Fisheries Management and Ecology, 1995, **2**, 299–308

Distribution and feeding of juvenile Pacific salmon in freshwater tidal creeks of the lower Fraser River, British Columbia

C.D. LEVINGS, D.E. BOYLE & T.R. WHITEHOUSE*

Department of Fisheries and Oceans, Biological Sciences Branch, West Vancouver Laboratory, West Vancouver, B.C., Canada

Abstract This study examined juvenile salmonid use of a freshwater tidal creek system draining a wetland on the floodplain of the lower Fraser River, British Columbia, Canada. Chum, *Oncorhynchus keta* (Walbaum), chinook, *O. tshawytscha* (Walbaum), and sockeye, *O. nerka* (Walbaum), salmon fry were abundant in the tidal creeks in spring. The fry were found in non-natal habitat up to 1.5 km from the main channel of the river. The salmon fry ate dipteran adults, larvae and pupae, cyclopoid and harpacticoid copepods, and Collembola. Mysids *Neomysis mercedis* Holmes (Walbaum), and amphipods, *Crangonyx richmondensis occidentalis* (Hubricht and Harrison),were also consumed. The upper reaches of an undisturbed creek were the winter rearing habitat for presmolt coho salmon, *O. kisutch* (Walbaum), where this species ate dipteran pupae and larvae as well as a freshwater isopod, *Asellus communis* Say (Walbaum).

KEYWORDS: food, habitats, Pacific salmon fry, tidal creeks.

Introduction

Juvenile salmon were studied in a tidal freshwater creek system draining a riparian wetland about 35 km upstream from the river mouth in the Fraser River estuary at Surrey, British Columbia, Canada. The objectives of the work were to determine patterns of fish use in the wetland and to determine feeding habits of juvenile salmon using the habitat. Fish habitat managers in northeast Pacific estuaries frequently use vegetation units as surrogates for fish habitat. In the Fraser River estuary, the areal extent of intertidal estuarine sedges such as *Carex lyngbyei* (Hornem) is used in the management of marsh compensation and restoration projects (Levings, Conlin & Raymond 1991). The rationale for using the plants as surrogates for fish habitat is based primarily on earlier detailed studies on the ecological role of the estuarine marsh plants in provision of refuge habitats and invertebrates that are eaten by juvenile salmonids (e.g. Levy & Northcote 1982). However, there are insufficient studies of fish use of tidal freshwater creeks bordered by emergent vegetation with terrestrial or riparian affinities, such as wet meadows, shrubs and swamp communities. The Fraser River is one of the world's major producers of salmon (*Oncorhynchus* spp.) and the estuary is generally thought of as a vital nursery area for several

Correspondence: C.D. Levings, Department of Fisheries and Oceans, Biological Sciences Branch, West Vancouver Laboratory, 4160 Marine Drive, West Vancouver, BC, Canada V7V IN6.

*Present Address: Department of Fisheries and Oceans, Fisheries Branch, 610 Derwent Way, Annaeis Island, New Westminster, B.C. Canada V3M 5P8.

species of salmonids (Northcote & Larkin 1989). Therefore, all habitats important for salmon rearing need to be identified and integrated into the habitat management system.

