

AN ABSTRACT OF THE THESIS OF

Anthony O. Olegario for the degree of Master of Science in Fisheries Science presented on December 15, 2006

Title: Over-wintering Diet, Growth, and Prey Available to Juvenile Coho Salmon (*Oncorhynchus kisutch*) in the West Fork Smith River, Oregon

Abstract approved:

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Over-winter growth of juvenile salmonids may be linked to ocean survival and thus species persistence. Diet, growth, and prey available to juvenile coho, *Oncorhynchus kisutch*, were examined from December 2004 to April 2005 in four tributaries of the West Fork Smith River (WFSR), Oregon. Juvenile coho growth rate and condition were greatest in spring. Growth rate varied through winter and was highest in Crane Creek, a small intermittent stream (4.3km² basin area) and lowest in Beaver Creek (7.5 km²), a perennial stream. Prey availability and growth rate decreased in January and February as temperatures dropped, however stomach fullness was highly variable and not correlated to growth rate.

The stomach contents of 477 juvenile coho (age-0), were quantitatively examined using an index of relative importance. Juvenile coho fed primarily on benthic invertebrates; rarely consumed non-insectan food included coho fry, salmon eggs, aquatic snails (*Juga silicula*), salamanders (*Dicamptodon tenebrosus*), and terrestrial invertebrates. The major portions of their diets, in order of relative importance, were aquatic chironomid larvae (Diptera), baetid mayfly larvae (Ephemeroptera), limnephilid

caddisfly larvae (Trichoptera), and winter stonefly larvae (primarily Capniid Stonefly). Similarities in Relatively Important prey distinguished the two intermittent streams from the two perennial streams. In the WFSR tributaries, juvenile coho appear to rely on a variety of food sources to sustain growth and condition during winter. Small intermittent headwater streams may be disproportionately more important to stream fish with greater availability of prey than larger perennial streams highlighting the need to conserve and restore these habitats.

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Over-wintering Diet, Growth, and Prey Available to Juvenile Coho Salmon
(*Oncorhynchus kisutch*) in the West Fork Smith River, Oregon

by

Anthony O. Olegario

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Anthony O. Olegario, Author

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INTRODUCTION

Many populations of wild salmon in the Pacific Northwest (PNW) have been in decline since the early 1900's. In the Oregon Coast Range, coho salmon (*Oncorhynchus kisutch*) have been listed as threatened under the Endangered Species Act of 1972 (ESA) by the National Marine Fisheries Service (NMFS). Extensive research has elucidated many aspects of salmon ecology in the adult ocean phase and freshwater spawning phase (e.g., Hassler 1987; Lawson et al. 2004; Sandercock 1991). These studies form the basis for resource management decisions. Despite this large body of work, a review of the literature reveals a need for a better understanding of the freshwater life stage of juvenile salmonids, which is intimately tied to overall survival and thus species persistence. Importance of this early life-stage was suggested in studies showing that ocean survival of salmon was closely linked with growth and size during their freshwater rearing life-stage (Bilton et al. 1982; Holtby et al. 1990; Nislow et al. 1999), suggesting an advantage towards a larger body size.

Winter can be a time of high mortality for stream rearing salmonids. Food and habitat requirements for juvenile salmonids may be distinctly different in winter than during the summer. However, few studies on feeding habits and food resources have been conducted during winter. Most published winter studies of juvenile salmonids are limited to regions in higher latitudes where temperatures typically fall near freezing ($<1^{\circ}\text{C}$) and ice formation commonly occurs within the stream (Cunjak et al. 1998; Hoffsten 2003; Johnson 1982; Murphy 2006; Tschaplinski 1983). According to Parrish et al. (2004) winter is presumed to be a period of uncertainty for food acquisition because of the dynamic and variable nature of winter habitat, and some studies suggest feeding and

growth for coho cease in winter because of low temperatures and turbid water conditions from winter floods (Sandercock 1991).

Juvenile coho behavior has been documented to be distinctly different in winter than summer. During winter, juvenile salmon adopt a variety of survival strategies such as shifting habitats towards deeper pools with cover, moving to beaver ponds and side channels (Bell et al. 2001; Pollock 2004), and moving to smaller tributaries (Bramblett et al. 2002; Miller and Sardo 2003).

In the PNW winters are characterized by cool mild temperatures with frequent rain events while summers are warm and dry. In winter months stream flows increase, discharge fluctuates markedly, water temperatures decrease, and the availability of food change (Romero et al. 2005). For juvenile salmonids, food sources from aquatic origin may be more important than from terrestrial origin during the winter (Nakano and Murakami 2001). Colder temperatures and dormancy of deciduous vegetation in riparian areas provides less habitat and food for terrestrial insects and in turn, less food for secondary consumers such as stream fishes.

Seasonal shifts may make aquatic food sources more important. However, aquatic invertebrates are also impacted by reductions in temperature and high stream-flows which can result in lower densities (Imbert and Perry 2000; Hoffsten 2003; Roninson et al. 2004). Previous studies have shown food can be a major factor in determining the abundance and distribution of juvenile salmonids (Wilzbach 1985; Giannico 2000). Temporary food sources such as fish eggs, fry, and flesh from spawning adult salmon may also be important to help juvenile coho maintain body size in the winter (Bilby et al. 1998; Wipfli et al. 1999). Recent results compiled by the Environmental Protection

Agency's (EPA) Western Ecology Division show patterns of differential growth between tributaries of the West Fork Smith River (WFSR) basin in Oregon (Ebersole et al. 2006). This study was designed to compare availability and abundance of winter food sources for juvenile salmonids in these tributaries.

This study examined the winter diet, benthic prey available, and growth of juvenile coho salmon in streams with intermittent and perennial stream-flow in an Oregon coastal watershed in the WFSR basin, Oregon. The objectives of this study were to examine 1) the diet composition, growth rates, and available prey biomass to juvenile coho during winter, and to determine 2) if the monthly variation in the diet composition, growth rates, and available prey biomass differed between intermittent tributaries compared to perennial tributaries during winter.

METHODS

Study location

The study took place in the WFSR located in the Umpqua River basin of the Oregon Coast Range (Figure 1). The WFSR drains approximately 69 km² and has an elevation range of 60 to 869 m. Vegetation in the WFSR is dominated by Douglas-fir (*Pseudotsuga mensiezii*), red alder (*Alnus rubra*), and western red cedar (*Thuja plicata*). Predominant deciduous vegetation along the riparian area includes red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), and thimbleberry (*Rubus parviflorus*).

The WFSR basin is characterized by annual peak flows in the winter. Stream flows in the basin respond quickly to precipitation because of shallow soils and relatively impervious underlying geology consisting of sandstone-siltstone (Bureau of Land

Management, unpublished report on the Umpqua Resource Area, 2005). Winter temperatures seldom fall below freezing and average annual precipitation ranges from 165 to 229 cm, falling mostly as winter rain.

Precipitation data were obtained from rain gages maintained by the National Centers for Environmental Prediction (NCEP) and located approximately 48 km east of the WFSR. Stream temperature data were obtained from a subset of Onset StowAway TidbiT (Onset Computer Corporation, Bourne, Massachusetts) temperature data loggers installed by EPA as part of a larger study on freshwater conditions for juvenile salmonids (Ebersole et al. in review). At least one temperature logger was located within each of the 4 stream sections studied (within the first 800 m of each stream). For further detail of temperature collection methods see Cairnes et al. (2005). Streamflow data used for the study were acquired from a stream gage located at the base of the basin. The gage is maintained and operated by the U.S. Geological Survey.

Study sites

Four main tributaries of the WFSR were selected (Crane, Moore, Beaver, and Gold creeks) for the study (Figure 1; Table 1). Two study reaches within each tributary were selected (lower and upper) as subsamples per tributary. Each study reach was 50-100 meters in length. All study reaches were located within the first 800 m of the confluence with the WFSR where supplemental data (temperature, spawning density, and physical habitat measurements) were available from past and ongoing studies.

Fish species present in the streams studied include coho (*Oncorhynchus kisutch*), steelhead (*O. mykiss*), cutthroat trout (*O. clarkii*), and sculpin, (*Cottus* spp.). Numbers of coho typically make up over 80% of fish within the streams examined (U.S. Bureau of

Land Management, Coos Bay District Office, unpublished).

Geomorphology of the four tributaries studied is characteristic of steep headwall areas and narrow valley bottoms. These basins have low groundwater storage or recharge capacities due to the shallow soils and underlying bedrock geology. Fine and coarse sediment and woody debris are delivered into the stream channel via landslides and stream bank erosion.

Crane and Moore creeks are the smallest of the four basins examined and are considered intermittent streams with little to no surface flow during summer months, frequently trapping fish in isolated pools. The two larger basins, Beaver and Gold creeks, are perennial streams with year round surface flow. Beaver Creek is the largest of the four tributaries and is dominated by gravel and sand substrates. There are greater numbers of large wood key pieces (>10m length; > 0.6m diameter) in Beaver Creek than the other tributaries and riparian vegetation contains greater patches of conifer trees. The dominant substrates in Gold Creek are gravel/bedrock (Bureau of Land Management, unpublished report on the Umpqua Resource Area, 2005).

Sampling design

Fish sampling

Preliminary netting in shallow areas within the chosen study reaches was conducted to verify fish presence and assess relative densities within habitat units. A monthly sampling of all 8 sites was conducted between December 2004 and April 2005 and generally was completed within a 2 week period. Sampling occurred a total of 24 individual days and covered the range of conditions encountered for an average winter. Prior to netting at a site we noted general observations of fish behavior (active feeding,

hiding, position within habitat) from the stream bank. Length, weight, location, and stomach contents for diet of juvenile fish were collected at each study location.

Due to high flows, lower temperatures, and shifting fish behavior during winter we assumed that sampling methods used during summer to estimate abundance (i.e. snorkel surveys, electroshocking) would not be practical during winter. Instead we chose an equal-effort sampling method to compare relative densities of fish among sites. Fish were caught using a modified seining technique. A beach seine (7.6 x 1.0m) was extended across the stream with one end fixed while the other was used to encircle fish. Once surrounded, the bottom of the net was slowly drawn upward so fish could be captured with a 15.2 cm aquarium net and transferred to a holding bucket. Maintaining the net's lead-line close to the stream bottom to prevent fish from escaping helped to increase capture efficiency. Because in preliminary field tests a total of three netting attempts were sufficient to capture at least 15 fish, this protocol was performed in each sampling reach. This method minimized disturbance to the stream bottom as well as providing a measure to compare fish abundances between sites. Numbers of captured fish were divided by the number of netting attempts to provide a measure of relative abundance.

Captured fish were checked for passive integrated transponder (PIT) tags (Prentice et al. 1990), previously inserted by EPA staff, using a hand held scanner (Destron Fearing 2001F model); the identification number was documented if a PIT tag was detected. Fish were anesthetized with MS-222® (Argent Chemical Laboratories, Inc., Redmond, WA 98052) then measured (fork length) to the nearest 1.0 mm and weighed to the nearest 0.1g (wet mass). Fish were then observed for complete recovery

and returned to their original habitat. No mortalities of captured fish occurred during the study.

Stomach contents

Fish stomach contents were flushed with a 10-mL syringe assembly (Meehan and Miller 1978; Giles 1980) between dawn and dusk (07:00 – 16:00) to reduce bias associated with aquatic invertebrate behavioral drift peaks that occur at twilight (Rader 1997). Gastric evacuation rates for juvenile coho salmon are slow at temperatures below 10°C (Koski and Kirchhofer 1982). Stomach contents are assumed to represent the diet in the last 24 hours. Fish diet samples were placed directly on a coffee filter and placed in a whirl-pack® with a 70% ethanol solution for later processing. In the lab, prey lengths and head widths in a diet sample were measured with an optical micrometer and identified to family when possible. Organisms were placed into categories based on their origin (aquatic, terrestrial). We calculated the percent composition by number and mass, as recommended by Bowen (1996).

Additional data

Additional diet samples were taken at 2 locations along the main-stem WFSR above Gold Creek, and at the confluence of Moore Creek, on April 3rd and 4th, 2005. These sites were suspected to contain juvenile coho preying on recently emerged fry because EPA contract field crews (Dynamac Corp.) observed juvenile coho with distended bellies. We attempted to sample a third site higher in the main-stem but no juvenile fish were captured or visually observed. We assume juvenile coho had either out-migrated or were displaced by recent high stream-flows.

Prey availability

To estimate the benthic component of prey available to juvenile coho, bottom dwelling stream macroinvertebrates were collected using a surber sampler that collected from an area of 0.093m² with a 500µm mesh net. A removable PVC collecting bucket with quick release clamps approximately 9 cm in diameter at the end of the mesh net facilitated multiple collections. Six randomly selected surber samples were taken at each of the 100 m sampling units monthly. All invertebrate samples were preserved in plastic sealable bags (Whirl-pak®) with a final concentration of approximately 70% ethanol.

