Life Histories, Feeding Tendencies, and Growth Rates of Juvenile Anadromous Salmonids of the Copper River Basin

by Carson Jeffres

INTRODUCTION

The Copper River basin in southeastern Alaska has 6 species of anadromous salmonids. The 6 species of salmonid (Oncorhynchus spp.) are coho salmon (O. kisutch), chinook salmon (O. tshawytscha), sockeye salmon (O. nerka), chum salmon (O. keta), pink salmon (O. gorbuscha), and steelhead trout (O. mykiss). The Copper River basin is predominantly glacial fed which has a great influence on the juvenile salmonid populations. Glacial rivers are generally turbid which reduces the visibility for the fish to locate prey. The turbidity also decreases the amount of primary productivity that takes place, thus reducing the amount of potential prey. The turbidity can be beneficial to the juvenile salmon because predation is reduced due the inability of the predators to locate the juvenile salmon in the water. The glacial system is also ever changing; flows drop to very minimal levels during the winter and reach flood stage almost every summer. The dramatic change in water level has a large influence on the habitat that is available to the juvenile salmonids at different times of the year. Although the Copper River system is extremely dynamic, the salmon and steelhead have adapted well, producing one of the largest salmon runs in the state of Alaska. The productivity in the Copper River basin is attributed to the clear water rivers and tributaries off of the main stem of the Copper River in the northern basin. The clear water habitats provide more food and higher temperatures for increased growth. The main glacial rivers in the basin are used primarily as migration corridors between the clear water habitats and the estuary. The following paper will discuss the life histories, feeding tendencies, and growth rates of the juvenile anadromous salmonids of the Copper River basin

COHO SALMON (Oncorhynchus kisutch)

Life History

Coho salmon generally emerge from their gravel redd during the night or at other low light times. Immediately after the fry emerge they are generally found in small schools or aggregations of newly emerged fry. After a few days the fry leave the main channel gravel and swim to the bank where they take shelter in backwaters, side channels, under branches and overhanging banks (Groot 1991). The juvenile coho prefer habitat with a low water velocity (<10 cm/s) and low turbidity (Murphy et al 1989). In the Copper River, the fry are most likely to be found in the tributaries, tributary mouths, beaver ponds and sloughs of the main channel. These habitats are desired by the coho because of the low water velocity and the low turbidity, relative to the main channel. The coho fry will spend the next year in the stream where they were born and will migrate to the ocean the following spring or summer. Some juvenile coho have been found to spend as many as 4 years in freshwater. Of the fry that stay longer than one year, coded-wire tagging showed that the survival rate is approximately 40% for each additional year in the fresh water (Murphy 1997). Generally the higher the latitude, the higher percentage of fry that stays longer than one year in fresh water.

Feeding

Juvenile coho are visual feeders and do not feed at night. They only feed on prey that is moving, such as drifting insects, terrestrial insects, flesh and eggs (Bilby 1998). Dipteran (Chironomidae) larvae in the water column comprise the majority of the prey from the aquatic environment. Eggs from spawning fish and the flesh from the spent fish carcasses also comprise a large amount of nutrition for the juvenile coho, but only during the times when the adult fish are present in the river system. Another important food source for juvenile coho is terrestrial insects that land or die on the water. After spending a year in the freshwater environment the juvenile coho may become predatory on other fish species as well as newly emerged coho (Groot 1991). Feeding occurs primarily in the warm summer months when food is available, and virtually ceases during the winter months in northern latitudes.

Growth

When the fry emerge from the gravel, they are generally about 30 mm in length. A month after the fry emerge they have been found to grow to a length of 52 mm (Groot 1991). In more northern latitudes the coho fry grow most rapidly during the spring just after the snow and ice have left the stream. The highest growth rate is generally around March, while little to no growth occurs during the winter or fall months. The decrease in growth rate during the winter is the result of low temperatures and a decrease in prey availability. The peak coho smolt migration in the Copper River basin is predicted to be similar to that found in Murphy et al. (1997), in a similar river in southeast Alaska (Figure 1). The peak migration will coincide with the large flows that result from the increased melting of the glaciers in the spring and early summer [refer to (Bowersox, 2002) in this volume for more detail]. The large flows in the main stem of the river increase the speed that the smolts can migrate down the river. The smolts will generally migrate out of freshwater at a fork length of around 100 mm (Groot 1991). This explains why in upper latitudes the fish may stay in the freshwater longer due to the decreased overall growth rate in the shorter growing season.