Study area sample sites and methods

Study area

The study area, known as Surrey Bend, is located between the margin of the Fraser River and the uplands of the north side of Surrey Municipality in southwestern British Columbia. The Surrey Bend wetland consists of approximately 507 ha of wetlands, classified as floodplain habitat by Ward, Moore & Kistritz (1992), or palustrine emergent (Cowardin, Carter, Golet & LaRoe 1979). Two unnamed creeks, hereafter referred to as Creeks A and B, drain the upland slopes (catchment area 3.6 km^2), flow through the wetland (area 5.40 km^2) and join about 350 m from the Fraser River (Kistritz, Porter, Radcliffe & Ward 1992). Creek A is located near the centre of the wetland (Fig. 1). The portion of the creek below the confluence of Creeks A and B is referred to as Lower Creek. Some important physical features of the creeks are given in Table 1. Both creeks flow under railway tracks through large culverts, and the culvert for Creek A was designed to allow the passage of adult salmon. The vegetation and topography of the wetlands along the margins of the tidal creeks at Surrey Bend were described in detail by Kistritz *et al.* (1992) and Ward *et al.* (1992). The tidal creeks are bordered by extensive areas of reed canarygrass, *Phalaris arundinacea* L., (25 ha), hardhack thicket, *Spiraea douglasii* Hook, (24 ha), hardhack-willow, *S. douglasii-Salix* spp., (51 ha), and smaller patches of black cottonwood, *Populus trichocarpa* Torr. & Gray ex Hook, and shore pine, *Pinus contorta* var. *contorta* Dougl. ex Loud (Kistritz *et al.* 1992). During 1991 and 1992, reed canarygrass developed in spring and summer on the bed of Creek A's upper reaches, but was not present on the bed of Creek B. Duckweed, *Lemna minor* L., and water starwort, *Callitriche* sp., was also observed in Creek A. Sedges, *Carex* spp., and rushes, *Juncus* spp. were the dominant plants on the foreshore where Lower Creek joins the Fraser River.

Fish sampling

A 15-m beach seine (mesh size 12.5 mm in the wings and 6.25 mm in the bunt, 2 m deep) was used in the wider and deeper areas of the creeks, and a 1.5-m-wide pole seine (6.25 mm mesh) was deployed in shallower and narrower reaches. Samples were taken in March, April, May and July 1991. Figure 1 shows the sample stations. For a fuller description of sample sites and other factors, see Whitehouse, Boyle, Levings, Newman & Black (1993). In February and March 1992, the upper reaches of Creek A were sampled using a pole seine only.

Subsamples of juvenile salmon catches were preserved in 10% formalin (v/v) for length measurement and stomach content analysis. Two hundred and fifty-one sockeye fry, 136 chinook fry, 122 chum fry and five coho presmolts (from 1992) were measured for fork length and analysed for stomach contents in the laboratory. Fish stomach contents were examined using a stereo-microscope and individual food organisms were counted. Because salmon catches varied widely between months, sample data from each of the three creeks were pooled to increase sample size for statistical analysis of the stomach contents data.

