Lake Billy Chinook Rainbow (Redband) Trout Life History Study — Final Report

Pelton Round Butte Hydroelectric Project

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Prepared for Portland General Electric Company by

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Chapter 1: Introduction

During Portland General Electric's first stage consultation process to relicense the Pelton Round Butte Hydroelectric Project in 1996, several governmental agencies and non-governmental organizations requested that more information be gathered on important resident fish species. Follow-up discussions with these parties determined that some of the highest priority questions centered on the rainbow (redband) trout *Oncorhynchus mykiss* (sub) populations in Lake Billy Chinook and the three major branches of the upper Deschutes River system: the Crooked, Deschutes and Metolius rivers. The following questions were raised:

- What is the relationship among (sub) populations of redband trout at the heads of the three arms of Lake Billy Chinook? Do life history characteristics suggest they are distinct (sub) populations?
- Is there a distinct adfluvial life history form? Is there a significant downstream migration of juveniles or adults into Lake Billy Chinook?
- What are the similarities and differences in life history and body characteristics?
- What are the major prey species for these fish?
- What is the density of juvenile redband trout in relation to pool and riffle habitats in areas where steelhead may spawn if passage is restored?
- Are redband trout that occupy historic steelhead spawning and rearing areas in Squaw Creek more like lower Deschutes River steelhead or lower Deschutes River redband trout?

This study of the life history of redband trout in Lake Billy Chinook attempted to address these questions. It was designed by biologists from Portland General Electric and Oregon State University with significant participation by the Oregon Department of Fish and Wildlife, U.S. Forest Service, Bureau of Land Management, and the Confederated Tribes of the Warm Springs Reservation of Oregon.

STUDY OBJECTIVES

Information collected in this and related proposed studies will document some population dynamics and life history characteristics of redband trout in the Deschutes River system and estimate the degree of interaction among these (sub) populations. This information is needed because baseline data were not collected prior to the construction of Round Butte Dam. As a result, it is unknown in what ways and to what degree the creation of Lake Billy Chinook may have influenced life history characteristics as well as the ecological and reproductive isolation of redband trout (sub) populations in the system. The information will provide a baseline for comparison of pre- and post-introduction redband trout (sub) populations if anadromous fish are restored to the upper Deschutes Basin.

Research conducted during this study followed the objectives and methods presented in the original study plan for the Lake Billy Chinook rainbow (redband) trout life history study (Ratliff and Shields 1997) with some slight modifications to the study described in subsequent annual study plans (Shields and Groves 1997, 1999). The following study objectives address the questions raised during the initial consultation period:

1. Inter-Relationships among Redband Trout (Sub) Populations

- **Objective 1a, tagging and movement studies:** Determine if there is movement or mixing among redband trout (sub) populations, either at the head of each arm of Lake Billy Chinook or within the reservoir.

- **Objective 1b, spawning and location times:** Determine the spawning location(s) and time(s) for the sub-population(s) of redband trout at the head of each arm of Lake Billy Chinook.

- **Objective 1c, adfluvial life history studies:** Determine if any of these redband trout (sub) populations contain significant numbers of trout with an adfluvial life history form. These fish would migrate from upstream spawning and initial rearing areas downstream into Lake Billy Chinook to reside for a significant portion of their life.

2. Differences in Biological Characteristics of (Sub) Populations

- **Objective 2a, age structure, growth rates, condition factors, and fecundity:** Characterize the age structure and differences in growth rates, condition factors, and fecundity for the (sub) populations of redband trout in each of the three tributaries of Lake Billy Chinook.

- **Objective 2b, meristic and morphometric analysis:** Define and compare the meristic counts and morphometric measurements for each of these (sub) populations.

- **Objective 2c, parasite faunal assemblages:** Characterize the parasite prevalence and mean intensity for redband trout (sub) populations in each of the three tributaries of Lake Billy Chinook.

3. Diet and Prey Studies

- **Objective**: Determine the major prey species (food items) important to these (sub) populations of redband trout.

4. Densities of Juvenile Redband Trout

- **Objective**: Determine the densities of resident redband trout in selected sections of Squaw Creek (Deschutes River system) and in McKay and Little McKay creeks (Crooked River system).

5. Future Genetic Studies

- **Objective**: Obtain samples for future genetic studies. Although genetic analyses are not included in the direct objectives of this study, samples have been collected as deemed necessary to support other projects. Some samples were collected for DNA analysis during the 1997 and 1998 field seasons. Additional samples were taken in 1999 from (sub) populations not sampled in the previous season.

This report summarizes data collected on each of these objectives over a three-year period (1997–1999).

STUDY AREA

The study area includes Lake Billy Chinook, a 1,585-ha reservoir created by the construction of Round Butte Dam on the Deschutes River in 1964, and portions of its three major tributaries (Crooked, Deschutes, and Metolius rivers) (Figure 1). Lake Billy Chinook extends 11 km up the Crooked River canyon, 14 km up the Deschutes River canyon, and 21 km up the Metolius River canyon. Information obtained to date indicates that, historically, redband trout were not very abundant in Lake Billy Chinook, except in reaches of the upper arms where the three rivers enter the reservoir. Therefore, the focus of this study was on the reservoir-river transition zones located within the lower 2 km of each river — between river kilometer (rkm) 7 and 9 in the Crooked, rkm 11 and 13 in the Deschutes, and rkm 19 and 21 in the Metolius, as measured from Round Butte Dam — in addition to the forebay area of the reservoir.

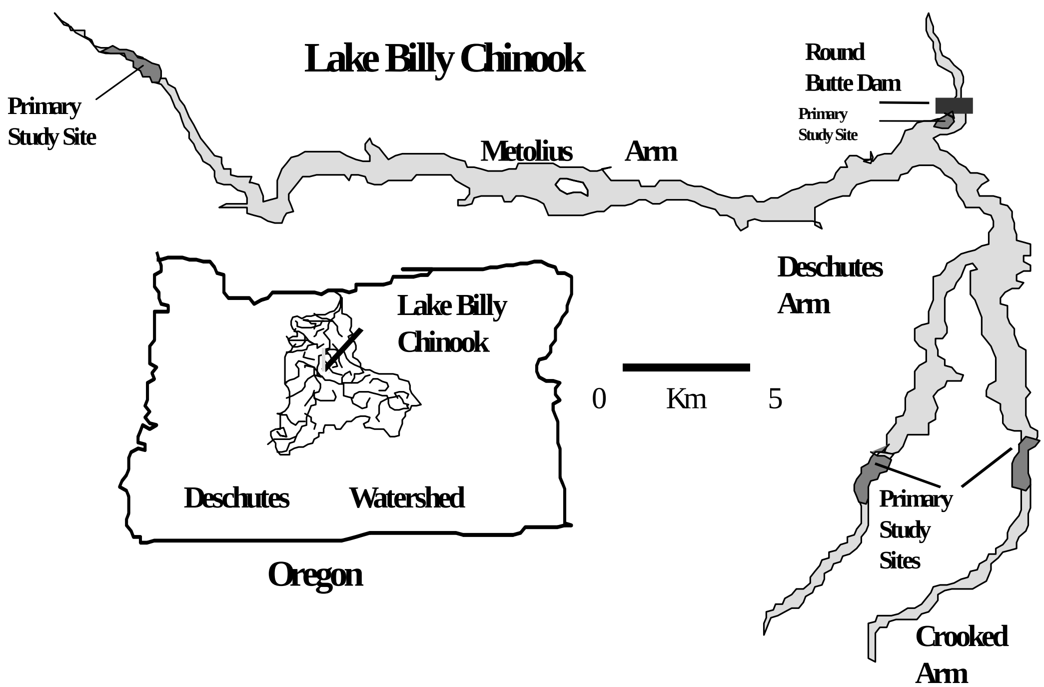


Figure 1. Location of primary study sites in Lake Billy Chinook, 1997–1999.

The Crooked River originates in the Ochoco Mountains and is the largest eastern tributary to the Deschutes River. Only the lower 2 km of the free-flowing river is available for use by the redband trout that inhabit Lake Billy Chinook. A diversion dam at the Opal Springs Hydroelectric Project stops upstream passage except during very high flows; however, downstream movement of trout from above the diversion dam into the reservoir is possible.

The Deschutes River originates in the Cascade Mountains southwest of Bend and flows north to Lake Billy Chinook for a distance of 212 km. Upstream passage of redband trout is blocked on the Deschutes River by Steelhead Falls, 13 km upstream of Lake Billy Chinook.

The Metolius River originates as a large spring near the base of Black Butte in the Cascade Mountains and flows for a distance of 45 km before reaching Lake Billy Chinook. Input from many spring-fed tributaries in the upper stretch of the Metolius River helps to maintain cool temperatures and stable flows throughout most of the year. Upstream passage in the Metolius River is unhindered, although it is not clear if redband trout from the upper and lower portions of the river readily mix.

Juvenile redband trout density surveys were conducted in 1.6-km sections of both McKay and Little McKay creeks, which are tributaries to the upper Crooked River, as well as in multiple sections of Squaw Creek, a tributary of the Deschutes River (Figure 2). These sites were chosen as long-term study sites to monitor juvenile densities.

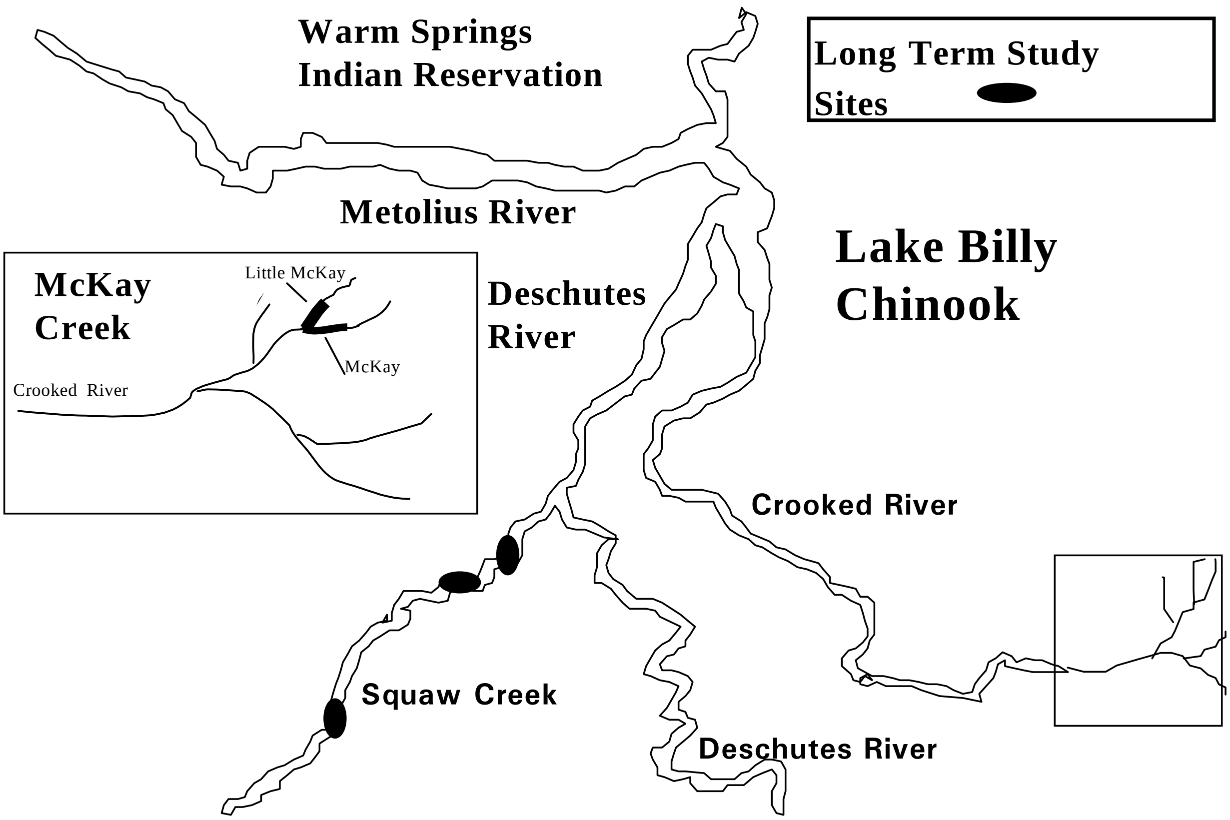


Figure 2. Locations of long term study sites on Squaw Creek and in the McKay Creek Watershed.

Chapter 2: Inter-Relationships among (Sub) Populations

It is unknown what effect the creation of Lake Billy Chinook had on the redband trout in this area because no baseline data were collected before the construction of the dam. Manipulation of natural streams with the construction of dams is likely to alter fish habitat in many ways and hence select for different life history strategies of those fish (Reyes-Gavilian et al. 1996). Possible effects of the reservoir could have included reduced ecological isolation through mixing facilitated by the reservoir (Sakai and Espinos 1994) or, alternatively, increased isolation due to lacustrine habitat avoidance of resident trout (Raleigh and Ebel 1968). Previous observations of intense sport fisheries on the main reservoir during the spring, summer, and fall have suggested that few redband trout utilize the reservoir during those seasons of the year (Thiesfeld et al. 1995). This indicates avoidance of the lacustrine habitat and could mean that Lake Billy Chinook represents a significant barrier to movement among redband trout (sub) populations in each tributary and exacerbates the isolation of (sub) populations.

2.1 — TAGGING AND MOVEMENT STUDIES

Mark-and-recapture methodology has been employed many times as a means of monitoring fish movements (Biette et al. 1981, Lindsey et al. 1959, and Sakai and Espinos 1994). One concern with using tags to monitor movement of wild fish is the inability to monitor tag-induced mortality. Tag-induced mortality, or "tag loss," can vary depending on many factors, including sex and age of fish (Brewin et al. 1995). Water clarity can also play a role in tag-induced mortality, particularly when avian predators are a major factor.

Methods

Floating Merwin trap nets, with leads extending perpendicular to the shore, were fished near the upper arms of Lake Billy Chinook (lower 2 km of the tributaries) and in the lower reservoir (forebay) near the dam during the spring and early summer of 1997 and 1999 and from winter through late summer in 1998. A more thorough description of this trap is given in Hiatt et al. (1997). An Oneida trap (Korn et al. 1967), rotary screw traps, and angling were also employed to capture fish at some of these locations. The Oneida trap was fished in the upper

Metolius arm where shallow depth and low current velocity allowed. Both the Merwin and Oneida traps are designed to capture fish moving laterally along the shoreline. Downstream migrant rotary screw traps were fished in the upper Deschutes and Metolius arms in 1997 and 1998 and in the upper Metolius arm in 1999 to sample downstream migrating juvenile redband trout.

To distinguish trout caught in the different tributaries and in the trap near the dam, fish greater than 22 cm fork length were marked with color-coded, individually numbered dart tags (yellow for the Crooked, orange for the Deschutes, white for the forebay, and green for the Metolius). Fish under 22 cm fork length were marked with a unique partial fin clip. Both the color code of the dart tag and the position of the fin clip were standardized by trap location to show the initial capture site of a given fish. A total of 1073 redband trout were tagged with numbered dart tags from 1997 through 1999. An additional 389 juvenile redband trout were fin clipped over this time period (Table 1).

Table 1. Tagging and recapture summaries of redband trout from Lake Billy Chinook and its three major tributaries, 1997–1999. All tagging and recaptures occurred within the river-lake transition zones in each of the three arms of Lake Billy Chinook.

Location	Year	# Dart Tags	Recaps	% Recap	# Fin Clips	Recaps	% Recap
Deschutes	1997	116	20	17.2	152	7	4.6
Crooked		94	15	16.0	15	1	6.7
Metolius		62	5	8.0	15	0	0.0
Total		**272**	**40**	**14.7**	**182**	**8**	**4.4**
Deschutes	1998	106	13	12.3	43	0	0.0
Crooked		134	18	13.4	11	2	18.2
Metolius		204	9	4.4	36	2	5.6
Forebay		126	6	4.8	15	2	13.3
Total		**570**	**46**	**8.1**	**105**	**6**	**5.7**
Deschutes	1999	102	19	18.6	42	2	4.8
Crooked		85	12	14.1	37	1	2.7
Metolius		38	3	7.9	19	1	5.3
Forebay		6	1	16.7	4	0	0.0
Total		**231**	**35**	**15.2**	**102**	**4**	**3.9**
Overall Total		**1073**	**121**	**11.3**	**389**	**18**	**4.6**

Intensive recapture efforts were made at various parts of the system using traps, volunteer anglers, and observations both from shore and with the use of snorkeling gear. Snorkel surveys were originally scheduled according to regular time intervals, but variations in water visibility led to an irregular schedule. Dates of 1997–1999 snorkel surveys are listed in Table 2. Notices of the ongoing study were posted at all reservoir and river access sites to encourage participation from other anglers.

Table 2. Dates of snorkel surveys conducted in the three arms of Lake Billy Chinook, 1997–1999.

Year	Deschutes	Crooked	Metolius
1997	July 10, 23	July 22	July 9
			August 4
1998	June 11, 26	July 9, 28	March 6
	July 9, 27	August 14	April 24
	September 8	September 9	June 12, 26
	October 1, 15	October 2	July 9, 27
			September 8
			October 1, 15
1999	April 4, 18	May 29	May 8, 22
	May 22, 31	June 15, 28	June 15, 28
	July 19	July 2, 19	July 1, 19
	August 18, 31	August 18, 31	August 18, 31
	September 13	September 13	September 13

Results

Tagging and movement studies showed that from 6% to 75% of the recaptures moved more than 2 km from their original tagging site during the study period (25% of 62 recaptured Deschutes-tagged; 19% of 73 recaptured Crooked-tagged; 6% of 21 recaptured Metolius-tagged; and 75% of 8 recaptured forebay-tagged).

In the Crooked arm, approximately 13% of the recaptures were from fish that had moved into this arm, from either the Deschutes River or the forebay area of the reservoir. In the

Deschutes arm, 13.5 % of the recaptures were found to have moved into the arm, having been originally tagged in either the Crooked River or in the forebay area of the reservoir. Approximately 75% of recaptured fish originally tagged in the forebay had moved into one of the three arms of Lake Billy Chinook. No fish originally tagged in the Metolius system were recaptured outside this system, although 39% of the recaptures within this arm were from other origins. Of those fish moving into the Metolius arm, 20% were identified as either hatchery origin or fish showing smolt-like characteristics. Figure 3 shows a graphical representation of movement of tagged redband trout recaptured in other tributary canyons.

During the initial three months of the study in 1997, no movement of tagged fish was observed, although 39 redband trout were recaptured at original tagging locations (5 in the Metolius, 20 in the Deschutes, and 14 in the Crooked). During subsequent recapture efforts and snorkel surveys in 1997, three redband trout from the Crooked River were identified as strays moving from original tagging locations. Of the three trout identified as strays, two were observed during a snorkel survey in the Metolius arm and the other one was recaptured by an angler in the Deschutes arm.

During the 1998 field season, a total of 40 tagged redband trout were caught in their original tagging locations (9 in the Metolius, 9 in the Deschutes, 14 in the Crooked, and 2 in the forebay). All fish recaptured in the Deschutes and six recaptures in the Crooked were from the previous year of tagging. More movement was observed in 1998. A total of 14 fish recaptured during this time were found to have moved more than 2 km from original tagging locations. Subsequent snorkel surveys in the three arms of Lake Billy Chinook during 1998 identified an additional two fish that had moved more than 2 km from original tagging locations.

During the 1999 field season, a total of 30 fish were recaptured from original tagging locations (3 in the Metolius, 16 in the Deschutes, and 11 in the Crooked). Of those, 2 fish were originally tagged in 1997 and 11 fish were originally tagged in 1998. A total of six fish were found to have moved from original tagging locations in 1999. Snorkel surveys during 1999 identified five additional fish that had moved from original tagging locations (Table 3).

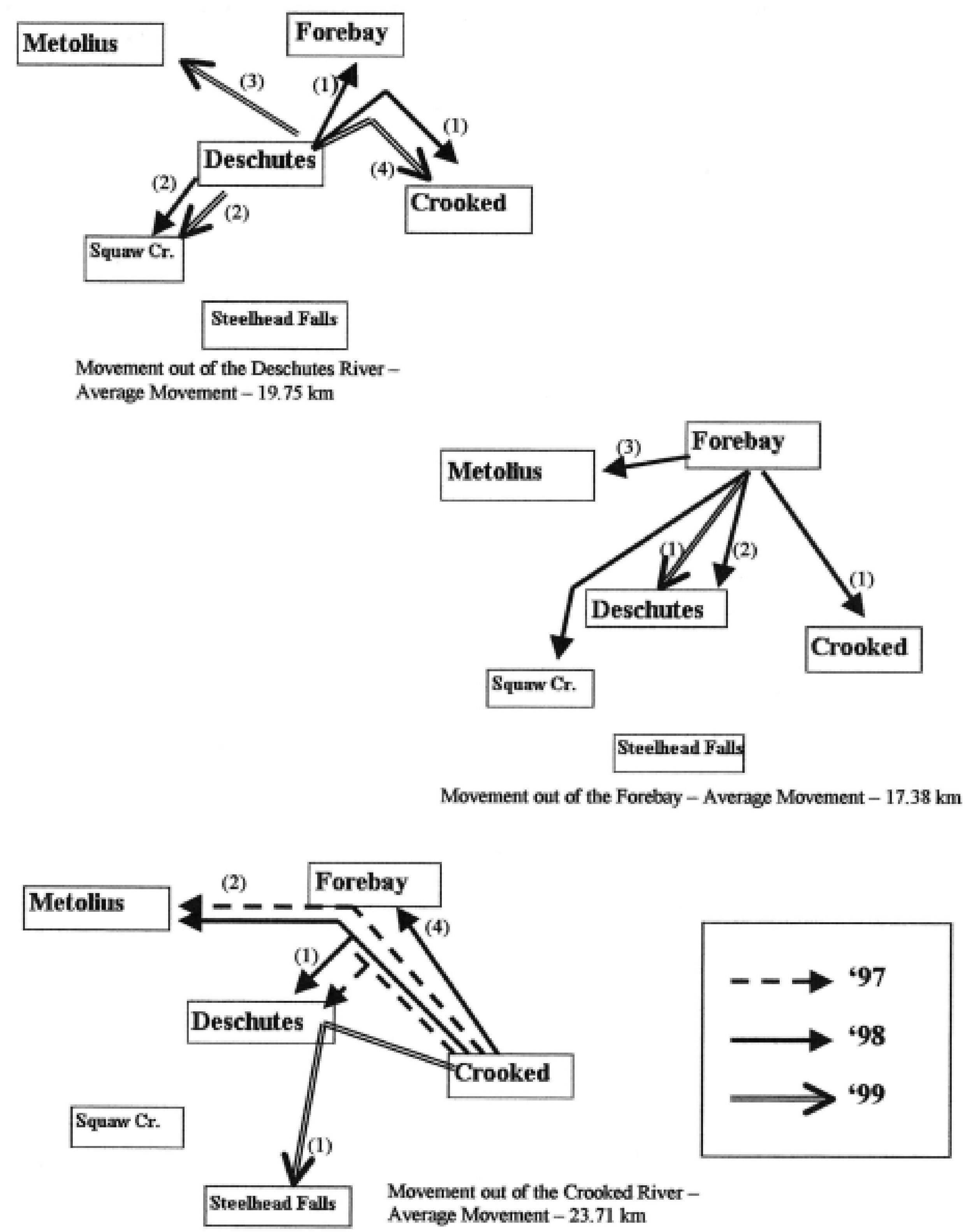


Figure 3. Movement into other tributaries canyons of tagged, recaptured redband trout observed from 1997 to 1999 in Lake Billy Chinook and its tributaries, Oregon. No redband trout tagged in the Metolius system were recaptured in other tributary canyons.

