusted correct classification rate [Ho: kappa ≤ 0 and Ha: kappa > 0; Z=kappa-0/SE of kappa (Liebetrau 1983; Titus et al. 1984)]

some instability in all but the canonical function from 1994. Because jackknifed correct classification rates exceeded their corresponding chance-adjusted correct classification rates [i.e., Cohen's kappa values (?)], at least one valley segment was correctly classified simply by chance in each year. Even so, valley segments were classified significantly (Pr>Z; P≤0.1) better by each canonical function than by random assignment. However, the usefulness of the canonical function from 1993 for classifying new observations was questionable given relatively unstable classification results and low jackknifed kappa values, so it was not considered further.

Of the four remaining canonical functions (1988, 1989, 1991, 1994), the highest jackknifed kappa values were for 1989 and 1994 (Table 3.6). Thus, these canonical functions performed best when classifying data used in their development. Whereas canonical functions from 1989 and 1994 were also associated with the largest squared canonical correlations, direct and indirect evaluations of canonical functions agreed (Tables 3.5 and 3.6). Similarly, the smallest kappa value and the smallest squared canonical correlation were observed for the canonical function from 1988. Significance levels of F-values for the Wilks' lambda from original parametric discriminant analyses and from randomization procedures were similar (Table 3.5). This suggested outcomes of classical statistical tests were not substantively affected by failures to meet parametric assumptions.

Among-year differences in channel unit features comprising canonical functions

The mean maximum depth of pools in valley segments did not differ significantly among three of the years that canonical functions were developed (1988, 1991, and 1994), but the means for these years were significantly (ANOVA; F3,50; P≤0.1) less than that for 1989 (Table 3.7). Neither the mean volume of pools (ANOVA; F3,50; P>0.1) nor the mean density of wood in pools (ANOVA; F3,50; P>0.1) differed significantly among the years that canonical functions were developed.

Applying models to classify new observations

Annual kappa values of the canonical functions ranged from approximately zero to 87% percent when classifying valley segments as new observations (i.e., based on valley segment and channel unit data from years other than those used to develop each canonical function) (Table 3.8 and Fig. 3.4). When chance-adjusted correct classification rates were averaged for years classified by each canonical function, means were between 44 and 52% and were not significantly different (ANOVA; F3,20=0.1; P=0.96) (Fig. 3.4). [[Figure 3.4 here]]

Although mean chance-adjusted correct classification rates did not differ, the canonical function from 1994 was least likely and that from 1989 most likely to misclassify valley segments as High use (Table 3.8). When presented with new observations, the canonical function from 1994 had the highest kappa values in three of six classified years (1989, 1990, and 1992) and matched the maximum kappa values for two other classified years (1988 and 1993). Relatively high kappa values for the canonical function from1994 stemmed from fewer misclassifications into the High use group of valley segments that were typically observed in the Low use group (Table 3.9).

Table 3.7. Annual mean (standard error) of selected channel unit features in tributaries of the Elk River, Oregon. Channel unit features were those that contributed significantly to discriminating between High and Low groups for juvenile chinook salmon use.

Year	Mean maximum depth of pools (m)	Mean volume of pools (m^3)	Mean density of wood in pools (number/100 m)
1988	0.91 (0.07)	54.7 (7.4)	8 (1)
1989	1.19 (0.09)	57.3 (8.9)	18 (3)
1991	0.95 (0.07)	47.9 (7.6)	13 (2)
1994	0.85 (0.04)	39.2 (5.3)	12 (3)

In general, the more years a valley segment was observed in a particular use group, the more often all four canonical functions classified it into that use group. Valley segments observed as High use in at least three years (Table 3.3) were classified as such more frequently by each canonical function than those observed as High use in fewer years. Each canonical function either correctly classified or misclassified into the High use group the seven valley segments that were observed as High use in at least three years when these were presented as new observations. The sole exception was the canonical function from 1991 that misclassified Red Cedar Creek 1 from the High into the Low use group in 1988 (Tables 3.3 and 3.9). Each of the eight valley segments that were observed as High use in fewer than three years (Table 3.3) were correctly classified as Low use by the canonical function from 1994 as were three of these eight valley

Table 3.8. Number of valley segments in the High and Low groups for observed use by juvenile chinook salmon in tributaries of the Elk River, Oregon (1988-1994). A valley segment was designated as either High or Low observed use for each year by comparing its estimated mean density of juvenile chinook salmon in pools to the threshold density for that year.