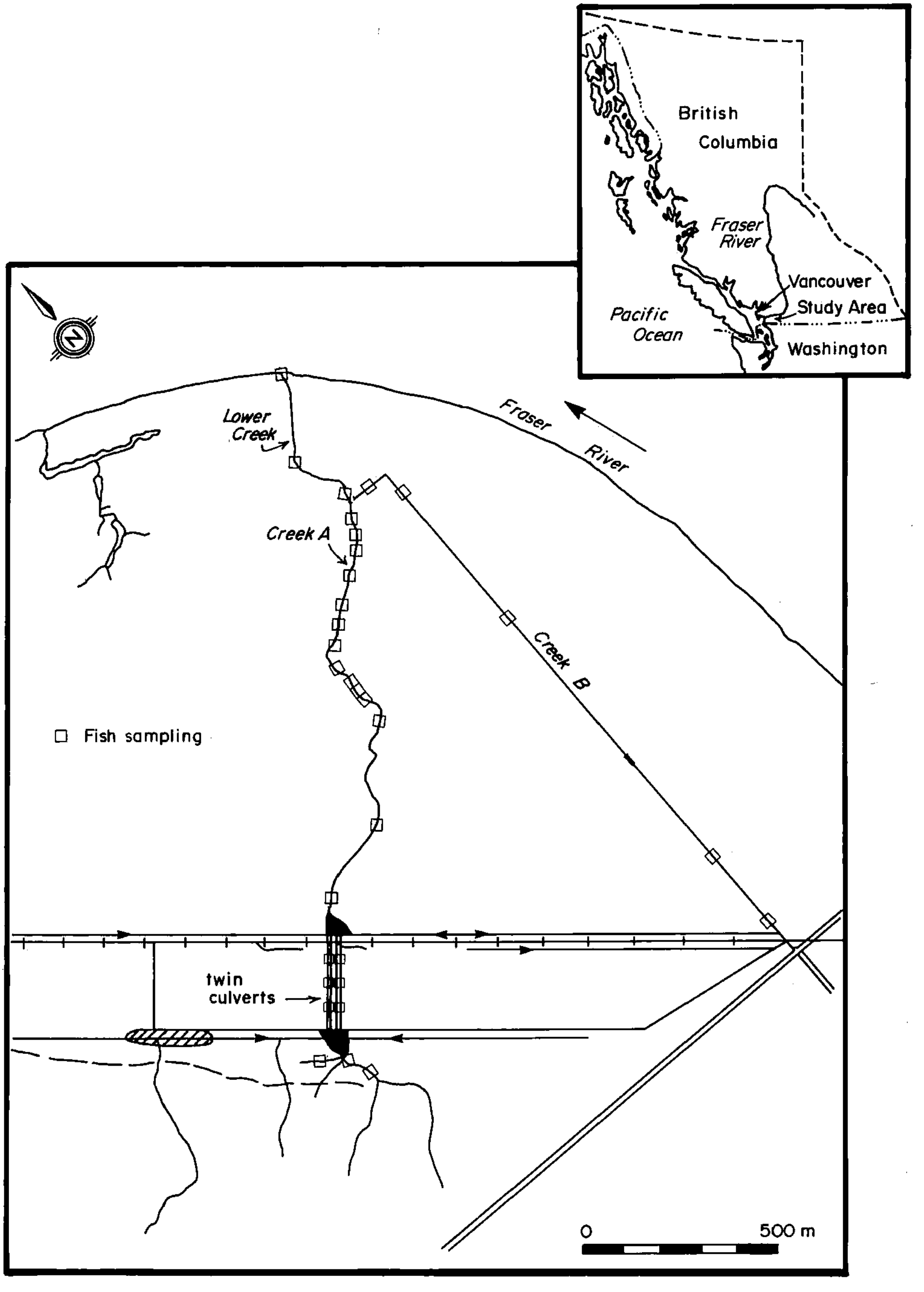

Figure 1. Map of the Survey Bend study area and sampling locations in the tidal creek system.

Table 1. Physical characteristics of the freshwater tidal creeks sampled at Surrey Bend, lower Fraser River

Creek	Depth at highest tide (m)	Width at highest tide (m)	Depth at lowest tide (m)	No. of spawning salmonids in headwaters	Status of development in lower reaches
A	1.0 in upper reaches, 2.5 in lower reaches	0.75 in upper reaches, 3.0 in lower reaches	0.30 in upper reaches[1] 0.1 lower reaches	10 coho; some cutthroat trout likely	undisturbed
B	1.0 in upper reaches, 2.5 in lower reaches	3.5	0.1 in all reaches	none reported; headwater habitats totally disrupted	frequently dredged; riparian vegetation disrupted on shore east
Lower Creek	3.0	6.0	0.2	n.a.[2]	undisturbed

[1] Flow blocked by reed canarygrass in stream channel.
[2] Average in past 1Day; Fisheries and Oceans unpublished data
[3] n.a. = not applicable.

Results

Distribution

Five species of salmon were caught in the study area and a summary of their abundance is given in Table 2. Tables of the catches from individual samples for all species caught (salmonids and non-salmonids) are given elsewhere (Whitehouse *et al.* 1993). Chum, *Oncorhynchus keta* (Walbaum), were found only as fry. Chinook, *O. tshawystcha* (Walbaum), sockeye, *O. nerka* (Walbaum), and coho, *O. kisutch* (Walbaum), were found as both fry and smolts, but the fry stage were by far the most numerous with the smolts accounting for <1% of the total catch. Coho were also found as presmolts, but only in February 1992 near the headwaters of Creek A. One adult cutthroat trout, *O. clarki* (Richardson), and three smolts were caught in Lower Creek in May 1991. One juvenile cutthroat trout was caught in the upper reaches of Creek A in February 1992. Salmon fry were most abundant in the March, April and May 1991 surveys. Some chum and chinook fry were also found in the February 1992 sampling. There were differences in catches between the creeks in the 1991 sampling (Table 2), but fry of sockeye, chum and chinook were the most abundant species in each. Because beach seining was used for most of the sampling in Lower Creek and Creek B, (both beach and pole seining were used in Creek A), a direct statistical comparison of the fish abundance was not possible. However, there was a trend for juvenile salmon to be relatively less abundant in Creek B.