Table 3. Summary of tags observed during snorkel surveys in the three arms of Lake Billy Chinook and Squaw Creek, 1997–1999. Deschutes – orange, Crooked – yellow, and Metolius – green.

Year	Deschutes	Crooked	Metolius	Squaw Creek
1997	2 – Orange* 1 – Yellow*	7 – Yellow*	--	--
1998	3 – Orange	8 - Yellow	4 – Green 2 – Yellow	--
1999	--	10 – Yellow 3 – Orange*	1 – Orange*	1 – Orange*

* Indicates fish were observed on the same day. All other tag totals were observed on different days so number of tagged fish may include re-observations of the same fish.

Discussion

Merwin traps were placed in locations in each of the three arms that would maximize the possibility of detecting redband trout movement among arms. The transition zones between the rivers and reservoir environment maximize the chance of catching fish moving into the river as well as those moving out to the reservoir, and represent favorable trout habitat for trapping.

To analyze the significance of tag recaptures in this study, it will be necessary to assume that rates of tag-induced mortality in both the Crooked and Deschutes arms (1) are low and (2) are similar between the two arms. These assumptions are reasonable because there are relatively few avian predators and because water visibility is similar on both arms. In the Metolius arm however, lower turbidity and large numbers of avian predators may be responsible for the low numbers of recaptures. This low recapture rate will greatly influence the analysis of movement from this arm.

The lack of observed movement from the Metolius arm of Lake Billy Chinook indicates limited dispersal from this population, suggesting ecological, and possibly genetic isolation of this population. However, low water turbidity and abundant avian predators may have contributed to high post-tagging mortality leading to the lower recapture percentage of tagged fish from this arm. However, juvenile bull trout tagged in the upper Metolius arm were recaptured in relatively high numbers in the same area (Ratliff et al. 1996) though differences in behavior and habitat selection and differences in tag color between the two species may explain this difference. During snorkel surveys in this system bull trout were typically observed along the bottom of the river or associated with cover while redband trout were seen higher up in the water column feeding in the open which is similar to behavior patterns of rainbow trout observed previously (Warner and Quinn 1995).

The greatest net movement occurred into the transition zone of the Metolius River. In addition to resident redband trout, hatchery rainbow trout and trout showing smolt-like characteristics were found in much higher numbers in the Metolius arm than in any other trap location, which may indicate that these fish are accumulating at this location. Previous studies have shown that because surface currents move from the other arms of Lake Billy Chinook up the Metolius arm, fish attempting to emigrate from the reservoir and following surface currents may become confused and end up in the upper Metolius arm (Ratliff and McCollister 1997; Korn et al. 1967). This movement indicates some possible recruitment into the gene pool of the Metolius population from the other two (sub) populations. However, in the absence of genetic (gene flow) data, only ecological interactions can be addressed. The extent of recruitment cannot be determined until spawning grounds are found for this Metolius population and origins of spawning fish are determined through observation of tags or through genetic analysis.

Ceratomyxa shasta infection studies on Lake Billy Chinook also demonstrated movement of fish into the Metolius arm. *C. shasta* has been found to have high infectivity in the upper portions of both the Crooked and Deschutes arms of Lake Billy Chinook, light infectivity in the forebay, and no infectivity in the Metolius arm (Bartholomew 1999, Ratliff 1983). In 1998, approximately 16% of the resident fish sampled in the Metolius arm were infected with *C. shasta* (Bartholomew 1999), indicating that these fish must have moved into this arm from either the Crooked or Deschutes arms where they had spent at least some part of their lives. In addition, more than half of all hatchery rainbow trout and approximately 20% of redband trout showing smolt-like characteristics were also infected with *C. shasta*, indicating that these fish also moved into the Metolius arm from one of the other arms of Lake Billy Chinook.

Over the three-year study, approximately equal numbers of redband trout were tagged in both the Crooked and Deschutes arms (313 and 324, respectively). An equal percentage of these tagged fished were also recaptured in each arm. Based on these data it was assumed that there were approximately equal population sizes in the two arms. Based on that assumption, percent recapture data indicated that approximately twice as many Deschutes fish moved into the Crooked River than Crooked River fish moving into the Deschutes (9.8% versus 4.9% of the recaptures from each arm).

2.2 — SPAWNING TIMES AND PLACES

Spawning has been observed in redband (rainbow) trout (both native and stocked) in the fall, winter, and spring and sometimes year round throughout their range (Greeley 1934, Biette et al. 1981, Dodge and MacCrimmon 1971, Narver 1969, Sakai and Espinos 1994). In the lower Deschutes River, spawning has been observed between March and August (Zimmerman and Reeves 1998). The degree of fidelity that rainbow trout forms show to natal areas is also variable, from as little as 5% up to 90% (Beitte et al. 1981, Sakai and Espinos 1994, Lindsey et al. 1959) and depends heavily on the stability of environmental conditions in natal streams. This section of the study was intended to determine both where and when fish from the three arms of Lake Billy Chinook spawn and whether or not they are discreet spawning (sub) populations.

Methods

Shoreline and underwater surveys were conducted periodically on discrete stream segments on the Deschutes and Metolius systems during presumed spawning periods (Table 4). These sites included the lower mainstem of Deschutes River, Squaw Creek (Deschutes system) and the lower mainstem of the Metolius River (Figure 4). Spawning ground surveys were also conducted by U.S. Forest Service personnel on the upper Metolius River. Surveyors estimated the numbers of redds and spawners at each location when observed. In addition,16 adult redband trout were captured in Squaw Creek during peak spawning activity in 1998. These fish were captured using trap nets, tagged with a uniquely numbered bi-colored (red/white) dart tag, and released.

Table 4. Dates of spawning ground surveys conducted in the mainstem of the Deschutes and Metolius Rivers and in Squaw Creek, 1997–1999.

Year	Deschutes River	Metolius River	Squaw Creek
1998	Not surveyed	September 12	March 27 April 3, 7 May 8, 16, 22, 30 June 7, 19, 28 July 2
1999	April 5, 8, 15, 18, 29 May 8, 20, 22, 27	May 2	April 12, 24 May 3, 17 June 18

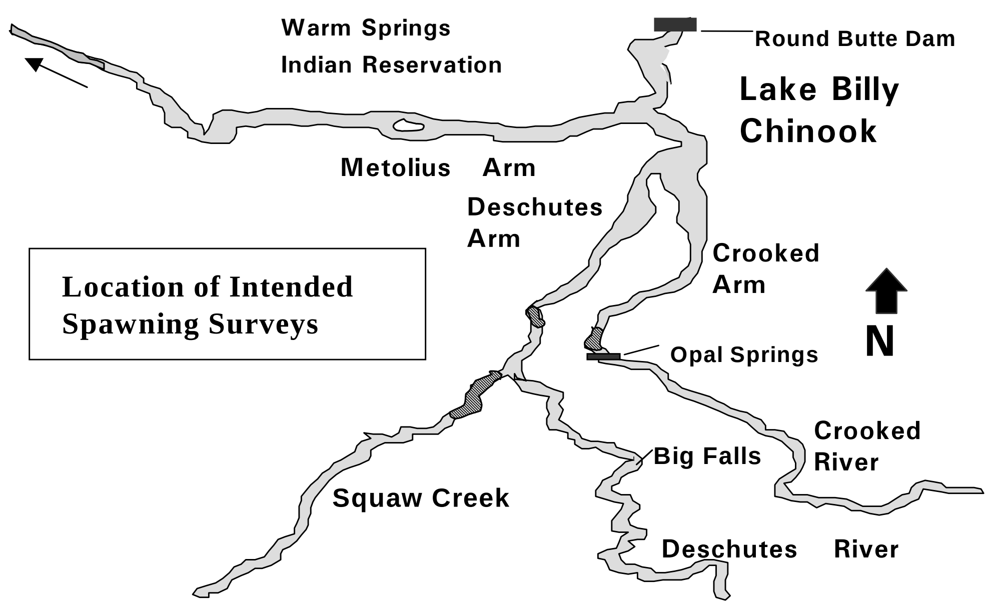


Figure 4. Location of spawning ground survey areas, 1998–1999.

In the Crooked River, a fyke trap was set up in the fish ladder at Opal Springs Hatchery during both 1998 and 1999 with the assistance of hatchery personnel. The trap was used to count the number of adult and juvenile redband trout moving up the fish ladder. The redband trout in the fish ladder were sampled on four separate occasions in 1998 to determine their age and stage of maturity.

Results

Deschutes River — 1999

Abnormally low reservoir levels during 1999 led to an increase of potential spawning habitat in the lower stretches of the mainstem of the Deschutes River. However, weekly surveys of the gravel bars in the lower mainstem from early April through the end of May indicated little usage by redband trout. While a few redband trout were observed on the gravel bar just downstream of the gauging station in mid- to late April, the majority of the spawning activity seen on the gravel bars was by largescale suckers. The number of largescale suckers utilizing these gravel bars increased from as little as four in early April to approximately 300 by mid-April and to over 400 by late May.

Squaw Creek — 1997–1999

During 1997, minimal surveys were done on Squaw Creek, but some evidence of spawning during the spring was observed. In 1998, approximately weekly ground and underwater surveys of Squaw Creek showed that peak spawning occurred in mid-May (weeks 20 to 21; Figure 5). During the fall of 1998, a ground survey was conducted on Squaw Creek, and no redds or fish were observed. Biweekly surveys during 1999 indicated that spawning activity began a week earlier than was observed in 1998. Larger numbers of adult redband trout were also seen during 1999 (Figure 6). During the latter part of the month of June however, glacial melt resulted in high flows and turbidity that precluded surveys until mid-July, at which time there appeared to be a second peak in spawning activity with increasing numbers of adult redband trout moving up into Squaw Creek.

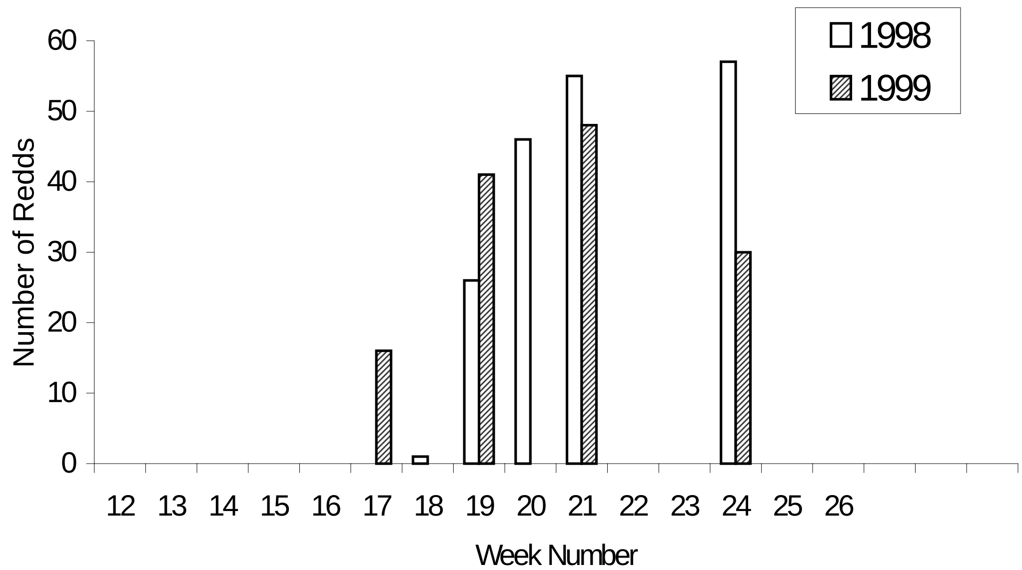


Figure 5. Number of new redds observed during 1998 and 1999 surveys in Squaw Creek.

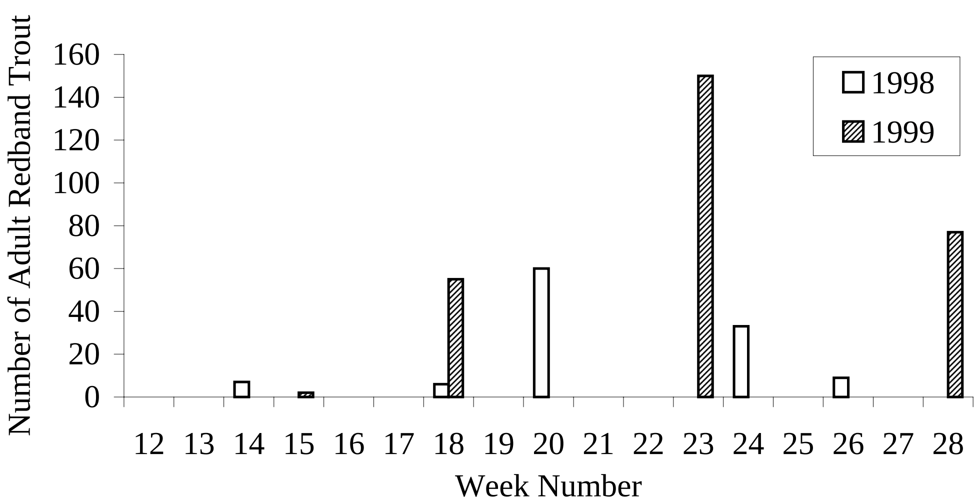


Figure 6. Number of adult redband trout observed during snorkel surveys in Squaw Creek, 1998 and 1999.

Currently no recaptures or re-observations of spawning fish tagged in Squaw Creek have occurred within the mainstem of the Deschutes River. However, fish tagged in both the mainstem of the Deschutes and near the dam were observed on the spawning grounds in Squaw Creek during 1998 and 1999.

Metolius River — 1998–1999

A total of 804 redband trout were counted during intensive snorkel surveys in the upper Metolius River during December of 1998 and February and April of 1999 (Riehle and Houslet 1999). During April 1999, out of a total of 348 adult redband trout observed, one tagged (green) redband trout was seen near the mouth of Lake Creek. (Riehle and Houslet 1999).

Ground surveys were conducted during the fall of 1998 and spring of 1999 in the lower mainstem of the Metolius River from approximately rkm 31 to the inflow into Lake Billy Chinook. These surveys revealed some suitable spawning habitat for redband trout but no evidence of spawning activity. However, during a sampling trip in late July 1999, two redds were observed near the Drift Campground at rkm 27.

Crooked River — 1998–1999

Counts of fish per day moving up the Opal Springs fish ladder indicate that peak movement occurred during the third to fourth week of June in 1998 and 1999 (Figure 7). Sub-samples of these fish on four separate occasions in 1998 indicated that the majority (>90%) of fish moving up the fish ladder were mature and probably on a spawning run. During 1998, two tags were observed on fish counted in the fish ladder, one yellow (Crooked) and one white (forebay) tag. In 1999, four yellow tags were observed on fish in the fish ladder. Snorkel surveys of fish in the mainstem of the Crooked River just below the Opal Springs diversion dam also indicated large numbers of redband trout gathering in this area from late May to late July.

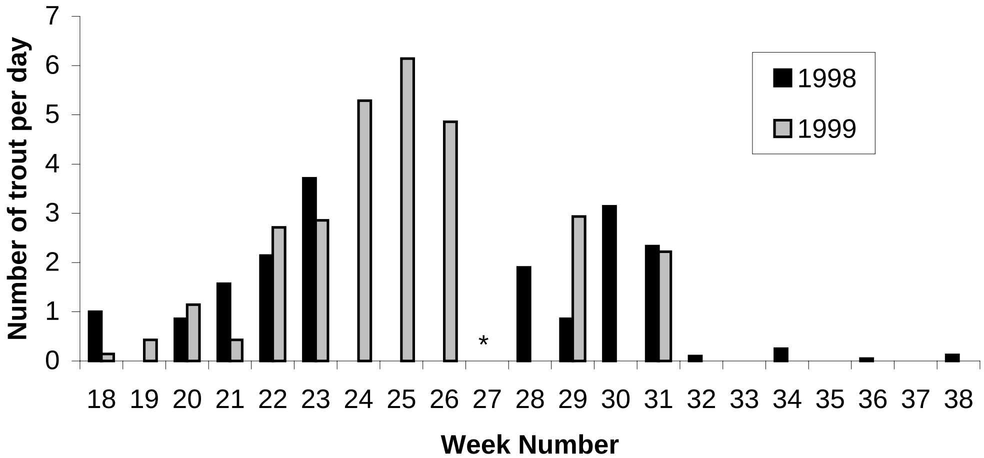


Figure 7. Number of adult redband trout moving up the Opal Springs fish ladder per day, 1998–1999. * no data were collected during this week, either year.

Discussion

Deschutes River

Snorkeling observations from 1997 through 1999 indicated that there is some minimum spawning activity by redband trout on the gravel bar just below the gauging station in the Deschutes River at approximately the same time spawning activity begins in Squaw Creek. In 1999, increased spawning habitat availability due to low reservoir levels throughout the spring did not appear to increase spawning activity by redband trout. Instead, usage by largescale suckers increased, possibly excluding redband trout from previously-used habitats.

Squaw Creek

During the 1997 season, spawning grounds were located on the lower 4 km of Squaw Creek. It was unclear at that time, however, whether the Squaw Creek trout population was part of the Deschutes arm population. In subsequent years more intensive surveys re-observed redband trout tagged in other parts of the system moving up into Squaw Creek from the mainstem of the Deschutes River to spawn in this tributary.

Metolius River

Genetic evidence has suggested that redband trout (sub) populations in the upper and lower portions of the Metolius River were separate populations (Williams et al. 1997). However, a redband trout with a green tag was observed during a snorkel survey of the upper Metolius River during April 1999 (Riehle and Houslet 1999). This fish was originally tagged in the lower Metolius River and, based on timing of the observation, may have been moving up to spawn with the upper Metolius population. It had previously been determined that peak redband trout spawning occurred in Lake and Abbot creeks during the month of April (Houslet and Riehle 1997). Although an observation of one tag is not in itself significant, it does indicate that some mixing between these two groups of fish does occur.

The only spawning activity in the lower mainstem of the Metolius River was observed in late July. This spawning time is more typical of resident redband trout than of fish that spawn in the upper Metolius River (Riehle and Houslet 1999). Future spawning surveys should be concentrated during this time of the year in the lower portions of the Metolius River. Additional spawning activity may be found in the Whitewater River, a tributary to the lower Metolius located on the Warm Springs Reservation. However, this tributary was not surveyed.

Crooked River

Although no spawning was observed in the Crooked arm of Lake Billy Chinook, movement of mature fish into the fish ladder at Opal Springs Dam indicates the timing of the spawning run. Spawning in the Crooked River was more protracted than in Squaw Creek and appeared to peak slightly later in the year. There was evidence that some fish tagged in the Deschutes River attempted to move upstream with the Crooked River population. The true origins of these fish, however, remain unclear. These fish may have originated in the Deschutes River or they may have originated in the Crooked River, moved to the Deschutes for some period where they were tagged, and then moved back into the Crooked River to spawn.

2.3 — ADFLUVIAL LIFE HISTORY STUDIES

Redband (rainbow) trout can be divided into two general life history forms: resident fish (remain in streams until they mature) and steelhead (migratory fish that have an adfluvial life history) (Northcote 1992). These adfluvial fish would migrate from upstream spawning and initial rearing areas downstream into Lake Billy Chinook to reside for a significant portion of their life.

Methods

Floating Merwin trap nets were fished near the upper arms of Lake Billy Chinook through the spring and summer, 1997–1999, and at various locations within the reservoir during the winter of 1998. From March through the end of the field season in –both 1998 and 1999, a Merwin trap was also fished in the forebay area of the reservoir near the dam. All trout captured within the reservoir were tagged with a white Floy tag to distinguish them from fish caught in the tributaries. Scales samples, weight, and length measures were then taken from the fish and growth rates were compared with those of fish taken from the tributaries. Screw traps were fished near the upper Metolius and Deschutes arms of the reservoir during the spring and summer of 1997 and 1998 and in the upper Metolius in 1999. These screw traps were used to monitor any significant downstream migrations of juveniles into the reservoir.

Results

During 1998, a large number of redband trout were observed using the reservoir, including a significant portion of age 2 fish showing smolt-like characteristics during summer. A total of 184 trout were captured, of which 126 were tagged, in the forebay during 1998. Thirty-five of those fish captured in the forebay were showing smolt-like characteristics. Subsequent recaptures of the fish tagged in the forebay in 1998 showed that many of these fish also utilize the tributaries, because 75% of recaptured fish originally tagged in the forebay were found to have moved into one of the three arms of Lake Billy Chinook.

During 1999, unlike the previous year, only 20 redband trout were captured in the forebay. Of those nearly half were showing smolt-like characteristics. Only six fish were tagged at this time. The only recapture from the forebay in 1999 was in the Deschutes arm of Lake Billy Chinook.

In general, those found to be using the lacustrine habitat of the reservoir were older, larger fish than those found in the rivers during 1998. However, fish captured in 1999 showed similar size and age distributions to those captured in the arms.

Based on low numbers of juvenile redband trout caught in the screw trap placed in the Metolius arm, there appeared to be no significant downstream migration of juveniles into Lake Billy Chinook during the spring and early summer (Table 5). In the Deschutes River, however, a large pulse of juvenile (age 0) redband trout was observed moving downstream into the reservoir during 1997. This large pulse was not repeated in 1998 and no data are available for 1999 (Figure 8a-b).

Discussion

The large numbers of redband trout showing smolt-like characteristics found in the forebay and those found to be moving up the Metolius arm of Lake Billy Chinook may suggest a significant number of redband trout are attempting to migrate downstream past the dam. Surface current studies during 1997 in Lake Billy Chinook indicated that prevailing currents at a depth of 5 m during normal operation of the dam moved down the Deschutes and Crooked arms and up the Metolius Arm (Ratliff and McCollister 1997). These surface current patterns may account for the large numbers of smolt-like redband trout seen at the head of the Metolius arm. If these fish were attempting to migrate downstream using current patterns, they would have been lead into the Metolius arm. At present, it is not known whether these fish are native or of hatchery origin. Data from the *C. shasta* study suggests that these fish are more like resident fish with respect to their susceptibility to infection from this disease (Bartholomew 1999).

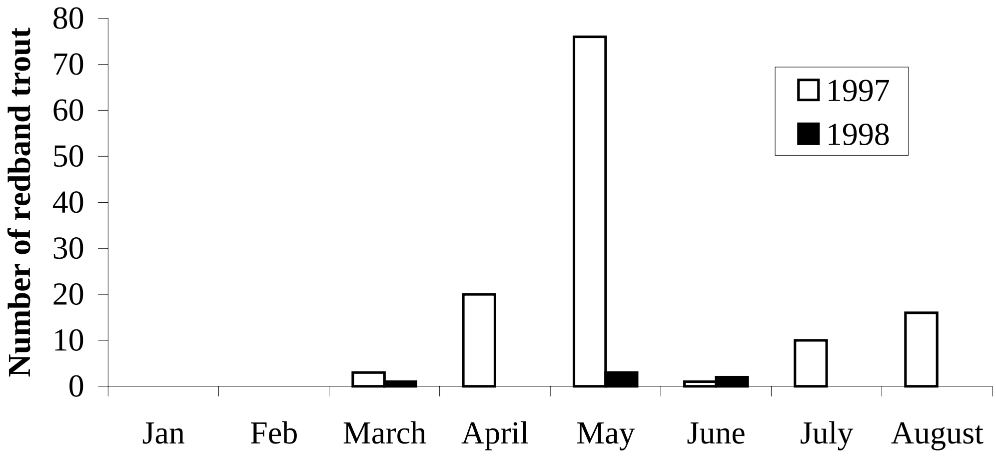
It is also not known whether a significant number of resident redband trout reside in or spend a significant portion of their life in the reservoir year round. Recaptures of tagged redband trout indicate that the majority of these fish may only be passing through the reservoir, not spending significant portions of their life rearing there. More extensive trapping and perhaps radio-tagging with stationary receivers within the reservoir is needed to answer this question.

