Life Histories and Distributions of Copper River Fishes

by Martin Koenig

INTRODUCTION

In the southeast corner of Alaska, extending inland from Prince William Sound and the lies the massive Copper River. As Alaska's fourth largest river, the Copper is dominated by glacial influences. Like the Taku River of British Colombia, described by Murphy et al. (1989), the upper reaches of the Copper are characterized by coarse sediments and upwelling groundwater [see (Bowersox 2002) in this volume for more detail]. This combines with cold running waters and a network of large lakes to establish a rich spawning ground for one the world's most famous populations of salmon. Seasonal fluctuations in river discharges may be enormous and the river floods regularly with the breaking of large ice dams [refer to (De Paoli 2002) in this volume for more detail]. Moving downstream, the habitat changes remarkably. Sediment loads increase in the downstream direction, making the Copper very turbid [see (Wooster 2002) in this volume for more detail]. This high turbidity in turn limits primary production in the main stem, making it less ideal than clearwater habitats for aquatic species. The lower river can be characterized by compacted substrates such as mud, sand and small gravel (Murphy et. al. 1989). This leaves little cover from the turbulent flow, and fish must take shelter in the available edge habitat [see (Wheaton, 2002) in this volume for more detail]. Spawning grounds are limited in the lower river by the heavy load of fine sediment, lack of upwelling and low gradient (Murphy et. al. 1989).

The goal of this paper is to give a broad, general summation of the fish species that are likely to be encountered while traveling through the Copper River watershed. This account will describe the key life history characteristics and distributions of the most abundant and widely distributed freshwater and anadromous fishes of the Copper River drainage. Habitats are numerous and variable, and the fish assemblages should change accordingly. The upper part of the drainage, characterized by smaller, clearwater tributaries and a number of headwater lakes may serve as the primary breeding grounds for many of the Copper River's migratory salmon and trout. Murphy et. al. (1997) described salmon habitat in large rivers as a "patch-dynamic system", with migration providing a connection between patches. These waters are also home to resident fish such as the Arctic grayling, rainbow trout, various sculpins and whitefish. As the Copper River nears the ocean,

its waters serve more as a transportation route for migratory fish, and less as a place for fish to reside year-round. The lowest reaches of the Copper River may be inhabited seasonally by pink and chum salmon, as well as anadromous smelts and sticklebacks. These lowest reaches of the river and the estuary may serve as important rearing grounds for large numbers of salmon before they make their way out to sea.

FISH SPECIES

The Copper River is home to a diverse array of freshwater fish species. The following table (modified from Hocutt and Wiley, 1986) gives a summary of species found in the Copper River, and their respective life histories and likely habitats.

Common Name	Scientific Name	Life History	Major Habitat (Copper River)	Distribution (Copper River)	Abudnance (Copper River)
Pacific lamprey	*Lampreta tridentata*	Anadromous	Tributaries to lower river	Lower river, Chitina	Common
Green sturgeon	*Acipenser medirostris*	Anadromous	Estuary, delta	Mainly marine	Rare
White sturgeon?	*Acipenser transmontanus*	Anadromous	Estuary	Probably estuary	Rare
American shad?	*Alosa sapidissima*	Anadromous	Mainstem?	Lower river?	Rare, if present
Lake whitefish	*Coregonus clupeaformis*	Resident	Headwater streams, lakes	Uppermost drainage	Fairly common
Pink salmon	*Oncorhynchus gorbusha*	Anadromous	Intertidal, delta	Estuary, delta, lower river	Abundant
Chum salmon	*Oncorhynchus keta*	Anadromous	Intertidal, delta	Estuary, delta, lower river	Common
Coho salmon	*Oncorhynchus kisutch*	Anadromous	Clearwater tribs	Upper drainage	Common
Sockeye salmon	*Oncorhynchus nerka*	Anadromous	Lakes, delta	Upper drainage lakes, delta	Abundant
Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous	Mainstem river, clear water tribs	Upper drainage	Common
Cutthroat trout	*Oncorhynchus clarki*	Anadromous	Clearwater tributaries	Coastal streams, lower tribs.	Fairly common
Rainbow trout	*Oncorhynchus mykiss*	Anadromous/Resident	Clear water tributaries, lakes	Throughout, mostly higher waters	Common
Pigmy whitefish	*Prosopium coulteri*	Resident	Lakes, clear water streams	Throughout?	Common?
Round whitefish	*Prosopium cylindraceum*	Resident	Clear water tributaries, lakes	Throughout?	Common?
Dolly Varden	*Salvelinus malma*	Anadromous/Resident	Clear water tributaries	Lower watershed	Locally common
Lake trout	*Salvelinus namaycush*	Resident	Lakes	Upper watershed	Fairly common
Arctic grayling	*Thymallus arcticus*	Resident	Clearwater tributaries, lakes	Throughout	Common/Abundant
Pond smelt	*Hypomesus olidus*	Resident	Ponds, streams	Delta, lower river	Common
Longfin smelt	*Spirinchus thaleichthys*	Anadromous	Coastal streams, estuary	Estuary, delta,	Not known
Eulachon	*Thaleichthys pacificus*	Anadromous	Lower mainstem, delta	Lower river, delta?	Common?
Longnose sucker	*Catostomus catostomus*	Resident	Lakes, streams	Upper part of drainage	Common
Burbot	*Lota lota*	Resident	Lakes	throughout? Mainly upper	Common
Threespine stickleback?	*Gasterosteus aculeatus*	Anadromous/Resident ?	Estuary?, Delta?, backwaters?	Lower river?	Not known
Coastrange sculpin?	*Cottus aleuticus*	Amphidromous	Estuary, Delta, small tribs	Lower 25-50km?	Not known
Prickly sculpin?	*Cottus asper*	Amphidromous	Estuary, clear water streams?	Lower river?	Not known
Slimy sculpin	*Cottus cognatus*	Resident	Clear water tributaries?	Upper drainage?	Common?

