William D. Muir, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Coastal Zone and Estuarine Studies Division, 2725 Montlake Boulevard East, Seattle, Washington 98112

and

Travis C. Coley, United States Fish and Wildlife Service, 9317 Hwy. 99, Suite A, Vancouver, Washington 98665

Diet of Yearling Chinook Salmon and Feeding Success During Downstream Migration in the Snake and Columbia Rivers

Abstract

The objectives of this study were to characterize and compare the stomach contents and feeding success of yearling chinook salmon smolts (*Oncorhynchus tshawytscha*) during their downstream migration at three sites in the Snake and Columbia Rivers. From 1987 to 1991, 26 to 38% of the yearling chinook salmon smolts sampled as they passed Lower Granite Dam, the first dam encountered by migrants in the Snake River, had empty stomachs. In 1991, smolts were sampled further downstream at McNary and Bonneville Dams on the Columbia River on the same sample dates. Empty stomachs occurred in 3% and 5% of these fish, respectively, and overall stomach fullness values were significantly higher. Smolts ate primarily dipterans (chironomids) at Lower Granite Dam; cladocerans, homopterans, and dipterans at McNary Dam; and amphipods and dipterans at Bonneville Dam—taxa typical of impounded waters. A series of dams on the Snake and Columbia Rivers has altered the conditions and habitat available for migrating juvenile salmonids and contributed to their decline. Large numbers of hatchery smolts, long residence times, altered food resources, and reservoir morphology may contribute to poor feeding success near Lower Granite Dam and could lead to reduced smolt survival.

Background

Salmonid smolts actively feed during their downstream migration (Becker 1973; Muir and Emmett 1988; Sagar and Glova 1988) to supply needed energy for the rigorous journey that may last many weeks, covering distances of 800 km or more. Metabolism increases during the parr-smolt transformation that accompanies downstream migration (McCormick and Saunders 1987; Farmer et al. 1978) and as water temperatures increase in spring, thus placing further energy demands on smolts.

Hydroelectric dams on the Snake and Columbia Rivers have created slack-water reservoirs that have increased travel times for migrating salmonid smolts, thereby contributing to a decrease in survival (Raymond 1979). Hatcheries have been built to offset losses in wild stocks. In 1993, approximately 81.3 million salmonids were released upstream of Bonneville Dam, of which 16.6 million were released above Lower Granite Dam (Figure 1) (FPC 1994). Yearling chinook salmon (*Oncorhynchus tshawytscha*) of hatchery origin often are released as inadequately developed smolts (Zaugg et al. 1985), a condition resulting in slow migration. For example, yearling chinook salmon released in late March or early April from Dworshak National Fish Hatchery in Idaho, took 3-4 weeks to travel to Lower Granite Dam (Muir et al. 1994). Historically, 3-4 weeks was sufficient for the entire migration to the ocean, 696 km downstream (Raymond 1979). Recent estimates of mortality for hatchery yearling chinook salmon migrating from release site to Lower Granite Dam tailrace have ranged from 21 to 83% (Muir et al. 1995).

In addition to the reduced flows caused by reservoirs, the slack water has led to increased sedimentation. Lower Granite Reservoir contains very fine sediments with high organic content. This sedimentation has led to a benthic community in Lower Granite Reservoir that is low in diversity and dominated by oligochaetes and chironomids (Bennett et al. 1990). Reservoirs downstream from Lower Granite Dam in the Columbia River generally have coarser sediments (Ebel et al. 1989) and greater benthic diversity (Parsley et al. 1989).