Size differences

There was little difference in the mean length of sockeye fry caught in the study area in April and May 1991; mean lengths ranged from 28 to 30 mm in both months. A two-way

Table 2. Abundance of four species of salmon fry (numbers m^{-2}) at Lower Creek, Creek A and Creek B from March to July 1991, as estimated from beach and pole seine catches. Numbers below name of creek indicate approximate area (m^2) sampled

Species	Lower Creek (2750 m^2)	Creek A (705 m^2)	Creek B (1925 m^2)
Coho salmon	<0.01	0.02	0.01
Chinook salmon	0.05	0.15	0.06
Sockeye salmon	0.30	0.21	0.07
Chum salmon	0.05	0.23	0.09

analysis of variance (ANOVA) showed the difference between months to be significant ($P < 0.05$); however, the difference between creeks was not ($P > 0.05$). An ANOVA on the chum length data indicated significant differences between the March (mean length 39 mm) and April (mean length 44 mm) values ($P < 0.01$), but not between the three creeks ($P > 0.05$). Chinook fry were approximately 40 mm in mean length in March and increased to 50 mm in mean length by May. As with the chum and sockeye, significant differences existed between monthly values ($P < 0.01$), but not between creeks ($P > 0.05$). Five coho presmolts caught in the upper reaches of Creek A in February 1992 ranged in size from 84 to 113 mm (mean length 103 mm, SE 5 mm). Four coho fry caught in April and May 1991 were measured; the lengths ranged from 32 to 41 mm (mean 36 mm, SE 4 mm).

Juvenile salmon food habits

Chum fry in Creek B consumed harpacticoid and cyclopoid copepods in addition to *Collembola*, and dipteran larvae, pupae and adults (Fig. 2). Chum fry from Creek A ate mainly larval, pupal and adult dipterans. In Lower Creek, major food items were dipterans and *Collembola*. A few amphipods, *Crangonyx richmondensis occidentalis* Hubricht and Harrison were eaten by chum fry in all three of the creeks. Mysids, *Neomysis mercedis* Holmes were found only in chum from Lower Creek.

Dipteran pupae, larvae and adults were the major taxa consumed by chinook fry in all three creeks (Fig. 3). More dipteran larvae and pupae were eaten in Creek A than in the other creeks. Mysids were found only in chinook from Lower Creek. *Collembola* were more common in chinook fry stomachs from Creek B, as were amphipods.

The stomach contents of sockeye fry from Creek B habitats were dominated by cyclopoid copepods as well as harpacticoid copepods (Fig. 4). Cyclopoida were also common in the stomachs of sockeye fry from Creek A and Lower Creek. Dipteran larvae were the main component in stomachs of the fry from Creek A and were also frequent in the stomachs of fry from the other creeks. *Collembola* were common in the stomachs of sockeye fry from Creek B. A few mysids were found in sockeye fry from Lower Creek.

The main food taxa for five coho presmolts caught in February 1992 in the upper reaches of Creek A were isopods, *Asellus communis* Say, and dipteran pupae and larvae (Fig. 5).