Classified year	n	Canonical function year	% Valley segments misclassified into Low	High	% Correct classification rate	Kappa (SE)	Kappa P>Z
1988	12	1989	17	17	83	67 (22)	0.001
		1991	33	17	75	50 (25)	0.02
		1994	17	17	83	67 (22)	0.001
1989	13	1988	14	33	77	53 (24)	0.01
		1991	14	33	77	53 (24)	0.01
		1994	14	0	92	85 (14)	<0.0001
1990	14	1988	33	38	64	29 (26)	0.13
		1989	33	38	64	29 (26)	0.13
		1991	33	38	64	29 (26)	0.13
		1994	33	25	71	42 (25)	0.05
1991	14	1988	0	14	93	86 (14)	<0.0001
		1989	14	29	79	57 (22)	0.005
		1994	14	14	86	71 (19)	0.001
1992	14	1988	50	58	43	-4 (24)	0.56
		1989	50	66	36	-7 (22)	0.62
		1991	50	58	43	-4 (24)	0.56
		1994	50	50	50	0 (27)	0.50
1993	15	1988	29	25	73	46 (23)	0.02
		1989	29	38	67	34 (24)	0.08
		1991	29	25	73	46 (23)	0.02
		1994	29	25	73	46 (23)	0.02
1994	15	1988	0	11	93	87 (13)	<0.0001
		1989	0	11	93	87 (13)	<0.0001
		1991	0	11	93	87 (13)	<0.0001

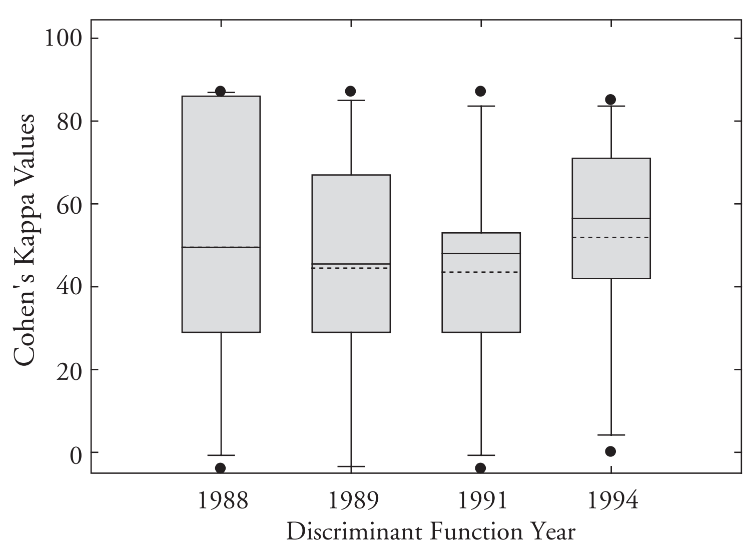


Figure 3.4. Box and whisker plots of chance-adjusted correct classification rates (i.e., Cohen's kappa values) when valley segments from tributaries of the Elk River, Oregon were classified as new observations by canonical functions developed with data from 1988, 1989, 1991, and 1994. Each canonical function classified valley segments as new observations into either the High or Low use group for juvenile chinook salmon using data on valley segment and channel unit features that were collected in each of six other years. Boxes designate the 25th and 75th percentiles, the solid line indicates the median, and the dotted line the mean, whiskers denote the nearest data point within 1.5 times the interquartile range, and 5th and 95th percentiles are shown by disconnected points. When kappa values were averaged over all six years classified, mean kappa values did not differ among the canonical functions (ANOVA; $F_{3,20}=0.1$; $P=0.96$).

Classified year	Misclassified valley segment	Observed High / Classified Low Canonical function year 1988	1989	1991	1994	Observed Low / Classified High Canonical function year 1988	1989	1991	1994
1988	Bald Mountain Creek 1	(X)	X	X	X				
	Panther Creek 1					(X)	X	X	X
	Red Cedar Creek 1			X					
1989	Bald Mountain Creek 1					X		X	
	Butler Creek 1					X		X	
	W. Fork Panther Creek 1	X		X	X				
1990	Bald Mountain Creek 1					X		X	
	Butler Creek 1	X	X	X	X				
	Butler Creek 2	X	X	X	X				
	Panther Creek 1					X	X	X	X
	Panther Creek 2					X	X	X	X
	W. Fork Panther Creek 1						X		
1991	Bald Mountain Creek 1		X		X				
	Panther Creek 1					X	X	(X)	X
	W. Fork Panther Creek 1						X		
1992	North Fork Elk River 1					X	X	X	X
	North Fork Elk River 2					X	X	X	X
	Panther Creek 1					X	X	X	X
	Panther Creek 2					X	X	X	X
	Panther Creek 3	X	X	X	X				
	W. Fork Panther Creek 1						X		
	E. Fork Panther Creek 1						X		
	Red Cedar Creek 1					X	X	X	X
	Red Cedar Creek 2					X	X	X	X
	Red Cedar Creek 3					X		X	
1993	Butler Creek 1	X	X	X	X				
	Red Cedar Creek 1					X	X	X	X
	Red Cedar Creek 2					X	X	X	X
	Red Cedar Creek 3						X		
1994	Panther Creek 3	X	X	X	X				
	Red Cedar Creek 1					X	X	X	(X)

Table 3.9. Identity of valley segments misclassified by canonical functions for tributaries of the Elk River, Oregon (1988-1994). Canonical functions, derived from data collected in 1988, 1989, 1991, and 1994, were used to classify each valley segment into either the High or Low juvenile chinook salmon use group based on data for valley segment and channel unit features collected in that year. The observed use group was determined by comparing the annual mean estimated relative density of juvenile chinook salmon in pools for each valley segment with the threshold density for that year. Valley segments that were misclassified when the canonical function year and the classified year were the same are in parentheses.