Table 1. General summary of the fishes known to inhabit the Copper River.

The Copper River receives migratory runs of several salmon species. These "runs" of fish are spread throughout the season, preventing several species from spawning at exactly the same time or in the same place. Other fish species live in the river year-round and may be available at certain times as well. Table 2 gives a general timetable of fish availability relating to the Upper Copper River.

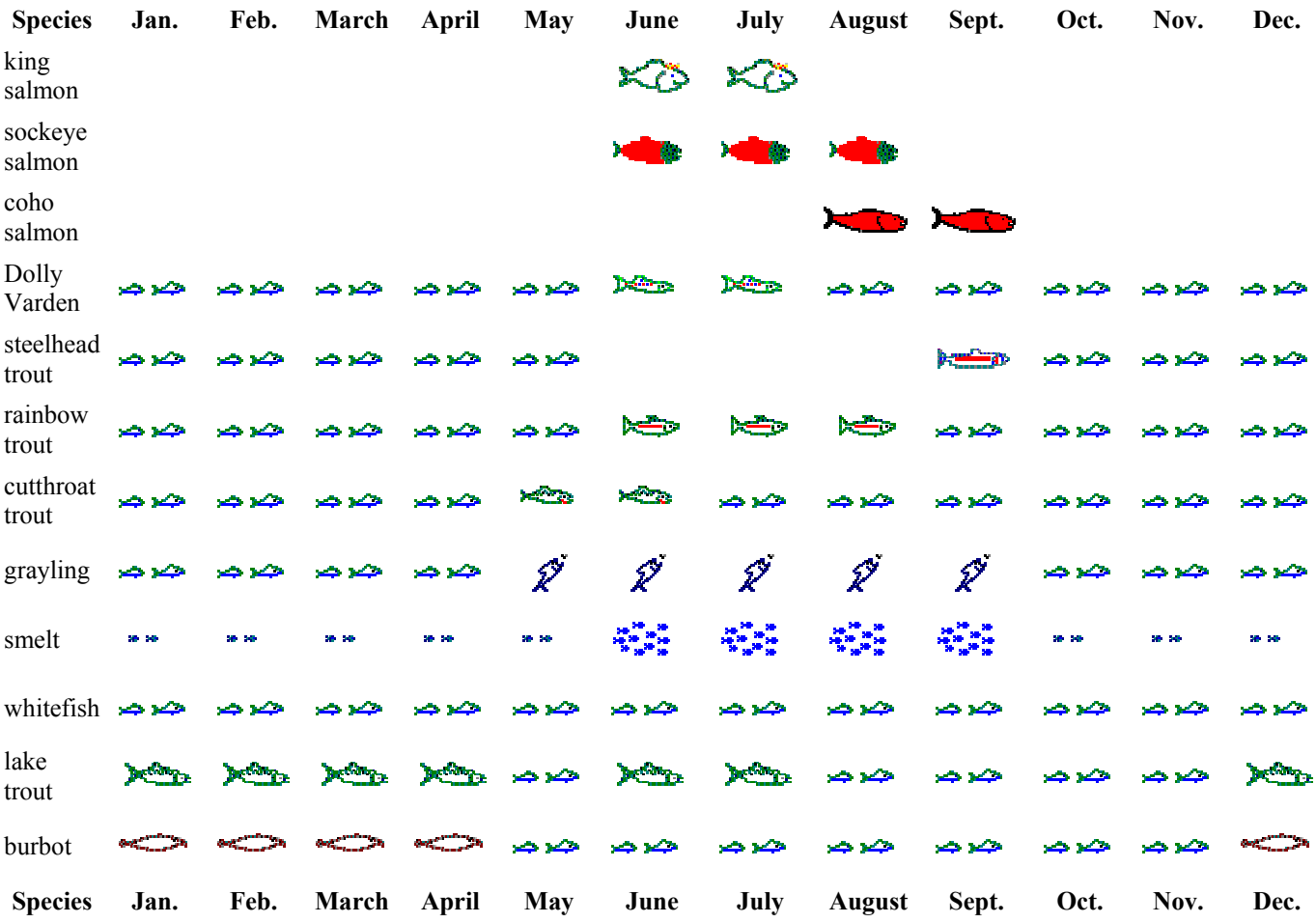

Table 2. This table indicates when sport fish are present (little fish) or at their peak availability (larger fish) in fresh water in the area of Alaska which includes Prince William Sound and drainages south of the Alaska Range serviced by the Richadson Highway, the Tok Cut-off, and the eastern half of the Glenn Highway. Communities in the area include Whittier, Valdez, Cordova, Glennallen, Copper Center, Sourdough and Paxson (AKDFG 2002).