Table 5. Numbers of redband trout and other salmonid species less than 100 mm captured in downstream migrant screw traps fished in the mouths of the Metolius and Deschutes Rivers entering Lake Billy Chinook from 1997–1999.

		Number Captured (Metolius Trap / Deschutes Trap)			
Year	**Month**	**Rainbow Trout**	**Brown Trout**	**Bull Trout**	**Mountain Whitefish**
1997	March	1/3	0/26	0/0	0/0
	April	5/20	1/19	2/0	0/0
	May	4/76	3/5	2/0	0/31
	June	5/1	1/0	15/0	6/118
	July	6/10	0/1	0/0	4/168
	August	0/16	0/0	3/0	1/2
1998	January	0/0	0/4	0/55	0/0
	February	0/0	1/15	2/0	0/0
	March	2/1	12/7	4/0	2/0
	April	2/0	0/7	31/2	2/1
	May	3/3	0/7	11/2	3/72
	June	0/2	0/3	20/0	11/122
1999*	January	9/	0/	23/	1/
	February	2/	0/	68/	3/
	March	7/	0/	153/	17/
	April	17/	0/	148/	36/
	May	23/	0/	34/	22/
	June	2/	0/	2/	25/

* Deschutes Screw trap not used in 1999

Screw traps were unsuccessful for documenting significant juvenile migrations into the reservoir from the Metolius River during 1998. Larger numbers of juvenile redband trout were observed moving into the reservoir from the Deschutes (Shields et al. 1998) during 1997. Although this significant migration was not repeated in 1998, it is possible that downstream migration only occurs during strong year classes like that observed in 1997, perhaps due to density-dependant displacement from stream habitats. More data will be needed to demonstrate a relationship between strong year classes and utilization of the reservoir.



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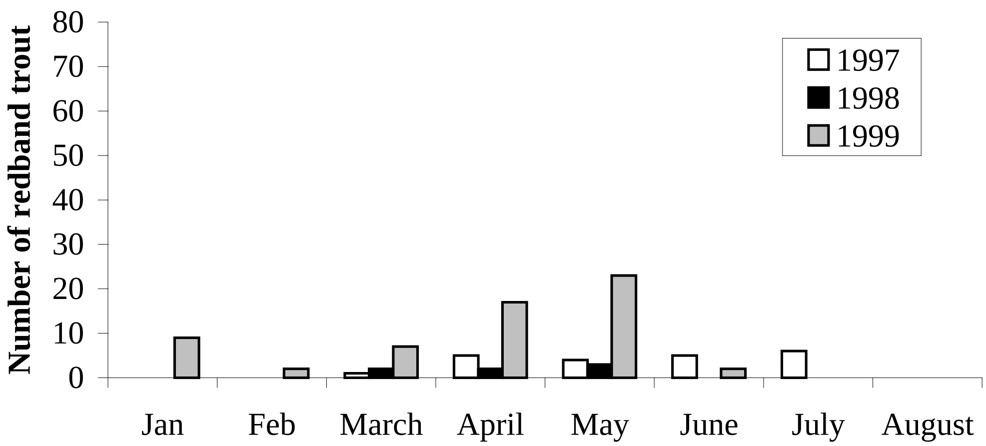


b.

Figure 8. **a.** Numbers of <100mm juvenile redband trout captured in the Deschutes River screw trap, 1997–1998. **b.** Number of <100mm juvenile redband trout captured in the Metolius River screw trap, 1997–1999.

Chapter 3: Biological Characteristics of (Sub) Populations

To determine if (sub) populations of fish are truly separate or if mixing occurs, it is necessary to identify individuals belonging to a given population. Historically, parasite assemblages (Kabata 1963, Sindermann 1961, Wood et al. 1989, Moser and Hsieh 1992), life history characteristics (Filbert and Hawkins 1995, Rulifson and Dadswell 1995), and meristic and morphometric characteristics (Mamontov and Yakhnenko 1995, Rinne 1985, Salmanov et al. 1991) have been used fairly reliably to assist in stock identification of several species of fish. Redband (rainbow) trout are known for their variability in life history traits among watersheds or even within streams. This part of the study focuses on determining if (sub) populations in the three arms of Lake Billy Chinook can be separated based on biological characters, and if so, attempting to establish some biological guidelines that will assist in identifying fish from any of these (sub) populations in the future.

3.1 — AGE STRUCTURE, GROWTH RATES, CONDITION FACTORS, AND FECUNDITY

Growth rates and condition factors can be highly variable among locations in a given system. Age, genetic, and environmental factors like temperature, total dissolved solids, food availability, and competition (both intra- and inter-specific) can have significant influences on growth rates and condition factors of rainbow trout (Currens et al. 1989, Hubert and Chamberlain 1996, Hubert and Guenther 1992, Barton and Bidgood 1980, Gipson and Hubert 1991). These same factors can also influence the fecundity of fish in a given system. There are environmental differences among the three tributaries to, and arms of, Lake Billy Chinook, that could result in physical (morphological) differences among the trout (sub) populations. As a result, these differences may be used to identify the different (sub) populations. Distinct body characteristics among (sub) populations may indicate some isolation if differences are due to genetic as well as environmental factors.

Methods

Weight, total length, fork length, and maximum thickness were recorded for most fish captured with floating traps and hook-and-line equipment. Scale samples were also taken from 1636 of the fish over the three-year study period. All scale samples were aged when possible and used to establish age structures for each population. Average length at age was calculated for each population, and von Bertalanffy growth curves were constructed. Growth parameters calculated from those curves for each population were compared using the method described by Kimura (1980). Fish lengths were also back-calculated for a sub-sample of fish to obtain relative growth rates for each population.

Condition factors for each tributary were calculated for each population using Fulton's equation for condition factors:

$$W \times 10^5/FL^3$$

where W is the weight of the fish in grams and FL is the fork length of the fish in millimeters.

A thickness condition factor was also calculated for these fish using the equation

$$TH \times 10/FL$$

where TH is the maximum body thickness in millimeters and FL is the fork length of the fish in millimeters. Known hatchery rainbow trout and trout showing characteristics of possible steelhead ancestry (ie., slender and bright with deciduous scales) were analyzed separately.

A few mature fish were discovered in those retained for meristics and morphometrics in 1998. The gonads were removed from these fish and weighed, and eggs were counted by hand. Sample sizes were too small to compare among (sub) populations in 1998. During 1999, despite a concerted effort to retain mature females, only an additional five mature females with full ovaries were obtained. These fish were subjected to the same procedures as the fish in 1998. Number of eggs per gram of body weight was calculated for redband trout in each sample. Too few fish were included in these samples for significant comparisons among systems, so only generalizations from these data can be made.

Results

Analysis of data collected from the tagging studies indicated that a large percentage of fish captured in the Metolius Merwin trap originated from one of the other arms of Lake Billy Chinook. Therefore, it was unclear if redband trout captured in this trap actually represented the Metolius population. To increase the possibility of characterizing a “true” Metolius population, only redband trout captured in 1998 and 1999 by angling upstream near camp Monty were used as representatives of this population. Data below are presented separately for Metolius trout trapped in the reservoir-river transition area and for trout caught further upstream in the fluvial portion of the Metolius River.

Age Structures

Overall, age structures were similar among trap locations. The majority of fish captured (38 to 65 percent of fish captured at a given location) were age 2 in all trap locations in all years except the forebay trap in 1998, which had a higher percent of age 3 fish (Figure 9a-c). Because hook and line sampling for redband trout in the Metolius arm above the trap location was biased towards larger fish, the age structures of these fish were not included in this analysis, but the majority of fish captured were of age 2. The second highest percentage of fish represented age 3 fish, due to gear bias (younger, smaller fish were not fully recruited to the gear).

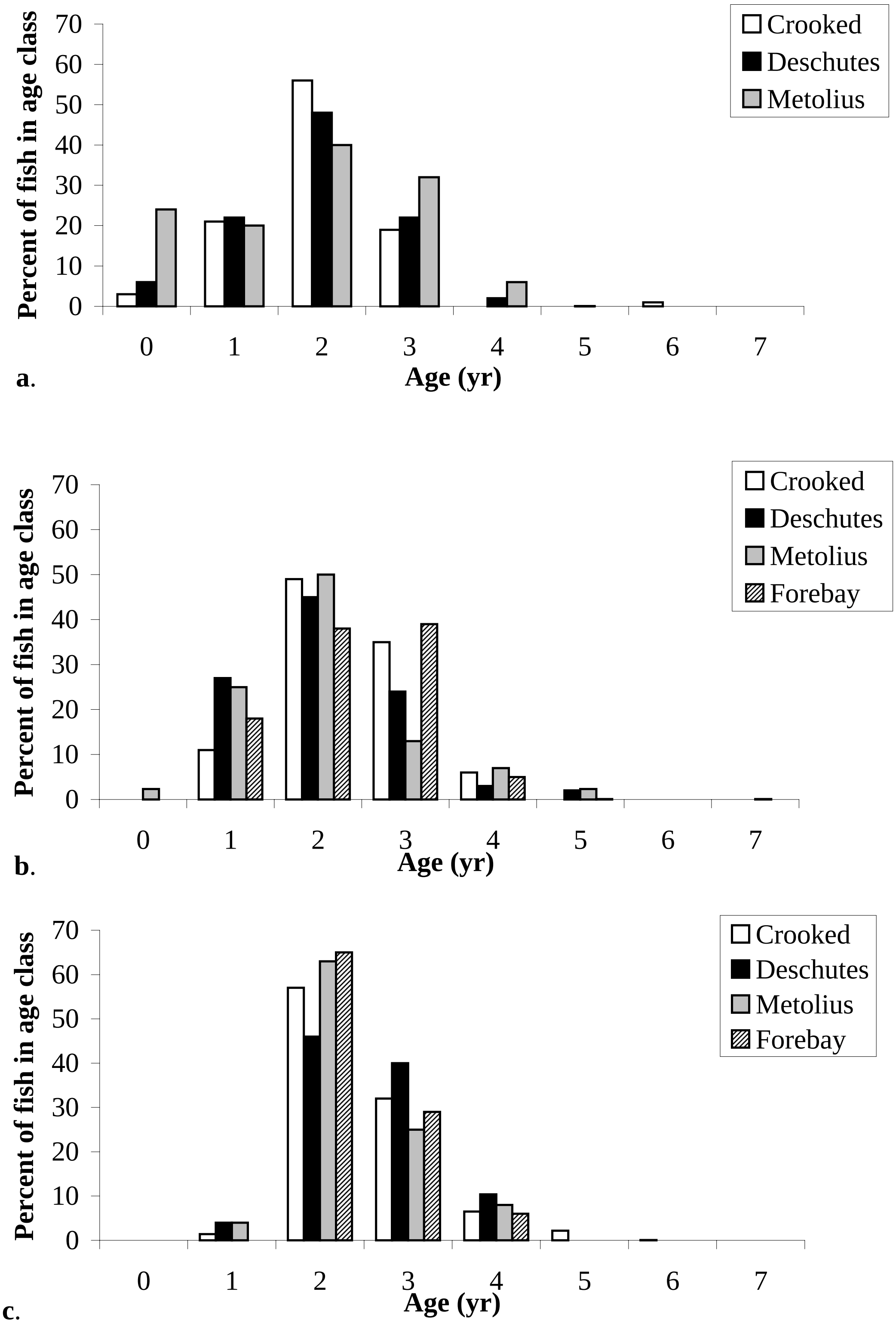


Figure 9. a. Percent of redband trout captured in the three tributaries to Lake Billy Chinook in each age class in 1997. **b.** Percent of redband trout in each age class captured in the forebay and three tributaries of Lake Billy Chinook in 1998. **c.** Percent of redband trout in each age class captured in the forebay and three tributaries to Lake Billy Chinook in 1999.

Growth

Analysis of average fork length (mm) at age data for redband trout captured in floating traps found significant differences in length at age for only age 2 and age 3 redband trout (p-value < 0.05, Tukey's HSD) (Table 6). In 1997, age 2 Metolius redband trout captured in floating traps were significantly larger than age 2 fish from other locations, while. age 3 redband trout from each location were significantly different in terms of length from those at other locations. In 1998, only Deschutes and forebay redband trout were significantly different in length at age 2, and age 3 Metolius redband trout were significantly larger than fish captured at other locations. In 1999, no differences in length at age were seen in age 2 trout; however, age 3 Metolius trout captured in the Merwin trap were significantly larger than both Deschutes and Crooked (but not forebay) redband trout in 1997–1999. Length at age of fish captured by hook and line in the Metolius River in both 1997 and 1999 were no different from those captured in the Crooked and Deschutes traps for age 3 fish and were smaller than age 2 fish caught at all locations.

Table 6. Summary of tags observed during snorkel surveys in the three arms of Lake Billy Chinook and Squaw Creek, 1997–1999. Deschutes – orange, Crooked – yellow, and Metolius – green.

Year	Deschutes	Crooked	Metolius	Squaw Creek
1997	2 – Orange* 1 – Yellow*	7 – Yellow*	--	--
1998	3 – Orange	8 - Yellow	4 – Green 2 – Yellow	--
1999	--	10 – Yellow 3 – Orange*	1 – Orange*	1 – Orange*

* Indicates fish were observed on the same day. All other tag totals were observed on different days so number of tagged fish may include re-observations of the same fish.

Von Bertalanffy growth curves were constructed with average fork length at age data. Parameters for these growth curves for all three years of data are shown in Table 7; trout captured by hook and line in the Metolius River in 1998 and 1999 are treated separately from trap data. However, because angling did not capture a full size range of fish, a reliable growth curve could not be developed for this group. In 1997, overall growth curves were significantly different among different locations, yet individual parameters were not. In 1998, no significant differences were seen in growth curves among trap locations. In 1999, fish captured in the Crooked River trap showed a significantly different growth curve than the other (sub) populations. Growth in the Crooked River appeared to be linear from age 1 to age 5. The redband trout captured in the Metolius River trap were expected to reach a larger maximum size than redband trout captured from other locations, except for those from the Crooked River in 1999.

Table 7. Von Bertalanffy growth parameter comparisons among sampling locations in Lake Billy Chinook, 1997–1999.

Year	Location	Crooked	Deschutes	Metolius	Significance
1997	L_∞	318.6	491.6	574.6	--
	K	0.37	0.20	0.17	--
	t_o	-1.42	-1.11	-1.15	--
1998	L_∞	438.6	403.7	481.1	--
	K	0.28	0.34	0.23	--
	t_o	-0.95	-0.61	-1.15	--
1999	L_∞	874	397.2	405.4	*
	K	0.07	0.37	0.39	*
	t_o	-2.36	-0.38	-0.36	*

* denotes significant difference among parameters ($p<0.05$, Likelihood Method)

Relative growth rates were calculated for both back-calculated age at length data and average fork length at age data. No significant differences were seen in relative growth rates by age class or year class for data taken from trap locations. Relative growth rates calculated for redband trout captured using hook and line in the Metolius River using length at age data indicated that their relative growth rates were also not significantly different from other groups of fish.

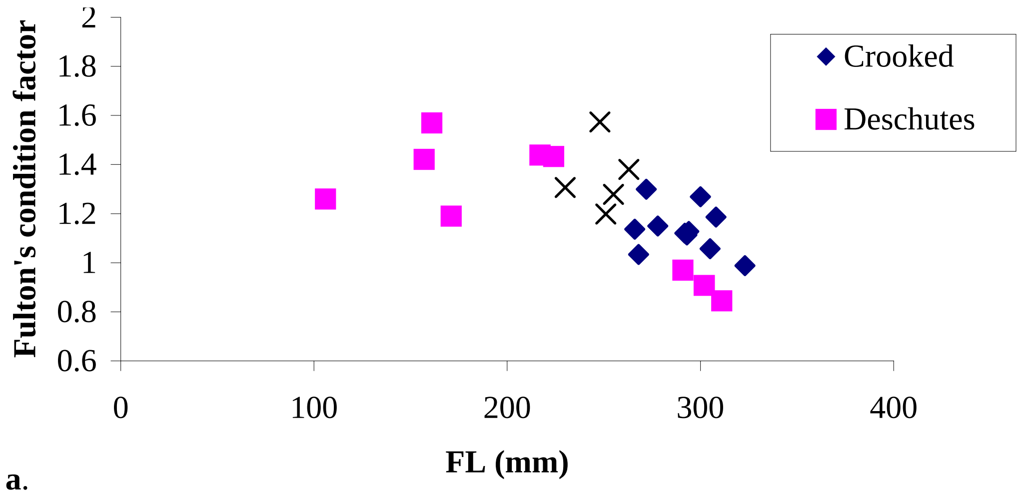
Weight at age data were also compared among capture locations. Redband trout captured by angling in the Metolius River were heavier at a given age than fish captured in other locations.

Condition Factors

Condition factors calculated for all trap locations and for fish captured using hook and line were compared using an analysis of variance (ANOVA). During 1997 and 1998, some significant differences were seen in both Fulton's condition factor and the thickness condition factor. In 1997, only the Deschutes and Metolius arms condition factors were significantly different (Figure 10a). In 1998, the Deschutes fish were heavier for a given length and the Metolius fish were thicker for a given length (Figure 10b). Fish captured by angling in the Metolius River were not significantly different from those captured in the Metolius Merwin trap in 1998. In 1999, no significant differences were found in either condition factor when analyzing only the trap data. However, both condition factors for trout captured with hook and line further up the Metolius River were significantly higher ($p < 0.001$, ANOVA) than all trap locations, including the Metolius arm (Figure 10c).

Fecundity

A total of nine mature female redband trout that still retained all of their eggs were examined in1998 and 1999 (four from the Crooked, one from the Deschutes, two from the forebay, and two from the Metolius). Number of eggs per female ranged from 390 to 1438, with highest number of eggs counted from fish captured in the Merwin trap in the Metolius River. One gonad sample from the Deschutes River was not weighed and was excluded from the analysis. The number of eggs was generally found to increase with increasing size, age, and body weight (Figure 11). Although sample sizes are small, it appears that the fish captured in the Metolius trap have more eggs per gram of body weight than fish captured in other traps (Figure 12).



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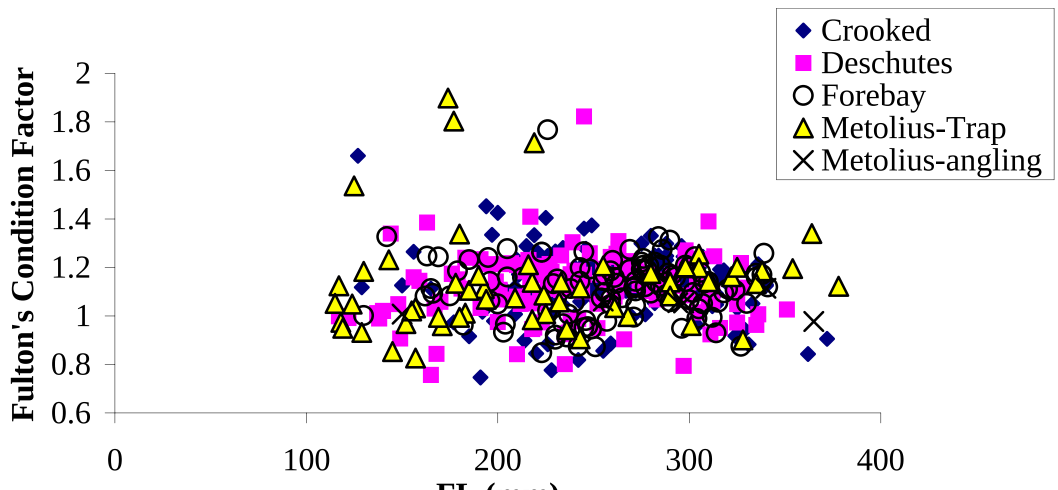

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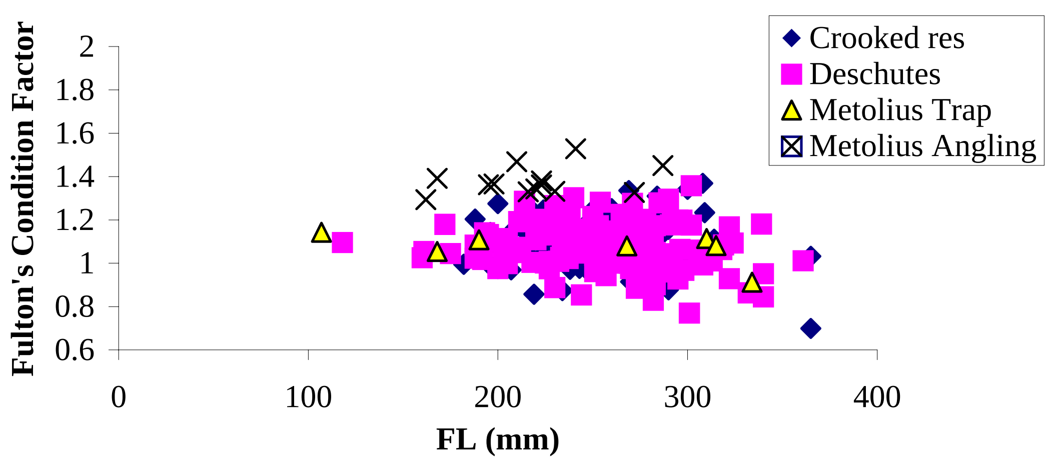


c.

Figure 10. a. Fulton's condition factor vs FL for redband trout captured in all study locations of Lake Billy Chinook, 1997. **b.** Fulton's condition factor vs FL for redband trout captured in all study locations of Lake Billy Chinook, 1998. **c.** Fulton's condition factor vs FL for redband trout captured in all study locations of Lake Billy Chinook, 1999.

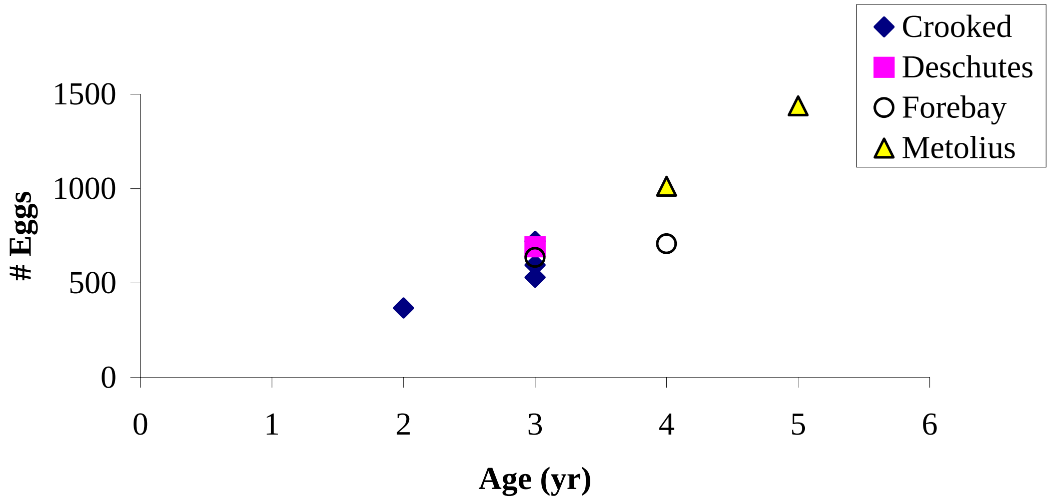


Figure 11. Relationship between number of eggs and age for mature females captured in the forebay and three arms of Lake Billy Chinook, 1998 and 1999.