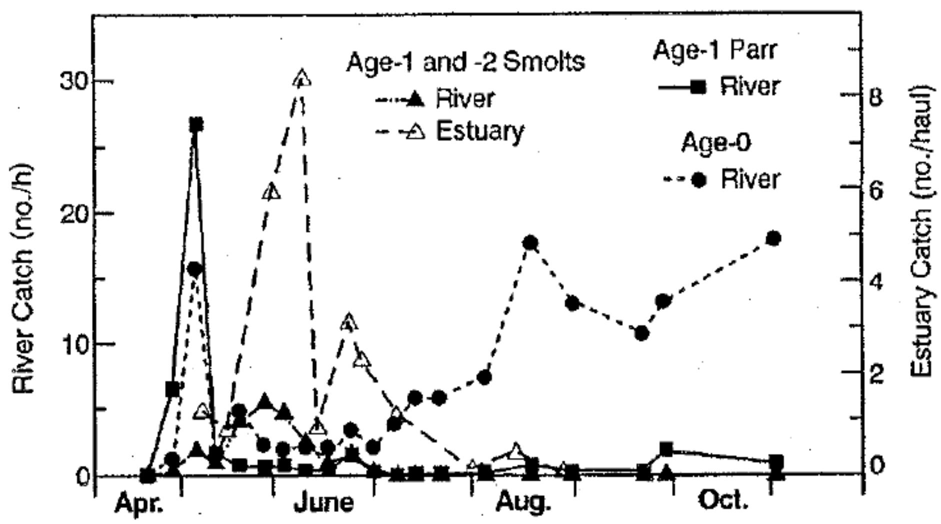
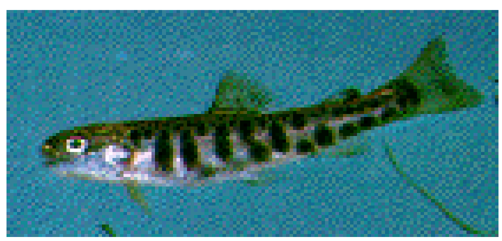


Figure 1. Plot of river and estuary catch vs. timing of catch. (Murphy et al. 1997)

CHINOOK SALMON (Oncorhynchus tshawytscha)



Life Histories

Chinook salmon emerge from the gravel at night as alevins, juvenile fry still possessing the yolk sac. When the alevins emerge they have reduced swimming ability until the yolk sac is absorbed. Due to the lack of swimming ability most of the fry are displaced downstream from high flows during emergence (Groot 1991). For possible population genetic diversity reasons, some fry will stop downstream migration and stay in the fresh water from a few weeks to a year. This difference in life histories results in an increase in genetic diversity from different age cohorts leaving from and returning to the river at different sizes and ages. River discharge at the time of emergence may play an important role in the in determining if the juvenile chinook will be the “stream type”, which over-winters in fresh water, or “ocean type”, which migrates straight to the ocean in the first summer after emergence. If the river has high discharge during emergence, then a higher percentage of the juvenile fish are swept downstream and become ocean type (Groot 1991). During the downstream migration or over wintering, the juvenile chinook prefer a faster water velocity than the other two types of upstream spawning salmon, coho and sockeye (Murphy et al 1989). The juvenile chinook are not affected by different turbidities as much as juvenile coho and sockeye, rather water velocity seems to be the determining factor in habitat selection by juvenile chinook (Murphy et al 1989). In the Copper River we expect to find the juvenile chinook in the margins of the main channel and the river braids. In these habitats the water is turbid, but has a slower water velocity than the main channel.

Feeding

Juvenile chinook salmon feed mainly on larval and adult aquatic invertebrates. The diet of juvenile chinook can be seasonal depending on the most prevalent insect at a given time of year (Sagar 1987). Feeding is mainly composed of larval dipterans and ephemeropterans (mayflies) in the drift. It has also been found that juvenile chinook in turbid waters feed primarily during the daylight. This may be due to the limited light that penetrates the water for the fish to distinguish prey from non-prey items in the drift (Sagar 1987).