The combination of large numbers of hatchery smolts, long residence times, altered food resources, and reservoir morphology may contribute to poor feeding success near Lower Granite Dam. This may lead to decreased smolt condition and eventually to reduced smolt survival. Since hatchery stocks generally enter the reservoir first and reside for an extended period, hatchery

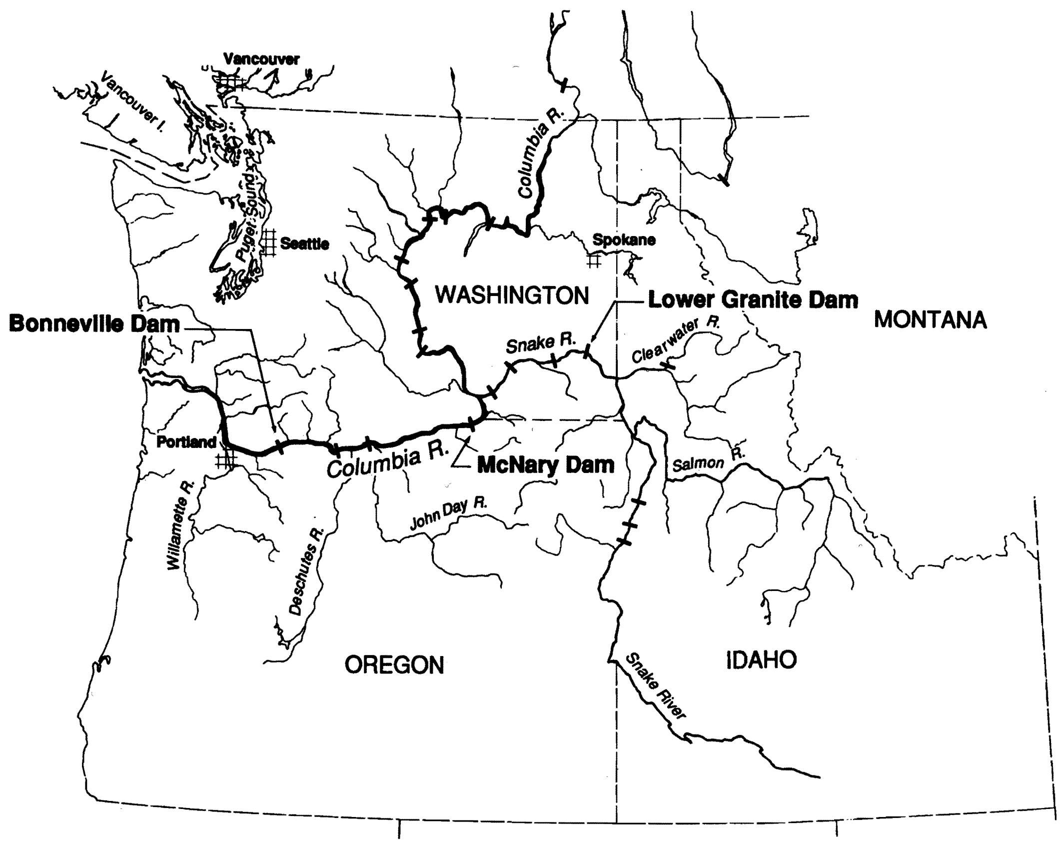

Figure 1. Study area showing location of the three dams (Lower Granite, McNary, and Bonneville) where yearling chinook salmon were sampled for food habit analysis on the Snake and Columbia Rivers.

production could deplete food resources available to later migrating wild smolts, stocks recently listed under the Endangered Species Act (NMFS 1991).

The purpose of this study in 1987 and 1989 was to characterize the food habits of migrating yearling chinook salmon smolts at Lower Granite Dam. Based on the results observed in the first two years, the study area was expanded in 1991 to compare their food habits and feeding success to sites downstream in the Columbia River.

Methods

During 1987 and 1989, freshly killed yearling chinook salmon smolts were collected from a turbine intake at Lower Granite Dam during tests to determine the fish guidance efficiency (FGE) of submersible traveling screens. Fish were taken from fyke nets suspended below the traveling screen to collect smolts passing underneath. Samples were collected between 2000 and 2200 h each evening on four dates in 1987 and three dates in 1989, over the spring smolt migration. Samples sizes varied between years (Table 1).