The Copper River basin consists of two major branches: the Copper River and the Chitina River. Most of the salmon that enter the system will travel through the mainstem of the Copper River enroute to spawning grounds in the Upper Copper River watershed. The main salmon

spawning areas in this region are the Gulkana, Tazlina, Tonsina and Klutina rivers and their associated lakes (Fig.1).

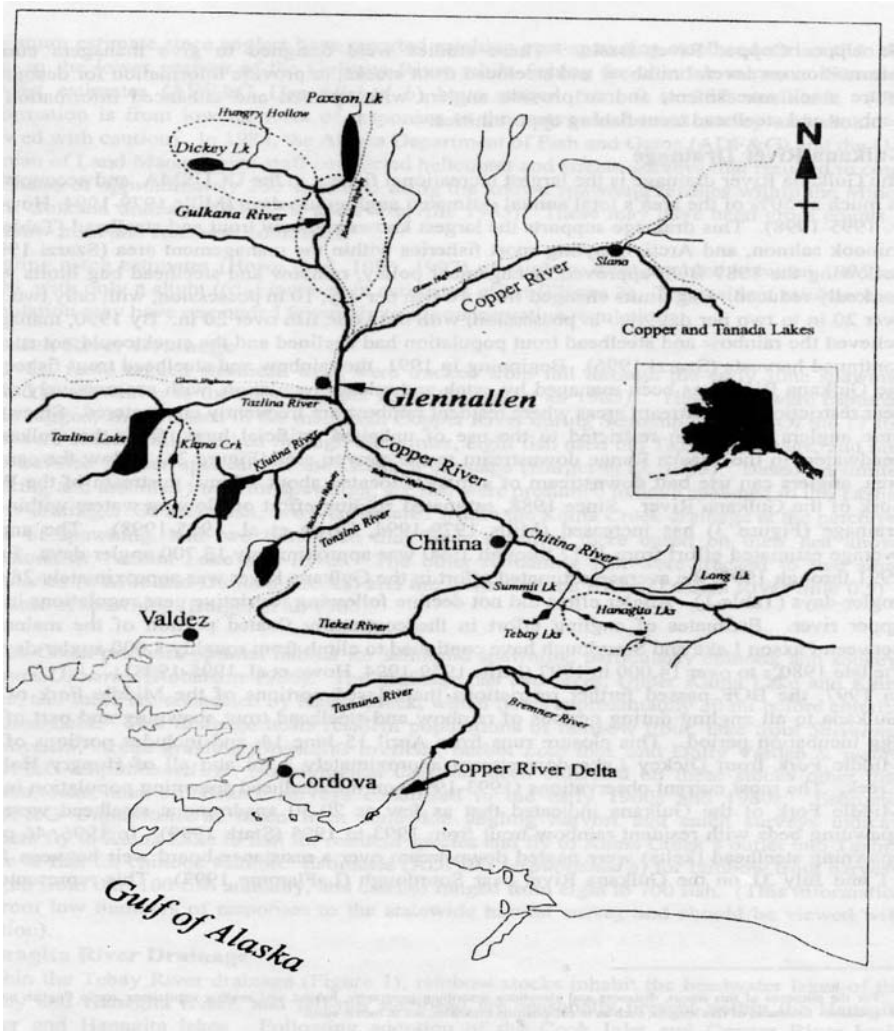

Figure 1. The major streams of the Copper River drainage (Fleming, 1999).

General Salmon Life-History

Each salmon species has it's own life-history traits and relative abundance. Each species also divides itself into separate races in different river systems and yet again into diverse stocks or races within the watersheds (Childerhorse, 1979). Salmon exhibit an anadromous life cycle, in which adult fish migrate from the ocean to spawn in freshwater (Fig. 2). Most species are also semelparous, spawning only once, and then dying soon after. Adults return to their natal stream, and the timing of this return is highly variable according to species, the particular run and latitude. Upon returning to the spawning grounds, females begin to dig nests in the river gravel called redds.

Courtship is followed by deposition of sperm and eggs into the gravel simultaneously. The female then covers the eggs with gravel and may guard the nest, until she dies a few days later.

Figure 2. Sockeye salmon during their upstream migration (Watson, 1999).

Eggs hatch while inside the gravel of the redd. The newly hatched larval fish called alevins have an attached yolk sac for the nutrition needed for initial growth (Fig. 3). Once the yolk sac is consumed, the alevins then emerge from the redd into the stream as free-swimming fry [refer to (Jeffres, 2002) in this volume for more detail].

Figure 3. Pacific salmon eggs and alevins (Watson, 1999).

Fry begin to feed heavily on various aquatic foods to grow quickly (Fig.4). The small, active fry develop a series of bars on their sides (parr marks) and are then called parr, a stage that may last a few months or years (Moyle and Cech, 2000). After reaching appropriate size, parr undergo significant hormonal changes that transform them into migrating smolts. Smolts take on a bright silvery appearance and become adapted to saltwater in preparation for their ocean residence.

Figure 4. Chum salmon fry (Groot and Margolis, 1991).

While at sea, adult salmon are aggressive predators, usually feeding on smaller fish and crustaceans. The abundant food of the ocean allows salmon to quickly reach large sizes. Ocean migrations of adult salmon vary heavily with each species and stock. Some salmon remain close to the coastlines, while others are know to travel great distances before returning to spawn. After two to five years at sea, adults begin to migrate back to their natal streams to begin their accent to the spawning grounds, where the cycle will repeat for another generation.