Growth

The fry that migrate downstream during the first year after emergence generally have two different size classes. Those that migrate immediately after emergence generally enter the estuary between 30 – 45 mm fork length. The fry that remain in the stream for a longer period of time, but not over winter, enter the estuary between 50 – 120 mm fork length. The fry that over winter in the freshwater streams tend to enter the estuary between 100 – 160 mm fork length (Groot 1991). The 3 different life history strategies may be a way to best utilize the resources available in the river system. The different life histories may also help to increase genetic diversity in the stream with different age classes of fish returning at different maturities and during different years [refer to (Koenig, 2002) in this volume for more detail].

SOCKEYE SALMON (Oncorhynchus nerka)

Groot 1991

Life History

Juvenile sockeye congregate just below the surface of the gravel just before emergence. During the darkest part of the night the fry will leave the gravel in a mass emergence. After the fry leave the gravel they are negatively buoyant and must dart to the surface to fill their swim bladders to reach neutral buoyancy (Groot 1991). Once the fry have filled their swim bladders and are able to swim efficiently, they will only migrate during night for the first few weeks after emergence. If a lake is downstream from the spawning site, then the fry will migrate down to the lake and become the stream-type of juvenile sockeye (Murphy 1989). Fry will then over winter in the freshwater lake for 1 to 3 years. Downstream migration from the lake is triggered by an increase in day length and temperature. When the smolts begin to migrate they leave the lake in a period of a few days. Migrations out of the lake can exceed 60 million smolts in a 24-hour period during the peak migration (Groot 1991). The migration is predicted to be similar to the findings of Murphy et al. (1991), in the Taku River in southeast Alaska. The majority of smolts that were reared in lakes, composed of age 1 and age 2 fish, will migrate when the flows increase in the spring and early summer (Figure 2). If emergence is in a stream with no lake downstream, then most of the fry will out-migrate in the summer of emergence and become ocean-type (Murphy 1989). The out-migration will happen over a few months time so that the fry can grow while in the fresh water to increase survivability in the estuarine environment (Figure 2). In some cases, some of the fry may over winter in a stream with no lake, thus becoming stream-type, and migrating the following summer. In both stream-type and ocean type sockeye the juvenile habitat selection during migration is very similar to coho salmon. The juvenile sockeye prefer slower water velocities (<10 cm/s), with less turbid water (Murphy et al 1991). This causes a habitat overlap with the juvenile coho salmon. There is competition for space, but due to the difference in feeding tendencies and prey both species are able to coexist in the low velocity and low turbidity habitat. In the Copper River basin the majority of sockeye habitat is in lakes and clear water tributaries of the main stem of the Copper River in the north and west of the watershed [refer to (Koenig, 2002) in this volume for more detail].

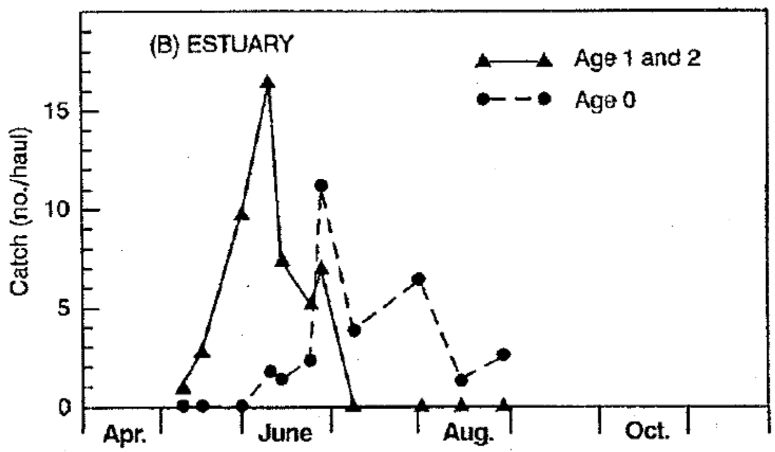


Figure 2. Plot of catch estuary catch of juvenile sockeye vs. time of catch. (Murphy et al. 1997).

Feeding

Soon after emergence from the gravel the fry will start to feed mainly on chironomid larvae. The fry will feed on the chironomid larvae until they leave the stream for the lake or ocean (Groot 1991). Once the fry have entered the lake environment the main source of food is zooplankton in the water column (Bailey 1975). The fry are visual predators and thus are restricted to feeding during the daylight hours. Zooplankton migrate in a diel pattern, and the fry will follow the pattern of the prey in the lake system (Groot 1991). As the year progresses prey abundance will change and the fry will change their feeding patterns so that they can maximize feeding and growth while in the lake environment.