During 1991, freshly killed smolts were collected from turbine intakes at McNary and Bonneville Dams (Figure 1) once per week during FGE tests. At Lower Granite Dam, no FGE tests were conducted during 1991, so live smolts were sampled from the juvenile fish bypass system as they exited the bypass channel (Matthews et al. 1977). Smolts were sampled simultaneously (same day and time, n = 20 at each site/day), over a 4- to 5-week period during the migration. No attempt was made to distinguish between smolts of wild or hatchery origin, although hatchery fish predominated at all three sites. Yearling chinook salmon were smaller at Lower Granite Dam averaging 124 mm (s.e. 1.3) in fork length compared to 142 mm (s.e. 1.9) at McNary and 142 mm (s.e. 1.6) at Bonneville Dam.

TABLE 1. Sample dates, numbers sampled, number empty (e) and stomach contents (percent IRI) of yearling chinook salmon at three dams on the Snake and Columbia Rivers. Only IRI values >3% are shown. IRI = Index of Relative Importance.

	Sample date		n	e	Diptera	Coleoptera	Homoptera	Hymenoptera	Thysanoptera	Trichoptera	Amphipoda	Cladocera	Fish
Lower Granite	1987	Apr 18	10	2	3.5	7.2	—	—	—	—	87.2	—	—
		Apr 24	20	5	—	4.8	—	—	—	6.8	86.5	—	—
		Apr 29	18	3	—	31.5	14.3	—	16.1	—	33.4	—	—
		May 3	20	9	88.4	—	—	—	—	—	11.7	—	—
	1989	Apr 16	104	21	73.0	21.8	—	—	—	—	—	—	—
		Apr 23	67	19	96.4	—	—	—	—	—	—	—	—
		Apr 27	89	28	47.4	4.3	—	—	—	27.0	17.7	—	—
	1991	Apr 25	20	8	—	96.6	—	—	—	—	—	—	—
		May 2	20	6	14.3	13.3	11.8	59.5	—	—	—	—	—
		May 9	20	10	62.7	—	—	29.6	—	—	6.3	—	—
		May 24	20	6	97.4	—	—	—	—	—	—	—	—
McNary	1991	Apr 25	11	2	—	—	—	—	—	—	—	90.9	—
		May 2	20	0	27.6	—	66.9	—	—	—	—	—	—
		May 9	20	0	15.2	—	21.2	—	—	—	—	51.3	8.0
		May 16	20	0	28.4	3.2	41.2	—	—	—	—	17.5	3.5
Bonneville	1991	Apr 25	20	4	63.0	—	—	—	—	—	29.3	—	7.5
		May 2	20	0	38.1	6.6	10.9	36.3	—	—	7.2	—	—
		May 9	20	1	43.7	—	—	—	—	—	55.6	—	—
		May 16	20	0	20.0	4.7	7.4	6.4	—	—	60.7	—	—
		May 24	20	0	11.6	—	3.6	—	—	—	80.9	—	—

To retard digestion of stomach contents, fish stomachs were injected with an 8% formaldehyde solution in 1987 and 1989 or placed on dry ice in 1991 as soon after capture as possible. Later, stomachs were removed and placed in individually labeled vials containing 70% ethyl alcohol for storage.

Stomach contents were identified to the lowest practical taxon (order for insects and species for amphipods). Prey items were weighed to the nearest 0.001 g after blotting and air drying for 10 minutes. When prey items were not intact, head capsules were counted, and body parts were combined for weighing. The number, weight, and frequency of occurrence of food items were used to calculate the Index of Relative Importance (IRI) (Pinkas et al. 1971), converted to percentages for each sample site and date. The percent empty stomachs, and in 1991, mean stomach fullness (Terry 1977) ranging from 1 (empty) to 7 (distended) were calculated for each site each week. Mean stomach fullness values among sample sites for 1991 were compared using the Kruskal-Wallis nonparametric analysis of variance.

Results

During 1987, yearling chinook salmon smolts at Lower Granite Dam ate primarily amphipods (*Corophium spinicorne*) and dipterans (chironomids); during 1989 and 1991, dipterans were the predominant prey item (Figure 2). The proportion of dipterans in the diet generally increased as the yearling chinook salmon downstream migration progressed in time (Table 1). Various terrestrial insect orders including Coleoptera, Homoptera, Hymenoptera, and Thysanoptera also were consumed during the 3 years at Lower Granite Dam (Table 1).