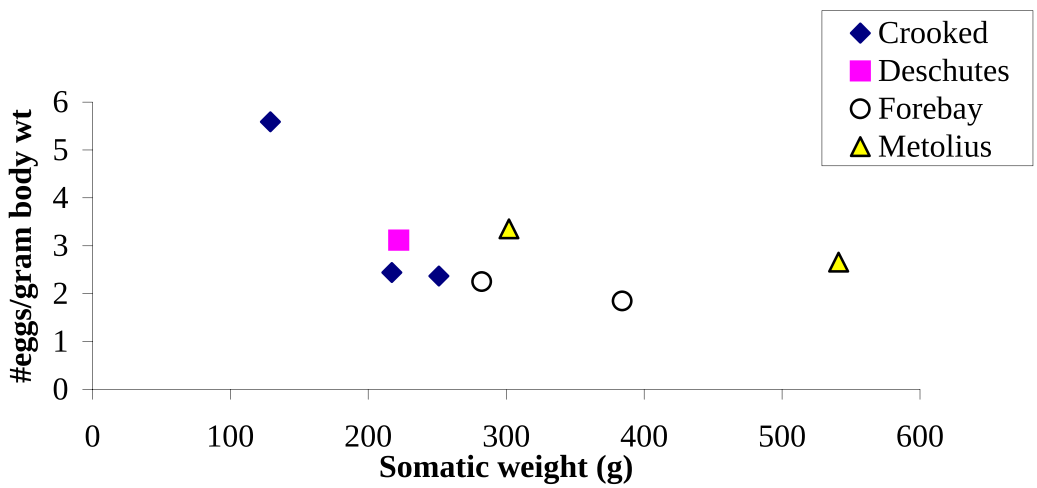


Figure 12. Relationship between number of eggs per gram of body weight vs. body weight for mature females captured in the forebay and three arms of Lake Billy Chinook, 1998 and 1999.

Discussion

Age Structure

Age structures were similar among systems. Data collected in 1998 suggested that older, larger fish utilized the reservoir; however, this was not seen in 1999. Because of gear bias against smaller fish in the Merwin traps, it is not possible to confirm the strong year class as seen with screw trap data in 1997. However the high percentage of age 2 fish in 1999 does give some evidence to support this. In addition, the high percentage of age 3 fish in 1998 and age 4 fish in 1999 may also indicate a strong year class in 1995.

Growth

Only fish captured in the Metolius Merwin trap were significantly larger at age 2 than fish captured at other locations for all three years and at age 3 in 1997 and 1998. The consistent difference in length at age data for those fish captured in the Metolius trap may signify a different life history type than those captured in other locations; typically, rainbow trout residing or spending a significant portion of their lives in lakes are larger for a given age than resident trout found in flowing water (Simpkins and Hubert 1996). Although not statistically significant, trout captured in the Metolius Merwin trap also tended to maintain a higher relative growth rate after age 2.

Condition Factors

Differences in condition factors among sites, particularly in 1999, indicate significant differences in body types. Resident redband trout captured using hook and line above the trap location in the Metolius River were characterized by the highest condition factors and were distinct from all other trout sampled in 1999. Although fish captured in the Metolius River by hook and line had higher condition factors, these fish did not have greater average lengths at a given age than redband trout from other (sub) populations. The difference in condition factors appears to be primarily due to increased weight for a given length in this population of fish.

Fecundity

Fecundities from fish captured in the Deschutes, Crooked, and forebay traps are similar to fecundities reported from other resident stream rainbow trout (Behnke 1992). Fecundities from two fish captured in the Metolius Merwin trap are more similar to that reported from steelhead and lake-dwelling rainbow trout (Behnke 1992, DuBois et al. 1989). The differences seen in the relationship of number of eggs per gram of body weight between the Metolius trap fish and other groups is similar to that seen between resident and adfluvial Westslope cutthroat trout (Downs et al. 1997). This may give some indication that these fish are members of an adfluvial population of redband trout and were caught in the trap while attempting to move upstream to spawn. Because sample sizes were small, additional documentation of egg counts from mature trout is required to confirm this evidence.

3.2 — MERISTIC AND MORPHOMETRIC ANALYSIS

Phenotypic traits of fish can be highly influenced by age as well as genetic and environmental factors. Because of differences in environmental factors among the current study sites, it is possible that these (sub) populations can be subdivided into distinctive groups. Characterizing the geometry of the fish shape tends to give the highest likelihood of finding morphometric differences that have biological meaning both within and among species. The crisscross pattern of triangles along the body form is known as a truss network (Figure 13). This method is different from more traditional morphometric measurements in that it alludes to a total geometry of the fish. The truss network was used, along with a few more traditional morphometric measures, to compare (sub) populations. Multivariate analysis of the morphometric data was used to examine multiple traits simultaneously. Cumulative incremental differences were then used to discriminate among (sub) populations.

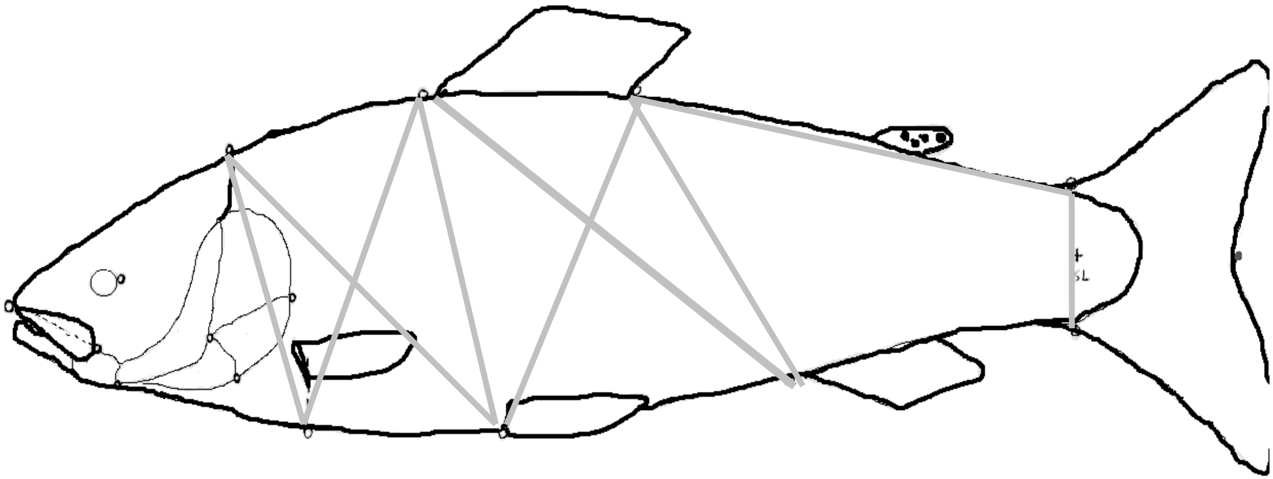


Figure 13. Truss measurements taken on retained redband trout.

Methods

During the study period, a total of 325 redband trout were retained for meristic and morphometric analysis (96 –from the Metolius, 98 from the Deschutes, 98 from the Crooked, and 33 –from the forebay). Redband trout were categorized into one of three groups:

- fish appearing to be of hatchery origin (fin clips),
- fish showing smolt-like characteristics (silvery, long narrow bodies, no ventral pigmentation, and deciduous scales)
- all other fish, classified as resident redband trout.

Of the 60 fish retained in 1997, 20 were classified as hatchery, 1 was classified as showing smolt-like characteristics, and 39 were classified as residents. In 1998, 31 of the retained fish were hatchery, 57 showed smolt-like characteristics, and 78 were residents. In 1999, 20 retained fish were classified as hatchery, 2 showed smolt-like characteristics, and the remaining 78 were classified as residents. Morphometric measurements taken on these fish were analyzed together with condition factors using discriminant function analysis. Morphometric measurements included maximum body thickness, maximum body depth, snout length, and minimum depth of the caudal peduncle in addition to 14 body measurements taken using a truss system (Figure 13). Meristic counts taken in 1997 were found not to vary significantly among (sub) populations, so counts were discontinued in 1998 (Groves and Shields 1998).

Discriminant function analysis (Statgraphics, version 3.0) was used to compare morphometric measurements standardized by fork length among each sub-population. With multivariate statistical analyses, variation in multiple traits is assessed simultaneously for each individual in each population. Although differences may not be statistically significant for each individual trait, the cumulative incremental differences may enable discrimination among (sub) populations when viewed in a multivariate context. In other words, multiple, small differences that by themselves are not significant may add up to discernable differences when analyzed in this way.

Results

In comparisons of the three types of redband trout identified (hatchery, smolt-like, or resident), group membership was predicted correctly 83% of the time (Table 8). The resident form of redband trout was separated from hatchery and smolt-like trout along discriminant function one, while discriminant function two separated the hatchery and smolt-like forms (Figure 14). Characters that were most prominent in the separation along discriminant function 1 were length of the caudal peduncle and a component of body depth. Separation along discriminant function 2 was related primarily to components of body depth. Although individuals from each form clustered in proximity to other members of that group, only the group centroid value for resident fish was significantly different among the groups.

Table 8. Discriminant analysis summary table for each of the three forms of rainbow trout in Lake Billy Chinook, 1998. The characteristics used for this analysis are the same as those used for the previous discriminant analyses.

Form	Number	% Classification
Resident	117	85.5
Hatchery	36	72.2
Smolt-Like	39	82.1

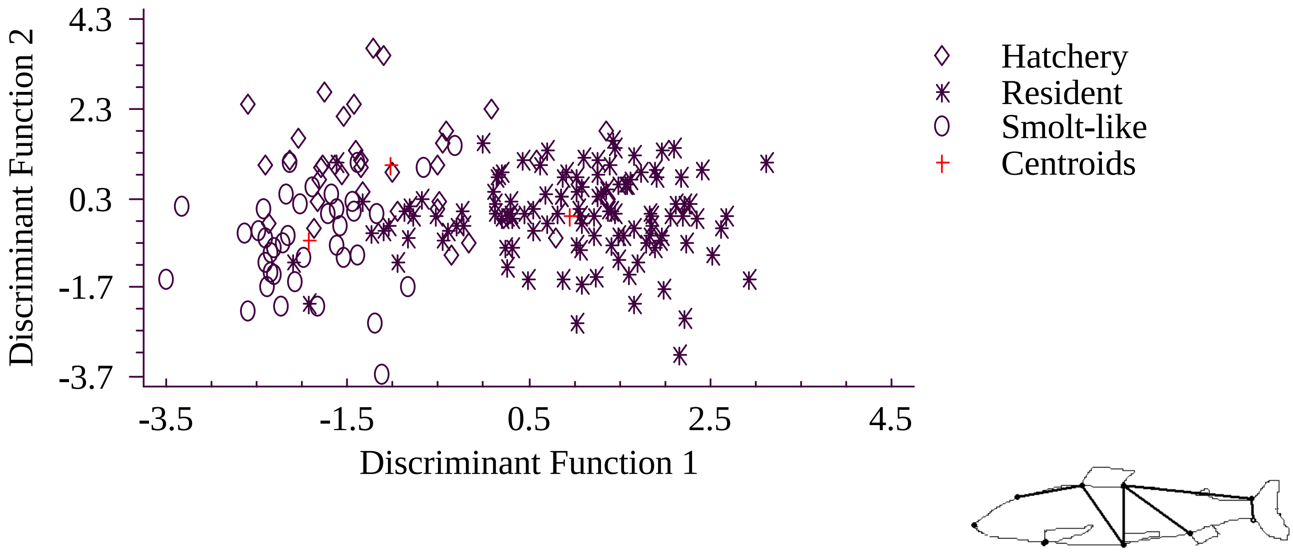


Figure 14. Plots of the first two discriminant functions for separation of the three forms of redband trout captured in Lake Billy Chinook, 1997–1999. Characteristics important in separating groups are highlighted on outline of fish.

In the analysis of only the resident form, redband trout could be classified based on location of initial capture only 62% of the time, on average. Percent classification ranged from 41% for Deschutes trout to 92% for Metolius trout captured above the river/reservoir transitional zone in the Metolius River (Table 9). Plots of the first two discriminant functions generated from standardized morphometric data on resident redband trout are represented in Figure 15. Discriminant function 1 separated Metolius River fish from Deschutes and Crooked river fish using components of caudal peduncle and body length along with the thickness condition factor. Discriminant function 2 separated Metolius fish captured by angling from those captured in the Merwin trap by using components of body and caudal peduncle depth and both condition factors. Individuals from each sampling location clustered in proximity to one another; however, there were no significant differences found among discriminant function's group centroids (p-value > 0.05, Scheffe's Multiple Comparison) between the Crooked and Deschutes groups, and between the Metolius trap and forebay groups. The Metolius angling group centroid was significantly different from all other groups. There was wide overlap of the boundaries enclosing all points plotted for both the Crooked and Deschutes sampling sites and for fish captured in the forebay and Metolius Merwin traps. However, boundaries enclosing all points plotted for those fish captured while angling further up in the Metolius River showed little overlap with discriminant function scores for redband trout from other locations, indicating the body shape of this group separates them from all other groups examined.

Table 9. Discriminant function analysis summary table for resident redband trout. This program creates functions of quantitative measurements that can be used to discriminate among groups when data can be classified into two or more groups a priori. Discriminant functions are created for each group and each individual is then subsequently removed and reclassified based on those discriminant functions. Percent classification refers to the percent of individuals that were reclassified correctly into their original grouping.

Location	Number	% Classification
Deschutes	34	41.2
Crooked	39	69.2
Metolius Merwin	15	73.3
Metolius Angling	12	91.7
Forebay	13	53.9

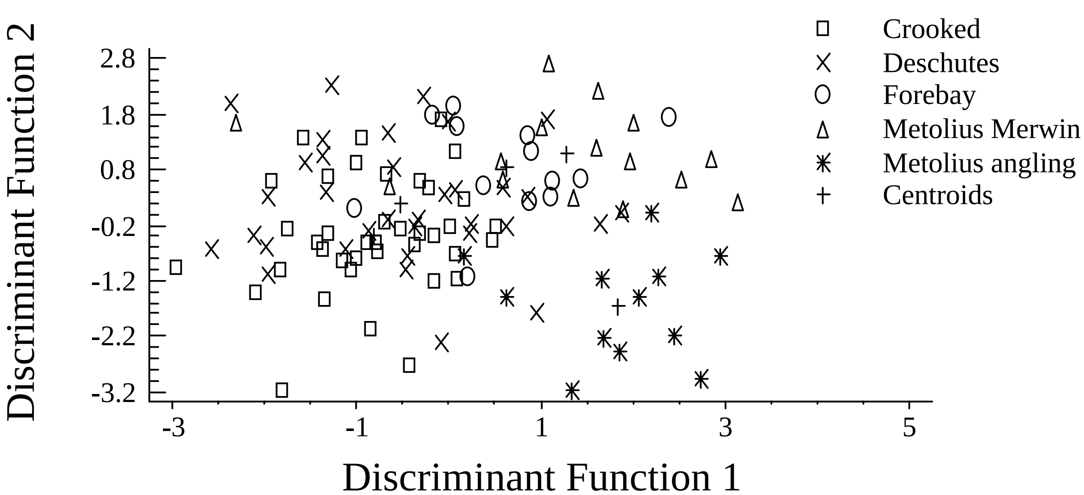


Figure 15. Plot of the first two discriminant functions in the separation of resident redband trout by location of initial capture site in Lake Billy Chinook, 1997–1999. Solid line indicates boundaries for redband captured by angling upstream in the Metolius River.

When the forebay classification was removed from the data set and the analysis rerun to determine the most likely origin of those fish, the majority of the fish were classified as Metolius Merwin fish (54% Metolius Merwin, 23% Deschutes, 15% Crooked, and 8% Metolius angling).

Discussion

Discriminant analysis revealed that there is justification for the separation of the fish into the three distinct forms described earlier. The distinct body shape and coloration of the smolt-like trout may indicate that at least some portion of the resident fish in this system have retained or developed an adfluvial life history form.

Analysis of morphometric characteristics from five locations in this study revealed that redband trout captured upstream in the Metolius River were identifiable from fish from all other locations. *C. shasta* data on this group of fish revealed that 1 of 12 fish tested was infected with this parasite (Bartholomew 1999). Because redband trout typically do not become infected with this parasite in the Metolius River, at least a small percentage of the fish found further upstream in the Metolius appear to have either moved there from another location or spent some time in another location, where they became infected. The former may suggest that environmental conditions in the Metolius River are one cause for the unique body shape of this group of fish.

Separation along the discriminant functions was primarily based on the truss system measurements along with Fulton's condition factor and a thickness condition factor. However, trout captured by angling upstream in the Metolius could also be reliably identified based only on the condition factors and depth of the caudal peduncle. These measurements can all be made simply in the field without the need to sacrifice any fish. These standardized measurements were not positively correlated to length or age of the fish, so the influence of fish size or age on these characteristics was not a significant explanation for the differences seen among (sub) populations along these axes within the size range of redband trout examined. This may indicate real ecologically or biologically determined differences in body shape rather than simple allometric growth.

Only about two-thirds of the fish in the Crooked River and only about half of the fish in the Deschutes River could be classified correctly based on morphometric data. The majority of the incorrect classifications misidentified Crooked River fish as from the Deschutes River, and vice versa. Similarities seen in body shape between the Crooked and Deschutes (sub) populations may be readily explainable in light of the frequency of movement between these (sub) populations that we have documented with tagging recaptures.

Fish captured in the forebay trap and the majority of fish captured in the Metolius Merwin trap also appeared to have a similar, unique body shape. Because redband trout captured in the forebay and those captured in the Metolius Merwin trap must have originated from one of the (sub) populations above the reservoir, and because these fish appear physically different from those in the Metolius River, the unique body may be a consequence of the influence of the lacustrine environment on phenotype. The unique body shape may also be a consequence of the phenotype of fish with a lacustrine genotype.

3.3 — PARASITE FAUNAL ASSEMBLAGES

One method of identifying and monitoring movements of discrete (sub) populations of fish is to use parasites as natural biological “tags” (Wood et al. 1989; Moser and Hsieh 1992, and Williams et al. 1992). Use of parasites as biological tags has been an invaluable tool in the identification of stocks of several commercially important marine and freshwater fishes (Sinderman 1961, Wood et al. 1989; Moser and Hsieh 1992). For utility in stock identification, a parasite must meet three criteria. First, the parasite must vary in prevalence or mean intensity among populations. Second, the infestation of the parasite must be of reasonably long duration relative to the lifetime of the fish. Finally, the prevalence or mean intensity of the parasite must remain relatively stable through time within host populations (Kabata 1963). Utility of parasites found in or on redband trout as biological tags depends on the nature of the parasite and its means of infection of the host. The most useful parasites are those that are acquired after fish have recruited to established post-juvenile assemblages, are transmitted by direct contact with other infected fish, or whose distribution is limited by the environmental requirements of an intermediate host (Whitaker and McFarlane 1997).

Methods

All fish retained for meristic and morphometric measurements, as well as all mortalities, were examined for both external and internal parasites. To minimize seasonal variation in parasitic infection and abundance, all fish captured beginning in June were retained until the total number needed was reached in both 1998 and 1999. In both years, no fish were retained later than July 30th. The total number of resident trout examined for parasites from each location were; 72 – Crooked, 52 – Deschutes, 44 – Metolius, and 20 – forebay. In addition, 52 hatchery fish and 62 trout showing smolt-like characteristics were examined. The examination for stock differentiation focused on parasitic copepods and internal helminths. All parasites removed from the fish were enumerated, fixed, and stored in 70% ETOH for later staining and identification. Parasites were identified down to genus when possible using a variety of taxonomic keys. Prevalence and mean intensity were then calculated for each sub-population and compared using principal components analysis and discriminant function analysis.

Results

Using parasite data and discriminant function analysis, Deschutes River fish were identified only 55% of the time, Metolius fish 63% of the time, and the other groups less than 40% of the time. This low percentage of classification is likely due to (1) bias induced by the lack of parasites in some fish from all (sub) populations, (2) small sample sizes, and (3) possibly a confounding problem of mixed stocks in reference samples and (sub) populations.

Seven parasites were commonly found in redband trout at all four sampling locations in Lake Billy Chinook in both 1998 and 1999. Two of these genera (Neoechinorhynchus sp. and Crepidostomum sp.) were found not to be suitable for use as biological tags, as they were found on very low percentages of fish in both years. The remaining five species of parasites at least partially fulfilled the criteria for suitable biological tags.

Two of these parasites, Metabronema sp., and Cucullanus sp. (stomach and intestinal nematodes, respectively) are typically found on redband trout and can be used to identify members of the Deschutes population of redband trout. The highest prevalence of these parasites occurs in redband trout captured in the Deschutes River, followed closely by those captured in the forebay area of the reservoir. Mean intensity of *Metabronema* sp. was also much higher in redband trout captured in the Deschutes River. In addition, all fish examined from Squaw Creek were infected with both of these parasites.

Proteocephalus sp. (intestinal tapeworm) was found in a higher prevalence in the Deschutes River in both 1998 and 1999, but mean intensities were variable among sites between years.

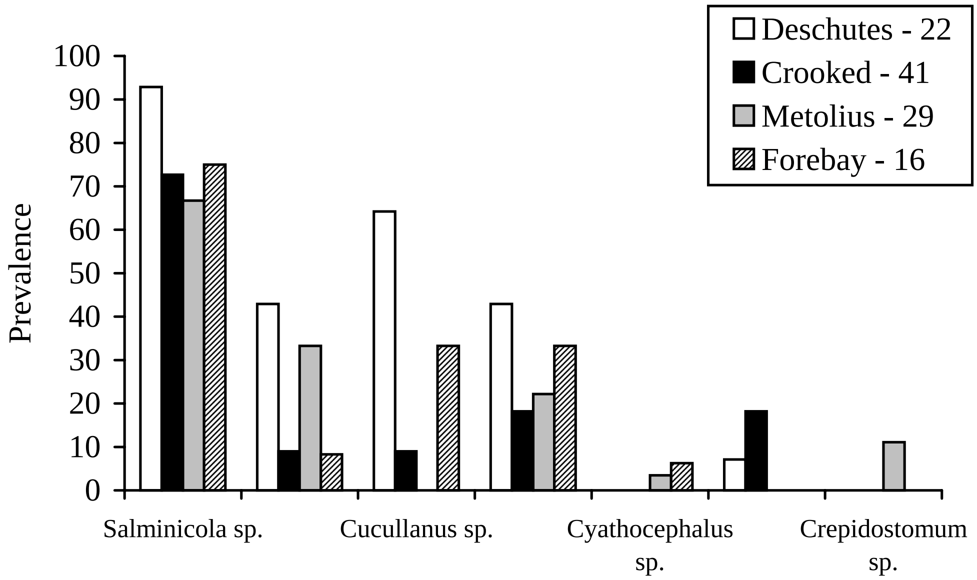
The parasite *Deropegus* sp. (stomach trematode) was more commonly found in the Crooked River population but not at a high enough prevalence to unquestionably identify all members of this population.