Growth

When the fry enter the lentic environment, they generally enter the new system at a length of 25-31 mm. The fry that are ocean type must first rear in the fresh or brackish water until they are a minimum of 50 mm fork length (Murphy 1997). It has been found that fry under the 50 mm fork length cannot survive the transition to salt water (Heifetz, 1989). When age 1 smolts start to out-migrate to the ocean their sizes range from 58-63 mm, while age 2 smolts range between 70-75 mm (Murphy 1997). Sockeye reared in a glacial system tend to have lower growth rates while in fresh water than fish reared in non-glacial systems (Groot 1991). The decrease in size is likely due to the turbidity of the water, which decreases the amount of light that can penetrate into the water. With a decrease in light penetration, the amount of phytoplankton in the water is reduced. The zooplankton that feeds on the phytoplankton will be decreased due to a limited food supply. Thus, if there is a decrease in light penetration then there will be a decrease in juvenile sockeye growth due to a limited food supply.

CHUM SALMON (Oncorhynchus keta)

Groot 1991

Life History

Chum salmon fry emerge from the gravel only at night. Emergence takes place from spring to midsummer, depending on the latitude of the stream. For the first few days after emergence the fry will only move downstream during the night, or low light hours, but will switch to daytime movements after a few days. Immediately after emergence the fry begin their downstream migration. The time spent in freshwater may be as little a 30 days in shorter river systems (Groot 1991). The fry generally form loosely packed schools when migrating downstream. When approached by another fry, there is a mutual recognition of each other, and the fry may not perform schooling behavior, but will still remain in loose packs during migration to the estuary. When fry are moving downstream they do not initiate a hiding behavior when predator attacks occur. When the schools of fry are attacked by predators they do not attempt find cover, they instead continue their migration. This response can increase the likelihood of mortality during migration. The mean mortality rates for chum fry while in the fresh water range from 37 – 58%. This is a high mortality rate considering the short length of the migration of the chum fry. The major predators on chum fry are yearling or older coho and sculpin (Groot 1991).

Feeding

Chum fry generally feed little during their downstream migration. This is mainly due to the short length of the migration. Feeding activity increases when they arrive in the estuary. In longer river systems where the adults spawn farther upstream, the fry have been known to feed during the downstream migration (Groot 1991). Feeding primarily takes place at dusk or low light conditions. The fry feed primarily on chironomid, mayfly, and stonefly larvae. The fry that feed in the freshwater tend to spend more time growing in the freshwater and reach the estuary at a larger size. Due to the difference in feeding habits, the size of the smolt during migration is highly variable. Sizes of smolts range from 29-107 mm (Groot 1991). The larger the smolt, the more time has been spent in freshwater feeding. The smolts of smaller sizes < 43 mm are more vulnerable to dispersion by currents and increased predation when they reach the estuary. Once the smolts reach the estuary they feed primarily on zooplankton (Bailey 1975).

PINK SALMON (Oncorhynchus gorbusha)

Groot 1991

Life History

Pink salmon fry emerge from the gravel mostly at night or low light conditions. After emergence the fry are negatively buoyant and need to swim rapidly to the surface to fill their swim bladders to obtain neutral buoyancy. Once the fry are able to swim sufficiently, then they start their downstream migration (Groot 1991). During the downstream migration, the fry start to move more during daylight hours, and less at night. The fry migrate downstream close to the surface of the river or stream. As the fry get closer to the estuary, they begin to form large schools. Once the fry have formed the schools, they will not abandon the school even during attacks by predators (Groot 1991). The fry will rear in the estuary until they are large enough to migrate to the ocean environment. A few stocks of pink salmon have been found where the immediate migration to the ocean is halted, forcing the fry to over winter in the fresh water of the stream. Due to a similarity of spawning habitat and timing, the possibility of a pink-chum hybrid does exist. The percentage of hybrids is very low and rarely seen in the wild populations. The hybridization occurs most of the time not from direct fertilization of the eggs, but from spermatozoa that is in the drift and fertilizes eggs downstream of the spawning site (Groot 1991).