Salmon species

Chinook Salmon

Chinook salmon (*Oncorhyncus tschawytscha*) is the largest of the Pacific salmon species (Fig. 5). Their life history is typical of most anadromous (moving from saltwater to freshwater to spawn) salmonids. Chinook may fall into one of two behavioral types: stream-type or ocean-type, with most northern stocks being of the stream-type life history. Ocean-type Chinook spend little time in the stream, and move to sea at an earlier age. Stream-type chinook salmon spend at least one year in freshwater before setting off to sea (Watson, 1999). These fish are also characterized by longer and more widespread ocean migrations. Juveniles feed aggressively during the summer after hatching, then seek shelter during the winter to conserve their energies [refer to (Jeffres, 2002) in this volume for more detail]. Migration for most ensues in the following spring, and some will remain in the stream another year. Most stream-type chinook return to their natal streams as adults in spring. For stream-type chinook, ages range from 3.69 to 5.64 years for males, and from 4.39 to 6.12 years for females (Groot and Margolis, 1991).

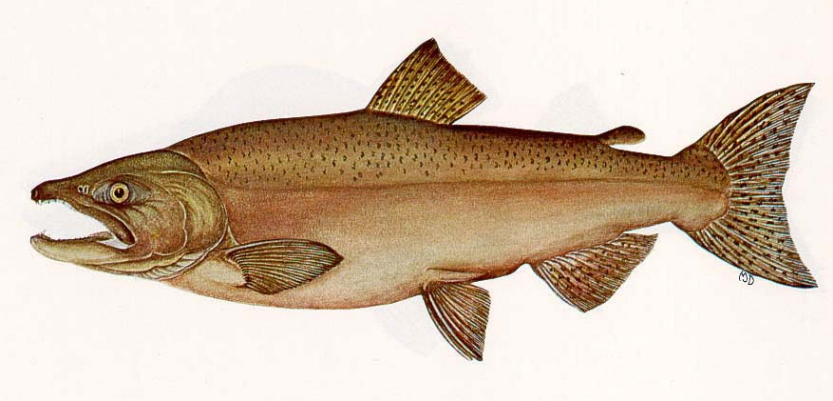

Figure 5. Male Chinook salmon in spawning colors (Morrow, 1980).

Spawning stocks of chinook salmon are distributed from northern Hokkaido to the Anadyr River on the Asian coast and from Central California to Kotzebue Sound, Alaska on the North American Continent (Groot and Margolis, 1991). Western Alaska chinook are widely distributed throughout the Bering Sea and the North Pacific Ocean. While at sea, chinook feed mainly on smaller fish, namely herring and anchovies. Other diet items might include squid, various rockfish, sand lance, pilchard, and Clupeids, depending on feeding location and food abundance.

The return time of adults to their natal streams is variable and depends on latitude and the run timing. Northern populations may spawn in May/June, while more southern populations spawn later in November to January. Since most of the chinook in the Copper River system are of the stream-type, returning runs of adults come in the spring.

Chinook return to the Copper River from May through July, with the bulk of the run arriving in June and July. Evenson et al. (2000) determined that the lower portion of the Copper River, which includes the Chitina, Tonsina, Klutina and mainstem Copper rivers accounted for 76% of the returning chinook salmon in 1999. The largest proportion of these fish returned to the Klutina river drainage with the Tonsina River a close second. The Chitina River accounted for 20% of the returning chinook in this study, with 12% returning to the Gulkana River and 10% returning to Upper Copper River tributaries. Evenson et al. (2000) estimated 32,090 chinook salmon passed through the personal use fishery area (confluence of the Copper River with the Chitina) in 1999.

Coho Salmon

Coho salmon, (*Oncorhynchus kisutch*), also known as silver salmon, normally spend at least one year in fresh water before going to sea, although some may go to sea at the end of the first

summer, and others, as in the Karluk River of Alaska, may stay two, three or even four years in fresh water (Morrow, 1980). For more complete information on the juvenile life histories of coho salmon see Jeffres (2002) in this volume.

Figure 6. Coho salmon fry (Watson, 1999).

Migration occurs in spring, and the timing can depend on a combination of many factors, including fish size, water flows, temperature, photoperiod and dissolved oxygen. Coho begin to mature during the summer after one winter at sea and arrive at their rivers of origin during late summer or autumn (Groot and Margolis, 1991). Higher latitude watersheds generally receive earlier runs. In southeast Alaska, silver salmon often mature at age 2.1 (Crone and Bond, 1976) (Fig. 7).