Benthic samples were sorted under a dissecting microscope to 5 orders: Ephemeroptera, Plecoptera, Trichoptera, Diptera, Coleoptera, and “other”. Dry biomass by category was estimated by weighing samples oven dried at 70 °C for 24 hours.

Diet analysis

Diet was analyzed by frequency of occurrence, numeric, and gravimetric (dry weight) methods (Bowen 1983). Macroinvertebrate biomass in the diet was estimated using taxon-specific published length-mass regression equations (Sample et al. 1993; Hodar 1996; Benhke et al. 1999) expressed as the dry weight (mg). *Juga silicula*, a Pleurocerid snail ubiquitous in the Pacific Northwest, was found in diet samples but there were no known regression equations to estimate biomass. We developed regression equations for length-weight using length measurements of *Juga* without shells. Approximately 40 *Juga* snails ranging in size from 5-21mm were collected from Oak Creek in Corvallis, Oregon. Dry biomass was obtained by oven drying at 70 °C for 24 hours then weighing samples with an analytical balance. The equation used was,

$$W = aL^b \quad (1)$$

where W is the dry weight, L is any linear dimension (body length, shell length, operculum length), and a and b are constants derived from the regression equation (Benke et al. 1999). Because shells and body parts of Juga in some diet contents were often broken or fragmented, but operculum (a lid on the shell of some gastropods) were typically present, we developed an additional regression equation using operculum length to estimate weight (Table 2).

The relative importance of food items were assessed using an index of relative importance (IRI) (Hyslop 1980) calculated for each food category,

$$\text{IRI} = (\%N + \%W) \times \%O \quad (2)$$

where,

$\%N$ = a food item's percentage of the total number of organisms ingested,

$\%W$ = a food item's percent of the total weight of food ingested, and

$\%O$ = a food item's percentage frequency occurrence in all stomachs that contained food.

The IRI is a composite index that combines three measures describing or quantifying animal diets that reduces bias that would occur if only one of the component measures were used (Hart et al. 2002).

Stomach fullness

To compare quantities of stomach contents between fish of different sizes, we normalized values by taking the dry mass of stomach contents (mg) of individual fish and dividing by the wet mass of that particular fish (g).

Growth and condition

Specific growth rates of tagged fish were calculated as the difference between the natural logarithms of mass over the time interval (Busacker et al. 1990):

$$G = (\ln M_{\text{final}} - \ln M_{\text{initial}}) / (t_{\text{final}} - t_{\text{initial}}) \quad (3)$$

where M_{initial} is the initial weight and M_{final} is the final weight of recaptured individual fish, and $(t_{\text{initial}} - t_{\text{final}})$ is the time period between recaptures. The natural logarithms of mass were used because growth rate is typically exponential over intervals of one year or less (Busacker et al. 1990). Growth for all fish captured (including fish with no PIT tags but that were measured and weighed) was also estimated by calculating the change in fork length and percent change in weight per day. The condition of fish was calculated using Fulton's condition factor (K) as follows:

$$K = W/L^3 \quad (4)$$

where W is the wet mass of individuals and L is length of individuals (Fulton 1902).

Spawning density

To determine if juvenile fish growth was influenced by the presence of spawning adults, spawning density within each tributary was estimated based on data collected by Oregon Department of Fish and Wildlife's (ODFW) annual surveys for the 2004-2005 spawning period. Densities are reported as total counts of adult spawners of coho salmon per 50 meter longitudinal stream length.

Movement

Movement of fish was monitored for PIT-tagged fish primarily using data collected by the EPA in addition to recaptured tagged fish during monthly sampling in my study. Larger scale movement patterns (in-out of tributaries) were documented using stationary PIT tag readers located near the confluence of each of the tributaries. The EPA

collected continuous data with a recorder attached to a transceiver (see also Wigington et al. 2003). Out-migration data was obtained from ODFW at a smolt trap located at the base of the WFSR (Figure 1). Smaller scale movement (<100m) was supplemented using data collected by the EPA where fish were collected bi-monthly using minnow traps and seining.

Statistics

One-way analysis of variance (ANOVA) was used to detect differences among measures of stomach fullness, length, weight and condition, of fish across locations (stream reach). Fish length and weight were transformed using natural logarithms to normalize variance before parametric analysis. A Kruskal-Wallis one-way ANOVA on ranks was used to test differences between growth rates and benthic biomass. The Kruskal-Wallis test does not require assumptions of normality and equal variance.

A multiple comparison procedure (Ramsey and Schaeffer 2002) was used to identify which measures differed and was followed by a Bonferroni correction factor. To compare growth, stomach fullness, and available prey across seasons, we used a two-way ANOVA with month and stream as fixed factors followed by a Bonferroni adjustment (Ramsey and Schaeffer 2002). Association between the number of prey in fish stomachs and gut fullness were examined using Spearman's correlation coefficient. This coefficient is a non-parametric measure of correlation which does not require assumptions of normality. Relationships between specific growth rate and mean monthly temperature were tested using linear regression (Splus v. 6.1).

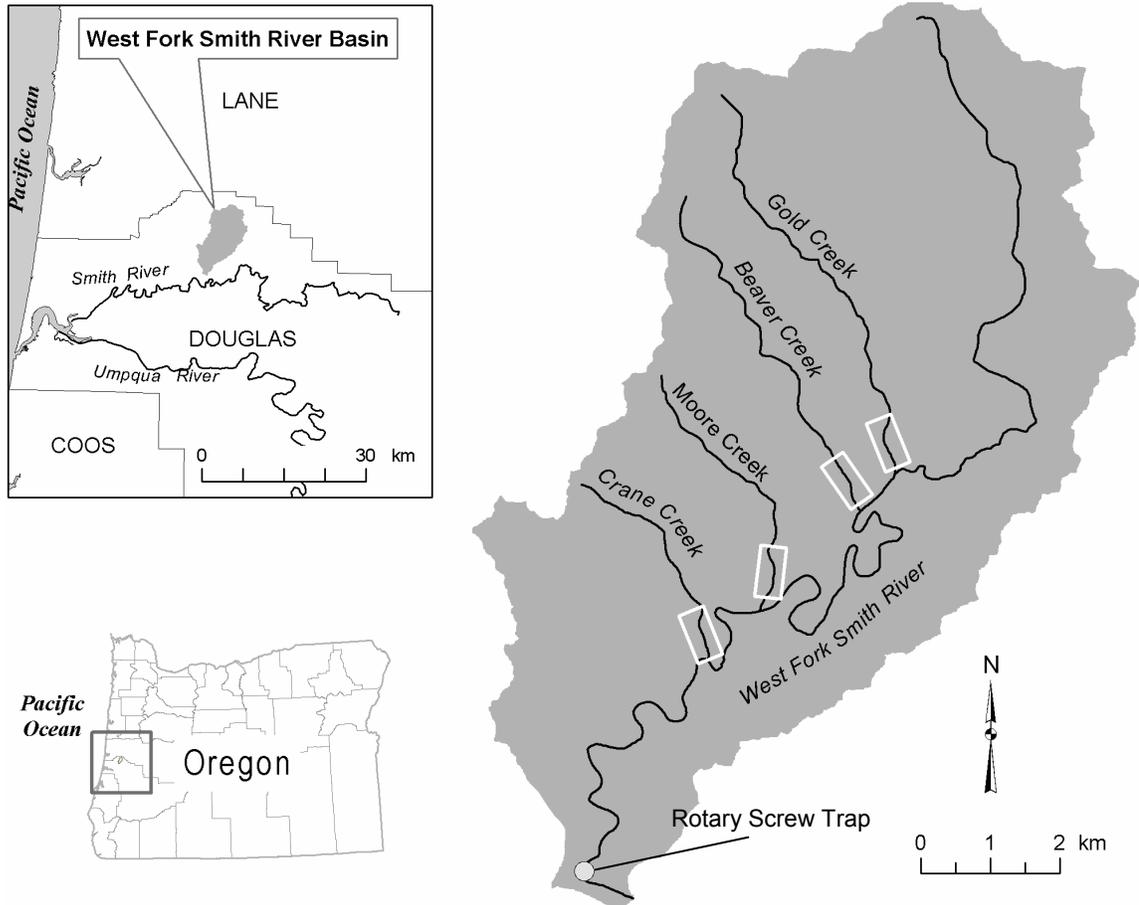


Figure 1. Study area location map within the West Fork Smith River basin, Douglas County, Oregon. Rectangles represent study reaches.

Table 1. Physical habitat characteristics and mean spawning densities for the stream sections studied and main-stem. Numbers in parentheses are standard errors.

Stream	Basin area (km ²)	Mean slope (%)	Mean depth (cm)	^a Mean		^b Spawning density	Stream order	Perennial (P) or Intermittent (I)
				winter water (°C)	Mean annual (°C)			
Crane	4.3	1.19(0.09)	14.58	7.97	11.11	2.81	3	I
Moore	4.7	0.69(0.04)	22.28	7.90	11.32	6.31	3	I
Beaver	7.5	0.42(0.08)	24.26	7.72	10.60	5.38	3	P
Gold	8.8	0.75(0.05)	26.21	7.51	10.50	1.94	3	P
West Fork Smith	68	-	-	7.51	11.40	-	4-5	P

^aMean water temperature from November through February from 2002-2005. Dataset obtained from EPA.

^bSpawning density totaled for all counts made for the first 800m of each of the 4 study tributaries. Numbers reported are in units of coho adults per 50 m.

Table 2. Intercept (a) and slope (b) from regression equations used to estimate biomass for *Juga*. R² indicates goodness of fit. Linear dimensions (L) used for equations depending on condition encountered in a particular diet sample.

L	Coefficients		Goodness of fit
	a	b	R ²
Shell length	0.0104	2.703	0.96
Body length (shell removed)	0.0435	2.424	0.92
Operculum length	0.2721	3.2688	0.94

RESULTS

Temperature and Discharge

The mean daily water temperature across all streams ranged from 4.65 to 10.66°C during winter (Nov. 2004-Feb.2005) (Figure 2). The lowest daily mean temperature (4.65°C) occurred on January 5, 2005. No ice or snow cover occurred throughout the winter sampling period. Streamflow for the WFSR was below average (based on 25 year record) from Nov. 2004-Apr.2005 (Figure 3). Two peaks in discharge occurred during the winter on Dec. 9, 2004 and Mar. 29, 2005 (Figure 4).

Relative fish abundance

Coho (age-0) were the dominant fish species and typically made up more than 90% of fish captured. No juvenile steelhead or cutthroat trout were captured in Beaver Creek. We visually observed juvenile fish actively feeding consistently throughout the winter. As ambient air temperatures began to rise fish were observed actively foraging both within the water column and at the water surface.

The numbers of fish captured at all 8 sites (2 sites per stream) throughout the sampling period remained relatively consistent (mean = 27) with the exception of March-April 2005 when numbers significantly dropped to an average of 10 fish per site (Table 3). Mean number of fish captured at each site per month ranged between 3 and 55 fish and was greatest in Moore and Beaver creeks, intermediate in Gold Creek, and lowest in Crane Creek (Table 3). Fish were somewhat evenly distributed: 56% at upstream sites compared to 44% at lower sites (Table 3). Numbers of fish caught between upper and lower sites were not statistically different ($P=0.1$).

Movement

Of the total tagged fish (n=157), that were captured more than once, relatively little movement (i.e. less than 50 m upstream or downstream) occurred throughout the sampling period from December 04 to March 05 (Table 4). Eighty two percent of fish stayed within 100 m of their original tag location. Ten percent of fish moved upstream between September 04 and December 04. Movement in the downstream direction occurred between March 05 and April 05. The distance fish moved downstream exceeded upstream distance (Table 4). One long distance upstream movement (5 km) occurred where a fish originally tagged in Coon Creek, a tributary to the WFSR, in September 2004 was recaptured in Crane in January 2005.

Spawning density

The highest density of spawning adult salmon occurred in Moore Creek (6.3 fish/50 m) while the lowest occurred in Gold (1.9 fish/50 m) (Table 1). Spawning densities occurred from December 17th to 23rd, 2004 for all streams (ODFW spawner survey data 2004-2005).

Diet

A total of 477 juvenile coho stomachs were examined. Juvenile coho, from 50-126 mm in total length, consumed prey from 55 families in 27 orders. The most common prey items were aquatic invertebrates, accounting for 75% of the total mass ingested. Entirely empty stomachs were found in only 5 (1%) of the fish sampled. Only 5 of fish sampled (1%) contained salmon eggs or recently emerged fry, which ranged from 13mm

to 40mm (Three fish with fry in stomachs were found in Moore Creek on 4/8/06; two fish with salmonid eggs were found in WFSR main-stem above Gold Creek on 4/4/06).