At McNary Dam, yearling chinook salmon smolts preyed primarily on cladocerans, homopterans, and dipterans (chironomids) during 1991 (Figure 3). At Bonneville Dam, amphipods (*Corophium*) and dipterans (chironomids) were the primary food items although hymenopterons and homopterans were also consumed regularly (Figure 3). The proportion of amphipods generally increased as the yearling chinook salmon downstream migration progressed in time at Bonneville Dam (Table 1).

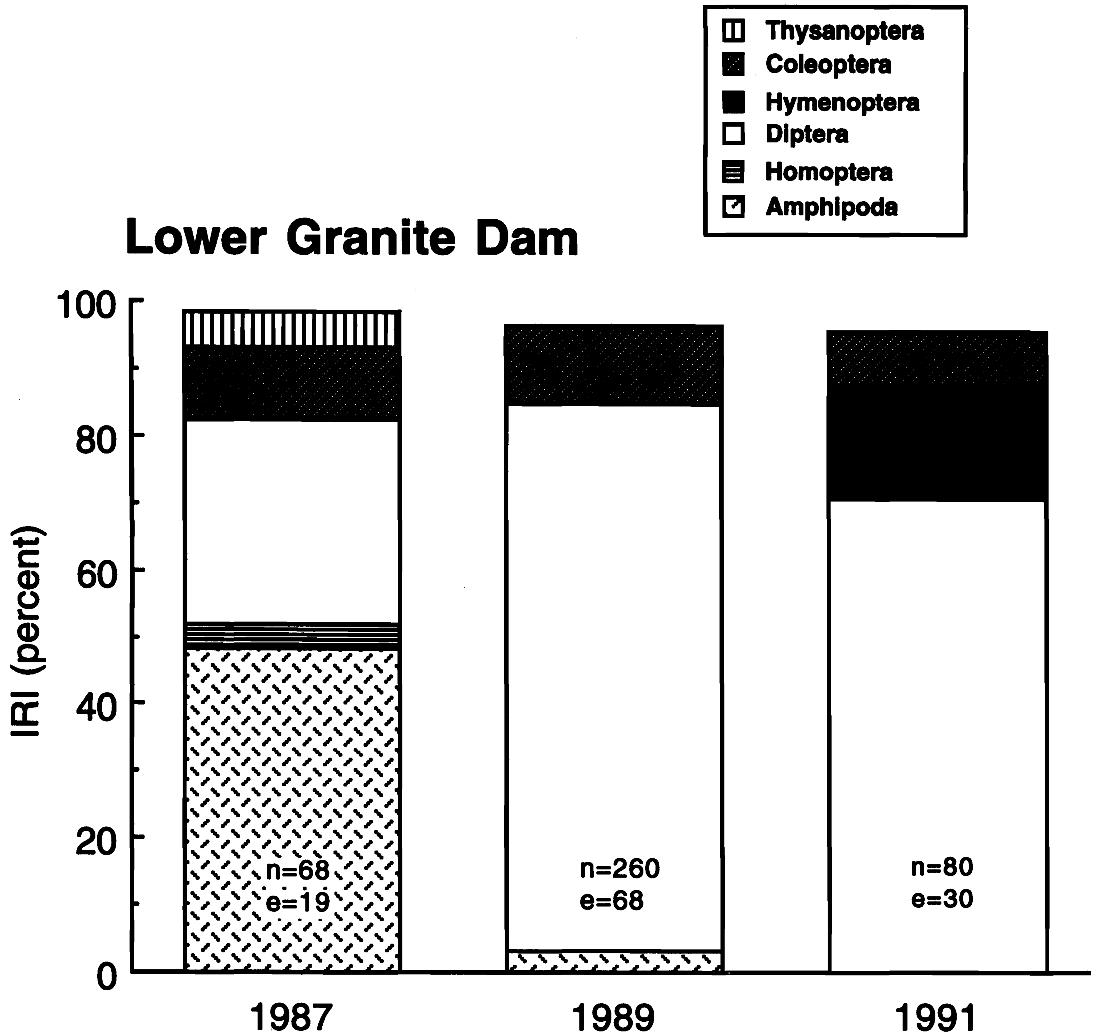

Figure 2. Index of Relative Importance (IRI) of food items for yearling chinook salmon sampled at Lower Granite Dam. Only IRI values > 3% are shown. The number of fish sampled (n) and the number of empty stomachs (e) are also shown.