segments (i.e., Bulter Creek 2, Panther Creek 3, and South Fork Elk River 1) by the canonical functions from 1988, 1989, and 1991. The canonical functions from 1988 and 1991 misclassified three (i.e., Bald Mountain Creek 1, Butler Creek 1, and Red Cedar Creek 3) of the eight valley segments into the High use group in at least 1 year, as did the canonical function from 1989 (i.e., W. Fork Panther Creek 1, E. Fork Panther Creek 1, and Red Cedar Creek 3) (Tables 3.3 and 3.9).

Each canonical function misclassified at least one valley segment into the Low use group when new observations were presented, but none made this mistake with more than two valley segments in any year (Tables 3.3 and 3.9). Six of fifteen valley segments were misclassified from the High into the Low use group in at least one year (i.e., Bald Mountain Creek 1, Butler Creek 1 and 2; Panther Creek 3; W.F. Panther Creek; and Red Cedar Creek 1); the remaining nine valley segments were never misclassified as Low use (Table 3.9). Of the six valley segments that were incorrectly classified into the Low use group, all except Red Cedar Creek 1 were observed as High use in fewer than three years. With data for 1989, 1990, 1992, and 1993, all canonical functions were consistent in the number and identity of valley segments that were misclassified as Low use. Red Cedar Creek 1 in 1988 was misclassified into the Low use group by the canonical function from 1991 as was Bald Mountain Creek 1 in 1991 by the canonical function from 1994.

DISCUSSION

Valley Segment Use by Juvenile Ocean-type Chinook Salmon

Juvenile ocean-type chinook salmon were usually not randomly distributed among valley segments in tributaries of the Elk River. Unconstrained valleys and adjacent downstream valley segments were more highly used by juvenile chinook salmon and more consistently classified as such by each canonical function than valley segments of another type or in a different position. Although valley segment types may differ in channel unit features (Cupp 1989; Frissell 1992), unconstrained valleys in Elk River tributaries did not differ significantly from other valley segment types for any channel unit feature used in step-wise discriminant analyses except that the frequency of pools was significantly greater for constrained canyons than for unconstrained valleys in 1994 (Chapter 2). The importance of unconstrained valleys to juvenile chinook salmon in Elk River tributaries may, therefore, derive from characteristics not routinely assessed in fish habitat surveys. Cupp (1989) found that moderate slope bound valley segments, subsumed in unconstrained valleys in this study, were best distinguished from other valley segment types by characteristics of the fish assemblage instead of by channel unit features.

Unconstrained valleys have low gradients and wide floodplains that slow water velocities and can cause gravel and wood transported from upstream to accumulate, creating an enlarged hyporheic zone (Edwards 1998) and complex channel patterns (Gregory et al. 1991). Less topographic shading and longer distances between the wetted channel and riparian vegetation allowed more sunlight to reach streams in unconstrained valleys of Elk River (Zucker 1993). These coarse-scale geomorphic features were thought to contribute to greater gross primary production and aquatic macroinvertebrate biomass (Zucker 1993), nutrient and particulate retention (Lamberti et al. 1989), protection of redds and juveniles from high flows (Gregory et al. 1991), and groundwater upwelling (Baxter and Hauer 2000) in unconstrained than in constrained channels. Such conditions may have increased the suitability of unconstrained valleys in Elk River tributaries for both adult spawning and juvenile rearing by chinook salmon.

The configuration of habitat patches of similar type and juxtaposition of habitat patches of different types are commonly thought to affect the distribution and abundance of biota (Dunning et al. 1992; Wiens et al. 1993; Schlosser 1995; Hanski and Gilpin 1997). The linear nature of streams may render habitat adjacency particularly important for lotic species. Indeed, the juxtaposition of habitat types was recognized as influencing habitat value for salmon at the subunit (Inoue and Nakano 1999) and reach scales (Kocik and Ferreri 1998) and trout at the channel unit (D'Angelo et al. 1995; Baran et al. 1997) and landscape scales (Dunham and Rieman 1999). Similar to adult bull trout (Salvelinus confluentus) in the Swan River, Montana (Baxter and Hauer 2000), juvenile chinook salmon in Elk River tributaries were likely affected by both the type and spatial arrangement of valley segments. We found that valley segments near unconstrained valleys were more highly used than those farther away. At a landscape scale, certain beaver-generated patches were source areas for fish dispersal, influencing assemblage structure in adjacent streams (Schlosser 1995). Unconstrained valleys may function similarly because these are thought to be key spawning areas for chinook salmon in Elk River tributaries (Burck and Reimers 1978) and elsewhere in southwestern Oregon (Frissell 1992). Juvenile chinook salmon in excess of available habitat in unconstrained valleys may disperse to nearby valley segments. Juvenile anadromous salmonids have been noted to disperse up- and downstream from release sites for hatchery fish (Scarnecchia and Roper 2000) and from spawning sites for wild fish (Murray and Rosenau 1989; Kocik and Ferreri 1998; Scarnecchia and Roper 2000). Unconstrained valleys may also supply downstream valley segments with key resources, such as drifting macroinvertebrate prey, that may increase habitat suitability for juvenile chinook salmon. The influence of unconstrained valleys appeared stronger and to extend farther downstream than upstream which is consistent with the interpretation that the direction of water flow affected the degree of influence.