The major portions of juvenile coho diets, in order of relative importance, were aquatic chironomid larvae (Diptera), baetid mayfly larvae (Ephemeroptera), limnephilid caddisfly larvae (Trichoptera), and winter stonefly larvae (primarily Capniid Stonefly) (Figure 5, Appendix I). Percent Index of Relative Importance (Figure 5) was calculated to total 100% for each stream and date. Juvenile coho also fed on a variety of non-insects including coho fry, salmon eggs, aquatic snails (*Juga silicula*), salamanders (*Dicamptodon tenebrosus*), and terrestrial invertebrates. These prey items comprise the ‘other’ category in Figure 5.

Monthly composition of the diet also grouped by tributaries: in Crane and Moore Diptera and Ephemeroptera were most important during December and January, when Diptera were less important in Beaver and Gold creeks. Ephemeroptera were dominant in February at all sites, and throughout the study in Beaver (Figure 5). In March prey categorized as “other” (see previous paragraph), became relatively more important in Crane and Moore creeks. The dominant taxa by weight were Oligochaetes in Crane Creek and both Oligochaetes and Coleoptera larvae in Moore Creek.

Though the mean length of prey consumed by fish increased from 2.49 to 4.24 mm from October to April, mean biomass of prey ($\text{mg} \cdot \text{fish}^{-1}$) declined from October to December then increased from December to April (Figure 6). Peak mean prey biomass per fish was in March-April (Figure 6). The mean number of prey generally exhibited the opposite trend, increasing from October to January then decreasing from January to early spring (Figure 7; Table 5).

Stomach fullness

Overall mean stomach fullness (Figure 8) followed trends similar to prey abundance (Figure 7) in the diet. Not surprisingly, overall mean stomach fullness was correlated to the mean number of prey items in fish stomachs ($r=0.58$; $p<.001$; $n=387$). Though not statistically significant, stomach fullness increased from October to January, where it peaked, then declined in February to March (Figure 8). Variation among tributaries was high; overall average stomach fullness values were skewed by high fullness in Crane Creek in January (Figure 9). Mean stomach fullness values for Crane Creek were significantly ($p=.03$) higher than Moore Creek, where values were lowest in February-March, but not significantly different than the other study streams.

Prey availability

Benthic prey availability was low throughout the study, peaking at $< 2 \text{ g}\cdot\text{m}^{-2}$ and less than $1 \text{ g}\cdot\text{m}^{-2}$ most of the winter. When prey availability between months was compared statistically it was significantly lower in January than March (Figure 10) ($p=.04$). Through the winter months Crane and Moore creeks displayed similar trends in biomass of prey availability and were generally higher than Beaver and Gold creeks, though not statistically significant (Figure 10). From December through March prey availability in Beaver Creek was an order of magnitude lower than Crane and Moore creeks (Figure 11). In general benthic biomass of Trichoptera and Ephemeroptera availability were greatest for all streams and months (Table 6), though mean Plecoptera biomass was also high at Moore Creek. Total mean biomass of benthic invertebrates available was lower in Beaver and Gold creeks, often reflected by a magnitude lower biomass of Diptera and Ephemeroptera and fewer Trichoptera each month (Table 6).

Though Plecoptera biomass was much lower in Gold Creek, stonefly biomass in Beaver Creek was comparable to Crane and Moore creeks.

Growth and Condition

Juvenile coho grew throughout the winter. The highest growth rates occurred in spring and the lowest growth rates occurred mid-winter from January to February (Figure 12). Fish condition did not follow the same pattern as growth, decreasing from September to December-January, increasing from January to February, with a slight decrease from February to March (Figure 13).

Pit-tagged fish that were captured multiple times during the study showed similar trends. Growth rates were highest in early spring and were significantly ($p = .001$) lower in February than other months (Figure 14). Growth rates were positively correlated with stream temperature (Figure 15). When compared among streams, growth rate for Crane Creek (mean instantaneous growth rate = $0.93 \text{ g}\cdot\text{g}^{-1} \text{ day}^{-1}$; SE = 0.09; Table 7) was significantly greater than Moore, Beaver, and Gold creeks ($p=.001$). Over-winter growth rate for Moore and Gold creeks were similar and the lowest growth occurred in Beaver Creek (Table 7).

In December 2004 there were no differences in initial size (Fork Length (mm)) among juvenile coho salmon in Crane, Moore, Beaver, and Gold creeks ($p=0.7$; Figure 16). An increase in length and weight of coho was observed from December to January except for Crane Creek where there was a slight decrease (Figure 16). Between January and February Crane and Moore creeks mean length and weight of coho increased while in Beaver and Gold a decrease was observed (Figure 16). Between February and March-April mean lengths and weights increased for all streams (Figure 16).

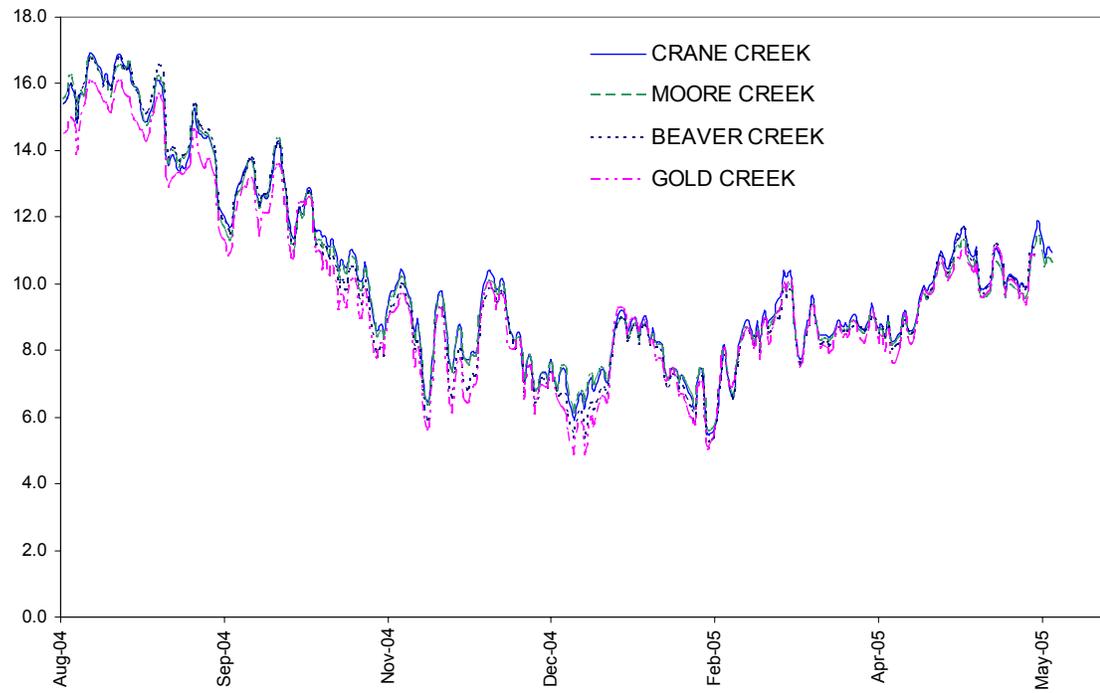


Figure 2. Mean daily temperature (Celsius °C) of the streams studied (Crane, Moore, Beaver, Gold creeks). Data obtained from EPA, Corvallis Laboratory temperature loggers.

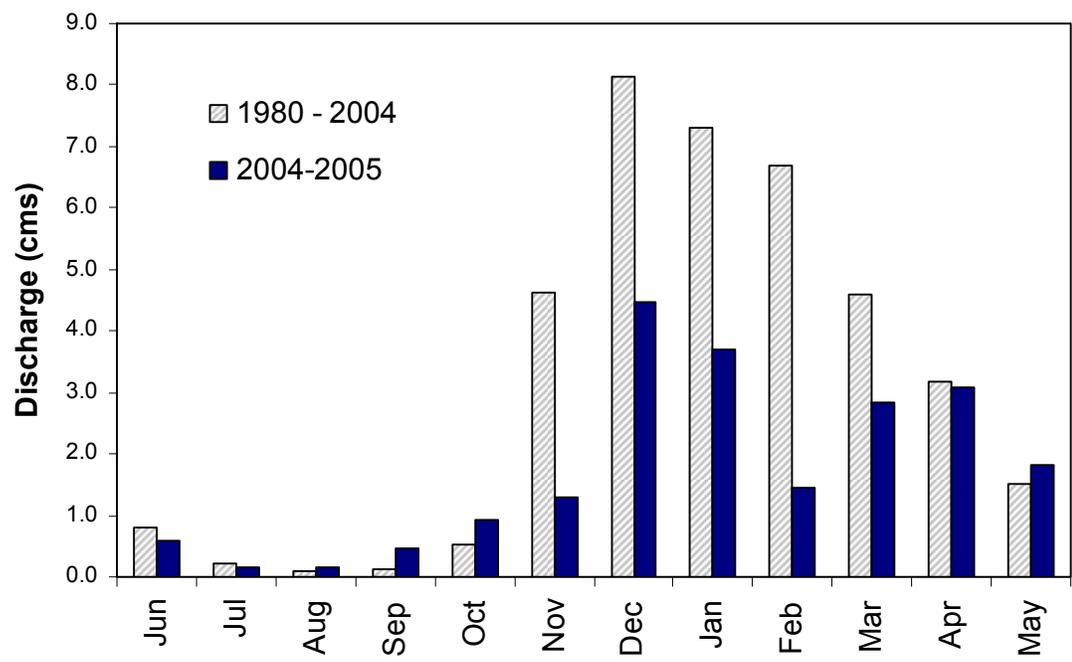


Figure 3. Mean daily discharge (m^3/s) per month for the West Fork Smith River averaged for 1980-2004 period of record (hatch bars) and the 2004-2005 sampling period for this study (solid bars). Data obtained from EPA, Corvallis Laboratory.

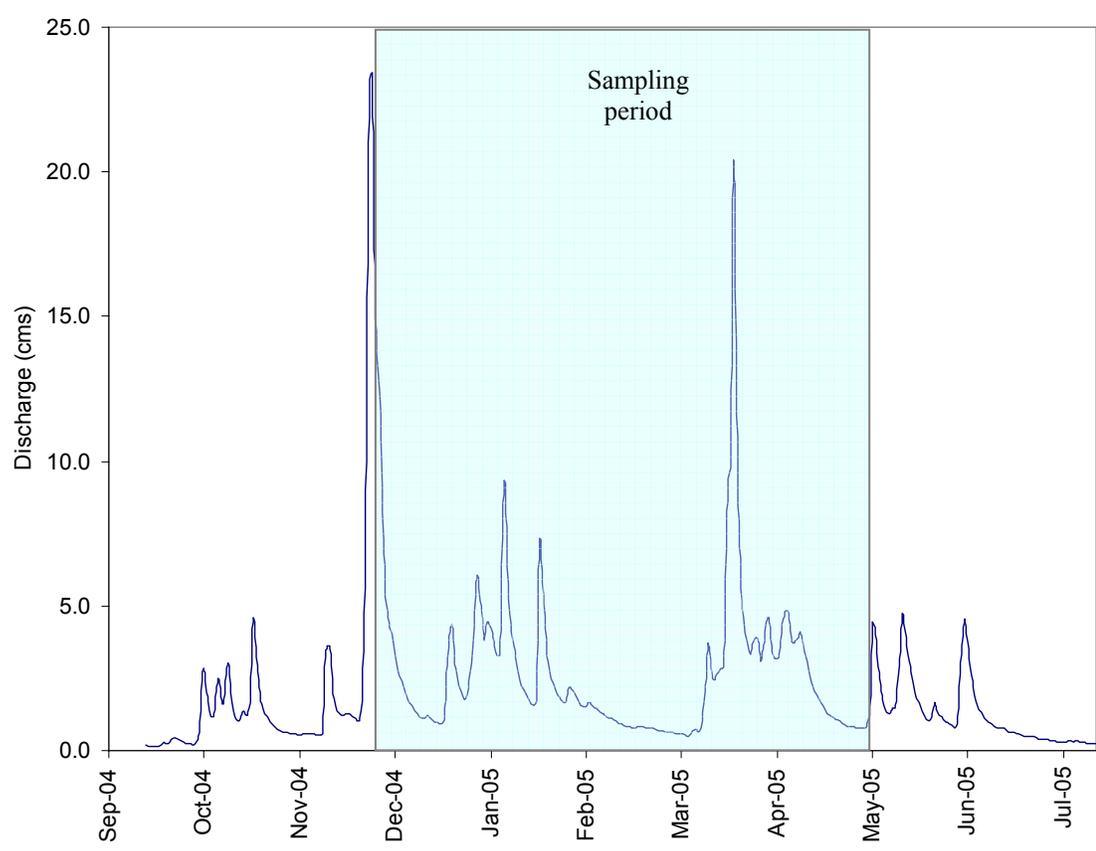


Figure 4. Mean daily discharge for the West Fork Smith River in 2004-2005. Shaded area depicts the time period sampling occurred. Douglas County, OR.