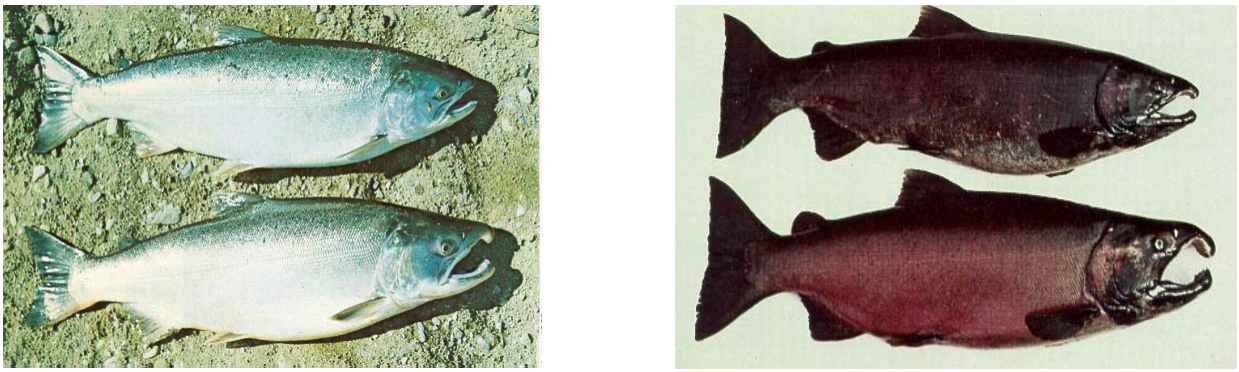

Figure 7. Ocean phase (left) and spawning phase (right) of adult Coho salmon (Morrow, 1980).

The oceanic movements of coho in the southern part of the range seem to be chiefly along the coast, with some fish apparently never venturing far from land (Milne and Ball, 1958; Allen, 1965). By contrast northern fish, particularly those from Alaskan streams, spread out all across the north Pacific and into the Bering Sea (Morrow, 1980).

The natural range of coho salmon extends from the Soviet Far East around the Bering Sea to Alaska, and then south along the North American Coast to California. Coho are caught all along the Alaskan coast from Norton Sound to the mouth of the Kuskowina River. These fish

generally spawn in smaller coastal rivers or smaller tributaries to larger rivers. For the Copper River basin, Coho begin to arrive in early August and are present through September. These fish are to be found in Elisnore Creek, Eyak River, Alagnak Slough, Clear Creek, the Rove River, Little Tonsina River, Kulitina River, and the Gulkana River. Smaller tributaries in the upper Copper River basin and also on the Chitina River could potentially hold coho salmon. The Alaska Department of Fish and Game has also planted coho in many lakes in the Upper Copper/Upper Susitna Management area. These lakes might include Paxson, Summit and Crosswind lakes, as well as several other smaller lakes in the region (AKDFG, 2002). Since these fish arrive later in the fall, it is unlikely that one would encounter them while on the Copper River in early to mid-summer.

Pink Salmon

The pink salmon (*Oncorhynchus gorbuscha* (Walbaum)), is the most abundant of the seven species of Pacific salmon, contributing about 40% by weight and 60% in numbers of all salmon caught commercially in the North Pacific Ocean and adjacent waters (Neave et al. 1967). Although great in number, pink salmon are the smallest, averaging just over 2kg. Pink salmon have the remarkable ability to spawn below the high water mark, with eggs washed by freshwater only at low tide (Watson, 1999). In Prince William Sound, Noerenberg (1963) estimated that the proportion of pink salmon spawning in the intertidal zone over a ten year period (1952-61), in even and odd-numbered years, averaged about 74% and 46%, respectively. The distinction between even and odd number years is important, since pink salmon have a rigid two-year life cycle. This can result in substantially different numbers of returning fish, depending on the year. Even though a large fraction of the returning salmon spawn in the intertidal zone, longer runs are common. Pinks arriving earlier generally spawn farther up in the system.

After emerging from the gravel, fry migrate out to the ocean immediately (Fig. 8). Downstream migration times vary from region to region, but usually falls between February and August, with almost all movement occurring at night. In general, the reported peak periods for fry migration in British Colombia, southeastern Alaska and Hokkaido occur from mid-April to mid-May (Groot and Margolis, 1991). Schools of marine fry stay close to the shoreline in the first few weeks at sea. During this time, they are often opportunistic generalist feeders, but can

sometimes specialize on certain prey items. As pink salmon fry become larger, they begin to migrate to off shore waters. Their diets change to incorporate larger items such as fish, and squid.

Figure 8. Pink salmon fry after emergence (Groot and Margolis, 1991).

Pink salmon have a very rigid two-year life cycle, with 18 months spent at sea. Ocean migration routes can involve considerable distances, and usually consist of a large counter-clockwise circular pattern. This pattern is completed once during the ocean phase. Sexual maturation begins on the last leg of the ocean migration, but is not completed until feeding has stopped and the fish has entered fresh water. The rigid two-year life cycle of the pink salmon may contribute to the odd and even-year cycles. Odd-year fish tend to be more closely related to odd-year fish of other rivers than to even-year fish of the same river. This is also a reflection of the fact that pinks generally have less accuracy in returning precisely to their natal streams. This tendency to stray away from their home streams is thought to help support populations threatened by disaster (Watson, 1999).

Figure 9. Male (top) and female (bottom) pink salmon in spawning colors (Morrow, 1980).

Pink salmon are distributed between Point Hope and Point Barrow and have been reported as far west as the Lena River on Russia's northern shores. Breeding populations also occur all along the Bering Sea coastline, and down to Puget Sound. These fish are able to colonize more northern habitats, since they can escape freshwater quickly before winter brings temperatures to lethal levels, and thus have extended their distribution considerably. Inshore runs in southeastern Alaska return primarily in July and August, but vary according to latitude and odd/even years (Fig. 9). Spawning occurs mostly in late August and September. In the Copper River, these fish should be seen in the lowest portions of the river, and in the intertidal portions of the Delta.