Salminicola sp. (parasitic copepod) was found on the majority of fish at all locations, with a higher prevalence generally found on Deschutes River and forebay fish. However, it was found at a higher mean intensity on Metolius River fish in both 1998 and 1999 (though not significantly higher than other locations).

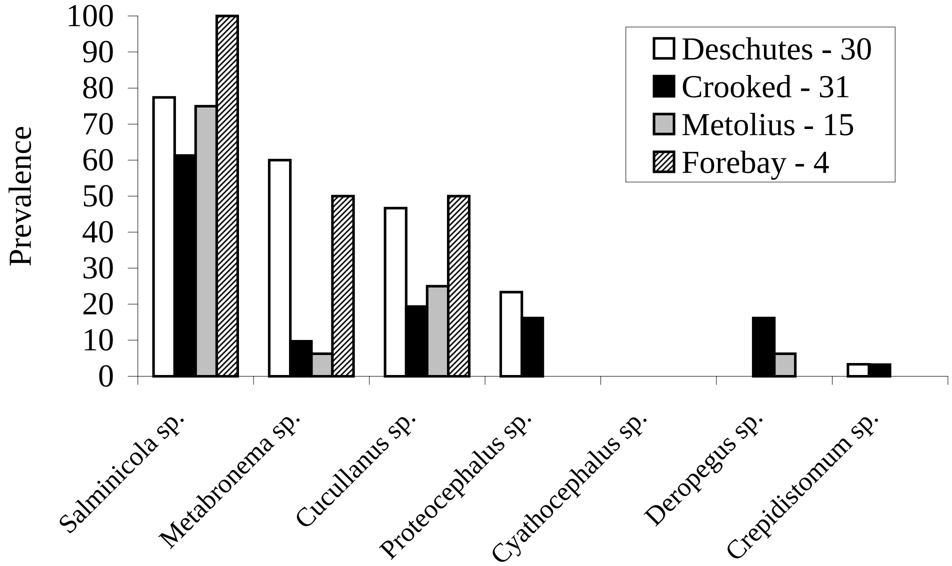
Prevalence and mean intensity of the most common parasites found during the study can be found in Appendix 1. The parasites shown in this appendix were subjected to both a principal component analysis and a discriminant function analysis to test the utility of using the above-mentioned parasites as stock identifiers.

Discussion

Following the guidelines given by Kabata (1963), five parasites that fulfill the criteria for suitable biological tags were found in the redband trout from the four sampling locations in Lake Billy Chinook. Two of those parasites can be used to distinguish Deschutes River redband trout from the other (sub) populations based only on prevalence and mean intensity. These parasites were also commonly found in forebay fish and fish examined from Squaw Creek, indicating that many forebay fish may have originated in the Deschutes River or that there is active interchange between the sampling locations (Figures 16a-b).



a.



b.

Figure 16. a. Prevalence of the most common parasites of redband trout in Lake Billy Chinook and its tributaries in 1998. Numbers of trout examined are shown in the legend. **b.** Prevalence of the most common parasites of redband trout in Lake Billy Chinook and its tributaries in 1999. Numbers of trout examined are shown in the legend.

Hatchery fish in this system were found to lack most internal parasites, which made it difficult to classify these fish into a river of origin based on parasite populations. Though very few were examined in 1999, trout showing smolt-like characteristics in all (sub) populations in 1998 had both high prevalence and high mean intensity of *Metabronema* sp., which is characteristic of the Deschutes population of resident redband trout. This may be an indication that these fish also originated from the Deschutes River, which is in general agreement with the discriminant function analysis of morphometric characteristics of this group of fish from 1998 (Groves et al. 1999) and the historical summer steelhead runs reported from the Deschutes River. The presence of this parasite also makes it doubtful that these smolt-like trout are of hatchery origin.

Principal components and discriminant function analyses were unable to reliably separate (sub) populations of redband trout based on prevalence and mean intensity of all parasites. Because there were several fish in each system lacking one or more parasite species, these fish were classified as separate (sub) populations by the program.

Chapter 4: Diet and Prey Studies

Many studies have examined the diet of rainbow trout and have provided insights on predation, competition, and food web dynamics (Amundsen et al. 1996). Aquatic invertebrates are the primary food source for most freshwater populations of rainbow trout (Angradi and Griffith 1990), but the composition of prey items in their diet varies with the availability of aquatic and terrestrial invertebrates over both spatial and temporal scales (Zadorina 1989). Food availability depends on the overall abundance as well as the species composition of the aquatic invertebrate community because not all potential prey items are equally "available" to trout (Radar 1997). The overall abundance of food and the species composition in the diet of fish, combined with other environmental factors, can influence many life history characteristics of a population. Diet has a strong influence on the growth rate and maximum size of trout, and may affect condition factors and robustness of trout in a given system (Pidgeon 1981). Lack of one or more preferred prey items can result in trout avoiding an area, and may be a determining factor limiting use of the main portion of Lake Billy Chinook by redband trout during most of the year. Food scarcity can result in limited productivity and emigration of trout to areas with more abundant prey (Baker 1989 as cited by Filbert and Hawkins 1995). Finally, the diet of a population may influence the composition of its characteristic assemblage of parasites, since many parasites have complex life cycles involving specific intermediate hosts, and infect only fish that consume infected intermediate hosts.

In some years, redband trout in the Metolius arm have been found to be larger than like-aged fish in the Crooked and Deschutes arms of Lake Billy Chinook (Groves et al. 1999). In addition, tagging studies have documented redband trout moving out from the Crooked and Deschutes rivers into the reservoir and into other river systems. Finally, significant differences have been noted in the parasite assemblages characteristically infecting redband trout in each of the tributaries. Studies of prey availability and feeding selectivity by redband trout in each of the Lake Billy Chinook tributaries could help determine if dietary differences may be one factor explaining observed differences in growth rate, inter-fluvial movements, habitat utilization, and parasite assemblages among (sub) populations.

4.1 — DIET VS. PREY AVAILABILITY IN THE THREE TRIBUTARIES OF LAKE BILLY CHINOOK — 1998

Because feeding habits and diets of trout are influenced by seasonality, time of day, and temperature (Jenkins et al. 1970), accurate assessment of the significance of among-population differences in the diets of fish requires information regarding the variations that also occur within each population over time. These variations may reflect changing availability and/or preference of prey due to changes in the drift and benthos composition of a stream or river (Mathooko 1996). Diet and available prey were studied for redband trout in fluvial reaches of the three major tributaries to Lake Billy Chinook during the summer of 1998. To minimize the artifact of temporal variation, three separate teams of OSU students simultaneously conducted diet and habitat sampling during three separate sampling periods in each of the three river systems. Fluvial stretches were selected as sampling sites because these reaches were considerably upstream from the areas where Merwin trap sampling was conducted and were less likely to contain adfluvial fish. Thus, they were designed to provide samples of "resident" redband trout diets representative of each river.

Methods

Collection of Stomach Samples from Trout

Trout were collected via cast-netting as well as by angling during three separate periods (June 26–27, July 17–18 and August 14–15) during 1998. Fish were anesthetized, then measured for total length, fork length, and body thickness. Stomach contents were removed using gastric lavage (Meehan and Miller 1978) and preserved in 70% ethanol for later identification. Fish were tagged, photographed, had scales sampled (for ageing) and a fin clipped (for future genetic studies), then released after full recovery from anesthetic.

Collection of Environmental Samples of Invertebrates

Invertebrate drift samples were collected by using a variety of nets set to capture drifting items during various sampling periods. Benthic invertebrates were collected with D-nets, Surber samplers, and selective rock gleaning. Dimensions of each rock used in selective rock gleaning were recorded for later surface area estimations for quantitative estimates of relative abundance of stationary invertebrates attached to rock substrate.

Invertebrate Identification

Invertebrates were identified using dissecting microscopes and various dichotomous keys. Stoneflies (Plecoptera), mayflies (Ephemeroptera), caddisflies (Trichoptera), and two-winged flies (Diptera) were identified to Family; other invertebrates were identified to Order, Class, or Phylum.

Diversity of Diets

Both taxon richness (total number of taxa) and the Shannon-Wiener Diversity Index (Krebs 1978) for the diets were calculated for each population at each sampling date. The Shannon-Wiener Index is a measure of evenness and relative abundance as well as richness represented in the samples from a given date for each population. It is influenced by both the total number of taxa and the proportions of each taxon in the total sample, and may be less heavily influenced by sample size than the measure of taxon richness.

Shannon-Wiener Index

The Shannon-Wiener Index is represented by the following equation:

$$H' = - \sum p_i \ln (p_i)$$

where:

H' = the Shannon-Wiener Diversity Index

p_i = the proportion of the total prey items that are represented by the i^{th} taxon

Analysis of Feeding Strategies

Feeding strategies of trout were analyzed using the modified Costello method (Amundsen et al. 1996). The Costello method compares the frequency of occurrence and the relative abundance of each invertebrate species in stomach samples. This is done by comparing the number of samples containing a prey taxon (frequency of occurrence) with the relative number of that prey item in the samples that contain it (prey-specific abundance) (Amundsen et al. 1996). The major strength of this method is that it enables one to draw conclusions about feeding strategies without comparing the relative abundance of prey items in stomach samples to their abundance in the environment. This eliminates both the variable of "availability" (Radar 1997) and the potential for quantitative error that may result when sampling invertebrates from the environment. Also, because diet contents of individual fish are examined, this method can discriminate between strategies characteristic of individuals and trends typical of whole populations (Figure 17).

Feeding Selectivity

Feeding selectivity was examined with the Neu test (Neu et al. 1974) to determine if any invertebrate taxa were consumed in proportions statistically different from the relative proportions at which they were documented in the habitat samples. The test establishes an expected consumption range, and then determines if the invertebrates consumed by the population falls within, above, or below this range. Thus, both positive (selective) and negative (avoidance) feeding selection can be detected.

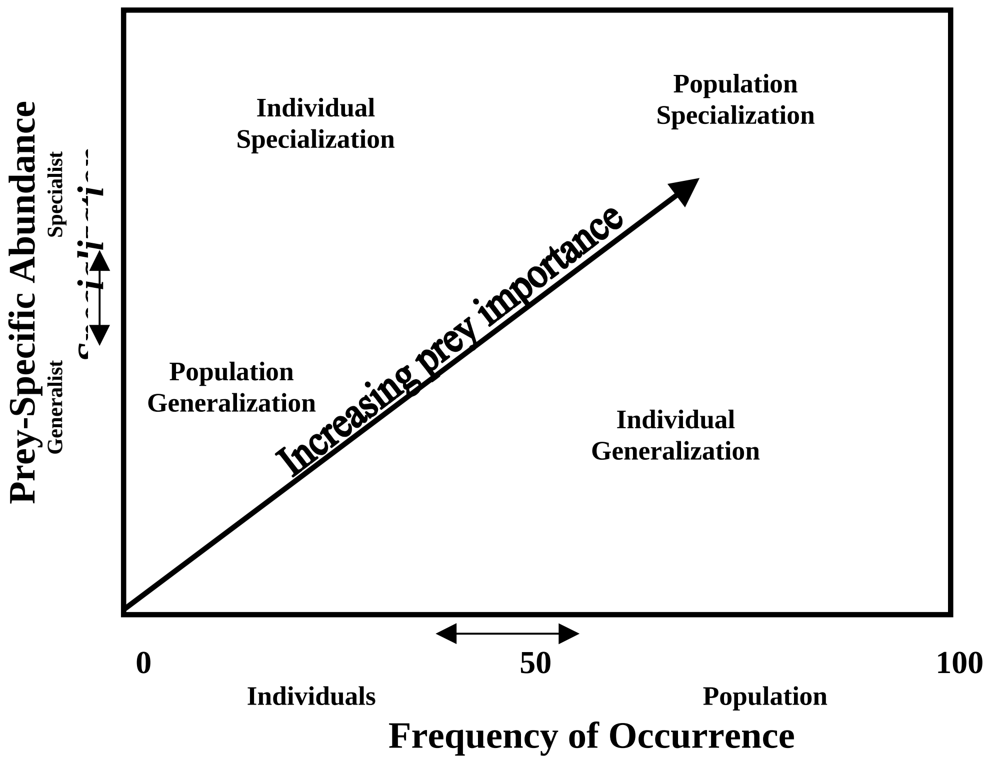


Figure 17. The **Frequency of Occurrence** is the percentage of stomach samples (out of all examined) that contained one or more specimens of the particular taxon. This shows what proportion of the population consumed a particular taxon. A taxon plotted on the left side of the graph has been consumed by fewer than 50% of the individuals in the population, while one plotted on the right side of the graph is included in the diet of the majority of the sampled population. **Prey-Specific Abundance** is the proportion of that prey taxon (relative to the total number of food items) in each stomach sample that contains at least one specimen of that taxon. A plot of frequency of occurrence vs. prey-specific abundance can be used to infer a generalist or specialist feeding strategy on a population or individual level.

Unfortunately, conclusions reached with the Neu test must be viewed cautiously because of several factors associated with both data collection and this method of data analysis. The Neu test only shows selectivity based on availability and resource comparisons. Therefore, it does not show feeding strategies of trout and cannot be used to differentiate between individual diet preferences and population-level specialization. The Neu test assumes environmental samples represent quantitative estimates of the prey that are available to trout; however, limits of accessibility and equipment prevented adequate environmental sampling in precisely the same locations and times as the feeding trout we sampled. Inefficient collection of any taxon found in stomach samples from the habitat samples would automatically be interpreted as selective feeding rather than a sampling bias.

Results

Diversity of Diets

Taxon richness ranged from 6 to 24 in the angling samples, and was positively correlated (R^2 = 0.4) with the number of fish sampled (Figure 18). The Shannon Diversity Index ranged from 1.02 to 2.64 and showed weak correlation (R^2 = 0.24) with the number of fish sampled. Diversity Index values of prey items in the diets showed temporal and spatial variation that was not directly correlated with sample size (Figure 18). Diversity peaked in July in both the Deschutes and Metolius samples, yet declined throughout the summer in the Crooked River samples (Figure 19). Because of small sample sizes in this portion of the study, direct statistical comparisons cannot be made among (sub) populations.

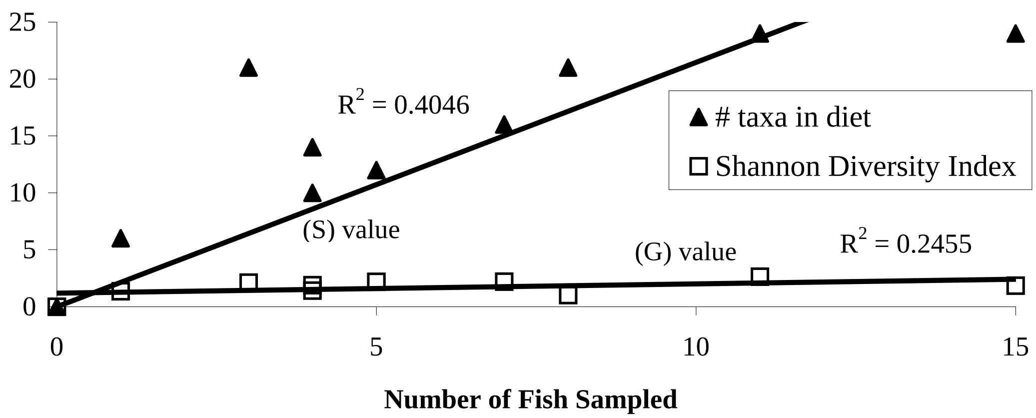


Figure 18. Relationship between number of taxa in diet and the Shannon Diversity Index with the number of fish sampled. Higher diversity was sometimes found in small samples of dietary generalists (G), whereas lower diversity was documented from some larger samples of dietary specialists (S).

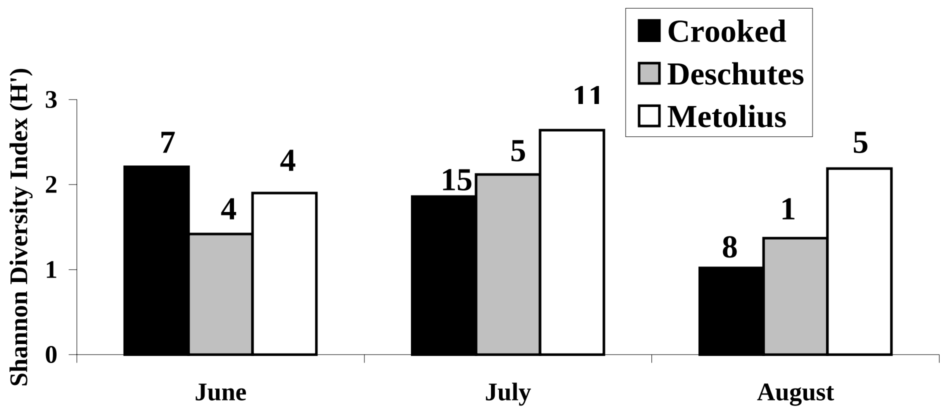


Figure 19. Diversity of prey items consumed by redband trout captured by angling during the summer months of 1998 in the three arms of Lake Billy Chinook. Diversity in the diet of trout in the Crooked River declined as the population became increasingly specialized on Chironomids, while peak dietary diversity occurred in July in both the Deschutes and Metolius populations. Numbers above the bars represent numbers of fish sampled.

Feeding Selectivity

Crooked River:

Chironomidae (midges) were consistently chosen as prey by the Crooked River redband trout sampled, composing 50–85% of the stomach contents of most individuals on each sampling date (Figure 20a). As the summer progressed, a higher percentage of Chironomids was found in stomach contents. This trend of increasing prey-specific abundance suggests Chironomids became increasingly important in the diet of these redband trout throughout the summer season. This correlates with decreasing diversity of prey items as indicated by the Shannon-Wiener Index (Figure 19). No other population-level specializations were identified, but some individuals fed preferentially on Simuliidae (black fly larvae) (July sampling) and Ephemerellidae (mayfly) (August).

The Neu test supported the interpretation of the results from the modified Costello method, as Chironomids were eaten in excess of the proportion expected from the samples of the environment at all three sampling dates. The test also suggested preferential feeding on Simuliidae (July) and Ephemerellidae (August), but did not identify any selective avoidance of taxa collected from the environment.

Deschutes River:

Because only one Deschutes River redband trout was captured during the August sampling period, only the June and July sampling results are included here. Some individual trout specialized in feeding on Ephemerellidae during the June sampling, and others fed specifically on Siphlonuridae (caddisfly) during June and July sampling events. In addition, the majority of the fish sampled in July included low numbers of Chironomidae and Tipulidae (crane fly) in their diets (Figure 20b). The Costello graph suggests the Deschutes River redband trout can be characterized as generalist in their feeding strategies

Results of the Neu test supported these observations. In June, Ephemerellidae was consumed in excess of what was expected; in July, there was evidence of selective feeding on Siphlonuridae, while Chironomidae was avoided.

Metolius River:

Although the Metolius River redband trout could be characterized as a population of generalists, several fish specialized on a few prey items at each sampling date. In addition, the majority of the population consumed low numbers of Chironomidae in June and Tipulidae and Ephemeroptera in July (Figure 20c).

The Neu test showed that no taxa were consumed in proportions greater than expected. In fact, the Neu test indicates that trout showed negative selection for most taxa, consuming them in proportions smaller than those expected. This correlates with the results of the modified Costello method that showed the majority of fish displayed generalist feeding habits. There was no evidence of strong prey selectivity, even though at times specific prey taxa were abundant in the environment. A high diversity of insects was documented in the habitat, and no single taxon was consistently more prevalent than others in the diets of these fish.

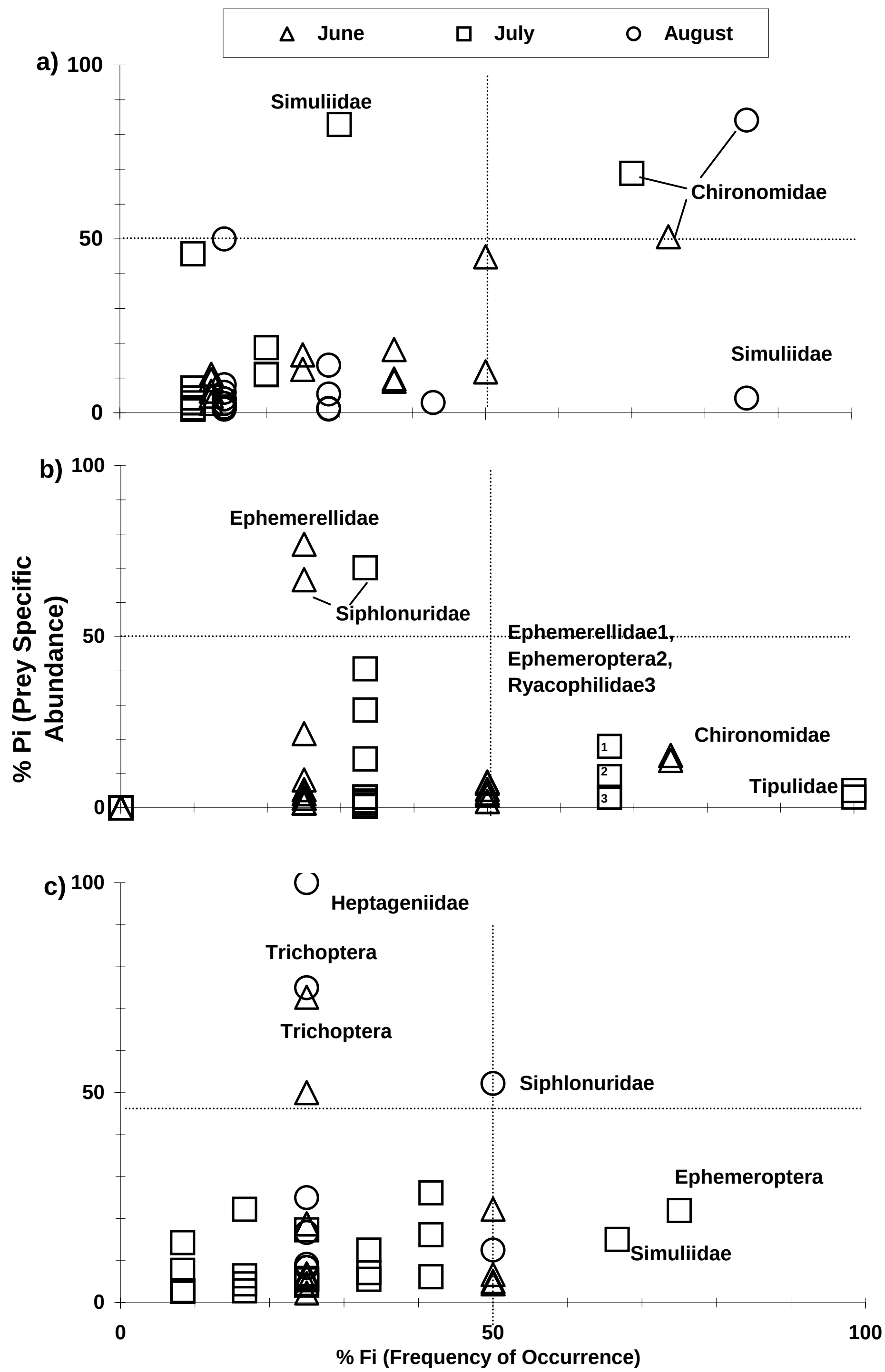


Figure 20. Feeding strategy plots using the Modified Costello Method. All fish captured by angling, 1998. Frequency of a given prey taxon found in redband trout stomachs (Frequency of Occurance) is plotted against the percent abundance within a stomach (Prey Specific Abundance). **(a)** Crooked River, **(b)** Deschutes River, and **(c)** Metolius River. The relative importance of specific prey taxa to a population is represented as a diagonal line running from the lower left to upper right of the graph.