Table 3. Numbers of fish captured at each site per month. Lower and upper sites are within the first 800m (confluence with West Fork Smith River upstream) of each sampling stream reach. Numbers reflect the sum of three netting attempts made at each site. PIT tag recaptures represent the number of tagged fish recaptured and used to calculate growth.

	CRANE		MOORE		BEAVER		GOLD	
	lower	upper	lower	upper	lower	upper	lower	upper
DEC	15	22	42	18	20	55	19	35
JAN	16	30	40	25	19	50	19	35
FEB	31	40	44	30	19	50	30	36
MAR	16	30	44	30	27	50	30	32
APR	4	9	24	12	3	14	11	11
Mean/site	16	26	39	23	18	44	22	30
PIT tag recaptures	3	15	55	18	6	6	8	24

Table 4. Movement summary of recaptured juvenile coho in the stream reaches studied in the West Fork Smith River, OR. Movement distance is the length moved between initial and final recapture locations.

Movement direction from original location	Number of fish	Time period of movement	Distance Min – Max (km)
up	15	Sept 04 - Dec 04	0.05-5.0
down	13	Mar 05 - May 05	0.01-6.0
stay	129	Dec 04 - Mar 05	-

Note: Twenty fish were recaptured at the smolt trap located at the base of the WFSR basin in May 05.

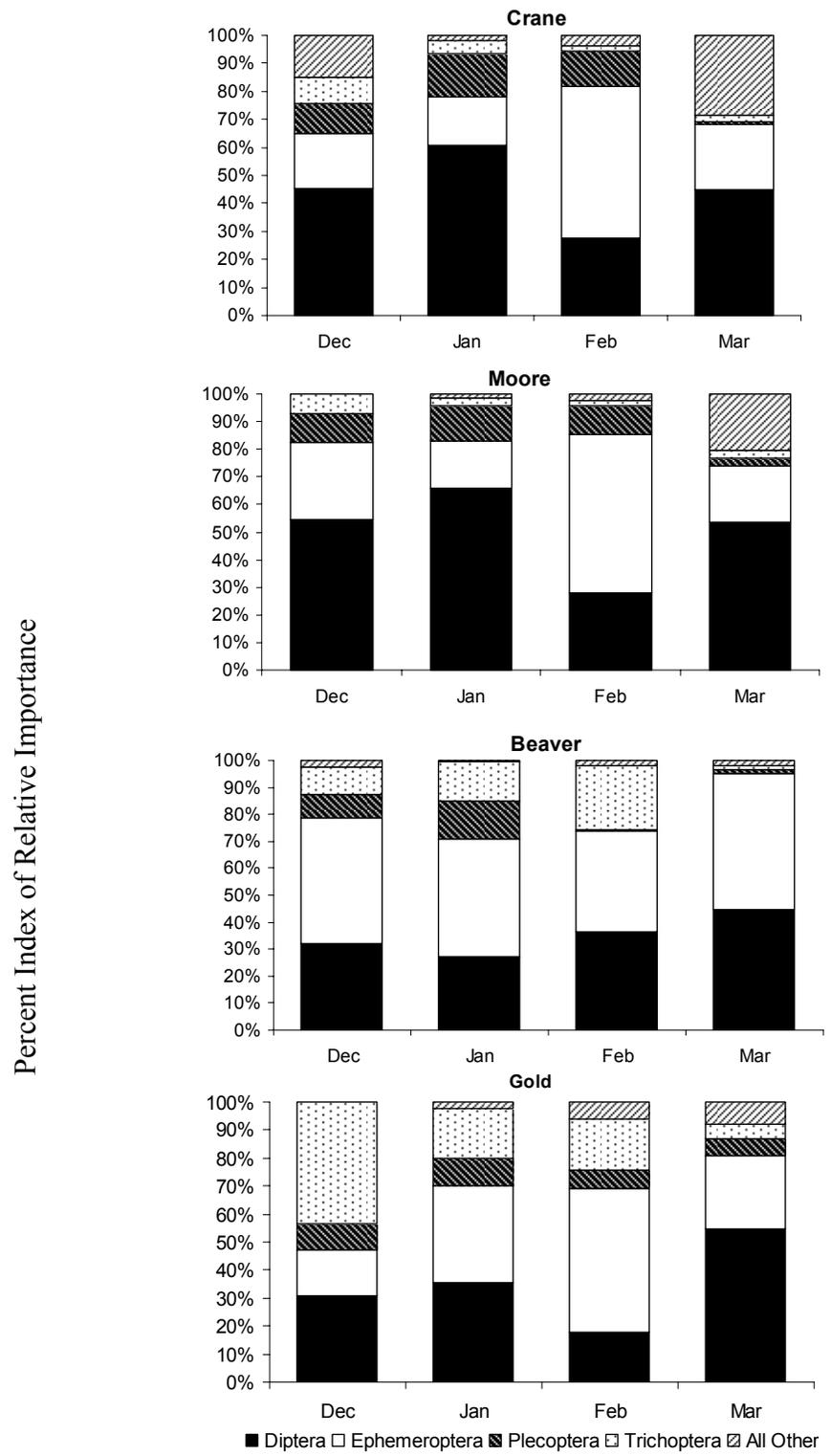


Figure 5. Major food items of juvenile coho in Crane, Moore, Beaver, and Gold creeks in the WFS basin by month. Food items are presented as percent Index of Relative Importance (IRI%) for each month.

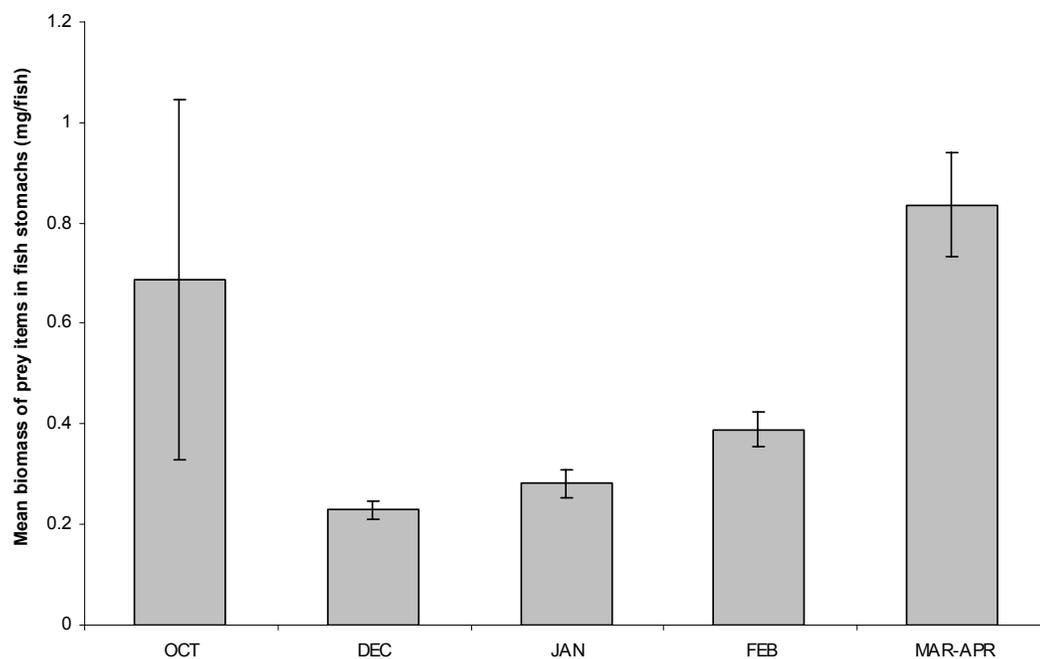


Figure 6. Mean monthly biomass of prey found in stomachs ($\text{mg}\cdot\text{fish}^{-1}$) of juvenile coho from December 2004 to March-April 2005. Vertical lines represent standard errors.

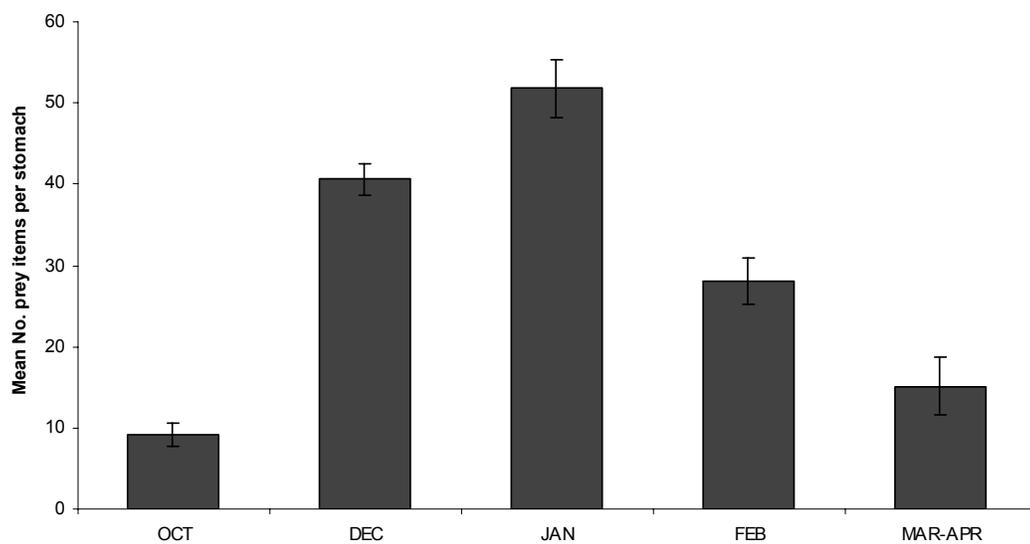


Figure 7. Mean monthly number of invertebrates in stomachs ($\text{No.}\cdot\text{fish}^{-1}$) of juvenile coho from December 2004 to March-April 2005. Vertical lines represent standard errors.

Table 5. Mean No. of prey items in diet samples (No.·fish⁻¹) for Crane, Moore, Beaver, and Gold creeks in winter (December 04 - March 05).

	Dec	Jan	Feb	Mar	Mean
Crane	17.8	49.4	20.8	9.3	26.5
Moore	9.7	20.3	11.0	5.8	12.4
Beaver	45.0	32.9	19.8	15.2	18.0
Gold	14.3	23.2	15.0	9.2	15.8
Mean	21.7	31.4	16.7	9.9	15.5

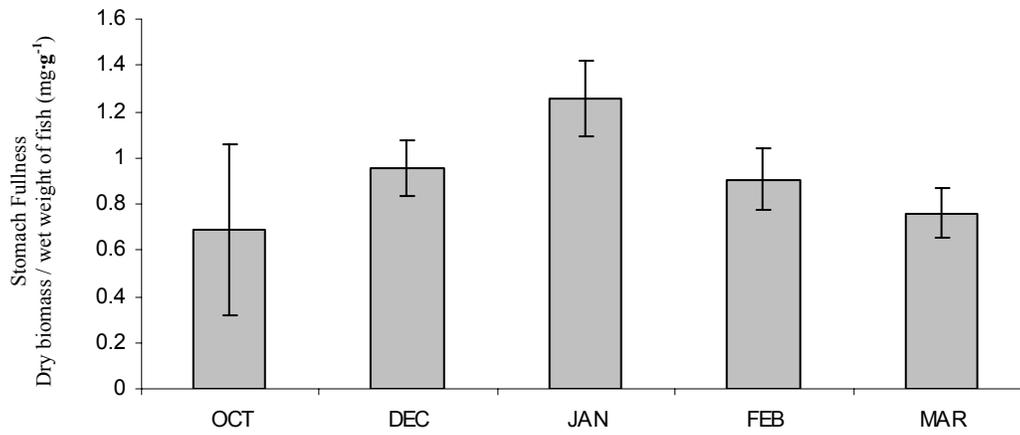


Figure 8. Mean stomach fullness per individual fish weight by month (mg·g⁻¹). Normalized by the wet weight of fish. Vertical lines represent standard errors.