In addition to the valley segment variable, each canonical function contained one of three channel unit features. The canonical function developed from 1994 data contained the mean volume of pools, from 1988 and 1991 data contained the mean maximum depth of pools, and from 1989 data contained the mean density of wood in pools. Juvenile chinook salmon in the Elk River used and often selected pools (Chapter 2), but neither the frequency nor percent area of pools contributed significantly to group discrimination. Reaches with more pool area did however support higher densities of juvenile spring chinook salmon in Jackson Creek, Oregon (Roper et al. 1994). The percent of surface area in pools for Jackson Creek was about half that for tributaries of the Elk River (Chapter 2) and may explain the difference between the two studies. The valley segment variable, influence of unconstrained valleys, was more significantly correlated with each canonical function and with the High juvenile chinook salmon use group than any of the channel unit features examined for Elk River tributaries. Similarly, Watson and Hillman (1997) found that coarser-scale independent variables were more consistently and significantly related to bull trout density than finer-scale independent variables.

Differences among years in the discriminating ability of channel unit features likely derived from inter-annual variation in size and abundance of juvenile chinook salmon, in densities of other salmonid species, and to a lesser extent, in channel unit features. In years that useable canonical functions were developed, the estimated mean fork length of juvenile chinook salmon measured at a smolt trap on the Elk River was largest in 1994, intermediate in 1988 and 1991, and smallest in 1989 (K.M. Burnett and G.H. Reeves, unpublished data). Larger stream-type juvenile chinook salmon selected deeper habitats than their smaller counterparts (Everest and Chapman 1972). Correspondingly, juvenile chinook salmon in Elk River tributaries used valley segments with deeper pools more highly in years when these fish were relatively large as evidenced by canonical functions from 1988, 1991, and 1994. The mean maximum depth of pools did not differ significantly among these years, but the means for these years were significantly less than that for 1989. Because juvenile chinook salmon were smaller and pools were generally deeper, the mean maximum depth of pools appeared less important in determining valley segment use in 1989 than in other years. Deep pools can increase the abundance, diversity, and survival of juvenile salmonids by providing space for species and age classes to segregate vertically (Hartman 1965; Olson 1995), refugia from predators or drought (Sedell et al. 1990; Labbe and Fausch 2000) and cool water to help moderate summer stream temperatures (Matthews et al. 1994; Nielson et al. 1994).

Among-year differences in densities of other salmonid species may also have influenced which channel unit features were important discriminators of valley segment use. Habitats used by juvenile chinook salmon somewhat overlap those used by juvenile coho salmon (Stein et al 1972; Taylor 1991) and age 1+ steelhead (Everest and Chapman 1972; Hillman et al. 1987). However, juvenile chinook salmon sympatric with juvenile coho salmon may move into deeper water farther from shore and cover (Taylor 1991). To minimize direct interactions in 1994, the year with the greatest estimated densities of juvenile coho salmon and age 1+ steelhead in the upper basin (Chapter 2), juvenile chinook salmon in Elk River tributaries may have favored valley segments that contained pools of larger volume. This was reflected in the canonical function from 1994. The mean volume of pools did not differ significantly among years that canonical functions were developed.

Because densities of juvenile chinook salmon in the upper Elk River basin were greater in 1989 than any other studied year, valley segments that were most highly used might be expected to be those containing more wood in pools. Greater densities of territorial fish may be supported in the presence of wood due to the visual isolation it affords (Dolloff 1986). Although juvenile chinook salmon with a stream-type life history were more aggressive than those with an ocean-type life history (Taylor 1988), juvenile chinook salmon from Elk River tributaries did display agonistic behavior and establish territories (Reimers 1968). Thus, we think that intra-specific territoriality may be heightened when juvenile chinook salmon are abundant and that valley segments with greater densities of large wood in pools may be more important during such times than when juvenile densities are lower. The mean density of wood in pools did not differ significantly among the years that canonical functions were developed. Large wood is often a conspicuous component of streams in forested basins of the Pacific Northwest, influencing many stream structures and processes that can affect fish including channel morphology and sediment transport (for recent reviews, see Maser and Sedell 1994; Bilby and Bisson 1998). The importance of large wood has been demonstrated for other anadromous (e.g., Reeves et al. 1993; Inoue and Nakano 1998) and non-anadromous salmonids (e.g, Flebbe and Dolloff 1995; Harvey et al. 1999), including stream-type juvenile chinook salmon (Swales et al. 1986).