Discussion

A general agreement between the two methods of diet analysis seem to indicate that all three (sub) populations of redband trout were feeding as opportunistic generalists, consuming a wide variety of prey taxa with only the redbands in the Crooked River showing a high degree of population-level specialization throughout this study period. Results of the Modified Costello graphs indicated that the majority of prey taxa were found in a low percent of stomachs and that each prey taxon makes up only a small proportion of the total stomach contents of most fish sampled (individual generalists). Although the Deschutes and Metolius (sub) populations could be best characterized as "generalists", a few "individual specialists" were observed in each month at both locations.

Apparent differences in feeding strategies among the three redband trout (sub) populations may be "real", and reflect the very different invertebrate communities of these rivers' very different habitats. Unfortunately, they may also be artifacts of the small sample sizes and the limitations inherent in the modified Costello method and Neu test. Though the Neu test is useful for comparing resource utilization versus availability, it does not provide insight on the feeding strategies of individuals or populations. The results of the test are also influenced heavily by the degree of accuracy in assessing the relative abundance of prey taxa in the environmental samples. Conclusions reached from data on environmental samples are weak because of both qualitative and quantitative biases in data collection that are difficult to assess or correct. The three most significant factors that may have led to differences in the environmental samples among sites as well as among dates include: variation in equipment employed, variation in the personnel involved in sample collection, and variation in the methodologies used by those personnel in collecting samples. The modified Costello method identified key prey items that were important components of the diet of sampled fish, characterized diet strategies of both individuals and populations, and was free of bias induced from errors in sampling prey availability.

4.2 — STOMACH CONTENT ANALYSIS – 1997-1999

In some years, redband trout in the Metolius River and the forebay have been found to be larger than like-aged fish in the Crooked and Deschutes arms of Lake Billy Chinook (Groves et al. 1999). Studies of feeding selectivity by redband trout in each of the Lake Billy Chinook tributaries could help determine if dietary differences may be one factor explaining observed differences in growth rate and body shape. In addition, trapping studies within Lake Billy Chinook have documented a number of redband trout moving from the Crooked and Deschutes Rivers into the reservoir (Groves et al. 1999). However, it is unknown whether these trout simply utilize the reservoir as a corridor to travel to other rivers, or if some of these fish exhibit true adfluvial life histories, utilizing the reservoir for a significant portion of their lives. Because the physical characteristics and prey assemblages in the reservoir are vastly different from those found in the fluvial portions of each of the tributary rivers, diets of redband trout living in the reservoir should reflect these differences. The limited data on the availability of prey to redband trout within the reservoir precludes performing statistical studies of utilization vs. availability (for example the Neu Test). However, because the modified analysis of Costello (Amundsen et al 1996, Costello 1990) has proven useful for inferring feeding strategies of redband trout from stomach contents alone (see section 4.1), this method was employed for investigating feeding strategies of redband trout that were captured in the fluvial/lacustrine transitional zones at each of the three arms of the reservoir.

Methods

Diet studies were conducted on stomach samples obtained from redband trout from the Metolius, Crooked, and Deschutes arms and the forebay area of Lake Billy Chinook. Fish were captured in Merwin and Oneida traps during the 1997, 1998, and 1999 field seasons. Fish were removed daily and processed as outlined in section 4.1 of this report, with the exception that samples were preserved in dilute (10%) formalin. Invertebrates were identified using dissecting microscopes and various dichotomous keys. Non-insect arthropods were identified to Order, while insects were identified to the Family level, as many of the characteristics used for further identification were degraded by digestion and mechanical damage.

Results

Redband trout inhabiting the fluvial/lacustrine transition zone of the three tributaries were "generalist" feeders, relying on small numbers of a wide variety of prey taxa. In contrast, redband trout in the forebay fed almost exclusively on cladocera and chironomid midges.

Although a total of 59 invertebrate taxonomic groups were documented in this study, the diets of redband trout inhabiting the transition zones in each arm of Lake Billy Chinook were dominated by five or six taxa that accounted for 80–90% of the total number of prey items. The remaining taxa were rare, often found in only a single fish sampled. Major prey species varied substantially between years both among and within rivers (Appendix 2), but few of the differences among rivers in the consumption of individual taxa were significant. Several taxa were consumed ubiquitously in rivers throughout the study, including chironomids, culicids (mosquitos), corixids (backswimmers), siphlonurids and baetids (mayflies). Significantly greater numbers of Cladocera (Daphnia) were consumed in the Crooked River in 1997, and1998, and in the forebay in 1997 when compared to the forebay in 1998. A large emergence of adult mayflies in the Deschutes in 1998 resulted in consumption of significantly greater numbers of this taxon during that time than at any other time or location.

Diet analysis using the method presented by Amundsen et al. (1996) made it possible to determine the feeding strategy of both individual fish and each sample population. Most fish from all rivers had consumed a relatively diverse array of prey items, utilizing individual generalist feeding strategies. There were two forms of variation from this individual generalist feeding strategy. Individual specialists (usually less than 10% of the sample population) were found to feed heavily or exclusively on certain taxa. Most often these were Cladocera, Hirundineans (leeches) and Ephemeroptera nymphs of various families. Population level specialization also occurred, in which a large portion of the population consumed large numbers of single or few taxa. Typical examples of this include large-scale consumption of chironomids and baetids in the Crooked and Deschutes systems, respectively, during 1999.

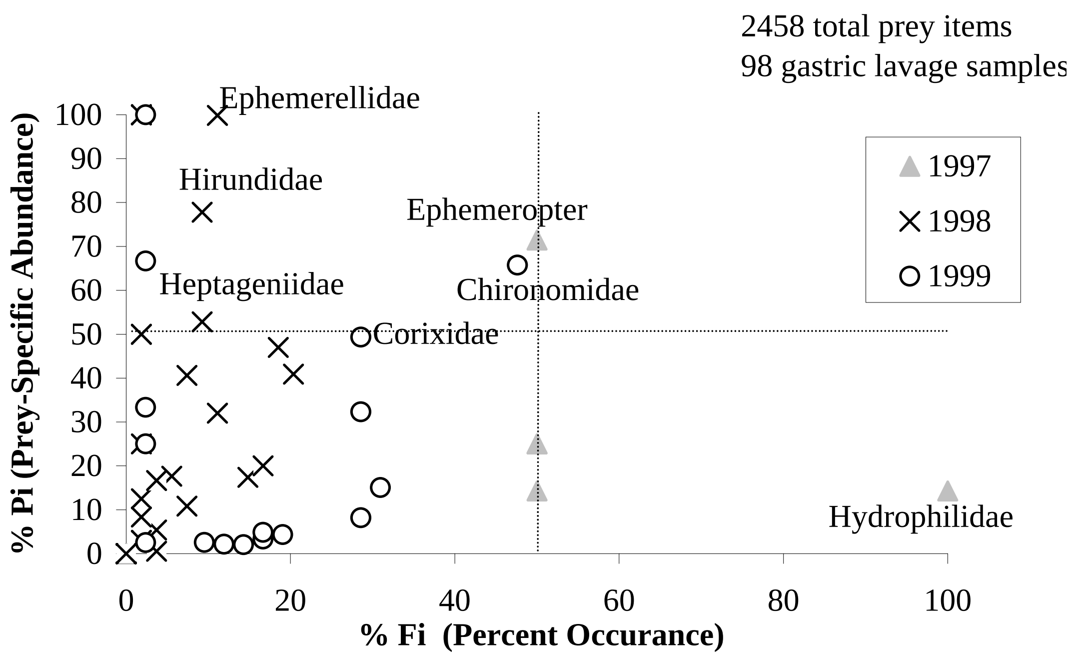
Crooked River

From 1998 to 1999, taxa such as chironomids, baetids, and corixids increased in relative importance to the Crooked River redband trout population, while ephemeropteran nymphs had reduced importance over the same time. Overall, however, fish captured in the Crooked River maintained a generalist feeding strategy by consuming a wide array of taxonomic groups that varied significantly from year to year (Figure 21a). Numerically dominant groups of prey were mainly lacustrine (lake dwelling) taxa such as leeches, cladocera, and corixids, which collectively composed 85% and 43% of the total prey numbers in 1998 and 1999, respectively. The high relative abundance of these prey types are primarily due to a few specialists in the population sampled. Several taxonomic groups composed the remaining bulk of the diet, with chironomids becoming the predominant food item in 1999.

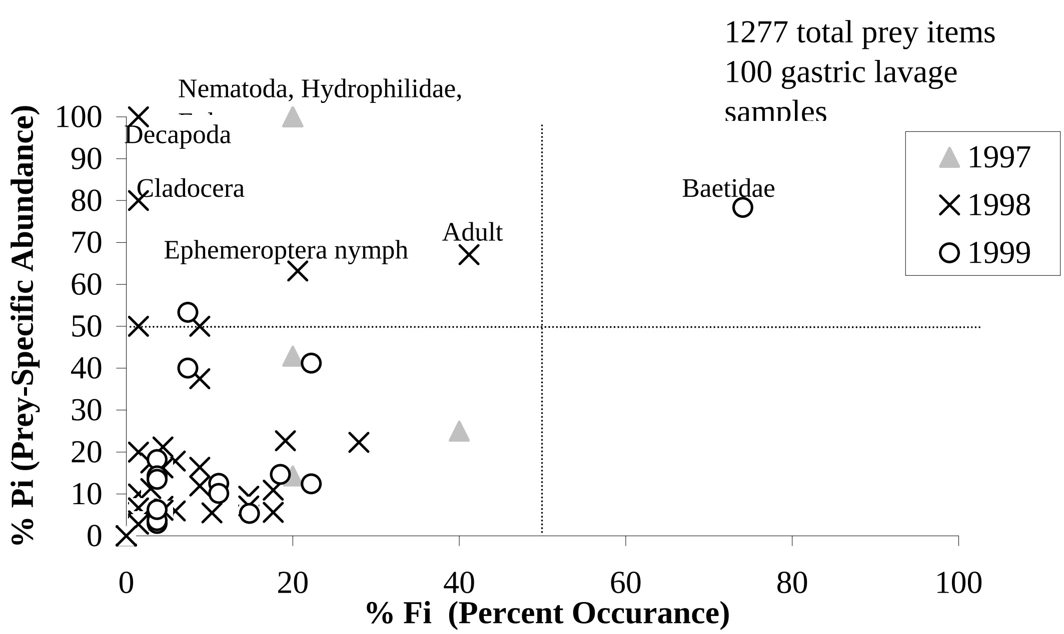
During 1999, there was also some individual specialization on ephemerellid and heptageniid mayflies. There also appeared to be a shift from May to June to specialization on emerging chironomid pupae, most likely due to seasonal warming of the Crooked River system and a corresponding increase in production of benthic Dipterans (True Flies). Chiromonids are generally unavailable to fish as their retreats are built into sediments and provide protection from foraging activities. During emergence from pupation, these insects are quite vulnerable to predation as they move to the water’s surface (Merrit and Cummins 1996).

Deschutes River

Redband trout of the Deschutes River showed individual generalist feeding patterns in 1997 and 1998, consuming a wide variety of prey types. In 1999, a shift occurred in which consumption of Cladocera and other lacustrine taxa decreased, while taxa such as baetid mayfly nymphs increased (up to 59% of total prey items consumed). Taxon richness also declined in 1999 from 20–30 taxa to15, indicating a feeding strategy shift towards population specialization (Figure 21b). Other taxa occurred far less often, with occasional individual specialization on culicid pupae (mosquitoes) by some trout, indicating possible utilization of still water habitats.

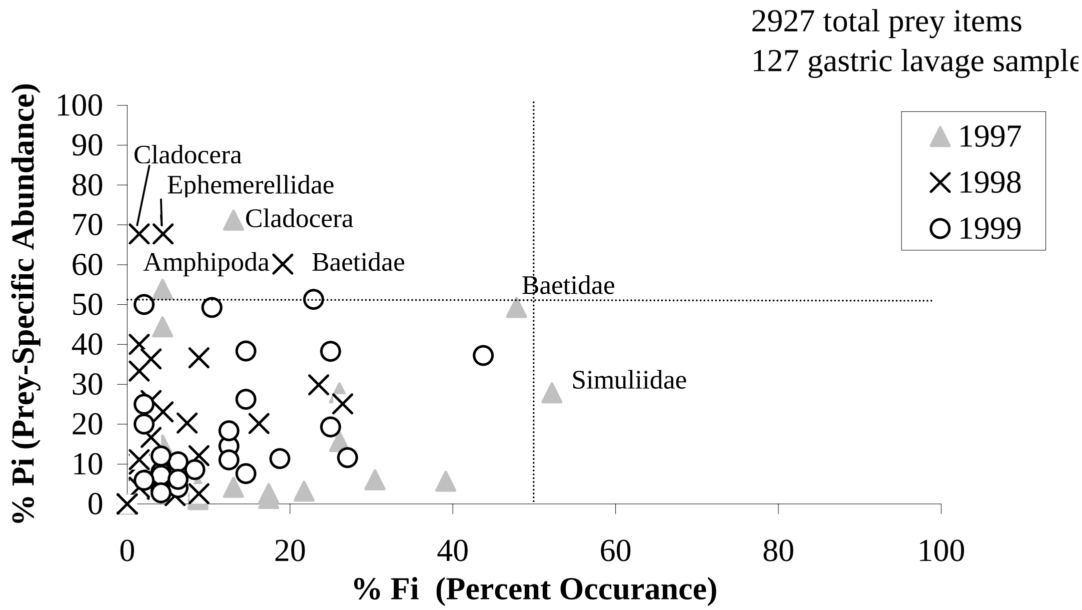


a.



b.

Figure 21. a. Modified Costello method describing feeding strategy of redband trout captured in the Crooked arm of Lake Billy Chinook, 1997–1999. **b.** Modified Costello method describing feeding strategy of redband trout captured in the Deschutes arm of Lake Billy Chinook, 1997–1999.



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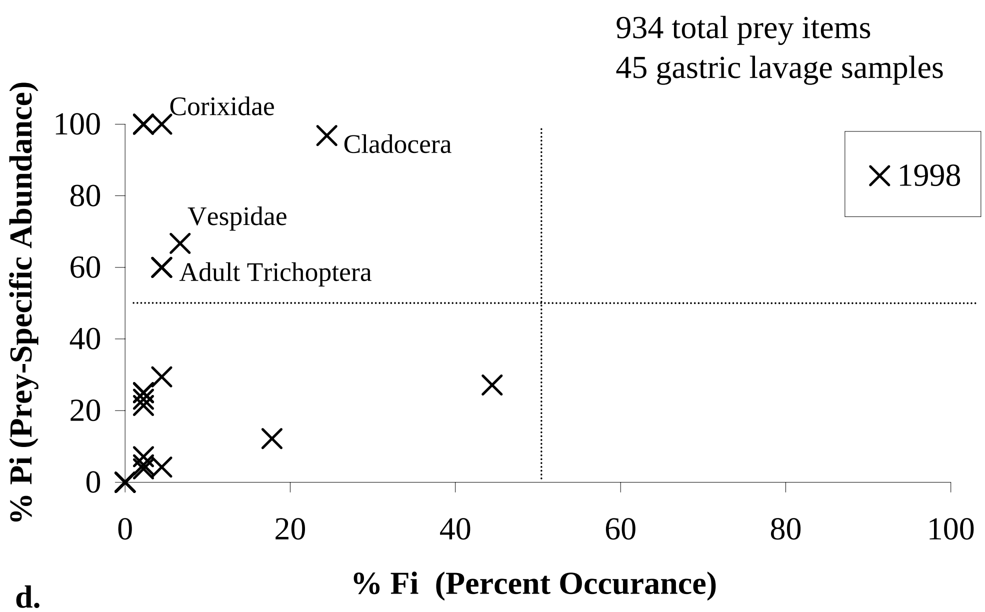


d.

Figure 21 (continued). c. Modified Costello method describing feeding strategy of redband trout captured in the Metolius arm of Lake Billy Chinook, 1997–1999. **d.** Modified Costello method describing feeding strategy of redband trout capture in the forebay of Lake Billy Chinook, 1998.

Metolius River

In 1997, the majority of the Metolius River redband trout fed as individual generalists. Sixteen taxa were represented in the 33 prey items found in stomach samples. In addition, a small segment of the population fed as population specialists on simuliids (Blackfly larvae).

The 1998 and 1999 diet samples also indicated a population of individual generalists with a significant number of individual specialists who fed heavily on three taxa (baetids, cladocera and ephemerellid mayflies) (Figure 21c). No such specialization on any of the 25 prey taxa in 1999 occurred.

Forebay

Only samples from 1998 were available from the forebay trap. Redband trout sampled during that year primarily specialized on cladocera and chironomids (91% of total prey items), with the remaining 9% divided among of 13 taxa (Figure 21d). Cladocera and chironimds both thrive in still water habitats and areas with high algal production and warm water temperatures, conditions present in the forebay during the summer months that led to extensive populations of these two taxa in the vicinity of the collection site.

Discussion

There appears to be little difference in the major taxonomic groups composing the diet of redband trout in the Crooked, Deschutes, and Metolius arms of Lake Billy Chinook. The taxonomic groups that account for more than 80% of the diets are widespread and common within local river systems. Other groups that made up less than 1% of the total dietary items often occurred in only one sample, making statistical analyses unreliable.

The results of the modified Costello feeding strategy analyses gave conclusive results about prey utilization. The majority of fish in all (sub) populations in all years were individual generalist feeders, using a wide variety of prey from numerous orders of invertebrates. Fewer fish were specialist feeders, consuming a few prey taxa in large numbers. The majority of specialist diets both on the individual and population level were composed of cladocera, chironomids, or ephemeropterans.

Environmental effects on prey populations can manifest themselves in the diet of animals that feed on them. Delays in algal production, low water temperatures, or disease can impede the spring growth of some groups of invertebrates, leading to decreasing competitive ability of some taxa and increasing the predominance of others. Shifts in dominant prey taxa from year to year within a river may be a manifestation of a variable environment favoring some groups and depressing others, resulting in a highly variable diet for fish. The Deschutes and Crooked river systems experience greater environmental variation and fluctuation (specifically temperature and sediment load) than does the Metolius River. Spring-fed systems such as the Metolius experience a narrower range of water temperatures and chemistry because most of the water comes from springs rather than surface runoff (Holloway et al. 1938). This constancy in environmental conditions may manifest itself in a constant yearly insect population, which could result in a more stable and consistently diverse diet and more uniform growth and recruitment rates for resident Metolius trout.

Environmental effects may encourage an individual generalist feeding strategy by the majority of the redband trout to take advantage of a fairly constant and diverse invertebrate population with a changing taxonomic composition. By specializing on different individual prey taxa in a diverse forage base, trout would reduce the degree of intra-specific competition for food resources, but their individual success would be reduced during periods of reduced abundance of their targeted prey taxa. A more successful feeding strategy for these populations would be an assemblage of individual generalists that rely on a diverse array of prey taxa, yet remain behaviorally flexible to switch prey in response to changes in their relative abundance. As demonstrated by shifts to population specialization on taxa such as baetid mayflies, redband trout within the arms of Lake Billy Chinook appear to be able to take advantage of seasonally abundant prey. The effect of high availability of a prey group can reveal itself in differentially high feeding rates on the abundant taxa (Radar 1997). This is likely the mechanism by which feeding efficiency is maximized during periods of high food availability resulting in increased growth and fecundity of individual fish. A large-scale study of diets in relation to the available prey items would be necessary to determine the relationships between variations in the composition of available invertebrates and the variations of prey choice and diet strategies in redband trout.

Chapter 5: Densities of Juvenile Rainbow Trout

Variation in trout density is directly related to growth and mortality rates, disease levels, consumption rates and a host of other density-dependent variables related to maintaining a healthy population (Diana 1995, LeCren 1962). High densities of trout can lead to increased mortality and reduced individual growth due to intra- and inter-specific competition for limited food, space, and refuge from predators.

McKay and Little McKay Creek (Crooked River system) (Figure 2) are partially spring fed first to second order streams that originate in the Ochoco Mountains. Squaw Creek is a third order major tributary stream for the Deschutes River. These streams maintain naturally reproducing (sub) populations of redband trout. Areas chosen as study sites for this objective were known historically as steelhead spawning habitat and are currently important sites for spawning and rearing of resident redband trout. Studies have indicated declines in densities of resident trout can occur with addition of juvenile steelhead (Zimmerman and Reeves 1998). If anadromous fish are reintroduced to this system, background information on the densities of resident redband trout in these areas will be critical for understanding the effect anadromous fish will have on resident fish and may indicate the maximum numbers of resident and anadromous fish these streams may support.

5.1 — MCKAY CREEK DRAINAGE – CROOKED RIVER SYSTEM – 1997-1999

Methods

Densities (fish per m^2 surface area) from electroshocked units were determined using a four-pass depletion method. Trout captured during all shocking and observed during snorkeling were sorted into 3 size classes (<100 mm, 100–200 mm, and >200 mm fork length [FL]) that correlate approximately with age 0, age 1 and age 2+ fish, respectively. Using data from pools that were both snorkeled and electroshocked, a calibration coefficient (R) was calculated for each size class:

$$R = Y / X$$

where:

Y = sum of the fish captured during electroshocking

X = sum of the fish observed snorkeling in electroshocked pools

This calibration coefficient was then used to convert snorkeling observation data to "actual" fish densities (Hankin and Reeves 1988). A measure of the actual average number of fish per pool (S) can be calculated by multiplying the mean number of fish of a given size class in all pools snorkeled by the calibration coefficient (R) for that size class.

$$S = R * T$$

where T = Average number of fish of a given size class observed in all pools snorkeled.

McKay Creek

Sampling took place on September 16 and 17 in 1997 and in early August in 1998 and 1999, from the confluence of McKay and Little McKay creeks to approximately 1 mile above the confluence. A total of nine riffles and 24 pools were sampled in this stretch. All pools were snorkeled by one technician (because of the narrow width of the stream) and every third pool and riffle was electroshocked. Each habitat unit within the study reach was isolated with block nets to prevent movement of fish into or out of the unit during the survey period; this step was taken to better facilitate quantitative assessment of fish abundance.

Little McKay Creek

Sampling took place on the September 18 in 1997, on August 3 and September 4 of 1998, and in the first week of August in 1999, from approximately 1408 m above the confluence with McKay Creek to the U.S. Forest Service Road 2750 crossing. Shocking protocol was identical to that in McKay Creek, with every pool snorkeled and every third pool and riffle shocked. A total of 5 riffles and 17 pools were sampled in this stretch.

Results

McKay Creek

Overall average densities of redband trout in 1997 (0.24 fish/m^2) were significantly greater (p-value < 0.001, t-test) than those in 1998 (0.11 fish/m^2) and in 1999 (0.11 fish/m^2) (Table 10). Values for 1999 were not significantly different from those in 1998 (p-value >.10).

Table 10. Average density (fish/m^2) of juvenile redband trout in McKay Creek with snorkel calibration adjustments for 1997–1999. N = number of units included in analysis.