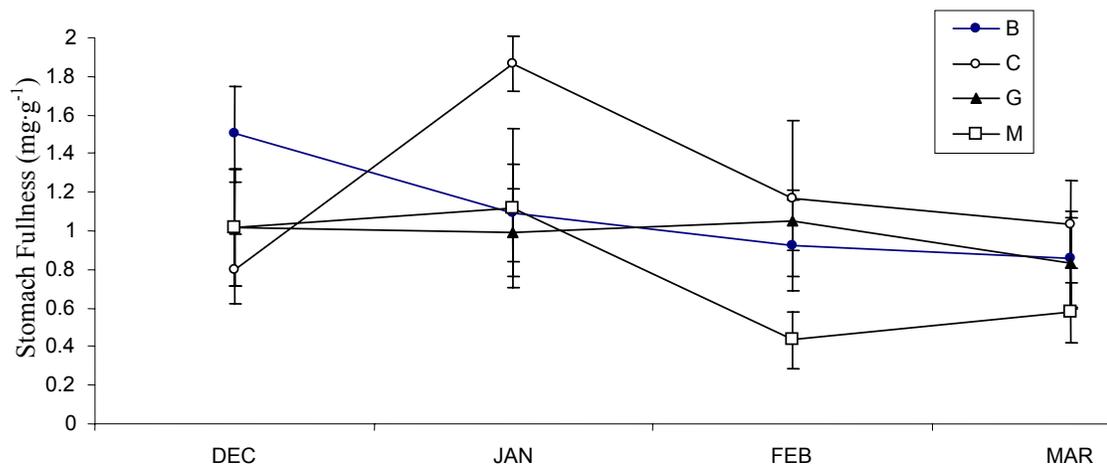


Figure 9. Mean stomach fullness (mg·g⁻¹) by stream B-Beaver, C-Crane, G-Gold, M-Moore. The vertical lines represent standard errors.

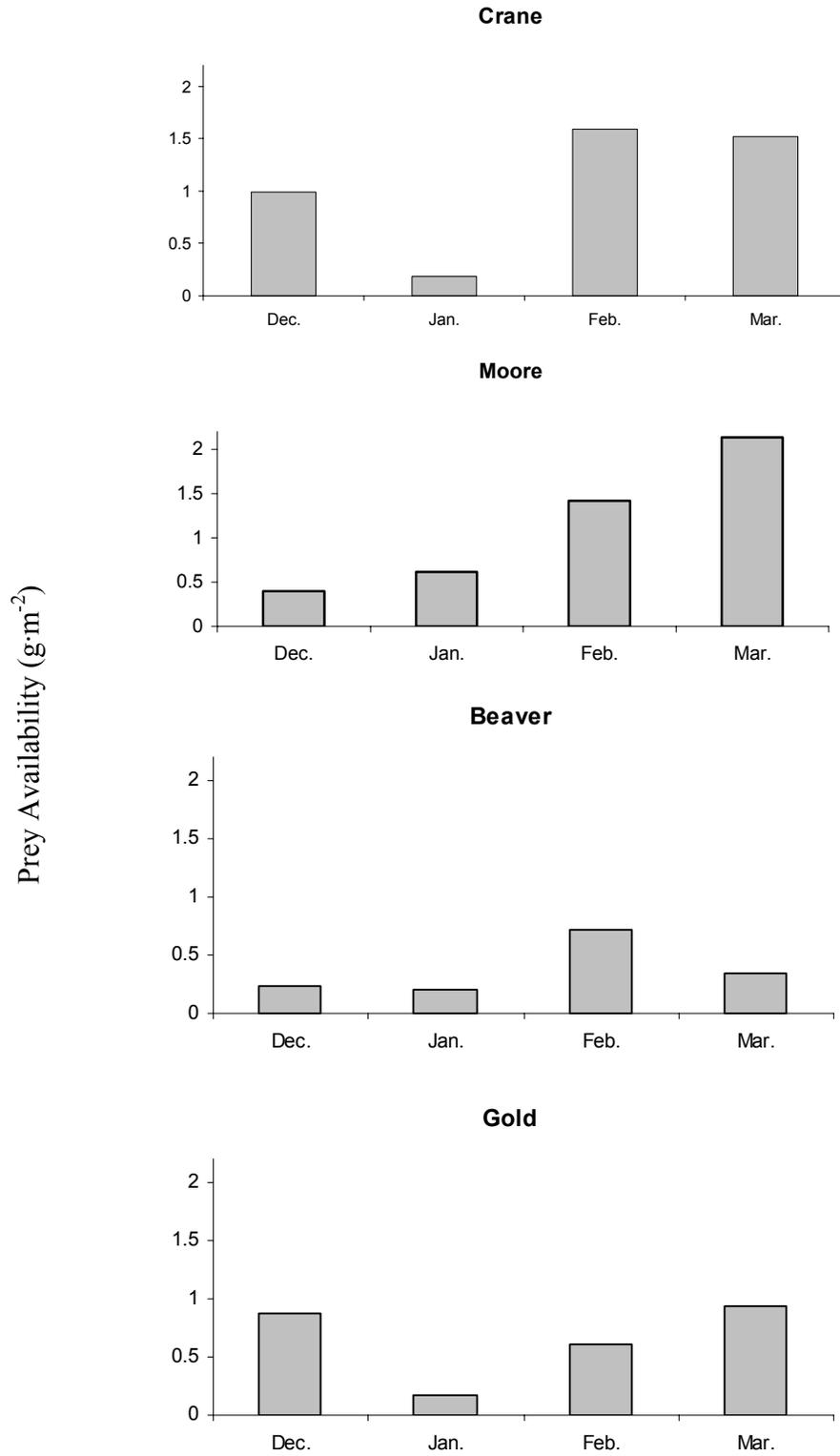


Figure 10. Monthly benthic biomass density (g·m⁻²) for Crane, Moore, Beaver, and Gold creeks.

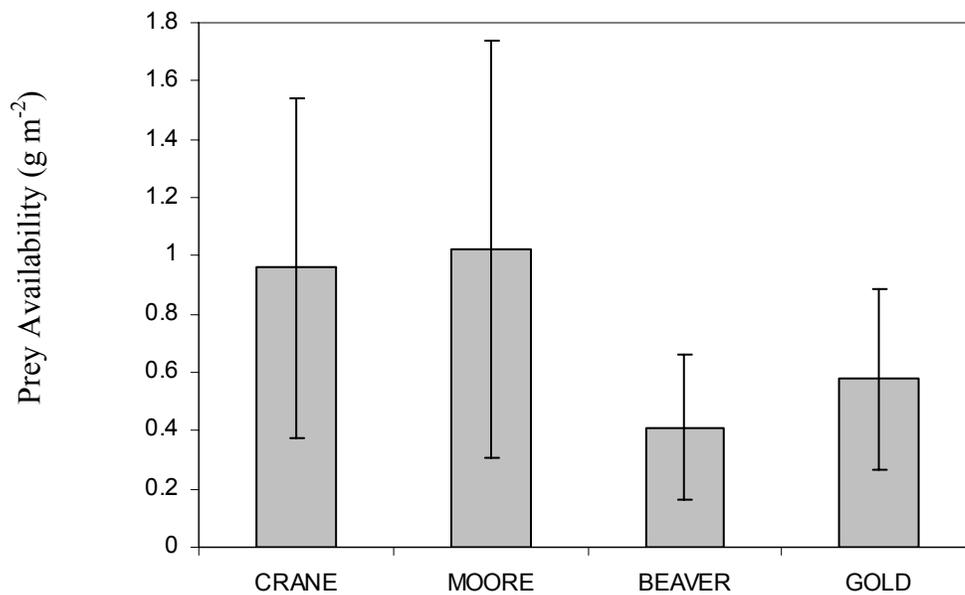


Figure 11. Total mean prey availability (g m⁻²) through winter (Dec. – Mar.) for Crane, Moore, Beaver, and Gold creeks. Error bars represent ± 1 standard deviation (SD).

Table 6. Prey availability expressed as mean dry biomass density ($\text{mg}\cdot\text{m}^{-2}$) by taxa order.

		Crane Cr.	Moore Cr.	Beaver Cr.	Gold Cr.
Diptera					
	Dec.	45	28	2	6
	Jan.	21	35	7	43
	Feb.	280	11	24	4
	Mar.	274	320	5	4
	Mean per month	155	98	10	14
Ephemeroptera					
	Dec.	73	128	111	6
	Jan.	51	151	93	43
	Feb.	475	375	208	4
	Mar.	426	106	183	4
	Mean per month	256	190	149	14
Plecoptera					
	Dec.	195	88	7	93
	Jan.	34	91	11	16
	Feb.	41	410	25	14
	Mar.	37	208	404	10
	Mean per month	77	199	112	33
Trichoptera					
	Dec.	573	75	43	324
	Jan.	55	255	54	56
	Feb.	465	457	396	317
	Mar.	455	637	3	355
	Mean per month	387	356	124	263
All other					
	Dec.	0	37	51	15
	Jan.	4	9	17	14
	Feb.	339	18	18	5
	Mar.	335	5	13	8
	Mean per month	169	17	25	10
Total mean biomass		209	172	84	67

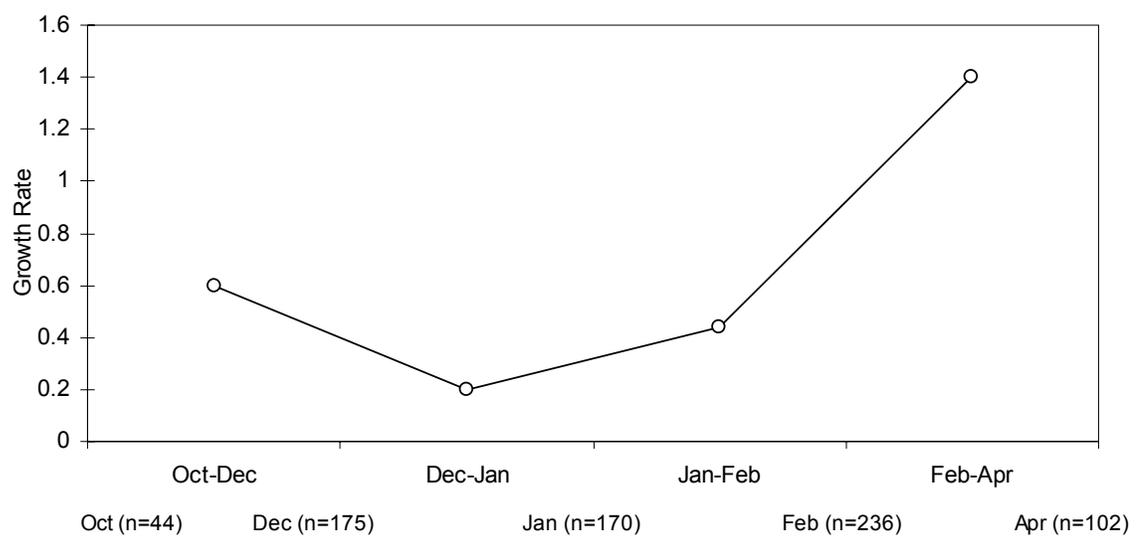


Figure 12. Juvenile coho salmon growth rates ($\text{g}\cdot\text{g}^{-1}\text{ day}^{-1}$) from October 2004 to April 2005 across all study streams.

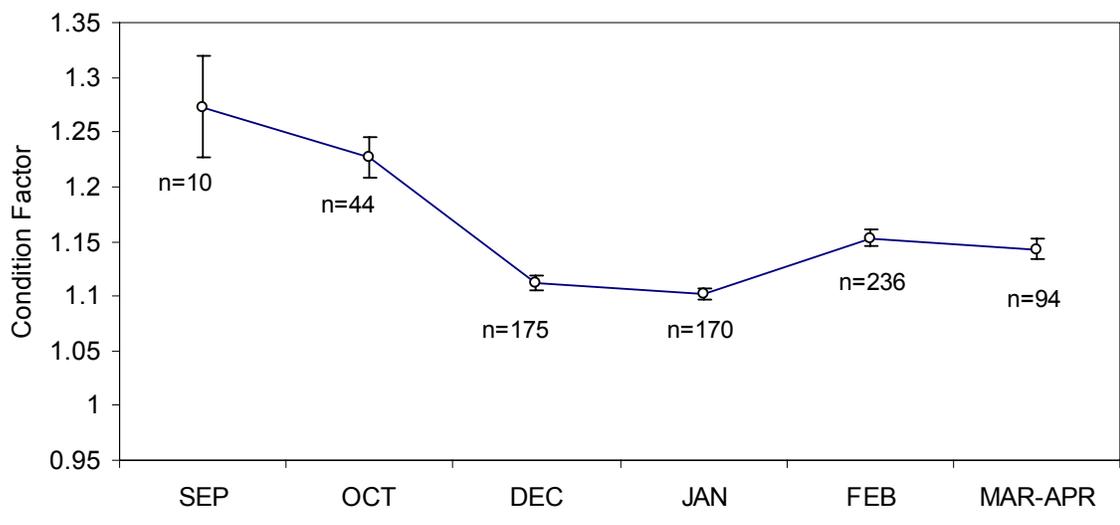


Figure 13. Average Fulton's condition factor for all fish from September 2004 to March 2005. Vertical lines represent standard errors.