Relevance of Multiple Years of Study

Because juvenile chinook salmon density and habitat characteristics were estimated in each of seven years, we had a context for interpreting discriminant analysis results for any particular year. Canonical functions were developed for four of the seven years that data were collected. These four canonical functions significantly discriminated among valley segments with High and Low use by juvenile chinook salmon and had a relatively high likelihood of reliably classifying new observations. Reasons varied for the inability to develop canonical functions with data from the other three years; for 1992, discriminant analysis was not attempted because only two valley segments were observed as High use; for 1990, analysis was attempted, but no variable differentiated between the High and Low use groups; and for 1993, a canonical function was developed but rejected because its reliability for classifying new observations was suspect. Multiple years of data allowed us to compare the selected canonical functions. The valley segment variable, influence of unconstrained valleys, discriminated between use groups and was positively associated with the High use group in all four years. Thus, we were reasonably certain of its significance to and consistency of relationship with juvenile chinook salmon. Channel unit features that discriminated between groups varied among years, most likely from inter-annual variation in attributes of the salmonid assemblage and, to a lesser extent, in the channel units themselves.

Had data from only one or two years been analyzed, which is typical of most studies relating fish and their freshwater habitats, quite different conclusions might have been drawn regarding the ability to discriminate among valley segments for juvenile chinook salmon use and which factors contributed to group discrimination. For example, if data from only 1990 had been analyzed, we might have erroneously concluded that juvenile ocean-type chinook salmon were typically randomly distributed in tributaries of Elk River and that freshwater habitat characteristics were uncorrelated with their use of valley segments. Because multiple years were examined, we determined instead that valley segment and channel unit features were often significantly related to the use of valley segments by juvenile ocean-type chinook salmon. Importantly, this suggested that freshwater habitat may be of greater consequence to ocean-type chinook salmon than previously thought. Our observations are consistent with findings from other systems of substantial interannual variation in stream fish population abundance (Grossman et al. 1990; Ham and Pearsons 2000) and reinforce warnings of problems that may arise when examining fish-habitat relationships over a limited temporal extent (Platts and Nelson 1988).

Multiple years of data allowed canonical functions to be compared based on classification outcomes for each year. Valley segments were classified by canonical functions based on abiotic data collected in each of six other years. Correct classification rates could be developed for each year because the relative density of juvenile chinook salmon had been estimated. We were also able to identify inter-annual patterns in observed and classified use of valley segments. Consequently, we determined that the four canonical functions shared many desirable properties. Each canonical function correctly classified new observations for four of six years at a rate that was significantly better than chance. Generally, the more years a valley segment was observed in a particular use group, the more often each canonical function classified it into that use group. Canonical functions tended to correctly classify valley segments that were observed as High use. Although canonical functions often misclassified valley segments that were observed as Low use, this can be a valuable attribute. The annual estimated abundance of juvenile chinook salmon in Elk River tributaries was positively related to the estimated number of adults returning to spawn the previous fall (K.M. Burnett and G.H. Reeves, unpublished data). Therefore, Low use of a valley segment by juvenile chinook salmon in a particular year may reflect low adult returns rather than unsuitable rearing habitat. The propensity of canonical functions to misclassify valley segments as High use would be valuable when attempting to identify valley segments with the potential to be highly used even though this potential may not be realized in every year.

Because multiple years of data were available, canonical functions were compared on their average classification performance. Mean classification rates of the four canonical functions did not differ significantly when classifying new observations. However, the canonical function from 1994 was less likely than the other three to misclassify valley segments observed as Low use which elevated its chance-adjusted correct classification rate in some years. Thus, the function from 1994 appeared better at describing the actual use of valley segments and those from 1988, 1989, and 1991 the potential for High use. The observed pattern of valley segment use by juvenile chinook salmon in 1994 may have approximated the 'average' use among years. This was supported by the finding that canonical functions from 1988, 1989, and 1991 correctly classified more observations from the 1994 data than from any other year (Table 3.8) and may explain why the canonical function from 1994 was somewhat less likely to misclassify new observations than the other canonical functions.

Management Implications

If unconstrained valleys are sources of juveniles or key resources as we have suggested, then these may be practical conservation elements. Unconstrained valleys may be termed nodal habitats in the restoration classification of Frissell (1997). Ensuring inchannel, upslope, and upstream processes necessary for their proper function may appropriately be a high priority in a regional strategy to protect and restore populations of ocean-type chinook salmon. This may also benefit other salmonids because unconstrained valleys were often selected by juvenile coho salmon and cutthroat trout (Chapter 2). Valley segments adjacent to, particularly those downstream of, unconstrained valleys may receive second priority in conserving ocean-type chinook salmon. Unconstrained valleys are relatively uncommon, persistent features that are identifiable on topographic maps or air photos and were initially mapped with this approach for southwest Oregon then field verified (Frissell 1992). Following ecological principles outlined by Frissell (1997), we propose a management framework for unconstrained valleys.