		Pool Snorkel N=24	Calibrated Snorkel N=24	Pool Electrofish N=8	Riffle Electrofish N=9
Average density 1997	<100 mm FL	0.44	0.52	0.43	0.44
	100-200 mm FL	0.13	0.72	0.71	0.20
	>200 mm FL	0.02	0.03	0.05	0.00
	Average	**0.19**	**0.42**	**0.39**	**0.21**
Average density 1998	<100 mm FL	0.01	0.09	0.09	0.05
	100-200 mm FL	0.22	0.38	0.47	0.20
	>200 mm FL	0.04	0.01	0.02	0.00
	Average	**0.09**	**0.16**	**0.19**	**0.09**
Average density 1999	<100 mm FL	0.08	0.03	0.02	0.21
	100-200 mm FL	0.15	0.75	0.35	0.34
	>200 mm FL	0.01	0.03	0.02	0.01
	Average	**0.08**	**0.27**	**0.13**	**0.18**

Similarly, electrofishing of riffle units yielded greater (p-value < 0.05) densities of fish in 1997 (0.21 fish/m^2) than in 1998 (0.09 fish/m^2) with no significant difference from the 1999 sampling period (0.18 fish/m^2). Data for these riffles revealed that significantly greater densities (p-value < 0.001) of fish <100 mm FL were present in 1997 (0.44 fish/m^2) than in 1998 (0.05 fish/m^2) or 1999 (0.21 fish/m^2). Riffles contained similar densities of 100–200 mm and >200 mm FL redband trout in 1997 when compared to 1998 and 1999 (p-value > 0.25 and 0.10, respectively).

Density estimates from pools exhibited a temporal trend similar to riffle densities. Densities of fish <100 mm FL dropped significantly (p-value < 0.001) from 1997 (0.44 fish/m^2) to 1998 (0.01 fish/m^2) with nearly a 10 fold increase in 1999 (0.08 fish/m^2). No significant change in densities of 100–200 mm or > 200mm size classes of redband trout was seen from 1997 to 1999.

Electroshocking calibration data revealed that the "countability" in snorkel surveys varied greatly among size classes in 1997 (Table 11). Calibration coefficients for the <100 mm, 100–200 mm, and >200 mm size classes were 1.6, 8.1, and 3.7, respectively. In other words, 1.6 (<100 mm fish), 8.1 (100–200 mm fish), and 3.7 (>200 mm) times as many fish were captured by electroshocking than were seen by snorkeling.

Table 11. Results of electrofishing calibration estimates for redband trout in McKay Creek*, 1997–1999. Estimates are given in number of fish per pool.

		1997	1998	1999
<100 mm FL	Average number per pool — shock	15.00	2.75	0.75
	Average number per pool — snorkel	12.63	0.33	2.50
	Calibration coefficient**	1.62	11.00	0.40
	Estimated number of fish per pool	**20.50**	**3.60**	**1.10**
100–200 mm FL	Average number per pool — shock	26.38	15.25	11.50
	Average number per pool — snorkel	3.54	5.96	4.75
	Calibration coefficient**	8.11	2.54	2.36
	Estimated number of fish per pool	**28.70**	**15.20**	**29.70**
>200 mm FL	Average number per pool — shock	1.38	0.50	0.50
	Average number per pool — snorkel	0.38	0.92	0.42
	Calibration coefficient**	3.67	0.50	2.00
	Estimated number of fish per pool	**0.50**	**0.50**	**1.10**

* 24 pools were snorkeled, of which 8 pools were also shocked for calibration purposes.
** Average number of fish shocked per fish observed during prior snorkeling.

Little McKay Creek

Overall average densities (Table 12) in 1997 (0.39 fish/m^2) were significantly greater (p-value < 0.05, t-test) than those in 1998 (0.17 fish/m^2) or 1999 (0.17 fish/m^2). Electrofishing of riffle units did not reveal any significant difference ($0.10 > p\text{-value} > 0.05$) in average densities of fish between 1997 (1.40 fish/m^2) and 1998 (0.65 fish/m^2) or 1999 (0.96 fish/m^2). However, data again revealed that for these riffles greater densities ($p\text{-value} < 0.001$) of trout <100 mm FL were present in 1997 (1.62 fish/m^2) than in 1998 (0.27 fish/m^2) or 1999 (0.95 fish/m^2). Riffles contained similar densities of 100–200 and >200 mm FL redband trout in 1997 when compared to 1998 and 1999.

Table 12. Average density (fish/m^2) of redband trout in Little McKay Creek with snorkel calibration adjustments for 1997–1999. N = number of units included in analysis.

		Pool Snorkel N=17	**Calibrated Snorkel N=17**	**Pool Electrofish N=6**	**Riffle Electrofish N=5**
Average density 1997	<100 mm FL	0.20	0.82	1.24	1.62
	100–200 mm FL	0.250	0.72	0.77	0.49
	>200 mm FL	0.03	0.00	0.01	0.00
	Average	0.17	0.52	0.67	0.70
Average density 1998	<100 mm FL	0.14	0.17	0.26	0.27
	100–200 mm FL	0.14	1.58	0.52	0.26
	>200 mm FL	0.01	NA*	0.01	0.07
	Average	0.10	0.87	0.27	0.20
Average density 1999	<100 mm FL	0.14	0.09	0.18	0.95
	100–200 mm FL	0.18	0.24	0.44	0.62
	>200 mm FL	0.01	0.06	0.01	0.02
	Average	0.11	0.13	0.21	0.53

* No fish were observed in a pool that was later electroshocked.

Snorkeling densities from pools exhibited a temporal trend similar to riffle densities. Densities of <100 mm FL fish dropped significantly ($p\text{-value} < 0.001$) from 1997 (0.23 fish/m^2) to 1998 and 1999 (0.14 fish/m^2). No significant change in densities of 100-200 mm or > 200mm size classes of redband trout was seen from 1997 to 1999.

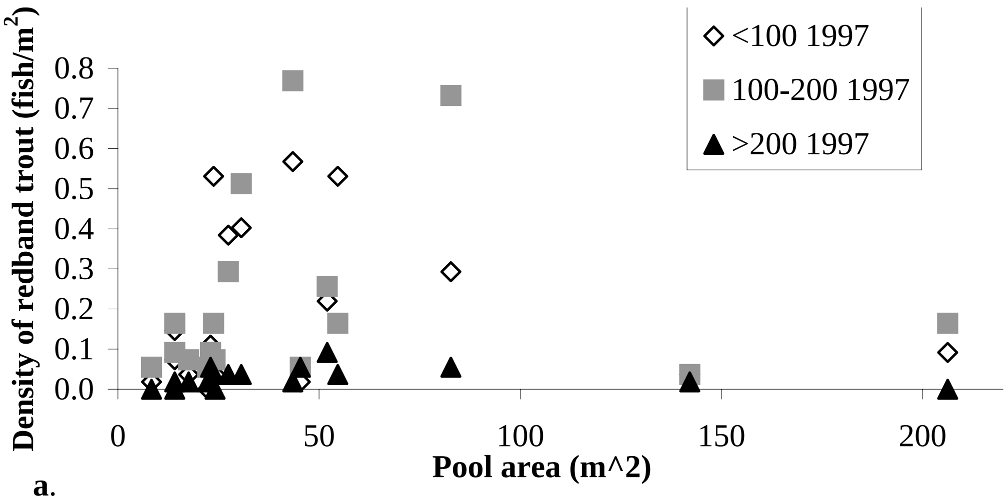
Electroshocking calibration of snorkeling data revealed a trend similar to McKay Creek (Table 13). Calibration coefficients ranged from 0.08 to 11.5 over all years.

Table 13. Results of electrofishing calibration estimates for redband trout in Little McKay Creek*, 1997–1999. Estimates are given in number of fish per pool.

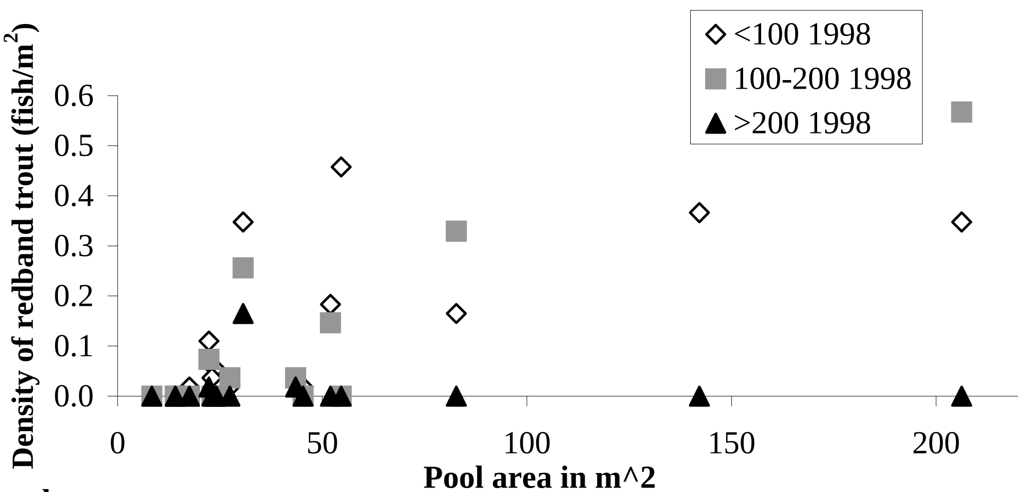
		1997	1998	1999
<100 mm FL	Average number per pool — shock	36.33	7.67	6.14
	Average number per pool — snorkel	11.24	6.94	7.76
	Calibration coefficient**	3.57	1.21	0.55
	Estimated fish number per pool	40.15	8.40	4.24
100–200 mm FL	Average number per pool — shock	22.50	15.33	13.14
	Average number per pool — snorkel	12.06	6.71	9.71
	Calibration coefficient**	2.93	11.50	1.21
	Estimated fish number per pool	35.39	77.12	11.75
>200 mm FL	Average number per pool — shock	0.17	0.33	0.42
	Average number per pool — snorkel	1.59	0.65	0.71
	Calibration coefficient**	0.08	NA	0.40
	Estimated fish number per pool	0.13	NA	0.28

* 17 pools were snorkeled, of which 6 pools were also shocked for calibration purposes.
** Average number of fish shocked per fish observed during prior snorkeling.
NA - No fish observed snorkeling in pools that were later electroshocked.

A plot of pool area versus trout density reveals that higher densities of redband trout occurred in pools with moderately small surface areas (Figure 22a). Particularly small pools (<25 m^2) had the lowest densities, with fewer than 0.1 fish/m^2. Moderately large pools (25–75 m^2) contained the highest densities of redband trout of 0.15 to 0.8 fish/m^2, consisting of predominantly the larger 100–200 mm and >200 mm FL fish, although a large proportion of the smaller fish occupied these pools also. Pools larger than 125 m^2 contained no more than 0.2 fish/m^2, with few fish of the <100 mm FL class. A nearly identical relationship between pool area and fish density was found in 1998, although larger pools (>125 m^2) did contain higher densities of redband trout (0.7 fish/m^2), similar to the moderately large pools of 1998 (Figure 22b). Results from 1999 showed a trend similar to 1997, with most fish, particularly the larger ones, preferring pools of moderate size (Figure 22c).



a.



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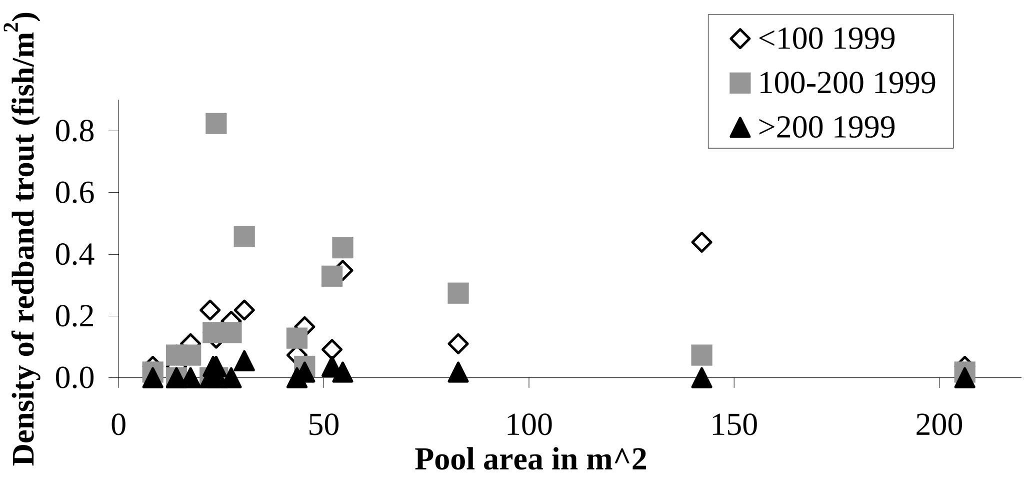

c.

Figure 22. a. Density of juvenile redband trout vs. pool surface area in Little McKay Creek, 1997. **b.** Density of juvenile redband trout vs. pool surface area in Little McKay Creek, 1998. **c.** Density of juvenile redband trout vs. pool surface area in Little McKay Creek, 1999.

Discussion

Electroshocking calibration of snorkeling data is dependent on the assumption that a fixed proportion of fish are “missed” during snorkeling surveys and that all fish are then captured during subsequent electroshocking. This allows extrapolation from established snorkeling and electroshocking data to non-electrofished habitat sections that were snorkeled. The relationship between snorkeling and electrofishing in McKay and Little McKay Creek did not show an ideal correlation between the counts obtained with the two survey methods, and thus calibrated densities may not represent “actual” densities. This should be taken into account when inferences about electroshocking and snorkeling data are made in these two systems.

McKay Creek

Densities of juvenile redband trout in McKay Creek dropped from 1997 to 1998 and 1999, and fewer <100-mm FL redband trout were found in both pools and riffles after 1997 (Figure 23). The higher numbers of young-of-year fish in this location in 1997 corresponds to the strong year class also seen in the Deschutes River. A high water event in 1996 resulted in extensive scouring and rearrangement of spawning gravel. The resulting higher quality of spawning habitat may have led to this strong 1997 year class. These floods may have also resulted in downstream movement of some of the smallest fish out of the study sections in 1996, thereby reducing intra-specific competition (and enhancing survival) for the 1997 year class. The lower densities of young-of-year seen in 1998 and 1999 may represent a return to normal densities following this event. A corresponding peak in the next size class was not seen in 1998. The approximately equal densities of greater than 100mm fish seen may be a density-dependant effect due to limited habitat availability indicating either mortality or outmigration.

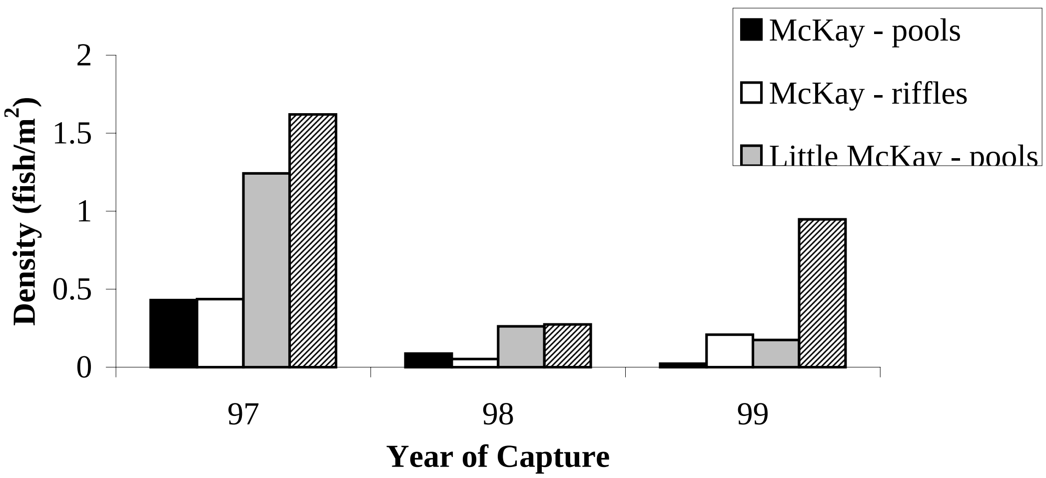

Figure 23. Change in density for smallest redband trout in McKay and Little McKay creeks from 1997–1999. All densites are calculated from a four-pass electroshocking depletion method.

Little McKay Creek

Although densities within Little McKay Creek generally declined over the three-year study period, this decline could not be attributed to one specific size class or year class, as was seen in McKay Creek. There did not appear to be a specific reduction of the <100 mm FL size class in the study reach, but rather an overall decrease in the density of all size classes of rainbow trout. Because Little McKay Creek is a first order stream, its flow is less dependent on surface water, and thus it is generally more stable than McKay Creek and probably did not experience the same degree of disturbance associated with the 1996 high flow event. As a result of this stability, the marked increase in the young of year in 1997 correlated with this high flow event was not documented in Little McKay Creek.

Although the data are not statistically significant, moderately sized pools exhibited the highest densities of fish from all age classes. Within Little McKay Creek, the pools of largest surface area generally have the shallowest depth and the fewest sanctuaries from the current (in the form of boulders and woody debris). Moderately large pools tended to be deeper and provided more cover, presumably leading to higher densities of trout. The smallest pools did not provide sufficient habitat (space, prey resources or cover) for large numbers of fish. It would appear that a balance is reached when sufficient cover (in the form of water depth or instream structure) is available in combination with sufficient space to provide an optimal habitat in Little McKay Creek.

5.2 — SQUAW CREEK – DESCHUTES RIVER SYSTEM – 1998-1999

Methods

Two reaches (reaches 1 and 2) of Squaw Creek were sampled in August of 1998. Reach 1 was located between Alder Springs and the next access site upstream. This reach was approximately 2 miles long and composed of 5 riffles and 14 pools. Reach 2 was extended upstream for 2570 m from the U.S. Forest Service Road 4360 road crossing and was composed of four riffles and nine pools. Shocking protocol was similar to that in McKay Creek, except that two riffles were also snorkeled.

During 1999, sampling was not performed at the access site upstream of Alder Springs because high flows throughout the summer and excessive leaf debris in this section of Squaw Creek during September precluded placement of block nets.

Sampling was conducted at the Camp Polk site on Squaw Creek. Sampling protocol was similar to that used in 1998, with the exception that all pools and riffles were snorkeled and electroshocked over a continuous 150-m stretch. Riffle 3 and pool 4 as well as riffle 4 and pool 5 were combined in both electrofishing and snorkeling surveys because of the small size of the riffle habitat between these sections.

Conversion of snorkeling data to "actual" fish densities using 4-pass depletion electroshocking calibration could not be performed because fish could not be captured in sufficient numbers by electroshocking. Even on occasions when two backpack electroshockers were used, fewer fish were captured than were observed during snorkeling surveys.

Results

Overall average densities (Table 14) in 1998 revealed that the average density of redband tout in reach 1 (0.06 fish/m^2) was significantly greater than in reach 2 (0.02 fish/m^2) (p-value < 0.05). Snorkeling densities of trout for each size class were significantly greater in reach 1 than in reach 2 (p-value <0.01).

Table 14. Average density (fish/m^2) of Rainbow trout in reach 1 (2750 m) and reach 2 (1609 m) of Squaw Creek. N = number of units included in analysis.

		Pool Snorkel	Calibrated Snorkel	Pool Electrofish	Riffle Electrofish	Riffle Snorkel
Average density Reach 1, 1998	<100 mm FL	0.14	0.03	0.01	0.01	--
	100–200 mm FL	0.06	0.03	0.01	0.01	--
	>200 mm FL	0.06	0.01	0.00	0.00	--
		N=14	N=5	N=5	N=5	--
Average density Reach 2, 1998	<100 mm FL	0.04	0.00	0.01	0.01	--
	100–200 mm FL	0.02	0.00	0.01	0.01	--
	>200 mm FL	0.02	0	0	0.00	--
		N=9	N=3	N=4	N=5	--
Average density Camp Polk, 1999	<100 mm FL	0.10	0.02*	0.02	0.01	0.14
	100–200 mm FL	0.10	0.02*	0.02	0.00	0.18
	>200 mm FL	0.03	0.01*	0.01	0.00	0.09
		N=5	N=5	N=5	N=2	N=2

* All pools that were snorkeled were also shocked.

In 1999, no significant differences were found in comparisons of densities of redband trout in riffles and pools, whether electrofished or snorkeled, (P-value >0.10) at the Camp Polk site. This was also true of brown trout and brook trout densities. Densities of trout also did not appear to vary with pool size for any size class or species, although 100–200 mm FL redband trout were found in higher densities in larger pools (Figure 24). Averages densities from pool electrofishing were 0.02 fish per m^2 for both < 100 mm FL and 100–200 mm FL fish, while >200 mm FL fish had a density of 0.01 fish per m^2.

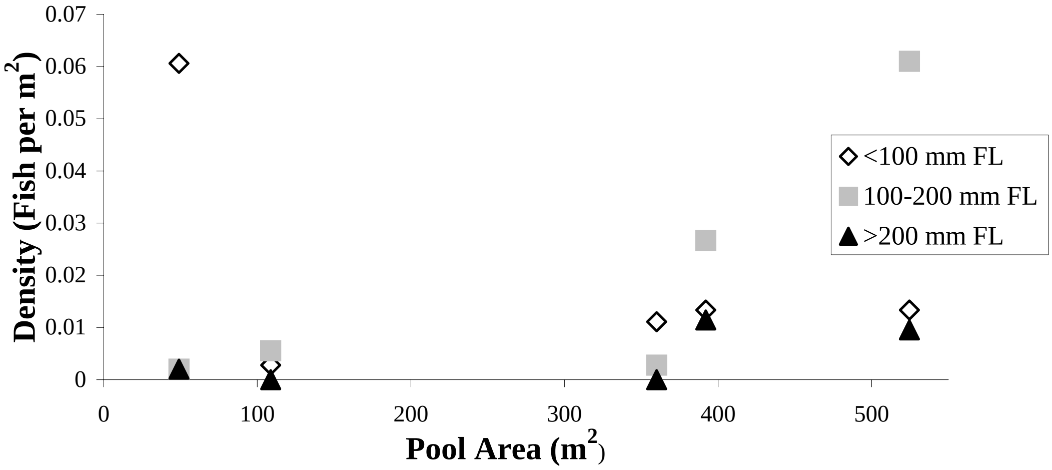

Figure 24. Redband trout size class (mm) densities in Squaw Creek (Camp Polk Site 1999) as a function of pool area (m^2) using data obtained from snorkel surveys of 5 pools averaging 286.9 m^2.

Discussion

Comparisons of between-year or between-site data could not be made for Squaw Creek because of technical difficulties involving high stream discharge or excessive instream debris. Densities of fish from a single year or site can shed little information on the processes influencing populations of fish. Given the limitation that this type of data presents, a number of observations could be made regarding the presence of a significant number of brook within the Camp Polk site and brown trout at the old road crossing site. Interspecific competition between these two species and redband trout may result in a depressed redband trout population in habitats that would otherwise be more productive for a single species. A similar situation was present farther downstream at the access site upstream of Alder Springs. Although brook trout were not present, brown trout were present in large numbers and often in higher densities than redband trout. These two introduced species may be shown to limit redband trout densities through aggression and/or competition for space, prey, and other resources. These same limitations would apply in these juvenile rearing areas when steelhead are returned to the system.