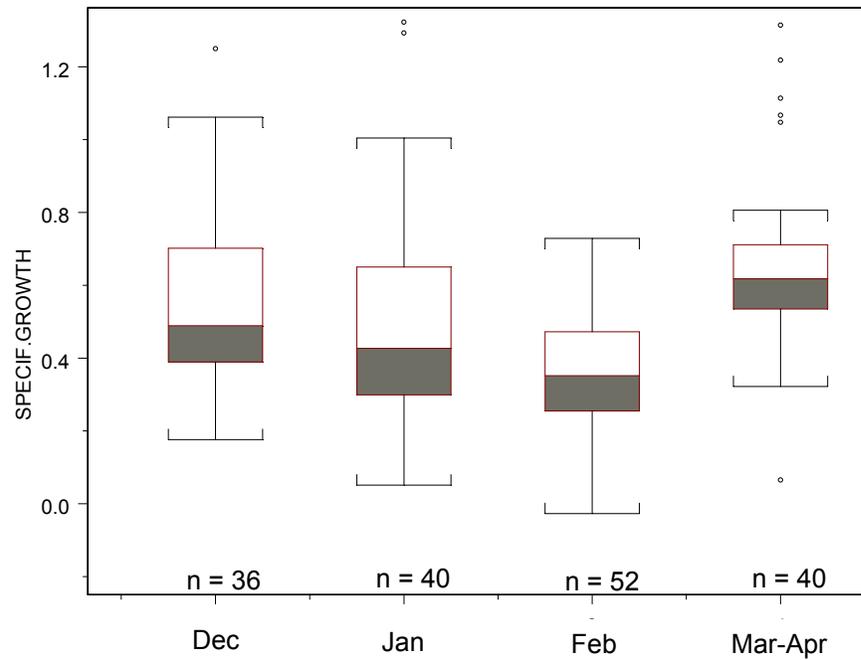


Figure 14. Box and whisker plot of mean specific growth ($\text{g}\cdot\text{g}^{-1}\cdot\text{day}^{-1}$) for all streams from Dec. 2004 to Apr. 2005 for PIT-tagged fish. The lower boundary of each box represents the 25th percentile, the midline represents the median, and the upper boundary represents the 75th percentile. The lower whisker represents the 10th percentile, the upper whisker represents the 90th percentile, and solid dots represent outlying points.

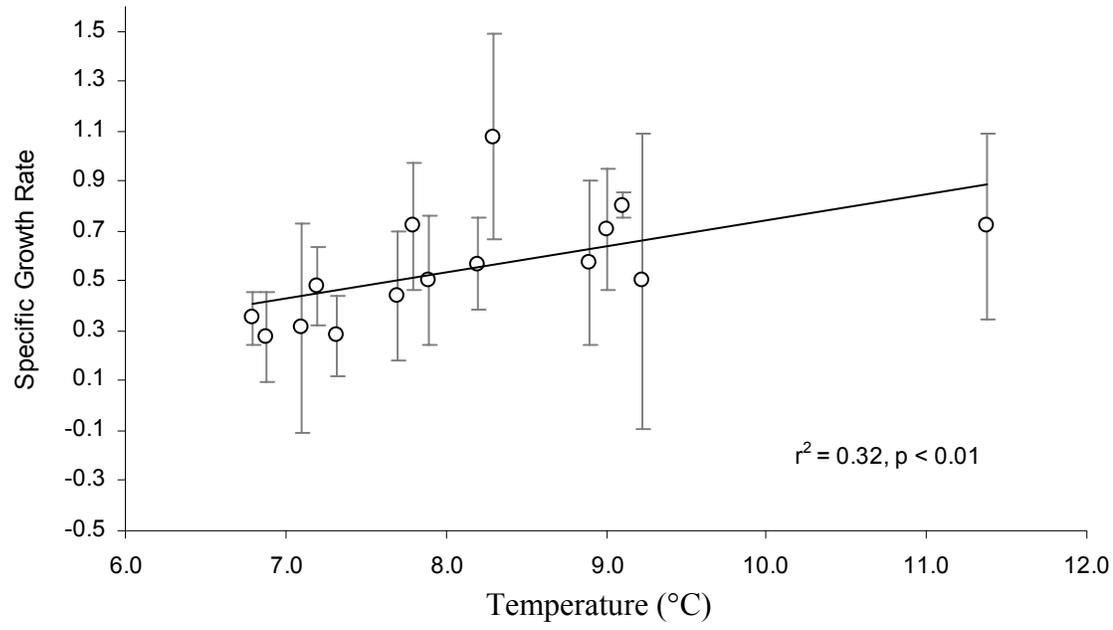


Figure 15. Relationship between specific growth rate ($\text{g}\cdot\text{g}^{-1}\text{ day}^{-1}$) and average temperature for recaptured Pit-tagged fish. Average temperature was calculated for the month fish were recaptured. Error bars represent ± 1 SD.

Table 7. Instantaneous over-winter growth rate ($\text{g}\cdot\text{g}^{-1}\text{ day}^{-1}$) of recaptured PIT-tagged juvenile coho salmon among four tributaries within the West Fork Smith River basin, Oregon.

	n	Mean	SE	95% confidence interval
Crane Creek	13	0.93	0.093	0.72-1.13
Moore Creek	63	0.43	0.043	0.34-.052
Beaver Creek	8	0.24	0.062	0.09-0.38
Gold Creek	17	0.49	0.065	0.35-0.63

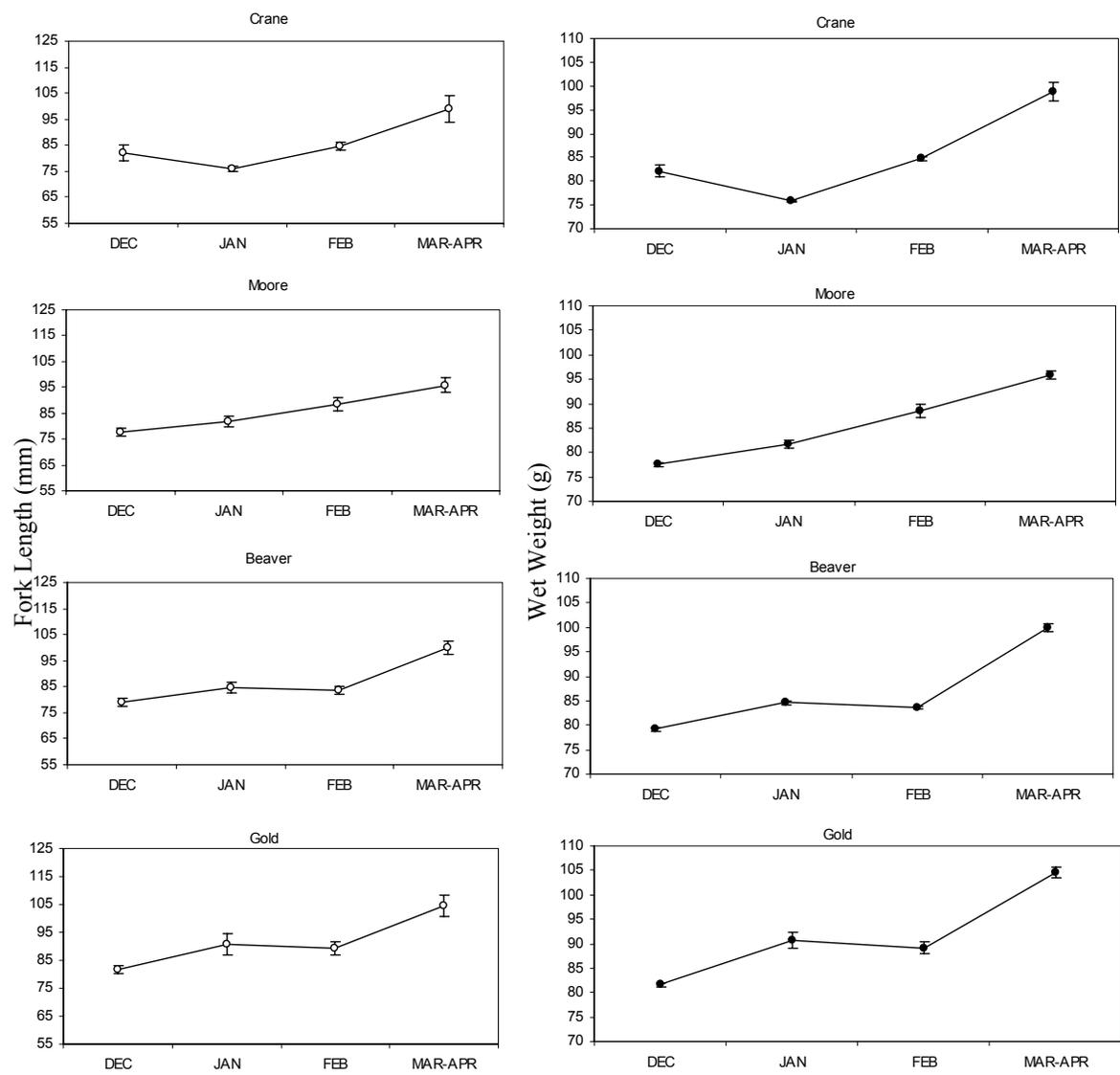


Figure 16. Mean FK lengths (mm) (left side) and weights (g) (right side) of juvenile coho in Crane, Moore, Beaver, and Gold creeks by month of observation in winter 2004/2005. Error bars represent ± 1 standard error (SE).

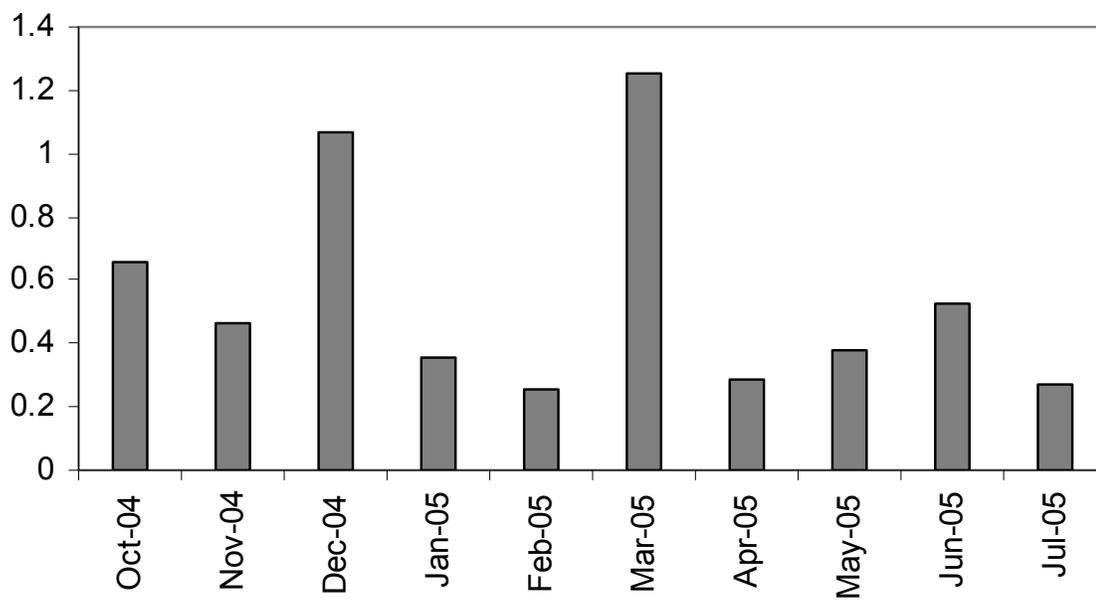


Figure 17. Coefficient of variation in stream-flow by month for the WFSR basin.

DISCUSSION

Feeding behavior and growth

Juvenile coho remained active and continued to feed and grow throughout the winter of the 2004/2005 sampling period. Differences were associated with seasonal temperatures, patterns of benthic prey availability and fluctuations in stream discharge. Benthic prey were more abundant in the two streams that were intermittent in the previous summer, and growth was highest in the stream that had been most dry.