Yearling chinook salmon smolts collected at Lower Granite Dam did not feed as much as smolts collected at downstream sites. From 1987 to 1991, empty stomachs were observed in 26 to 38% (yearly average) of the yearling chinook salmon smolts sampled at Lower Granite Dam (Figure 2). In 1991, this compared to 3% and 5% empty stomachs (yearly average) in yearling smolts sampled downstream at McNary and Bonneville Dams, respectively, on the Columbia River on the same sample dates and times (Figure 3). Furthermore, mean stomach fullness values were significantly lower ($F = 41.3$, 2 df, $P < 0.0001$) at Lower Granite Dam than at downstream sites in 1991 (Figure 4). Stomach fullness averaged 2.2 at Lower Granite Dam, whereas at McNary and Bonneville Dams, stomach fullness averaged 4.1 and 4.0, respectively.

Discussion

We found that feeding success of yearling chinook salmon smolts collected at Lower Granite Dam was significantly lower than feeding success of smolts collected at downstream sites during 1991. Mean stomach fullness values from McNary and Bonneville Dams during 1991 were similar to levels reported in the lower Columbia River by

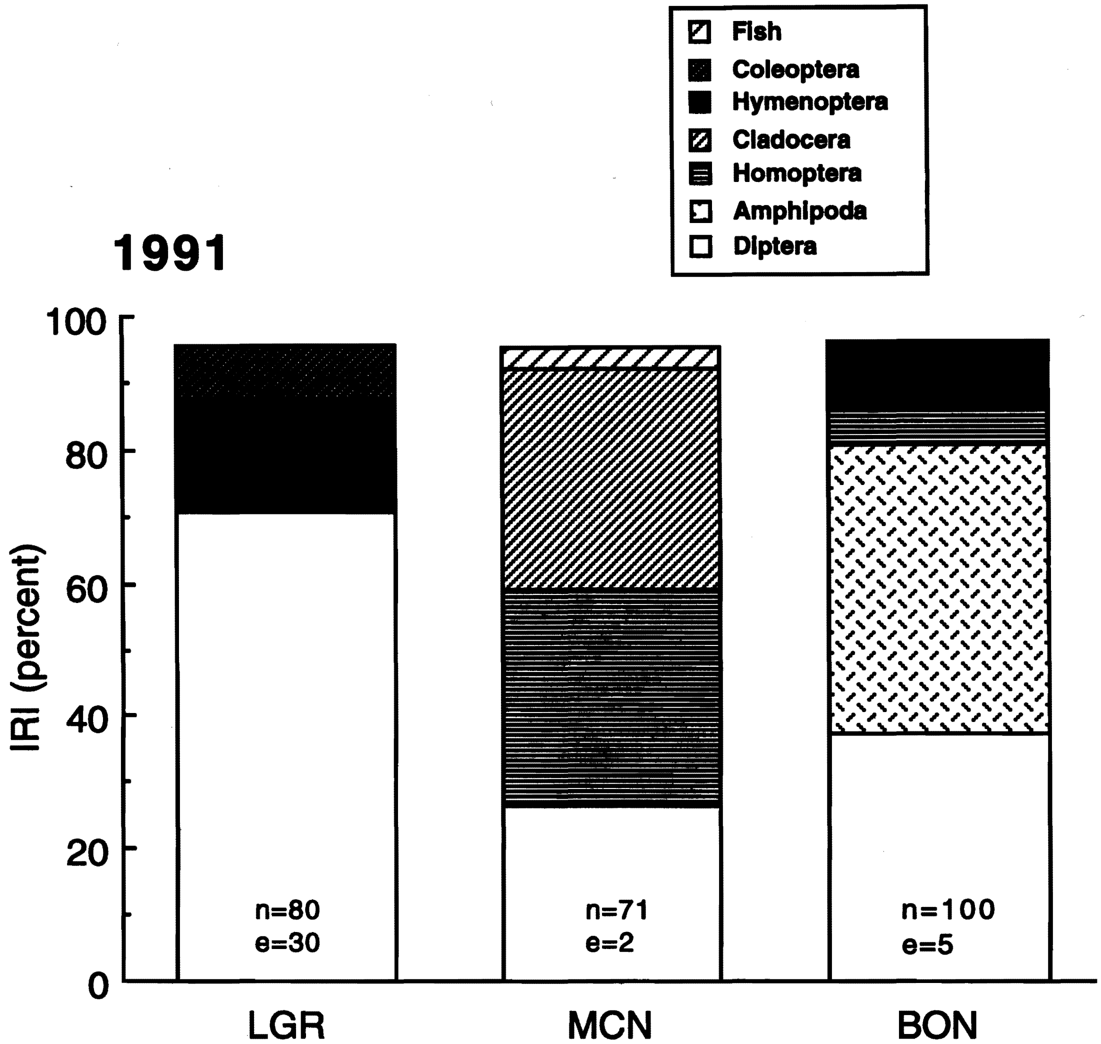

Figure 3. Index of Relative Importance (IRI) of food items for yearling chinook salmon sampled at Lower Granite (LGR), McNary (MCN), and Bonneville (BON) Dams during 1991. Only IRI values > 3% are shown. The number of fish sampled (n) and the number of empty stomachs (e) are also shown.

Dawley et al. (1986), a fullness level they considered inadequate, but still substantially higher than those observed at Lower Granite Dam. Bennett (personal communication, D. Bennett, University of Idaho) found that chinook smolts generally had full stomachs in Lower Granite Reservoir upstream from where fish were collected for this study. A possible explanation for the difference is the morphology of Lower Granite Reservoir. Bennett found shallow water habitat in Lower Granite Reservoir to be important feeding areas for migrating salmonid smolts, and that most of the shallow areas occur in the upper end of the reservoir (Bennett et al. 1990). The lack of shallow feeding sites in the forebay of Lower Granite Dam could be responsible for the lower feeding success observed at this site. Furthermore, yearling chinook salmon may spend considerable time in Lower Granite Dam forebay before they pass the dam. Thorne et al. (1992) determined in a 1989 hydroacoustic survey that the majority of fish in Lower Granite Reservoir accumulate in the forebay area. Thus, fish we collected at the dam may not have eaten for some