Chum Salmon

The chum salmon, *Oncorhynchus keta* (Walbaum), is second only in adult size to the chinook. Individuals have been reported at over a meter long, weighing over 20kg. Chum salmon, like the pinks, often spawn below the upper reaches of high tide, but may also make longer migrations. Like the pink salmon, chum salmon fry migrate downstream soon after emerging from the gravel. Fry may migrate long distances to the ocean, or just a few hundred meters, depending on where they were spawned. Most migrations occur at night, but some exceptions occur. Longer migrations require fish to travel during some daylight hours to cover enough distance each day. Turbid glacial waters also provide similar protection from predators that nightfall usually brings. Chum fry often travel in large shoals to reduce individual predation risk.

Estuaries provide an important stopover point for chum fry as they make their way towards the ocean. Chum fry increase their chance of survival in the ocean by growing quickly on the rich food supply of estuary habitats, although they are less dependent on this stage of migration than are chinook. The time spent in the estuary is variable, but usually lasts a few weeks. It seems likely that chum salmon of the Copper River system would capitalize on the large Copper River Delta as an ideal rearing habitat. The timing of juvenile chum salmon entry into seawater is commonly correlated with the warming of the nearshore waters and the accompanying plankton blooms (Groot and Margolis, 1991). After inshore resources have declined, and the chum have reached an appropriate size to avoid predation, they then move to offshore waters. Most chum spend 2 to 5 years at sea, explaining their larger size. Northern

stocks of chum stay out for 3-4 years, while chum on the southern end of the range usually stay out for 2-3 years (Watson, 1999). Pink salmon may be major competitors for food while at sea. Chum salmon have strong homing abilities and usually return to their natal streams. Spawning times for northern stocks are usually earlier than southern stocks. Distinct summer and autumn runs or autumn and winter runs are often present in the same streams (Fig. 10).

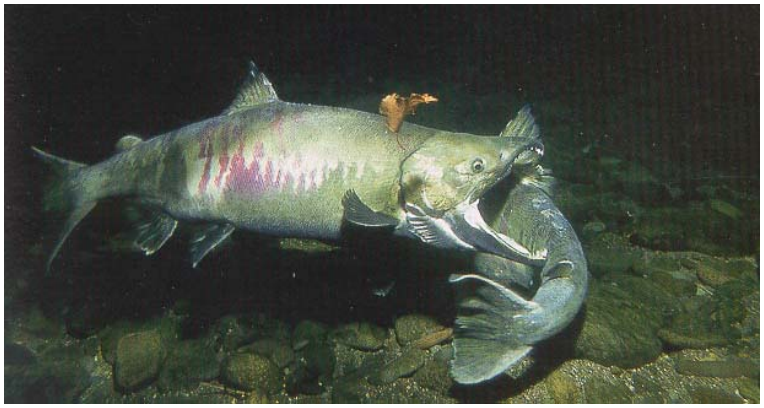

Figure 10. Chum engaging in spawning behavior (Watson, 1999).

For chum salmon native to the southeastern Alaska, the peak of the nearshore abundance was established, for 1984, as the first two weeks of in August (Clark and Weller, 1986). In the Copper River-Prince William Sound area, chums are available to fishermen during July and August.

Sockeye Salmon

The sockeye or red salmon, *Oncorhynchus nerka*, exhibits the most diverse life cycle of all of the Pacific salmon species. These salmon usually weigh between 4 and 8 pounds as adults. Spawning usually takes place in streams that flow directly into lakes, but also may occur in the outlets of lakes, and in lakes themselves. In different areas of the Sitkine River drainage, in northern British Colombia, sockeye have adopted all three different life strategies; some river-spawned young head straight to sea after emerging, others spend almost a year in the river, while those with access to a lake use that as their nursery (Watson, 1999). It is estimated that in the Copper river of Alaska about 20% of the run spawns in the Delta (Morrow, 1980). Sockeye usually spawn in the inflows of what are to be the nursery lake for their young, which drift down on the current into the lake immediately after they emerge (Watson, 1999). This dependence on large lakes along rivers systems constrains the sockeye salmon range to northern latitudes, where such habitat is more common.

After spending one winter in the gravel, eggs hatch, and the fry migrate to the lakes, where they will spend at least another winter (Fig. 11). Typically, but not universally, juvenile anadromous sockeye utilize lake rearing areas for one to three years after emergence from the gravel; however, some of the population utilize stream areas for rearing and may migrate to sea soon after emergence (Groot and Margolis, 1991). Emergence occurs mainly at night, with peak out migrations during the darkest part of the night. Fry emergence usually coincides with the peak in plankton blooms in downstream natal lakes in which they will rear. Here, they will grow quickly to prepare for smoltification and migration to the ocean.

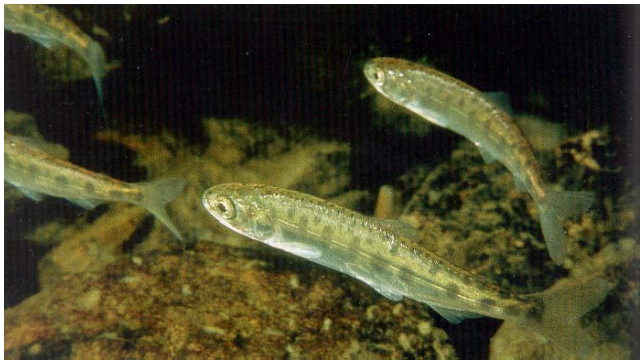

Figure 11. Sockeye smolts (Watson, 1999).