Winter conditions in Oregon coastal streams are not as severe or harsh as those in higher latitudes of the range of coho salmon and may explain differences in patterns observed elsewhere. In northern California, Maciolek and Needham (1952) found brown and rainbow trout were active and continued feeding in winter even at water temperatures as low as 0°C. Similarly, McMahon and Hartman (1989) found juvenile coho continued feeding and displaying territorial behavior at temperatures as low as 2.5°C. In contrast, Murphy (2006) showed negative growth during winter months for juvenile Atlantic salmon. Sandercock (1991) suggested juvenile coho cease feeding and growth stops during winter months when temperatures are near freezing or floods are extreme. In our study, temperatures remained close to the optimal range (10°C-14°C) for stream rearing coho (Piper et al. 1982), and high flood flows (i.e. stream flows causing high turbidities and sediment movement) were absent during much of the study period. These milder conditions likely permit juvenile coho to continue to feed and remain active during winter.

Consistent with other Pacific Northwest studies (Quinn and Peterson 1996, Bell 2001, and Bilby et al. 1998) juvenile coho continued to grow through the 2004/2005

winter in WFSR tributaries. However, streams studied in colder climates in British Columbia and northeast US suggest that trout growth ceases as water temperatures cool in winter (Cunjak and Power 1986, Metcalfe and Thorpe 1992). Stream temperature differences may explain conflicting results between studies. Because metabolism is strongly dictated by water temperature for salmonids, growth is strongly temperature dependent. The studies exhibiting positive growth for stream rearing salmonids were conducted in milder climates where temperatures typically remained above freezing during winter months. Giannico and Hinch (2003) showed greater growth benefits from juvenile coho occupying a warmer groundwater-fed stream than those occupying a colder surface-fed stream, highlighting the limitations on growth temperature may impose.

In our study, a reduction in growth rate occurred between December and January, coincident with the lowest temperatures during the study. Other studies have indicated that salmonids continue to feed over-winter, but assimilation of the food into biomass is reduced at lower temperatures (Smirnov et al. 1976; Cunjak and Power 1987; Cunjak 1988). Similarly growth decreased as temperatures decreased despite no apparent difference in stomach fullness during our study, suggesting that temperature reduced digestion and limited growth.

At Crane Creek a combination of lower coho densities, highest mean stomach fullness values and higher prey availability likely contributed to higher growth in this stream in comparison to other sites. Differential growth between streams or reaches have been found to be caused by nutrient differences from spawning salmon (Bilby et al. 1998) (i.e. marine derived nutrients from salmon carcasses) and differences in temperature (i.e. groundwater vs. surface fed streams) (Giannico and Hinch 2003), but average

temperatures for all streams in our study remained within several degrees of one another, precluding temperature as the likely cause of growth differences between streams.

Though lower fish density in Crane Creek could have contributed to higher growth rates, our inability to measure fish density using standard methods (snorkel counts) precluded our ability to detect the relative importance of density. Despite equivalent fish sampling efforts winter conditions hampered our ability to estimate precise densities.

Crane and Moore creeks are ephemeral streams that typically dry in the summer months, particularly during years of low precipitation. Though they are relatively small (basin area 4.3- 4.7 km²) greater benthic availability and higher growth rates (in Crane Creek) suggest these streams provided greater food resources to juvenile coho than the larger tributaries during winter. Regulations regarding intermittent streams aimed at protecting salmonids should consider their importance in providing habitat and food during winter.

Movement

Our results indicate there was limited movement (defined as greater than 50 meters in this study) of fish through winter. Long distance movements occurred in the fall and spring coinciding with the changing seasons (fall to winter and winter to spring). Direction of movement in late fall was from the main-stem WFSR up to its tributaries while movement in spring was downstream.

Movement during winter for coho is largely thought to be a direct response towards avoidance or displacement by large flood flows. The lack of such large stream-flows associated with winter storms during the study period may not have necessitated

movement nor caused displacement, and provided an opportunity to examine the importance of localized food resources. In our study, the mild temperatures, moderate stream-flows, and adequate food sources may have reduced movement by juvenile coho.

Diet and food availability

In our study prey biomass consumed increased as the number of prey consumed declined, and greatest consumption occurred in the fall, then in spring when growth also peaked. They may also complement their diet with infrequent but potentially profitable food items (salmonid eggs, emerging fry, terrestrial prey and aquatic snails) when available. The non-insectan prey consumed in spring at WFSR tributaries were primarily oligochaetes and beetles. Other studies have shown that larger prey are selected by trout as they grow since they typically provide a greater energy return (Ringler 1979; Allan 1981). Although coho occasionally supplemented their diets with these foods, the estimated mean prey item size ingested was less than 4 mm.

Juvenile coho ingested a greater abundance of the stream snail *Juga* in February/2005 when the precipitation and discharge were lowest despite *Juga*'s hard outer shell and low propensity to drift within the water column. Coho typically feed primarily at or near the water surface (Johnson and Ringler 1980; Glova 1984) and the consumption of *Juga* may indicate a switch to less desirable benthic prey. As prey availability changes, juvenile coho may select food items based on a vertical hierarchy where prey on the water surface are most preferred, followed by prey drifting within the water column then benthic prey. Hawkins and Furnish (1987) suggested *Juga* may indirectly depress higher trophic levels, such as fish, by depressing prey abundance. Densities of *Juga* can be extremely high and can comprise over 90% of the invertebrate

biomass. In our study, *Juga* comprised 48%, 24%, and 7% in Beaver, Gold, and Moore creeks respectively. Interestingly, the lack of these snails in Crane could have contributed to the higher observed growth rates. Additional studies are recommended to explore the effects of *Juga* on the food resources of rearing juvenile salmonids.

Growth rate at Crane Creek was higher than other streams, including Moore Creek where benthic prey biomass was similar. Differences in growth rates and stomach fullness suggest that prey availability or delivery may vary among streams. Fluctuations in stream-flow may have temporarily increased the availability of prey by dislodging aquatic insects from the stream bottom. Stream-flows for the study period typically remained lower than those that can initiate streambed movement or bed scour described by Leopold et al. (1964); those levels can cause mortality to the aquatic invertebrate population and affect the prey base of juvenile fish. Since stream-flows for the study period remained below thresholds associated with bed scour, we did not expect mass movement of the available benthic food base for fish. However, less dramatic differences in flow can change delivery of prey to fish. For example, juvenile Atlantic salmon in artificial channel experiments contained stomach content values two times greater in high velocity artificial channels compared to those in lower velocity channels (Parrish et al. 2004).

The greatest monthly variation in stream-flow for the study period appeared to coincide with the period of highest growth rates although the lack of data for multiple years precluded any tests for significance across years (Figure 17). Other juvenile salmonid growth studies have also found that growth rates are highest in the fall and early spring, coinciding with highest stream flow fluctuation. In PNW streams in particular,

winter is a time of high variation in flow. This high variation may disturb the stream invertebrate community makeup in favor of taxa that are efficient at exploiting recently disturbed habitats. Power et al. (1996) found that these taxa were the same taxa that are most available as food to salmonids. Similarly in our study, Ephemerellid mayfly larvae and Chironomid larvae, both considered pioneer taxa, were the most consistent prey consumed by coho throughout the sampling period, suggesting a positive link between stream-flow variation and taxa with a high availability index (as described by Rader (1997).

Given the incised characteristic of stream banks in our study, winter pulses in stream-flow likely flushed terrestrial invertebrates from adjacent riparian areas into the stream. Although not directly examined in this study, other studies have suggested a positive relationship between floods and prey availability to salmonids and trout (Minakawa and Kraft 1999; O'hop and Wallace 1983; Pert 1993; Rader1997).

Spawning density

We hypothesized that spawning salmon tissue, eggs and fry would directly be consumed by juvenile coho and manifest as greater growth. The consumption of fry and eggs appeared to be limited to habitat where spawning sites and juvenile rearing areas were in close proximity to one another (e.g. at Moore between EPA markers 3-4). The lack of significant effects due to spawning density on growth rate of juvenile coho was unexpected. We initially expected that greater growth would occur coincident with the adult spawning time period by direct consumption of salmon tissue and eggs. The lack of growth response is probably due to the low number of returning adults during the 2004-2005 spawning season. Other studies that found greater growth with increased spawner

density were conducted in regions with naturally high spawning densities (Wipfli et al. 1999), such as those stocks in southeast Alaska, or were performed through carcass addition and placement in artificial stream channels (Bilby et al. 1998; Claeson et al. 2006). Our study suggests the spawning densities encountered for the 2004-2005 year were too low to directly influence coho growth.

Average densities of spawners in the streams studied were below 30 fish/km, an order of magnitude lower than that used in a study by Bilby et al. (1998), and 3-5 times lower than that thought to be needed to provide maximum ecological benefit from marine derived nutrients (MDN) (Gresh et al. 2000). Meengs and Lackey (2006) estimated the current coho runs are between 3-6% (poor ocean conditions) and 11-19% (favorable ocean conditions) of historic (mid 1800's) run sizes. It is possible that below a certain threshold spawning density does not directly affect juvenile coho growth rates.

The WFSR is typical of many other coastal streams that support coho salmon and contains comparatively large areas of good habitat and high numbers of spawners. Despite this fact, current spawning densities are well below historical levels. The lack of MDN once delivered to these streams has likely changed ecosystem function. Differences in coho diet at WRSR in 2004/5, in comparison to other streams where coho returns are much greater illustrate the potential loss of a resource feedback mechanism in coho life history. Though the potential for higher production with higher coho spawners exists, our study demonstrates how juvenile coho successfully over-winter and grow on instream and terrestrial resources. Higher growth rates in one of our ephemeral streams illustrates the previously unrecognized seasonal potential of those tributaries to juvenile coho production.

CONCLUSION

The winter period for coho salmon can be critical for fish growth in preparation for the ocean phase. In the WFSR basin juvenile coho continued to feed and grow during winter. Variability in prey composition between headwater streams was high, and juvenile coho switched food sources in adapting to changing conditions commonly encountered during winter. During a mild winter, juvenile coho consumption and growth appear to be limited primarily by temperature.

Survival of coho salmon is ultimately tied to understanding year-round habitat requirements. Small intermittent headwater streams appear to be important over-wintering locations positively influencing growth of juvenile coho. Conservation of winter habitat including small intermittent streams will ultimately be required for the long-term persistence of declining coho salmon populations.

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APPENDICES

Appendix I

CRANE CREEK								
	Dec		Jan		Feb		Mar	
Diptera								
	Chironomidae	39.2%	Chironomidae	46.5%	Chironomidae	56.9%	Chironomidae	76.3%
	Ceratopogonidae	28.6%	Ceratopogonidae	28.1%	Simuliidae	28.9%	Ceratopogonidae	15.4%
	Diptera sp.	11.8%	Tipulidae	10.6%	Blephariceridae	5.2%	Tipulidae	4.8%
	Tipulidae	8.9%	Simuliidae	5.5%	<i>Diptera</i> sp.	4.6%	Chloroperlidae	1.4%
	Simuliidae	4.0%	Mycetophilidae	4.0%	Ceratopogonidae	3.6%	Diptera sp.	1.1%
	Ephydriidae	3.6%	Diptera sp.	2.9%	Tipulidae	0.6%	Empididae	0.5%
	Tabanidae	2.9%	Blephariceridae	1.1%	Empididae	0.1%	Cecidomyiidae	0.4%
	Dixidae	0.5%	Empididae	0.5%				
	Athericidae	0.3%	Chloroperlidae	0.4%				
	Blephariceridae	0.2%	Dixidae	0.1%				
	Muscidae	0.1%	Sciaridae	0.1%				
Ephemeroptera								
	Baetidae	51.9%	Baetidae	35.9%	Baetidae	44.5%	Baetidae	45.9%
	Ameletidae	23.3%	Heptageniidae	32.9%	Heptageniidae	24.3%	Ephemerellidae	18.3%
	Heptageniidae	11.5%	Ephemerellidae	18.3%	Ephemerellidae	13.7%	Leptophlebiidae	18.2%
	Leptophlebiidae	11.1%	Ameletidae	9.1%	Ameletidae	6.5%	Heptageniidae	11.2%
	Ephemerellidae	2.2%	Leptophlebiidae	3.7%	Leptophlebiidae	6.4%	Ameletidae	6.4%
					Ephemeroptera	4.6%		
Plecoptera								
	Plecoptera sp.	50.4%	Taeniopterygidae	54.3%	Taeniopterygidae	72.3%	Chloroperlidae	63.5%
	Nemouridae	24.5%	Capniidae	13.6%	Capniidae	10.9%	Nemouridae	36.5%
	Capniidae	10.6%	Perlidae	13.1%	Plecoptera sp.	8.1%		
	Chloroperlidae	8.4%	Leuctridae	8.1%	Chloroperlidae	7.8%		
	Taeniopterygidae	3.7%	Nemouridae	5.5%	Nemouridae	0.9%		
	Leuctridae	2.4%	Plecoptera sp.	2.7%				
			Chloroperlidae	2.2%				
			Perlid/Perlodidae	0.5%				
Trichoptera								
	Rhyacophilidae	89.0%	Rhyacophilidae	67.1%	Limnephilidae	76.3%	Limnephilidae	93.1%
	Limnephilidae	9.6%	Limnephilidae	23.2%	Rhyacophilidae	19.5%	Rhyacophilidae	6.9%