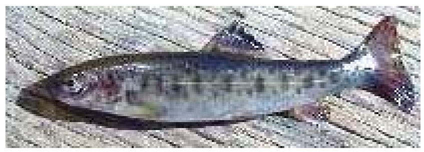
Feeding

Due to the short nature of the pink salmon migration, very few of the fish feed during the downstream migration. Some fry have been found to feed on small amounts of chironomid larvae. In addition to insect larvae, relatively large amounts of sand have been found in the stomachs of juvenile pink salmon (Groot 1991). The sand is thought to have originated from the emergence when the fry were swimming through the gravel to emerge. Many of the fry that emerge early still have yolk sacs during their migration toward the estuary. The yolk sac provides enough energy so the fry do not need to feed during the short journey to the estuary.

Growth

The pink salmon fry are small during the downstream migration relative to other salmon species. The fry length is generally between 28 and 35 mm (Groot 1991). It has been found that during the downstream migration some fish may actually have a negative growth rate (Groot 1991). This is likely due to the fact that very little feeding occurs during downstream migrations. With little feeding and energy being expended to go downstream, the fry may have to use bodily reserves until they reach the nutrient rich waters of the estuary.

STEELHEAD TROUT (Oncorhynchus mykiss)



Life History

Steelhead trout are the anadromous form of the rainbow trout. Steelhead trout emerge form the gravel as alevins and absorb their yolk sac over a period of 3 to 7 days (Pauley 1986). As the fry grow they begin to establish territories for feeding. The use of instream cover is very important in the survival rates of juvenile steelhead. Items such as rocks, logs, and aquatic vegetation provide protection from both current and predators. The juvenile steelhead will stay in fresh water from 1 to 4 years before migrating to the ocean (Pauley 1986). The juvenile fish that rear in the freshwater longer have increased survivability in the ocean environment. The juvenile steelhead are found in the clear water tributaries and rivers of the upper Copper River basin [refer to (Koenig, 2002) in this volume for more detail]. The steelhead require the clean water with larger amounts of food and increased temperatures for growth. The steelhead smolts only use the turbid main stem of the Copper River as a migration corridor from the clear water habitats of the upper river to the estuary.

Feeding

While in the fresh water, juvenile steelhead act very similar to non-anadromous rainbow trout. They feed primarily on aquatic and terrestrial invertebrates throughout year. When other adult species of anadromous fish are present in the system, the eggs from spawning and the flesh from the decaying carcasses provide increased nutrient value to the juvenile steelhead (Bilby 1998). After the anadromous adults have spawned, the juvenile steelhead will feed on the emergent alevins and fry of salmon species that inhabit the same watershed. The juvenile steelhead will migrate to the ocean when they reach a size of 140 to 160 mm (Pauley 1986). In streams with high productivity, the fry will have an increased growth rate and spend less time in the fresh water. Fry living in low productivity areas or short growing seasons will have to spend more time in the fresh water until they are large enough to out-migrate. It is likely that the steelhead in the Copper River basin remain in fresh water longer, due to the short growing season, and the northern most distribution of the anadromous species of rainbow trout.

DISCUSSION

The life histories of juvenile salmon and steelhead in the Pacific Ocean are dependant on many environmental factors. The change in latitude for different populations of the same species of salmon can have a major influence on emergence, growth, and migration of juveniles. Salmon and steelhead in lower latitudes tend to grow faster and migrate to the ocean sooner than the same species of the more northern latitudes (Groot 1991). This is mainly due to the longer growing season, along with milder winters that allow the fry to continue growing during the winter months. With a decrease in growth rate, a higher percentage of the fry will not be ready to enter the ocean environment. They will rear up to 3 more years in the fresh water environment until they are large enough for survival in the ocean (Groot 1991).

Latitude also plays a role in the type of stream that the salmon will rear in. In the more northern latitudes, glaciers are more prevalent. In glacial rivers the sediment load in greatly increased, which increases the turbidity, and reduces light penetration as compared to a clear water stream. As a result, there is less primary productivity, fewer aquatic invertebrates, and less food for the juvenile salmon and steelhead (Sagar 1987). The high turbidity also reduces the success of juveniles in seeing and capturing prey. The increased turbidity does have the positive effect of decreasing mortality from predators (Milner 1994). Decreased visibility makes it more difficult for predators to find juvenile salmon and steelhead.