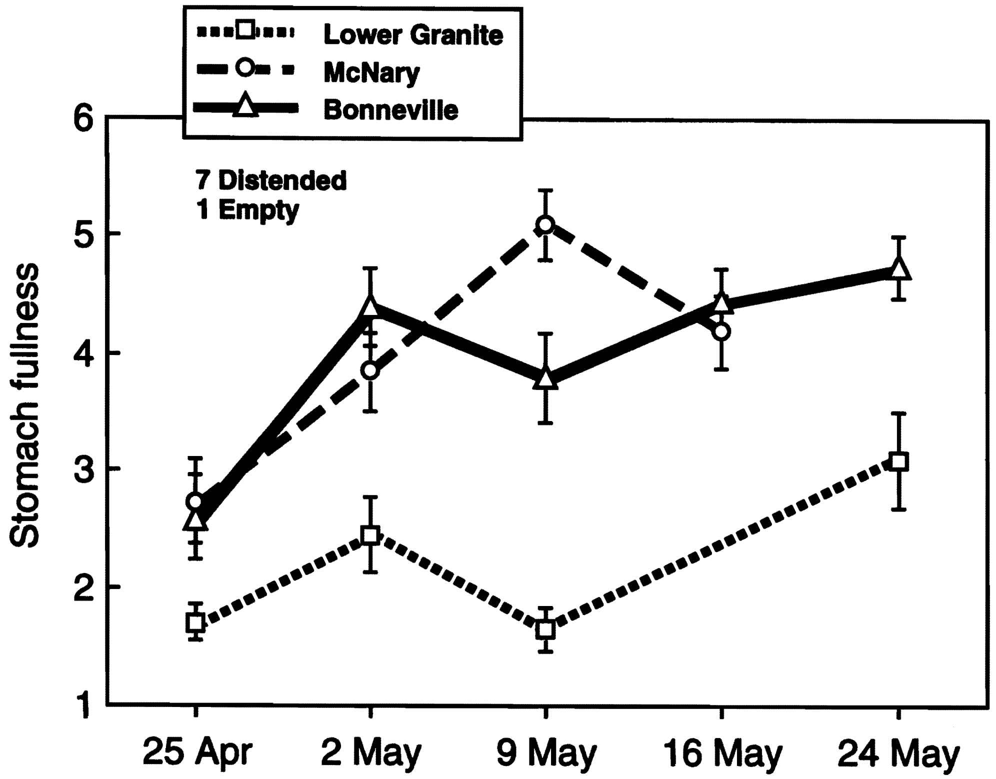

Figure 4. Means stomach fullness in yearling chinook salmon sampled at three dams during 1991 (n=20/site/date except on 25 April at McNary Dam where n=11).

time prior to capture. Similar delays in passage have not been documented at downstream dams.

Salmonids are opportunistic feeders with their diet generally reflecting invertebrate drift availability (Elliot 1967; Sagar and Glova 1988; Rondorf et al. 1990), although some selection occurs (Griffith 1974; Ringler 1979; Sagar and Glova 1987). The difference in overall food habits of fish between dams and between years at Lower Granite Dam probably reflect differences in prey availability.

There is little information on food resources available to migrating salmonids in Snake and Columbia River reservoirs. In Lower Granite Reservoir, Bennett et al. (1990) found chironomids and oligochaetes to be the only abundant organisms in benthic samples. Rondorf et al. (1990) reported cladocerans and terrestrial insects to be the most abundant taxa in zooplankton and insect drift sampling in McNary Dam forebay in summer. Muir (1990) sampled the epibenthic drift just below Bonneville Dam over a three year period and found *Corophium* spp. to be the most abundant drift organisms with highest numbers occurring in May, coinciding with the peak migration of yearling chinook salmon. *Corophium* spp. also were found to be abundant in benthic samples in Bonneville Reservoir (Parsley et al. 1989).

Hatchery salmonids have been found to be ineffective predators immediately after release (Ware 1971; Sosiak et al. 1979; Ersbak and Haase 1983). However, this should not have affected the results observed in this study. The long residence time for yearling chinook salmon in Lower Granite Reservoir should have provided adequate time for adjustment to effectively feed in their new environment. Paszkowski and Olla (1985) determined that coho salmon (*O. kisutch*) smolts switched readily from artificial to natural foods (which they preferred) in a marine environment. Furthermore, hatchery stocks also predominated at Bonneville and McNary Dams, where feeding success was much higher.

With increasing hatchery production and long residence times in Lower Granite Reservoir, the carrying capacity of this reach (or portions of it) may be exceeded, resulting in smolts of poor quality that are unable to resist disease or predation. Starvation could reduce smolt survival by affecting smolt development (Virtanen and Soivio 1985, Fowler 1991), swimming performance (Snyder 1980), making them more susceptible to disease (Snyder 1980), or by impairing fish immune response (Landolt 1989; Henken et al. 1987). This could contribute to the high post-release mortality (Muir et al. 1995) and poor adult returns (Matthews and Waples 1991) reported for hatchery yearling chinook salmon in this reach. There are probably other areas where food availability or potential feeding sites are limited along the Snake and Columbia Rivers migration corridor within the series of impoundments between Lower Granite and Bonneville Dams. The relation between reduced feeding success and migration and survival of yearling chinook salmon is presently unknown and should be examined.

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