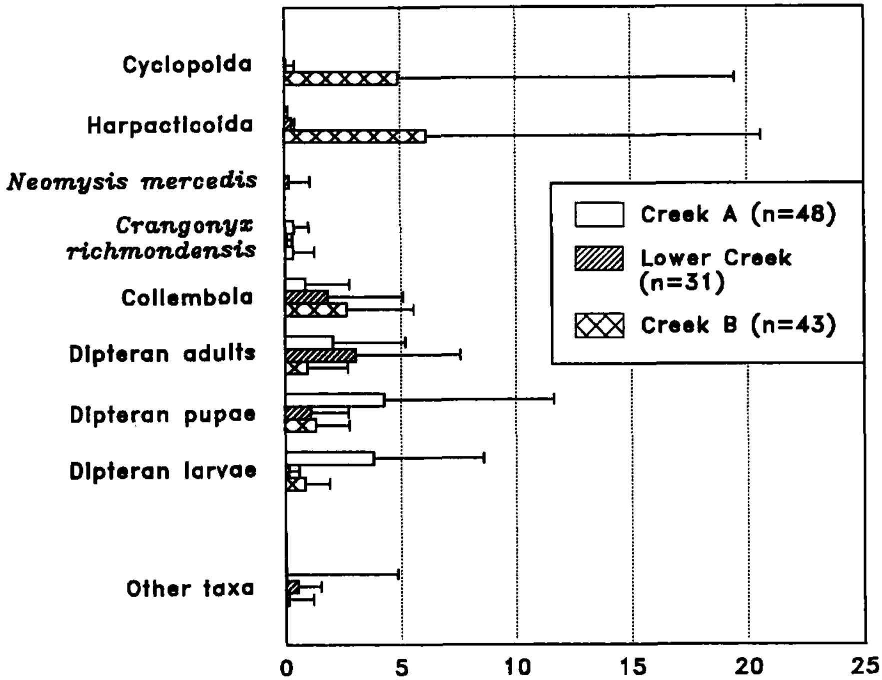

Figure 2. Mean number (with standard error) of various prey taxa in stomachs from chum salmon fry caught in Creek A Creek B and Lower Creek habitats (March to July 1991).

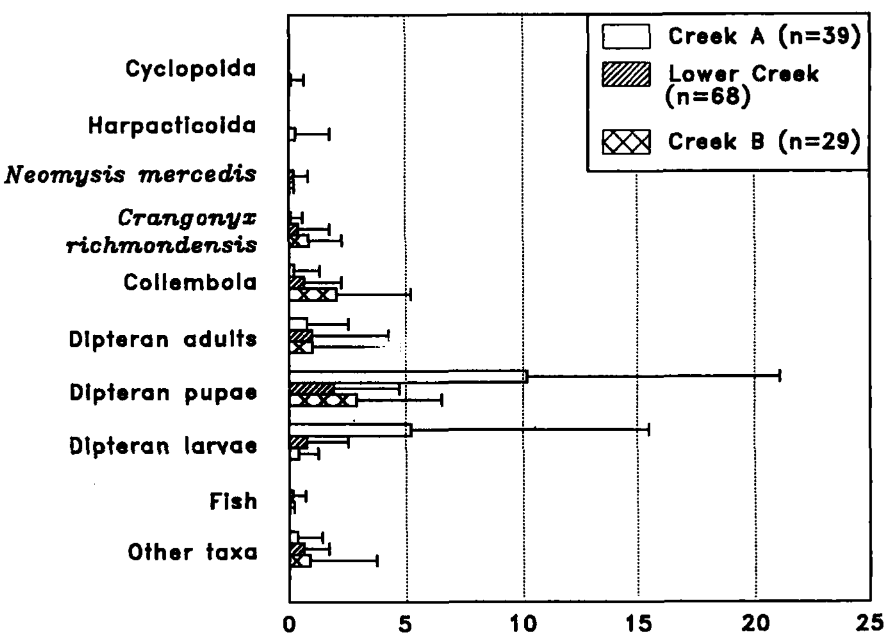

Figure 3. Mean number (with standard error) of various prey taxa in stomachs from chinook salmon fry caught in Creek A, Creek B and Lower Creek habitats (March to July 1991).