The ecology of the stream environment plays a critical role in the development of adult fish from eggs. In the Copper River most of the rearing of juvenile salmonids is in clear water tributaries and clear rivers in the upper watershed. It is in the clear water environment that juvenile salmonids can find sufficient food and temperatures to grow enough in the short growing season of the northern latitudes. After the fry emerge from the gravel, most species heavily rely on aquatic invertebrates as a source of food [refer to (Passovoy 2002) in this volume for more detail] (Groot 1991). It is the nutrition from the aquatic invertebrates that allows the fry to grow and prepare for the out-migration and life in the ocean. The terrestrial environment provides the streams with plant material to support aquatic insect communities, which in turn feed the juvenile salmon. Terrestrial insects can also be an important source of prey for growing juvenile salmon (Groot 1991).

The physical processes of the river are important in habitat construction and destruction, and downstream migration [refer to (Wheaton 2002) in this volume for more detail]. Glacial systems have a much larger difference in the high summer flows and the low winter flows. The change in flows causes large changes in habitat from summer to winter. Summer high flows are constantly creating or destroying habitat for juvenile salmon, and can help fry during their downstream migration (Groot 1991). Floodwaters may also be beneficial to the juvenile salmon and steelhead, by providing access to the flood plain that is rich in nutrients, thereby promoting increased growth. Because low flows may not provide enough habitat for all of the juvenile salmon in the system, some juvenile salmonids may be forced to migrate to the estuary earlier, thus utilizing the entire river system (Murphy 1989). Physical processes upslope of the river also play an important role in the survival of juvenile salmon.

CONCLUSION

The life histories of juvenile salmon and steelhead are dependent on many factors in the environment, from changes in latitude to physical processes that happen both in-channel and upslope of the stream. It is the combination of all of these environmental factors that makes each population adapted to various environments. The coho, chinook, sockeye, and steelhead use the clear water habitats in the upper basin for rearing, and then use the main river as a migratory route. The chum and pink salmon utilize the lower river and delta for spawning and rearing. The juvenile salmonids partition the habitats temporally, spatially, and by prey selection. How each species utilizes the different niches of these environments is what makes each species unique and interesting.

Works Cited

Bailey, Jack E., Bruce L. Wing, Chester R. Mattson 1975. Zooplankton abundance and feeding habits of fry of pink salmon, *Oncorhynchus goruscha* and chum salmon *O. keta*, in a Traitors Cove, Alaska, with speculations on the carrying capacity of the area. Fishery Bulletin. 73: 846-857.

Bilby, Robert E., Brian R. Fransen, Peter A. Bisson, Jason K. Walter. 1998. Response of juvenile coho salmon *Oncorhynchus kisutch* and steelhead *O. mykiss* to the addition of salmon carcasses to two streams in southwest Washington, U.S.A.. Can. J. Fish. Aquat. Sci. 55: 1909-1918.

Groot, C., L. Margolis. Pacific Salmon Life Histories. Vancouver: UBC Press, 1991.

Heifetz, Jonathan, S.W. Johnson, K.V. Koski, M.L. Murphy. 1989. Migration timing, size and salinity tolerances of sea-type sockeye salmon (*Oncorhynchus nerka*) in an Alaska estuary. Can. J. Fish. Aquat. Sci. 46: 633-637.

Milner, Alexander M., Geoffrey E. Petts. Glacial rivers: physical habitat and ecology. Freshwater Biology 32: 295-307.

Murphy, Michael L., Jonathan Heifetz, John F. Thedinga, Scott W. Johnson, KV. Koski. 1989. Habitat utilization by juvenile pacific salmon (*Onchorynchus*) in the glacial Taku River, Southeast Alaska. Can. J. Fish. Aquat. Sci. 46: 1677-1685.

Murphy, Michael L., KV. Koski, J. Mitchel Lorenz, John F. Thedinga. 1997. Downstream migrations of juvenile pacific salmon (*Oncorhynchus* spp.) in a glacial transboundary river. Can. J. Fish. Aquat. Sci. 54: 2837-2846

Pauley, Gilbert B., Bruce Bortz, Michael Shepard. 1986. Steelhead Trout. Biological Report, National Wetlands Research Center. 82 (11.82)

Sagar, P.M., G.J. Glova. 1987. Prey preferences of a riverine population of juvenile chinook salmon, *Oncorhynchus tshawytscha*. J. Fish Biol. 31: 661-673.