If the ultimate goal is a regional network of properly functioning unconstrained valleys, then a prudent course is to ensure those with few human impacts maintain their function and to restore function in impacted unconstrained valleys deemed critical for completing the network. Characteristics of properly functioning unconstrained valleys include that stream channels interact with floodplains by meandering and overbank flows, that relatively low sediment transport capabilities not be overwhelmed, and that water temperatures are maintained within a suitable range through hyporheic exchange and riparian shading. Unconstrained valleys tend to be low gradient, depositional zones so may be especially susceptible to negative effects of land management (Montgomery and Buffington 1997).

After a region is mapped, each unconstrained valley can be assessed for the potential to supply habitat now and into the future then managed to meet conservation objectives. Maps of unconstrained valleys can be overlain with maps of land ownership, land use, and land cover to identify unconstrained valleys with a low probability of human impact. Because easily accessible areas downstream in a watershed were generally targeted for management first (Lichatowich 1989), minimally impacted unconstrained valleys will most likely occur on relatively remote public lands farther upstream in a watershed. After a low level of impact is confirmed, safeguarding against future anthropogenic threats and recovering any past damage is advantageous. These may often be viable management options, particularly for unconstrained valleys on public lands or for those on private lands when a common interest in conservation is established, incentives are provided, and landowner needs can be met.

Reconnecting the subset of minimally impacted unconstrained valleys that anchor the regional network is a next logical step. Restoring connections both within and among river basins is important. But the first choices for restoration may be degraded unconstrained valleys in basins with those that are relatively intact. Function will likely be restored only when natural processes that create and maintain habitat are recovered and any damaging activities can be stopped (Frissell 1997). Unconstrained valleys located downstream on larger rivers may offer the greatest long-term benefit for conserving ocean-type chinook salmon (Lichatowich 1989; Frissell et al. 1997) but may be more difficult to incorporate into a regional strategy. For Oregon coastal rivers, the property within each downstream unconstrained valley has generally been sub-divided and is held by many different private non-industrial owners (K.M. Burnett and G.H. Reeves, unpublished data). Working with these landowners to discover ways of meeting their needs while restoring ecological function appears an especially productive approach given the value of downstream unconstrained valleys to conservation.

Although process-based links to salmonid habitat have been identified in unconstrained valleys (e.g., Baxter and Hauer 2000), much remains to be learned about how these function from the site to the region. For example, valley segments meeting the definition of unconstrained valleys (i.e., valley floor width > 2x active channel width) may also include stream channels that are locally constrained by terraces. These valley segments may differ from unconstrained valleys in Elk River tributaries regarding geomorphic processes (e.g., interaction with riparian forests) and habitat characteristics (e.g., presence of large wood). Understanding potential differences and roles played by each sub-type is essential for effective management. Given such uncertainties, any regional strategy focused on, and site-specific restoration in, unconstrained valleys will profit if approached experimentally from an adaptive management framework with planned and funded monitoring and evaluation.

Channel unit features were also important to juvenile chinook salmon so may be reasonably considered in conservation strategies. Valley segment use by juvenile chinook salmon was positively related to the mean maximum depth of pools, mean density of large wood in pools, and mean volume of pools. Land management activities may reduce the depth and volume of pools (McIntosh et al. 2000) and decrease the abundance of wood in the channel (Montgomery et al. 1995). Habitat conditions are usually assessed by comparing local conditions to a suite of regional benchmarks (e.g., NMFS 1996; Reeves et al. 2001). However, relationships between any individual benchmark and fish use are not always clear. For example, juvenile chinook salmon in Elk River tributaries were observed almost exclusively in pools, but pool availability did not help distinguish between High and Low use valley segments even though the percent area of pools in these valley segments ranged from 'good' to 'poor' as defined in Reeves et al. (2001). Meeting a specific benchmark through inchannel engineering projects is unlikely to restore ecological function because the symptoms of habitat degradation rather than causes are addressed (Frissell 1997). Engineering approaches may have a role in watershed restoration by helping to secure areas in stream channels until natural processes recover and by halting and reversing the causes of degradation outside of stream channels. But as previously indicated, we believe that if the objective is restoring function throughout a watershed, then reliance on inchannel structural solutions will not be adequate because only a relatively few areas can be treated and projects typically have a relatively short life span (Frissell 1997; Reeves et al. 1997), thus actions that protect and recover natural processes will be necessary.