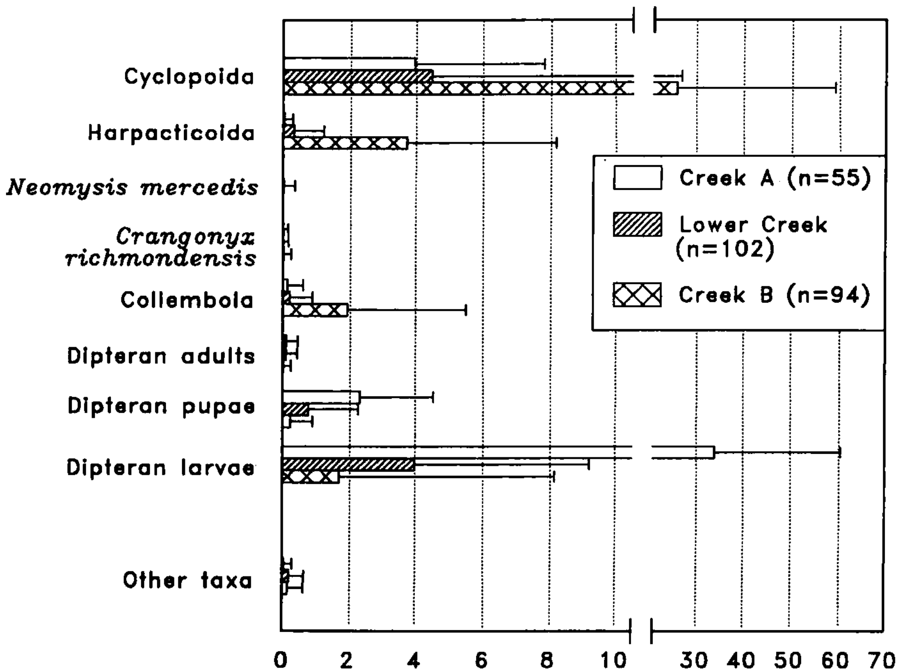

Figure 4. Mean number (with standard error) of various prey taxa in stomachs from sockeye salmon fry caught in Creek A Creek B and Lower Creek habitats (March to July 1991).

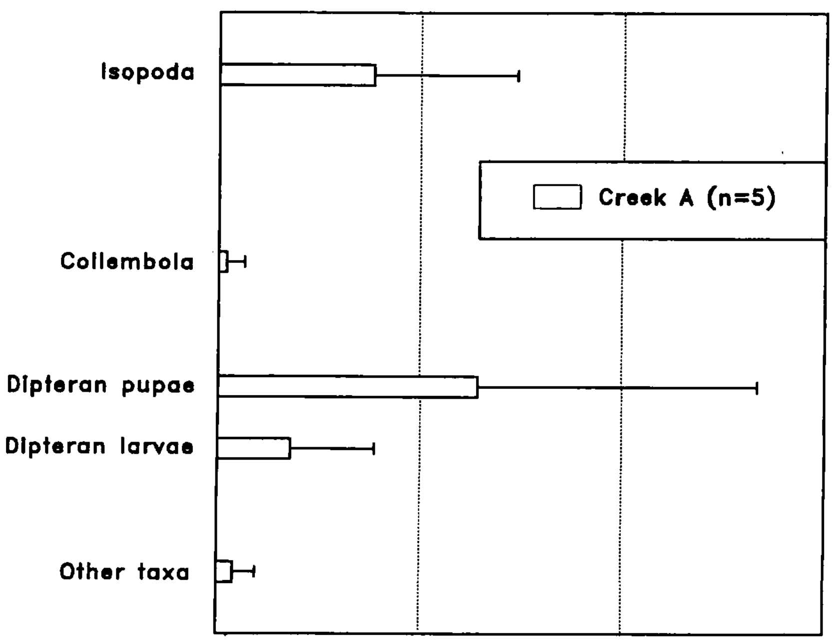

Figure 5. Mean number (with standard error) of various prey taxa in stomachs from coho salmon presmolts caught in the upper reaches of Creek A (February 1992).

Discussion

Use by juvenile salmon

Chum, sockeye and chinook fry were caught in the upper reaches of Creeks A and B, up to 1.5 km from the channel of the river mainstem. This indicates that the tidal creeks in the reed canarygrass wetland were used extensively by juvenile salmon from spawning grounds elsewhere in the Fraser River system since the latter three species do not spawn in Creek A. The uppermost reaches of Creek A were characterized by standing or slow-flowing water at all stages of the tide because the reed canarygrass impeded flow in the narrow channel. This area was used as winter habitat by coho salmon, as shown by our catches of presmolts in February 1992. The presmolts were probably progeny of coho salmon that had spawned in the headwaters of Creek A, since very few coho fry were caught in the lower reaches of the tidal creeks. Coho fry were also rare in surveys of the mainstem lower Fraser (e.g. Levy & Northcote 1982). A variety of vegetation communities in British Columbia coastal streams were identified as coho winter rearing habitat (e.g. Brown 1987) but this is the first instance where reed canarygrass was recorded as a structural component of salmon habitat. In other areas of North America, reed canarygrass is thought to pose a major threat to wetland ecosystems because of its tendency to crowd out other plant species (Apfelbaum & Sams 1987).