In spring, smoltification is triggered, and sockeye migrate in schools out of their natal lakes within days of ice-breakup. Some sockeye never leave the lakes, and complete their whole life cycle in freshwater. These so called "kokanee" are usually reproductively isolated from sockeye by differences in spawning timing and areas.

Sockeye spend one to four years in the ocean before returning in late summer and autumn (Fig. 12). Sockeye salmon are distributed throughout the North Pacific Ocean, the Bering Sea and over to the eastern Sea of Okhotsk. During the winter, there is a general shift of distributions southward. Stocks then shift again northward with the approach of spring and the warming of ocean surface waters. Adaptations to lake environments seem to require better homing skills to locate such restricted spawning areas. The adult sockeye return to their natal streams during the summer and fall – from July to October in most areas – but as late as December in the southern part of their range (Morrow, 1980).

In Alaska, the largest harvest of sockeye salmon occurs in Bristol Bay, with other large harvests coming from Cook Inlet and Prince William Sound. Around Cordova, sockeye salmon are the first salmon to return. Good numbers of adults begin to return to Eyak River in late May

and early June. Alaganik Slough and Clear Creek receive their runs from mid-June through early July. In the Copper River drainage, June and July offer anglers the chance to catch these migrants in the Gulkana, Robe and Klutina rivers. According to the Alaska Department of fish and Game, the annual run of sockeye salmon returning to the Gulkana occurs from late June to mid-August. Sockeye migrate up the entire length of the Gulkana through Paxson and Summit lakes (AKDFG, 2000). These two lakes are two of the largest lakes in the Gulkana system and provide essential spawning and rearing habitat for these fish. A sockeye salmon hatchery operated by Prince William Sound Aquaculture releases fry into Paxson, Summit and Crosswind lakes in early summer (AKDFG, 2002). Other lakes in the area that may function as sockeye spawning grounds are Dickey Lake and Swede Lake. Tazlina Lake and Klutina Lake are both large lakes at the headwaters of the Tazlina and Klutina rivers (two other important salmon spawning streams on the Upper Copper River). These lakes are likely to be the destinations for sockeye traveling up these large Copper River tributaries.

The Alaska Department of Fish and Game (AKDFG) operates a sonar station at Miles Lake to estimate the numbers of returning fish (escapement). The data from this station offers a good opportunity to understand the relative abundance of sockeye salmon. According to the AKDFG web page listing the Miles Lake sonar data, 26, 287 sockeye passed the station on June 3, 2002. The yearly total for that date was given as 109,306 fish. This number will continue to increase until the run peaks in July.

Figure 12. Ocean phase (left) and spawning phase (right) of adult sockeye salmon (Morrow, 1980).

Other Salmonids

Arctic Grayling

The arctic grayling, *Thymallus arcticus* (Pallus), is another member of the family Salmonidae. It is confined completely to freshwater, and is not semelparous. Grayling do show some degree of migratory behavior on a seasonal basis, moving into different reaches of their home streams at different times of the year. Grayling are generally small, with 4-year-old fish averaging 26.5cm in interior Alaska. They can be distinguished from trout and juvenile salmon by their dramatic dorsal fin and tiny mouth (Fig. 13).

Figure 13. Arctic grayling displaying large dorsal fin (Morrow, 1980).

Grayling usually spawn in mid-May to mid-June when stimulated by increasing water temperatures and spring flooding. According to Tack (1973), a temperature of 4°C triggered grayling to spawn in interior Alaskan streams. Alt (1976) reported a similar spawning temperature for western Alaska as well. Spawning occurs in various habitats, including mainstem rivers, large and small tributaries to rivers and lakes, intermittent streams and in lakes – usually at the stream mouth. Eggs are usually deposited in riffle areas within the stream. While spawning, grayling do not construct redds like those characteristic of salmon. The male forces the posterior of the female into the substrate, where eggs are quickly deposited and fertilized. Males defend territories, and courtship behaviors preclude spawning activity. Embryonic development is rapid, with eggs held at 15.5°C hatching after only 8 days (Wojcik, 1955). After hatching, alevins stay in the gravel 3-4 days (Kratt and Smith, 1977). Emergent fry then inhabit quiet water areas of the stream, such as between rocks, backwaters, side channels and adjacent sloughs.

In late summer, the young grayling move to deeper waters, and later in fall, they will leave the headwaters of their stream to overwinter in larger rivers and lakes. At Poplar Grove Creek (Mile 136 Richardson Highway, in the Copper River drainage) young-of-the-year grayling began outmigration in early September and by 19 October, 62,000 fish had passed through weir traps (Williams and Morgan, 1974). Grayling reach maturity between ages 4 to 8, with maturity

depending more on body size than age. Most adult grayling leave their overwintering areas and enter a bog-fed or unsilted rapid-runoff stream to spawn (Tack, 1980). Only in large unsilted rapid runoff rivers do grayling spawn in the same stream in which they overwinter; even in these rivers, most grayling migrate upstream to parts not used for overwintering (Armstrong, 1986). Migrations to feeding areas depend on the size and age of the fish. Post-spawning adult fish move into higher reaches in the river, above or in the vicinity of the spawning grounds to feed. Subadults tend to migrate to feeding grounds in the middle portions of the stream, while juveniles occupy lower reaches of the stream.