CONCLUSIONS

Our results indicated that juvenile ocean-type chinook salmon were usually not randomly distributed in Elk River tributaries. Unconstrained valleys and nearby valley segments were the most consistently and highly used by these fish. One of three channel unit features also helped identify highly used valley segments but each was a less significant discriminator than the valley segment variable. Factors limiting fish abundance or production of fish may differ among years in a given basin or among basins in a given year, thus fish habitat models developed with data for a particular time or place may not successfully transfer to other times or places (Leftwich et al. 1997). Multiple years of data in this study allowed variables contained in and classification outcomes of disciminant models to be compared. We are, therefore, reasonably confident in the transferability of the developed models to other years in Elk River. However, the transferability of the models to other basins should be evaluated where data on valley segment use by juvenile ocean-type chinook salmon are available or can be obtained. To assess if unconstrained valleys function as we hypothesized will require examining a range of basins by methods such as quantifying juvenile density, juvenile movement, and resource availability in unconstrained valleys and in nearby and more distant valley segments. The greater the extent of volitional movement by juveniles within the Elk River basin, the more likely their distribution will reflect their habitat choices rather than those of adults during homing and spawning. A data set of sufficient sample size will allow the components (i.e., distance, length, spatial position) comprising the variable, influence of unconstrained valleys, to be modeled separately and the relative importance of each to be judged. If unconstrained valleys are sources of juveniles or key resources as we have suggested, then these may be practical units for inclusion in conservation strategies for ocean-type chinook salmon.

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Appendix 3.1. Annual estimates of channel features for tributary valley segments in the Elk River, Oregon (1988-1994).

		Pools:							Fastwater:	
Year	Valley segment	Mean maximum depth (m)	Mean volume (m^3)	Mean density of wood (no./100m)	%Area	Number per km	%Area with boulders as dominant substrate	%Area with bedrock as dominant substrate	% Area with large gravel as dominant substrate	% Area with cobble as dominant substrate
1991	Anvil 1	0.83	22.9	10	38	45	3	0	50	47
1992	Anvil 1	0.97	18.0	6	24	32	26	0	39	50
1993	Anvil 1	0.77	22.4	11	37	47	31	0	35	31
1994	Anvil 1	0.78	21.5	11	34	42	24	0	36	50
1988	Bald Mountain 1	1.32	97.3	6	22	45	7	1	11	69
1989	Bald Mountain 1	1.93	62.2	20	17	33	4	4	19	59
1990	Bald Mountain 1	2.02	53.9	6	20	30	22	2	30	2
1991	Bald Mountain 1	1.65	118.7	14	18	34	6	2	26	46
1993	Bald Mountain 1	1.14	64.8	12	29	48	2	1	7	72
1994	Bald Mountain 1	0.97	53.3	10	33	54	13	1	0	71
1988	Butler 1	0.78	56.3	4	24	58	12	2	14	79
1989	Butler 1	1.51	107.9	22	20	66	27	29	0	41
1990	Butler 1	1.10	94.4	10	22	60	0	14	2	77
1991	Butler 1	0.95	64.7	10	23	58	2	17	31	53
1992	Butler 1	0.94	55.1	6	21	48	2	7	30	42
1993	Butler 1	1.01	60.6	7	26	61	14	4	12	76
1994	Butler 1	1.10	55.6	6	24	58	0	0	10	81
1988	Butler 2	0.83	61.6	1	19	56	4	22	5	83
1989	Butler 2	1.39	83.0	3	14	60	1	51	1	64
1990	Butler 2	1.26	77.1	1	18	48	0	14	18	71
1991	Butler 2	1.06	60.8	1	18	54	1	14	27	48
1992	Butler 2	0.97	87.6	1	18	51	0	16	47	30
1993	Butler 2	0.84	48.8	1	21	58	0	16	31	48
1994	Butler 2	1.04	54.1	1	23	63	1	5	32	53
1988	N. Fork Elk 1	1.35	73.0	7	9	13	21	67	0	14
1989	N. Fork Elk 1	1.21	79.7	12	11	26	35	13	0	0
1990	N. Fork Elk 1	0.95	51.9	9	17	38	21	0	37	53
1991	N. Fork Elk 1	0.94	35.4	10	21	28	34	14	49	38
1992	N. Fork Elk 1	0.90	40.8	8	25	46	16	0	15	54
1993	N. Fork Elk 1	0.96	61.7	14	23	47	100	0	0	0
1994	N. Fork Elk 1	0.94	52.4	5	25	45	56	0	0	57
1988	N. Fork Elk 2	1.08	81.6	13	16	38	36	0	11	37
1989	N. Fork Elk 2	1.12	67.7	23	13	31	25	7	5	22
1990	N. Fork Elk 2	1.13	125.5	17	10	40	4	0	29	64
1991	N. Fork Elk 2	1.09	82.7	16	14	35	4	1	52	42
1992	N. Fork Elk 2	1.12	83.7	21	14	46	10	0	19	77
1993	N. Fork Elk 2	0.96	93.5	21	16	49	41	0	8	53
1994	N. Fork Elk 2	1.02	78.1	45	16	44	25	0	2	43

Appendix 3.1. (continued)