Elsewhere in the lower Fraser River, non-natal river mouths and estuarine tidal creeks are also rearing areas for young salmon, but other vegetation characterizes those habitats. The lower reaches of the nearby Brunette River (drainage basin of 69 km^2), which joins the Fraser River 10 km downstream from the mouth of Lower Creek, has significant rearing areas for chinook fry (Murray & Rosenau 1989). The wetlands at the mouth of the Brunette River were modified significantly by industrial activity (Ward *et al.* 1992), although some remnants of riparian vegetation persist. Juvenile salmon were also found using disturbed wetland habitat in this study (Creek B, Table 2), possibly in reduced abundance. Further downstream in the estuary of the Fraser River, tidal creeks within the salt wedge portion of the estuary were found to be important for juvenile chum and chinook salmon (Levy & Northcote 1979). These tidal creeks are part of extensive wetlands (448 ha) dominated by the estuarine sedge *Carex lyngbyei* (Ward *et al.* 1992).

Feeding

The feeding habits of chum, chinook and sockeye fry in the tidal creeks were similar to those observed downstream in the Fraser River estuary, and in other northeast Pacific estuaries, with some notable exceptions. Chinook and chum fry in many estuaries feed on harpacticoid copepods, the mysid, *N. mercedis*, and dipterans in various life stages (Levy & Northcote 1982; Levings *et al.* 1991; and other authors summarized in Higgs, Macdonald, Levings & Dosanjh, 1995). Some of the feeding habits identified in this study may be unique to aquatic habitats bordered by wet meadow or riparian vegetation; for example, the fry of three salmon species fed on *Collembola*, which live primarily in wet meadow and riparian habitats. Extensive invertebrate surveys in the lower Fraser mainstem and estuary (Northcote, Johnston & Tsumura 1976) have not reported this taxa in samples of benthos, epibenthos or drift from the intertidal zone. However, *Collembola* were reported in juvenile salmon diets in Tilbury Slough, further downstream in the Fraser River estuary (Macdonald, Kistritz & Farrell 1990). Extensive stands of riparian vegetation and marsh characterize the shoreline of this estuarine tidal slough. The present study indicates that the amphipod *C. richmondensis occidentalis* and the isopod *A. communis* may be widely available as prey for salmonids in freshwater tidal creeks or ponds in the estuary. Chum, chinook and sockeye fry caught in the tidal creek system ate *C. richmondensis occidentalis*, an important food item for salmonids in lakes (Mathias 1971). Coho presmolts taken in the upper reaches of Creek A fed on *A. communis*. At low tide, the two crustaceans were found mainly in the ponded areas at upper reaches of Creeks A and B (C.D. Levings, unpublished data). Neither species has been reported from drift, plankton or benthic surveys on the Fraser River mainstem or estuary (e.g., Northcote Johnston & Tsumura 1976).

In summary, the results of this study at Surrey Bend in the lower Fraser River showed that freshwater tidal creeks draining wetlands characterized by riparian vegetation such as reed canarygrass and hardhack were extensively used by salmon fry. Chum, sockeye and chinook fry immigrated into the habitats from the mainstem Fraser River, and therefore, the habitats were used by the progeny of fish from upstream populations. Coho fry and presmolts, and juvenile cutthroat trout were from spawning populations in the upper reaches of the creeks. The salmon fry ate invertebrates from a variety of sources, including epibenthos (e.g. mysids) from the main river stem, insects (likely to be from both the tidal creek and the main river foreshore), and lacustrine amphipods and isopods from a ponded area of the tidal creek. The Fraser River is tidal about another 80 km upstream of the study area, and therefore, there are numerous additional freshwater tidal creek systems in the lower Fraser River. Most of them are characterized by vegetation units similar to those of the study area (Ward *et al.* 1992). Because of their importance for salmon fry, these areas should be protected and managed as key rearing habitats.

Acknowledgments

Thanks are due to a number of field staff, who assisted with collecting data at Surrey Bend under arduous conditions, including K. Calla, D. Duff, R. Sauvé and H. Stalberg. Additional field and laboratory support was provided by A. Allan, J. Black, J. Newman, and R. Palmer, participants in the Job Development Program sponsored by the West Vancouver Chamber of Commerce. We are grateful to Perry Poon for his diligence and patience while conducting stomach analyses. Tom G. Brown, Bob Gregory and Marvin Rosenau reviewed earlier versions of the manuscript.