CRANE CREEK (Continued)

		Dec	Jan	Feb	Mar			
	Lepidostomatidae	1.3%	Glossosomatidae	4.2%	Brachycentridae	4.2%		
			Lepidostomatidae	2.9%				
			Leptoceridae	2.1%				
			Plilopotamidae	0.6%				
All other	Oligochaeta	69.4%	Oligochaeta	30.6%	Oligochaeta	81.1%	Coleoptera sp.	63.9%
	Nematoda	14.3%	Araneae	29.4%	Lepidoptera	9.1%	Oligochaeta	11.8%
	Collembola	7.1%	Nematoda	11.7%	Araneae	7.3%	Chilopoda	11.0%
	Coleoptera sp.	5.2%	Elmidae	7.5%	Isoptera	1.3%	Araneae	6.2%
	Araneae	3.0%	Coleoptera sp.	4.9%	Collembola	1.3%	Diplopoda	3.1%
	Chilopoda	0.9%	Collembola	4.7%			Isopoda	2.8%
			Hemiptera	3.9%			Hemiptera sp.	1.1%
			Isopoda	3.1%				
			Chilopoda	2.2%				
			Dytiscidae	2.0%				

MOORE CREEK

		Dec	Jan	Feb	Mar			
Diptera	Chironomidae	50.8%	Chironomidae	43.3%	Tipulidae	31.7%	Chironomidae	29.7%
	Simuliidae	22.4%	Ceratopogonidae	31.4%	Chironomidae	28.5%	Ceratopogonidae	29.0%
	Mycetophilidae	12.1%	Simuliidae	8.4%	Diptera sp.	20.4%	Mycetophilidae	16.3%
	Diptera sp.	8.4%	Diptera sp.	8.1%	Simuliidae	16.3%	Empididae	14.0%
	Ceratopogonidae	3.1%	Tipulidae	5.6%	Ceratopogonidae	1.6%	Tipulidae	5.4%
	Culicidae	1.1%	Mycetophilidae	1.4%	Mycetophilidae	1.4%	Cecidomyiidae	3.0%
	Chloroperlidae	1.1%	Sciaridae	1.4%			Dixidae	1.9%
	Tipulidae	0.7%	Blephariceridae	0.4%			Simuliidae	0.6%
	Blephariceridae	0.2%						
Ephemeroptera	Baetidae	23.5%	Baetidae	42.3%	Baetidae	82.1%	Heptageniidae	53.3%
	Leptophlebiidae	21.5%	Heptageniidae	25.6%	Leptophlebiidae	7.0%	Leptophlebiidae	17.0%
	Ameletidae	20.7%	Leptophlebiidae	19.6%	Ephemerellidae	5.9%	Ameletidae	16.1%
	Heptageniidae	16.4%	Ephemerellidae	10.2%	Heptageniidae	4.1%	Baetidae	11.3%
	Chironomidae	10.1%	Ameletidae	2.2%	Ameletidae	0.9%	Ephemerellidae	2.2%
	Ephemerellidae	7.8%						

MOORE CREEK (Continued)

	Dec		Jan		Feb		Mar	
Plecoptera	Capniidae	55.9%	Capniidae	64.1%	Taeniopterygidae	77.5%	Leuctridae	54.5%
	Chloroperlidae	22.6%	Chloroperlidae	13.9%	Capniidae	17.9%	Chloroperlidae	28.9%
	Leuctridae	19.1%	Nemouridae	13.5%	Chloroperlidae	2.8%	Taeniopterygidae	9.7%
	Plecoptera sp.	1.9%	Taeniopterygidae	4.4%	Nemouridae	1.8%	Nemouridae	7.0%
	Taeniopterygidae	0.5%	Perlodidae	4.0%				
Trichoptera	Limnephilidae	95.2%	Rhyacophilidae	76.8%	Lepidostomatidae	55.1%	Leptoceridae	49.5%
	Rhyacophilidae	4.8%	Lepidostomatidae	13.8%	Glossosomatidae	44.2%	Limnephilidae	41.2%
			Limnephilidae	9.4%	Rhyacophilidae	0.6%	Glossosomatidae	9.4%
					Limnephilidae	0.1%		
					Brachycentridae	0.1%		
All other	Coleoptera	47.9%	Coleoptera	51.5%	Salmonidae	84.5%	Coleoptera	36.5%
	Araneae	30.0%	Carabidae	13.8%	Oligochaeta	8.5%	Oligochaeta	26.1%
	Collembola	22.1%	Oligochaeta	13.5%	Collembola	6.6%	Araneae	12.4%
			Araneae	12.3%	Coleoptera	0.4%	Gastropoda	8.3%
			Chilopoda	6.8%	Hydracarina	0.0%	Diplopoda	6.6%
			Collembola	1.8%			Chilopoda	3.5%
			Saldidae	0.2%			Hymenoptera	2.5%
							Isopoda	1.8%
							Megaloptera	1.3%
							Hemiptera	0.9%

BEAVER CREEK

	Dec		Jan		Feb		Mar	
Diptera	Simuliidae	59.4%	Chironomidae	42.7%	Chironomidae	44.5%	Chironomidae	65.4%
	Chironomidae	34.6%	Simuliidae	36.5%	Tipulidae	44.2%	Ceratopogonidae	25.1%
	Ceratopogonidae	3.0%	Tipulidae	13.5%	Simuliidae	9.0%	Dixidae	7.0%
	Culicidae	1.7%	Ceratopogonidae	5.7%	Ceratopogonidae	1.7%	Empididae	1.9%
	Tipulidae	0.7%	Muscidae	1.0%	Empididae	0.6%	Simuliidae	0.6%
	Dixidae	0.3%	Mycetophilidae	0.3%			Tipulidae	0.1%
	Muscidae	0.3%	Empididae	0.3%				
	Blephariceridae	0.1%						
Ephemeroptera	Baetidae	59.4%	Baetidae	41.3%	Baetidae	43.1%	Baetidae	31.7%
	Ephemerellidae	12.2%	Ephemerellidae	21.8%	Ephemerellidae	24.8%	Heptageniidae	25.4%

BEAVER CREEK (Continued)

		Dec	Jan	Feb	Mar			
	Heptageniidae	11.5%	Leptophlebiidae	18.6%	Ephemeroptera	12.7%	Leptophlebiidae	19.7%
	Leptophlebiidae	9.5%	Heptageniidae	17.0%	Leptophlebiidae	11.1%	Ephemerellidae	17.2%
	Ameletidae	7.3%	Ameletidae	1.3%	Heptageniidae	8.3%	Ameletidae	5.9%
	Ephemeroptera	0.0%						
Plecoptera	Nemouridae	51.2%	Nemouridae	35.0%	Capniidae	100.0%	Capniidae	92.6%
	Capniidae	26.9%	Capniidae	34.6%	Nemouridae	0.0%	Taeniopterygidae	7.4%
	Leuctridae	21.4%	Taeniopterygidae	18.3%				
	Chloroperlidae	0.5%	Leuctridae	11.9%				
			Chloroperlidae	0.3%				
Trichoptera	Limnephilidae	78.8%	Limnephilidae	88.2%	Lepidostomatidae	42.0%	Limnephilidae	91.9%
	Rhyacophilidae	13.5%	Rhyacophilidae	6.9%	Limnephilidae	29.5%	Rhyacophilidae	7.9%
	Lepidostomatidae	6.6%	Trichoptera sp.	4.6%	Rhyacophilidae	16.2%	Brachycentridae	0.3%
	Leptophlebiidae	1.1%	Glossosomatidae	0.2%	Uenoidae	6.4%		
			Brachycentridae	0.1%	Hydropsychidae	4.5%		
			Plilopotamidae	0.1%	Glossosomatidae	0.7%		
All other	Coleoptera	30.7%	Chilopoda	41.0%	Lepidoptera	50.1%	Pleuroceridae	60.3%
	Caudata	24.7%	Gastropoda	37.9%	Collembola	16.6%	Hymenoptera	13.6%
	Gastropoda	20.6%	Araneae	10.2%	Pleuroceridae	14.9%	Collembola	7.7%
	Collembola	12.6%	Coleoptera	7.5%	Elmidae	10.3%	Hemiptera	6.9%
	Nematoda	8.6%	Isopoda	2.0%	Coleoptera	3.3%	Coleoptera	6.4%
	Isopoda	2.8%	Elmidae	1.3%	Oligochaeta	2.8%	Araneae	2.9%
					Homoptera	1.9%	Oligochaeta	2.2%

GOLD CREEK

		Dec	Jan	Feb	Mar			
Diptera	Chironomidae	60.8%	Chironomidae	49.5%	Tipulidae	37.6%	Chironomidae	41.1%
	Simuliidae	17.5%	Simuliidae	42.7%	Chironomidae	34.3%	Ptychopteridae	14.5%
	Tipulidae	10.7%	Tipulidae	4.1%	Simuliidae	15.2%	Anisopodidae	13.1%
	Dixidae	5.8%	Sciaridae	2.6%	Ceratopogonidae	8.9%	Tipulidae	11.7%
	Ceratopogonidae	4.0%	Empididae	0.6%	Empididae	1.0%	Ceratopogonidae	9.4%
	Blephariceridae	0.6%	Blephariceridae	0.5%	Mycetophilidae	0.9%	Dixidae	6.7%
	Culicidae	0.5%			Dolichopodidae	0.8%	Simuliidae	2.8%

GOLD CREEK (Continued)

	Dec		Jan		Feb		Mar	
	Thaumaleidae	0.1%			Culicidae	0.8%	Empididae	0.6%
					Thaumaleidae	0.4%	Cecidomyiidae	0.1%
Ephemeroptera	Baetidae	52.2%	Baetidae	45.2%	Heptageniidae	40.9%	Baetidae	62.2%
	Heptageniidae	22.4%	Heptageniidae	35.7%	Baetidae	26.1%	Leptophlebiidae	19.1%
	Ephemerellidae	16.2%	Leptophlebiidae	14.5%	Ephemerellidae	22.1%	Heptageniidae	14.8%
	Leptophlebiidae	9.3%	Ephemerellidae	4.7%	Leptophlebiidae	7.4%	Ameletidae	2.0%
					Ephemeroptera	2.4%	Ephemerellidae	2.0%
					Ameletidae	1.1%		
Plecoptera	Chloroperlidae	45.3%	Nemouridae	31.5%	Nemouridae	50.5%	Nemouridae	71.3%
	Nemouridae	34.4%	Taeniopterygidae	29.2%	Taeniopterygidae	17.8%	Chloroperlidae	19.7%
	Taeniopterygidae	12.1%	Leuctridae	17.0%	Chloroperlidae	16.3%	Perlid/Perlodidae	5.3%
	Capniidae	8.2%	Chloroperlidae	16.9%	Leuctridae	15.4%	Perlodidae	3.7%
			Perlid/Perlodidae	5.4%				
Trichoptera	Limnephilidae	47.7%	Rhyacophilidae	48.3%	Rhyacophilidae	50.2%	Rhyacophilidae	39.2%
	Rhyacophilidae	47.2%	Limnephilidae	42.3%	Limnephilidae	45.8%	Limnephilidae	32.3%
	Lepidostomatidae	2.9%	Hydropsychidae	6.8%	Hydropsychidae	2.2%	Hydropsychidae	28.4%
	Hydropsychidae	1.4%	Glossosomatidae	2.7%	Glossosomatidae	1.8%		
	Uenoidae	0.5%						
	Leptoceridae	0.3%						
All other	Nematoda	58.5%	Oligochaeta	52.7%	Pleuroceridae	50.1%	Gastropoda	48.0%
	Collembola	30.8%	Pleuroceridae	29.4%	Oligochaeta	15.0%	Coleoptera	16.7%
	Oligochaeta	10.6%	Coleoptera	5.2%	Lepidoptera	14.2%	Pleuroceridae	15.9%
			Elmidae	5.0%	Isopoda	12.0%	Oligochaeta	10.4%
			Chilopoda	4.6%	Chrysomelidae	3.6%	Rhaphidophoridae	3.7%
			Collembola	3.0%	Araneae	2.4%	Hymenoptera	3.2%
					Gastropoda	1.0%	Hemiptera	2.3%
					Collembola	1.0%		