Year	Valley segment	Pools: Mean maximum depth (m)	Mean volume (m^3)	Mean density of wood (no./100m)	%Area	Number per km	%Area with boulders as dominant substrate	%Area with bedrock as dominant substrate	Fastwater: % Area with large gravel as dominant substrate	% Area with cobble as dominant substrate
1988	Panther 1	0.89	85.5	5	19	43	0	36	7	71
1989	Panther 1	1.51	98.4	8	15	43	10	34	20	42
1990	Panther 1	0.83	60.1	6	18	61	0	22	3	67
1991	Panther 1	0.83	49.9	7	20	48	0	9	15	50
1992	Panther 1	0.87	76.9	11	18	42	0	27	39	48
1993	Panther 1	0.89	39.1	3	33	57	43	13	9	28
1994	Panther 1	0.86	52.7	2	28	63	0	46	0	57
1988	Panther 2	0.90	71.8	1	12	32	0	0	3	93
1989	Panther 2	1.40	111.3	4	8	34	6	0	0	47
1990	Panther 2	1.24	53.0	7	13	38	7	0	20	75
1991	Panther 2	0.99	56.6	5	12	25	5	0	22	49
1992	Panther 2	0.80	98.4	8	15	42	7	9	35	46
1993	Panther 2	0.91	69.8	2	16	41	30	5	15	52
1994	Panther 2	0.88	56.9	2	15	40	3	6	38	62
1988	Panther 3	0.69	34.2	9	19	29	0	0	0	83
1989	Panther 3	0.82	34.5	8	10	21	0	0	7	4
1990	Panther 3	0.94	28.5	9	9	18	0	0	6	71
1991	Panther 3	0.68	22.9	10	16	23	3	0	32	53
1992	Panther 3	0.75	45.7	11	9	17	0	0	35	53
1993	Panther 3	0.75	37.1	8	14	26	29	0	3	71
1994	Panther 3	0.64	26.2	5	19	33	5	0	66	30
1988	W. Fork Panther 1	0.51	8.7	12	20	15	0	0	2	82
1989	W. Fork Panther 1	0.73	16.5	43	14	19	22	0	16	62
1990	W. Fork Panther 1	0.41	6.2	51	11	12	0	0	29	71
1991	W. Fork Panther 1	0.47	11.3	34	21	28	13	1	11	83
1992	W. Fork Panther 1	0.55	14.5	49	17	21	0	0	29	63
1993	W. Fork Panther 1	0.63	7.5	16	18	18	35	0	1	83
1994	W. Fork Panther 1	0.55	7.4	19	22	21	15	4	30	63
1990	E. Fork Panther 1	0.46	11.4	13	25	35	21	0	0	86
1992	E. Fork Panther 1	0.66	16.3	31	35	38	11	2	23	36
1993	E. Fork Panther 1	0.72	12.1	23	39	34	63	1	3	44
1994	E. Fork Panther 1	0.61	7.4	13	55	43	18	3	23	33
1989	Red Cedar 1	0.90	11.4	20	11	11	0	0	30	70
1990	Red Cedar 1	0.69	10.4	15	27	32	0	0	16	66
1991	Red Cedar 1	0.80	18.3	12	20	30	0	0	37	80
1992	Red Cedar 1	0.94	20.3	12	15	21	0	0	52	56
1993	Red Cedar 1	0.74	15.5	12	38	46	10	5	20	42
1994	Red Cedar 1	0.72	12.7	5	38	43	0	3	31	74

Appendix 3.1. (continued)

		Pools:							Fastwater:	
Year	Valley segment	Mean maximum depth (m)	Mean volume (m^3)	Mean density of wood (no./100m)	%Area	Number per km	%Area with boulders as dominant substrate	%Area with bedrock as dominant substrate	% Area with large gravel as dominant substrate	% Area with cobble as dominant substrate
1988	Red Cedar 2	0.81	19.7	13	20	34	28	0	22	69
1989	Red Cedar 2	0.82	17.6	24	14	20	0	4	60	45
1990	Red Cedar 2	0.74	15.3	35	23	33	0	0	23	32
1991	Red Cedar 2	0.68	18.7	19	24	37	1	4	32	77
1992	Red Cedar 2	0.77	17.1	22	20	29	10	3	73	59
1993	Red Cedar 2	0.75	20.3	28	26	38	6	0	63	19
1994	Red Cedar 2	0.70	18.6	21	24	36	0	3	9	25
1988	Red Cedar 3	0.80	13.1	17	31	42	33	41	11	89
1989	Red Cedar 3	0.84	17.2	9	32	49	5	19	18	51
1990	Red Cedar 3	0.90	22.2	9	31	56	0	14	9	91
1991	Red Cedar 3	0.93	24.6	5	35	71	0	33	14	48
1992	Red Cedar 3	1.06	24.1	14	26	41	19	16	10	58
1993	Red Cedar 3	0.90	22.8	32	46	72	14	0	17	47
1994	Red Cedar 3	0.79	19.9	8	41	61	6	0	0	89
1988	S. Fork Elk 1	1.17	63.4	9	17	27	70	4	0	7
1990	S. Fork Elk 1	0.97	43.0	12	16	25	53	0	5	6
1991	S. Fork Elk 1	0.87	27.5	8	29	38	20	0	33	16
1992	S. Fork Elk 1	0.88	25.0	15	24	31	37	0	7	41
1993	S. Fork Elk 1	1.09	35.3	16	15	23	58	5	6	38
1994	S. Fork Elk 1	0.91	33.4	12	29	41	49	0	2	31