References

Apfelbaum S.I. & Sams C.E. (1987) Ecology and control of reed canary grass (*Phalaris arundinacea* L.). *Natural Areas Journal* 7, 69–72.

Brown T.G. (1987) Characterization of salmonid overwintering habitat within seasonally flooded land on the Carnation Creek flood plan. *Land Management Report*, No. 44. Victoria, B.C.: Research Board Ministry of Forests and Lands. 42 pp.

Cowardin L.M., Carter V., Golet F.C. & LaRoe E.T., (1979) *Classification of Wetlands and Deepwater Habitats of the United States*. Washington, DC. Office of Biological Services, Fish and Wildlife Service, U.S. Dept of the Interior, FWS/OBS-79/31. 103 pp.

Higgs D.A., Macdonald J.S., Levings C.D. & Dosanjh B. (1995) Nutrition and feeding habits of Pacific salmon (*Oncorhynchus* spp.) in relation to life history stage. In: R. Brett, W.C. Clarke, K. Groot, & L. Margolis (eds). *Physiological Ecology of Pacific Salmon.*, Vancouver, B.C: University of B.C. Press. **510**, 159–316.

Kistritz R.U., Porter G.L., Radcliffe G. & Ward. P.R.B. (1992) *An ecological study of Surrey Bend.* Prepared for the Fraser River Estuary Management Program and the District of Surrey. Available: Suite 301–960 Quayside Drive, New Westminster, British Columbia, V3M 6G2. 120 pp.

Levings C.D., Conlin K. & Raymond B. (1991) Intertidal habitats used by juvenile chinook salmon (*Oncorhynchus tshawytscha*), rearing in the North Arm of the Fraser River estuary. *Marine Pollution Bulletin* **22**, 20–26.

Levy D.A. & Northcote T.G. (1979) Juvenile salmon utilization of tidal channels in the Fraser River estuary, British Columbia. *Westwater Research Centre Technical Report.*, No. 23. Vancouver, B.C. University of B.C. 117p.

Levy D.A. & Northcote T.G. (1982) Juvenile salmon residency in a marsh area of the Fraser River estuary. *Canadian Journal of Fish and Aquatic Sciences* **39**, 270–276.

Macdonald J.S., Kistritz R.U. & Farrell M. (1990) An examination of the effects of slough habitat reclamation in the lower Fraser River, British Columbia: detrital and invertebrate flux, rearing and diets of juvenile salmon. *Canadian Technical Report of Fish and Aquatic Sciences* 1731. 71p.

Mathias J.A. (1971) Energy flow and secondary production of the amphipods *Hyalella azteca* and *Crangonyx richmondensis occidentalis* in Marion Lake, British Columbia. *Journal of the Fisheries Research Board of Canada* **28**, 711–726.

Murray C.D. & Rosenau M.L. (1989) Rearing of juvenile chinook salmon in non-natal tributaries of the lower Fraser River, British Columbia. *Transaction of the American Fisheries Society* **118**, 284–289.

Northcote T.G. & Larkin P.A. (1989) The Fraser River: a major salmonine production system . In: D.P. Dodge, (ed.) *Proceedings of the International Large River Symposium. Canadian Special Publication Fisheries and Aquatic Science* 106. pp. 172–204

Northcote T.G., Johnston N.T. & Tsumura K. (1976) Benthic, epibenthic, and drift fauna of the lower Fraser River. *Westwater Research Centre Publication* No. 18. Vancouver, B.C. University of British Columbia. Press. 51 pp.

Ward P., Moore K. & Kistritz R. (1992). Wetlands of the Fraser Lowland, 1989: an Inventory. *Environment Canada, Canadian Wildlife Service Technical Report* 146. 216 pp.

Whitehouse T.R., Boyle D.E., Levings C.D., Newman J. & Black J. (1993) Fish distribution within a tidal freshwater marsh in the lower Fraser River. *Canadian Data Report of Fisheries and Aquatic Sciences* 917. 49 pp.