Chapter 6: General Conclusions and Suggestions

It is unknown in what ways the construction of Round Butte Dam and Lake Billy Chinook may have influenced life history characteristics or the ecological, reproductive, and genetic isolation of redband trout (sub) populations in the upper Deschutes River system. Utilization of the lacustrine environment by trout may facilitate interaction among (sub) populations, whereas avoidance of the lacustrine environment created by the reservoir may have increased isolation among (sub) populations. Lacking prior baseline data, this study attempted to characterize the current life history characteristics and ecological, reproductive, and genetic isolation of redband trout residing in the three major tributaries to this reservoir.

From tagging studies, we have documented evidence of limited movement among river systems, with fidelity of Metolius River resident trout to their system and considerable mixing between the Deschutes and Crooked arms (Groves et al. 1999). While these studies inferred some direct ecological interaction and possible competition among (sub) populations, they were inconclusive for demonstrating the degree of genetic isolation of each population.

Documentation of phenotypic, morphometric, and life history characteristics [spawning time and location, fecundity, rates of growth and age structure of (sub) populations], as well as differences in diet and parasite assemblages, have provided additional evidence of some degree of isolation among these redband trout (sub) populations. Redband trout captured further up in the Metolius River displayed unique morphometric characteristics and may constitute a distinct population. Although it is still unclear whether this difference in body shape is a product of genes or the environment, *Ceratomyxa shasta* infection evidence suggest that the difference may be due to the environment. While trout captured in the Metolius arm of Lake Billy Chinook shared some characteristics with those from the Deschutes and Crooked arms, many other characteristics were found only in this group of fish and those captured in the forebay area of the reservoir. These observations offer tantalizing suggestions of either the persistence of a stock of remnant steelhead or a population of trout that has adapted to the reservoir by developing an adfluvial life history form.

Redband trout in the Metolius Arm were found to be generally larger at a given age than trout captured in other locations except the forebay. This is typically characteristic of trout utilizing a lacustrine environment (Simpkins and Hubert 1996). In addition, the fecundity of the trout examined captured in the Metolius arm was much higher than in similar-sized females from other locations. Higher fecundities are also seen as evidence of either steelhead or trout utilizing a lacustrine environment (Behnke 1992). In addition to these specific life history characteristics, large numbers of trout showing smolt-like characteristics were found to be moving into the Metolius arm of Lake Billy Chinook. Studies during 1997 in Lake Billy Chinook indicated that prevailing surface currents during normal operation of the reservoir moved down the Deschutes and Crooked arms and up the Metolius arm (Ratliff and McCollister 1997). These current patterns may account for the large numbers of smolt-like redband trout accumulating in the Metolius arm. If these fish were attempting to migrate downstream using current patterns, they would have been lead into the Metolius arm, where it appears they have taken up residence

Because the native populations evolved in rivers characterized by very different physical conditions, genetic diversity probably does exist among these major (sub) populations of redband trout in these three river systems. Although evidence presented in this report is suggestive of separate (sub) populations and the existence of an adfluvial life history form that may or may not be a remnant stock of steelhead, conclusions drawn from this evidence are speculative and inconclusive at best. Genetic studies could provide a more conclusive insight into geographic patterns, genetic diversity, degree of population isolation, and patterns of gene flow among (sub) populations of redband trout and possible steelhead-like trout in the Lake Billy Chinook system.

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Literature Cited

Amundsen, P.A., H.M. Gabler, and F.J. Staldvik. 1996. A New Approach to Graphical Analysis of Feeding Strategy from Stomach Contents Data—Modification of the Costello (1990) Method. Journal of Fisheries Biology 48: 607-614.

Angradi, T.R., and J.S. Griffith. 1990. Diel Feeding Chronology and Diet Selection of Rainbow Trout (*Oncorhynchus mykiss*) in the Henry's Fork of the Snake River, Idaho. Can. J. Fish. Aquat. Sci. 47:199-209.

Bartholomew, J. 1999. Fish Disease Risk Assessment: Whirling Disease and Ceratomyxosis, 1998 Annual report, FERC No 2030. Unpublished report. Portland General Electric, Co., Portland, Oregon.

Barton, B.A., and B.F. Bidgood. 1980. Competitive Feeding Habits of Rainbow Trout, White Sucker and Longnose Sucker in Paine Lake, Alberta. Fisheries Report 16, Alberta Energy and Natural Resources, Calgary.

Behnke, R.J. 1992. Native Trout of Western North America. American Fisheries Society Monographs; No. 6. 275p.

Biette, R.M., D.P. Dodge, R.L. Hassinger and T.M. Stauffer. 1981. Life History and Timing of Migrations and Spawning Behavior of Rainbow Trout (*Salmo gairdneri*) Populations of the Great Lakes. Canadian Journal of Fisheries Aquatic Sciences 38: 1759-1771

Brewin, M.K., L.L. Stebbins, and J.S. Nelson. 1995. Differential Losses of Floy Anchor Tags between Male and Female Brown Trout. North American Journal of Fisheries Management 15: 881-884.

Costello, M.J. 1990. Predator Feeding Strategy and Prey Importance: a New Graphical Analysis. J. Fish Biol. 36: 261-263.

Currens, K.P., C.S. Sharpe, R. Hjort, C.B. Schreck, and H.W. Li. 1989. Effects of Different Feeding Regimes on the Morphometrics of Chinook Salmon (*Oncorhynchus tshawytscha*) and Rainbow Trout (*O. mykiss*). Copeia 1989(3): 689-695.

Diana, J.S. 1995. Biology and Ecology of Fishes. 1st ed. Carmel. Cooper Publishing Group. 439 p.

Dodge D.P., and H.R. MacCrimmon. 1971. Environmental Influences on Extended Spawning of Rainbow Trout (*Salmo gairdneri*). Transactions of the American Fisheries Society 2: 312-318.

Downs, C.C., R.G. White, and B.B. Shepard. 1997. Age at Sexual Maturity, Sex Ratio, Fecundity, and Longevity of Isolated Headwater Populations of Westslope Cutthroat Trout. North American Journal of Fisheries Management 17: 85-92.

DuBois, R.B., S.D. Plaster, and P.W. Rasmussen. 1989. Fecundity of Spring- and Fall-Run Steelhead from Two Western Lake Superior Tributaries. Transactions of the American Fisheries Society 118: 311-316.

Filbert, R.B., and C.P. Hawkins. 1995. Variation in Condition of Rainbow Trout in Relation to Food, Temperature, and Individual Length in the Green River, Utah. Transactions of the American Fisheries Society 124: 824-835.

Gipson, R.D., and W.A. Hubert. 1991. Factors Influencing the Body Condition of Rainbow Trout in Small Wyoming Reservoirs. Journal of Freshwater Ecology 6: 327-334.

Greeley, J.R. 1934. The Growth Rate of Rainbow Trout from some Michigan Waters. Transactions of the American Fisheries Society. 63: 361-378.

Groves, K., and B.A. Shields. 1998. Lake Billy Chinook Rainbow (Redband) Life History Study, 3rd Quarterly Report, FERC No. 2030, Portland.

Groves, K., B.A. Shields, and A. Gonyaw. 1999. Lake Billy Chinook Rainbow (Redband) Life History Study, 1998 Annual Report, FERC No. 2030, Portland.

Hankin, D.G., and G.H. Reeves. 1988. Estimating Total Fish Abundance and Total Habitat Area in Small Streams Based on Visual Estimation Methods. Canadian Journal of Fisheries and Aquatic Sciences. 45(5): 834-844.

Hiatt, B.A., S.D. Lewis, and D.M. Craig. 1997. Resident Fish Sampling in Lake Billy Chinook, Oregon 1997. Unpublished Report. Portland General Electric Company. Portland, Oregon.

Holloway, R.C., R.C. Rittenour and F.P. Griffiths. 1938. A survey of the Metolius and its Tributaries from its Source to a Point Ten Miles Downstream with Recommendations for the Management of this Area. Division of Scientific Investigation in Fisheries, Oregon State Game Commission. August.

Houslet, B., and M. Riehle. 1997. Inland Redband Trout Spawning Survey of the Upper Metolius River Subbasin. Deschutes and Ochoco National Forest Service Report. Sisters, Oregon.

Hubert, W.A., and C.B. Chamberlain. 1996. Environmental Gradients Affect Rainbow Trout Populations Among Lakes and Reservoirs in Wyoming. Transactions of the American Fisheries Society 125: 925-932

Hubert, W.A., and P.M. Guenther. 1992. Non-Salmonid Fishes and Morphoedaphic Features Affect Abundance of Trouts in Wyoming Reservoirs. Northwest Science 66(4): 224-228.

Jenkins, Jr., T.M., C.R. Feldmeth and G.V. Elliott. 1970. Feeding of Rainbow Trout (*Salmo gairdneri*) in Relation to Abundance of Drifting Invertebrates in a Mountain Stream. Journal of the Fisheries Research Board, Canada. 27: 2356-2361.

Kabata, Z. 1963. Parasites as Biological Tags. ICNAF Special Publication 4(6): 31-37.

Kimura, D.K. 1980. Likelihood Methods for the Von Bertalanffy Growth Curve. Fishery Bulletin 77(4): 765-776.

Korn, L., L.H. Hrena, R.G. Montagne, W.G. Mullarkey, and E.J. Wagner. 1967. The Effect of Small Impoundments on the Behavior of Juvenile Anadromous Salmonids. Fish Commission of Oregon Research Division (now Oregon Dept. of Fish and Wildlife). Clackamas, Oregon.

Krebs, C.J. 1978. Ecology: The Experimental Analysis of Distribution and Abundance. Harper And Row. New York. 678 pp.

LeCren, E.D. 1962. The Efficiency of Reproduction and Recruitment in Freshwater Fish. Pages 283-296 *in* E.D. LeCren and M.W. Holgate, editors. The Exploitation of Animal Populations. Blackwell Scientific Publications, Oxford.

Lindsey, C.C., T.G. Northcote, and G.F. Hartman. 1959. Homing of Rainbow Trout to Inlet and Outlet Spawning Streams at Loon Lake, British Columbia. Journal of the Fisheries Research Board of Canada 16: 695-719.

Mamontov, A.M., and V.M. Yakhnenko. 1995. Morphological, Genetic, and Biochemical Estimate of Population Differentiation of Lake Baikal Whitefish, *Coregonus lavaretus pidschian* (Coregonidae). Journal of Ichthyology 35(5): 136-146.

Mathooko, J.M. 1996. Rainbow Trout (*Oncorhynchus mykiss* Walbaum) as a Potential Natural "Drift Sampler" in a Tropical Lotic Ecosystem. Limnologica. 26(3): 245-254.

Meehan, W.R., and R.A. Miller. 1978. Stomach Flushing: Effectiveness and Influence on Survival and Condition of Juvenile Salmonids. Journal of the Fisheries Research Board of Canada 35: 1359-1363.

Merritt R.W., and K.W. Cummins. 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company. Dubuque. 862pp.

Moser, M., and J. Hsieh. 1992. Biological Tags for Stock Separation in Pacific Herring *Clupea harengus pallasi* in California. Journal of Parasitology 78(1): 54-60.

Narver, D.W. 1969. Age and Size of Steelhead Trout in the Babine River, British Columbia. Journal of the Fisheries Research Board of Canada 26(10): 2754-2760.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A Technique for Analysis of Utilization-Availability Data. Journal of Wildlife Management 38(3): 541-545.

Northcote, T.G. 1992. Migration and Residency in Stream Salmonids- Some Ecological Considerations and Evolutionary Consequences. Nordic Journal of Freshwater Research. 67: 5-17.

Pidgeon, R.W. 1981. Diet and Growth of Rainbow Trout, *Salmo gairdneri* Richardson, in Two Streams on the New England Tableland, New South Wales. Australian Journal of Marine and Freshwater Research. 32: 967-974.

Radar, R.B. 1997. A Functional Classification of the Drift: Traits that Influence Invertebrate Availability to Salmon. Canadian Journal Fisheries and Aquatic Sciences 54: 1211-1234.

Raleigh, R.F., and W.J. Ebel. 1968. Effect of Brownlee Reservoir on Migration of Anadromous Salmonids. *In* Proceedings of the Reservoir Fishery Resources Symposium, April 5-7, 1967, Athens, Georgia, pp. 415-443. Am. Fish. Soc.

Ratliff, D.E. 1983. *Ceratomyxa shasta*: Longevity, Distribution, Timing, and Abundance of the Infective Stage in Central Oregon. Can. J. Fish. Aquat. Sci. 40(10): 1622-1632.

Ratliff, D.E., S.L. Thiesfeld, W.G. Weber, A.M. Stuart, M.D. Riehle, and D.V. Buchanan. 1996. Distribution, Life History, Abundance, Harvest, Habitat, and Limiting Factors of Bull Trout in the Metolius River and Lake Billy Chinook, Oregon, 1983-94. Oregon Dept. of Fish and Wildlife Information Report No 96-7. ODFW, Portland.

Ratliff, D.E., and B.S. Shields. 1997. 1997 Study Plan, Lake Billy Chinook Rainbow (Redband) Life History Study. Unpublished Study Plan, Spring 1997 Workshop. Portland General Electric Company. Portland, Oregon.

Ratliff, D.E., and S.A. McCollister. 1997. Surface Currents in Lake Billy Chinook during the Spring of 1997. Unpublished Report. Portland General Electric Company, Portland, Oregon.

Reyes-Gavilan, F.G., R. Garrido, A.G. Nicieza, M.M. Toledo and F. Brana. 1996. Fish Community Variation along Physical Gradients in Short Streams of Northern Spain and the Disruptive Effect of Dams. Hydrobiologia 321: 155-163.

Riehle, M., and B. Houslet. 1999. Adult Redband Trout Counts in the Metolius River during the Winter of 1998-1999. Deschutes and Ochoco National Forest Service Report.

Rinne, J.N. 1985. Variation in Apache Trout Populations in the White Mountains, Arizona. North American Journal of Fisheries Management 5:146-158.

Rulifson, R.A., and M.J. Dadswell. 1995. Life History and Population Characteristics of Striped Bass in Atlantic Canada. Transactions of the American Fisheries Society 124: 477-507.

Sakai, M., and A. Espinos. 1994. Repeat Homing and Migration of Rainbow Trout to the Inlet and Outlet Spawning Streams in a Patagonian Lake, Argentina. Fisheries Science 60(2): 137-142.

Salmanov, A.V., N.S. Rostova, and Y.A. Dorofeyeva. 1991. Morphometric Features of the Amu Darya Trout (*Salmo trutta oxianus*, Salmonidae). Journal of Ichthyology 31(6): 58-79.

Shields, B.A., and K. Groves. 1997. Lake Billy Chinook Rainbow (Redband) Life History Study. 1998 Study Plan, FERC No. 2030, Portland.

Shields, B.A., and K. Groves. 1999. Lake Billy Chinook Rainbow (Redband) Life History Study. 1999 Study Plan, FERC No. 2030, Portland.

Shields, B.A., K. Groves and A. Gonyaw. 1998. Lake Billy Chinook Rainbow (Redband) Life History Study. 1997 Annual Report, FERC No. 2030. Portland.

Simpkins, D.G., and W.A. Hubert. 1996. Proposed Revision of the Standard-Weight Equation for Rainbow Trout. Journal of Freshwater Ecology 11(3): 319-325.

Sindermann, Carl J. 1961. Parasite Tags for Marine Fish. Journal of Wildlife Management. 25(1): 41-47.

Thiesfeld, S.L., A.M. Stuart, D.A. Nolte, M.A. Buckman, and D.E. Ratliff. 1995. Angler Surveys on Lake Billy Chinook, Oregon, 1990–1993. Information Report 95-1. Oregon Department of Fish and Wildlife. Portland, Oregon.

Warner, E.J., and T. P. Quinn. 1995. Horizontal and Vertical Movements of Telemetered Rainbow Trout (*Oncorhynchus mykiss*) in Lake Washington. Canadian Journal of Zoology 73:146-153.

Whitaker, D.J., and G. A. McFarlane. 1997. Identification of Sablefish, *Anoplopoma fimbria* (Pallas, 1811), Stocks from Seamounts off the Canadian Pacific Coast using Parasites as Biological Tags. NOAA Technical Report NMFS 130: 131-136.

Williams, H.H., K. MacKenzie and A.M. McCarthy. 1992. Parasites as Biological Indicators of the Population Biology, Migrations, Diet, and Phylogenetics of Fish. Reviews in Fish Biology and Fisheries 2: 144-176.

Williams, R.N., R.F. Leary, and K.P. Currans. 1997. Localized Genetic Effects of a Long-term Hatchery Stocking Program on Resident Rainbow Trout in the Metolius River, Oregon. North American Journal of Fisheries Management 17: 1079-1093.

Wood, C.C., D.T. Rutherford and S. McKinnell. 1989. Identification of Sockeye Salmon (*Oncorhynchus nerka*) Stocks in Mixed-Stock Fisheries in British Columbia and Southeast Alaska using Biological Markers. Canadian Journal of Fisheries and Aquatic Sciences 46: 2108-2128.

Zadorina, V.M. 1989. Importance of Adult Insects in the Diet of Young Trout and Salmon. Journal of Ichthyology. 29(1): 49-55.

Zimmerman C.E., and G.H. Reeves. 1998. Steelhead and Rainbow Trout: Early Life History and Habitat Use in the Deschutes River, Oregon, 1997 Annual Report. FERC No 2030. Portland General Electric Company. Portland, Oregon.

APPENDIX 1.

PREVALENCE, MEAN INTENSITY AND RANGE OF THE MOST COMMON PARASITES FOUND IN REDBAND TROUT IN LAKE BILLY CHINOOK, 1998–1999.

Appendix 1. Prevalence, mean intensity and range of the most common parasites found in redband trout in Lake Billy Chinook, 1998–1999.

Location	Species	Prevalence	Mean Intensity	Range
Crooked Arm, 1998	*Salminicola* sp.	58.5	4.17	0–13
	Metabronema sp.	9.76	4.75	0–15
	Cucullanus sp	14.63	2.5	0–5
	Proteocephalus sp	9.75	3.5	0–8
	Deropegus sp	24.39	6.6	0–36
	Crepidostomum sp	2.44	79	0–79
	Neoechinorhynchus sp	2.44	2	0–2
Deschutes Arm, 1998	*Salminicola* sp.	81.82	3.83	0–18
	Metabronema sp.	59.09	39	0–326
	Cucullanus sp	63.64	5.36	0–14
	Proteocephalus sp.	40.9	5.55	0–16
	Deropegus sp	9.09	2	0–3
	Crepidostomum sp.	4.54	26	0–26
	Neoechinorhynchus sp.	4.54	2	0–2
Metolius Arm, 1998	*Salminicola* sp	82.76	9.83	0–28
	Metabronema sp.	13.79	2.5	0–5
	Cucullanus sp.	24.14	13.29	0–85
	Proteocephalus sp	17.24	3.8	0–11
	Deropegus sp.	3.45	1	0–1
	Crepidostomum sp.	17.24	8.2	0–14
Forebay, 1998	*Salminicola* sp	81.25	6.08	0–18
	Metabronema sp	12.5	7.5	0–13
	Cucullanus sp	31.26	3.8	0–10
	Proteocephalus sp	37.6	10.83	0–41
	Deropegus sp.	6.25	1	0–1
	Crepidostomum sp	0	0	0
Crooked Arm, 1999	*Salminicola* sp	61.29	7.42	0–24
	Metabronema sp.	9.68	7.67	0–18
	Cucullanus sp	19.35	3.33	0–6
	Proteocephalus sp	16.13	2	0–3
	Deropegus sp	16.13	2.60	0–6
	Crepidistomum sp	3.23	1	0–1

Appendix 1, continued.

Location	Species	Prevalence	Mean Intensity	Range
Deschutes Arm, 1999	*Salminicola* sp	77.42	7.67	0–20
	Metabronema sp.	60	27.28	0–146
	Cucullanus sp.	46.67	4.50	0–13
	Proteocephalus sp	23.33	2.71	0–5
	Deropegus sp	0	0	
	Crepidistomum sp	3.33	39	0–39
Metolius Arm, 1999	*Salminicola* sp	75	12.50	0–26
	Metabronema sp.	6.25	9.25	0–3
	Cucullanus sp	25	8	0–3
	Proteocephalus sp	0	0	
	Deropegus sp.	6.25	7.25	0–1
	Crepidistomum sp	0	0	
Forebay, 1999	*Salminicola* sp	100	10	3–27
	Metabronema sp.	50	5	0–6
	Cucullanus sp	50	4	0–4
	Proteocephalus sp	0	0	
	Deropegus sp	0	0	
	Crepidistomum sp	0	0	

APPENDIX 2.

TOP 5 (NUMERICAL) PREY TAXA OF REDBAND TROUT FOR THE THREE TRIBUTARIES TO LAKE BILLY CHINOOK, 1997–1999.

Appendix 2. Top 5 (Numerical) prey taxa of redband trout for the three tributaries to Lake Billy Chinook, 1997–1999.

River	Year	Top 5 taxa (Scientific)	Top 5 taxa (Common)	% of total
Metolius	1997	Baetidae	Small minnow mayfly	31.46
		Cladocera*	Daphnia	28.66
		Simuliidae	Mayfly adult	19.33
		Corixidae	Backswimmers	5.31
		Chironomidae	Midge larvae	5.19
	1998	Cladocera*	Daphnia	86.81
		Hirundidae	Leeches	3.61
		Ephemeroptera nymph	Mayfly adult	2.18
		Siphlonuridae	Small minnow mayfly	2.02
		Corixidae	Backswimmers	1.18
	1999	Hirundidae	Leeches	35.19
		Chironomidae	Midge larvae	18.47
		Baetidae	Small minnow mayfly	12.42
		Nematoda	Roundworms	11.94
		Amphipoda	Scud	5.10
Deschutes	1997	Nematoda**	Roundworms	66.67
		Trichoptera larvae	Caddisfly	11.11
		Corixidae	Backswimmers	7.40
		Coleoptera	Beetles	3.70
		Ephemeroptera nymph	Mayfly	3.70
	1998	Adult Ephemeroptera	Mayfly adult	48.49
		Ephemeroptera nymph	Mayfly nymph	14.66
		Chironomidae	Midge larvae	6.83
		Baetidae	Small minnow mayfly	6.22
		Tipulidae	Cranefly	3.41
	1999	Baetidae	Small minnow mayfly	53.61
		Various terrestrials	True bugs/beetles	17.18
		Chironomidae	Midge larvae	6.19
		Heptageniidae	Mayfly nymph	4.47
		Formicidae	Ants	3.78

Appendix 2, continued.

River	Year	Top 5 taxa (Scientific)	Top 5 taxa (Common)	% of total
Crooked	1997	Cladocera*	Daphnia	86.88
		Hirundidae	Leeches	3.53
		Ephemeroptera nymph	Mayfly nymph	2.19
		Siphlonuridae	Small minnow mayfly	2.02
		Corixidae	Backswimmers	1.18
	1998	Cladocera*	Daphnia	81.54
		Chironomidae	Midge larvae	4.96
		Hirundidae	Leeches	2.78
		Baetidae	Small minnow mayfly	2.58
		Siphlonuridae	Small minnow mayfly	1.85
	1999	Corixidae	Backswimmers	46.75
		Baetidae	Small minnow mayfly	31.17
		Chironomidae	Midge larvae	5.19
		Simuliidae	Black fly larvae	5.19
		Ephemeroptera nymph	Mayfly nymph	2.60
Forebay	1998	Cladocera*	Daphnia	71.90
		Chironomidae	Midge larvae	19.41
		Culicidae	Mosquito	1.53
		Vespidae	Wasps	0.06
		Corixidae	Backswimmers	0.06

* Often occurred in a small percentage of samples but in large numbers in those stomachs.
** Nematodes may have been parasites or prey items