The arctic grayling is common throughout Alaska and northern Canada and is found from the west side of Hudson bay to the western shores of Alaska. In the Copper River drainage, they most likely occupy most clearwater tributaries and streams. They are known to exist in Haley Creek, Uranatina River, O'Brien Creek, Gulkana River, Tonsina River, Bear Creek and others. The Gulkana River is noted as having a particularly abundant grayling fishery.

Rainbow Trout and Steelhead

Rainbow trout (*Oncorhynchus mykiss*) are widely distributed throughout western North America and have been introduced around the globe. The following life history summary will focus on those populations of rainbow trout inhabiting the coastal regions of North America. Rainbows are very similar to their salmon relatives, but exhibit a variety of life histories with significant differences. Coastal rainbows comprise distinct populations of fish that migrate, and fish that do not. The behavior of the individuals making up these populations is remarkably consistent (Watson, 1999). Rainbow trout live as residents to freshwater for the duration of their lives. Rainbow trout also occur in an anadromous form, which are called steelhead. These two very distinct forms may often overlap in the same reaches of a stream and can sometimes be difficult to tell apart based on appearance alone.

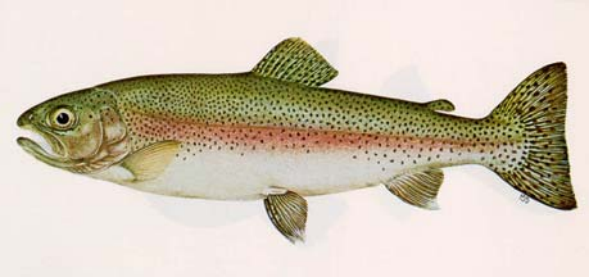

Figure 14. Typical rainbow trout coloration (left) (Morrow, 1980). The author (right) with a typical steelhead trout in ocean colors.

There are no major physical differences between rainbow and steelhead trout. However, the nature of their differing lifestyles has resulted in subtle differences in color, shape and general appearance (Van Hulle, 2002). Rainbow trout are often much more colorful, with greater numbers of black spots and a characteristic red band along the lateral line. Steelhead, especially during their ocean phase, are bright silver, with few spots. As they enter freshwater, their coloration begins to resemble that of the resident rainbow trout (Fig.14).

Rainbow trout are generally considered to be spring spawners, with most fish spawning in mid-April to late June. Typical of most salmonid behavior, females will select the nest site, while males exhibit courting behavior and chase off competing males. Eggs are laid in redds dug into the gravel of riffle areas above pools. Fry will emerge after consuming their yolk sacs as alevins and will then move to sheltered areas of the stream. Juvenile forage primarily on insects, while adults forage opportunistically on larval and adult insects, crustaceans, and other small fish and even leaches. Migration patterns of rainbow trout are variable, but usually do not involve great distances. Stream resident trout will remain in the stream after spawning, while lake resident rainbows will return to their lake habitats after completing their spawning run in a tributary stream. Many rainbow trout spawn more than once. If environmental conditions are good, rainbows may spawn annually for up to five successive years (Hartman, 1959).

Steelhead return to their natal streams to spawn at different times of the year, depending on the particular stream and latitude. In Alaska, some rivers receive strong runs of steelhead in the fall, while some southeastern rivers have spring run fish that arrive in mid-April, May and June. Steelhead trout in the Copper River are believed to have a fall run timing (Fleming, 1999). Fry emerge from the gravel in mid-summer and then seek refuge along the steam edges and quiet waters. Juveniles spend up to three years in freshwater before undergoing smoltification and migrating to the sea in spring. After reaching the ocean, steelhead will feed aggressively and grow large for up to three years before returning to spawn. While in the ocean, steelhead may feed on crustaceans, squid, small fish and large zooplankton.

Steelhead are distributed all along the North American coast as far south as southern California, and as far west as the Kamchatka Peninsula. Rainbow and steelhead trout populations that inhabit the Upper Copper/Upper Susitna drainages are considered the northernmost wild

stocks of this species in North America (Fleming, 1999). These trout populations are comprised of resident rainbow trout (year-round presence) and steelhead trout (anadromous) in varying combinations. The large size of the upper Copper River drainage, the small stock sizes, and the seasonal migration patterns have constrained the knowledge of the distribution of wild rainbow and steelhead trout in this area (Fleming 1999). The Gulkana River, Kaina Creek and the Tebay River drainages are all known to have steelhead and rainbow trout in their waters. Rainbow trout have been reported in other Upper Copper tributaries like the Tonsina and Klutina rivers, as well as other small tributaries such as Menedeltna Creek and Tyone Creek. The overall population of rainbow trout in the region is rather low, and the fishery has been recently managed more strictly in an effort to increase numbers of rainbow trout. The Gulkana became a catch-and-release only rainbow trout fishery in 1990. Taube and Sarafin (2001) reported the average total annual harvest of rainbow trout in the Upper Copper/Upper Susitna drainage from 1989 to 1999 was 587 fish. This is estimate must be an underestimate of the relative population, since the Gulkana River (managed as zero take) didn't contribute to the harvest numbers. Even still, one can see that the rainbow trout population is not abundant.

The average total number of steelhead trout caught by sport anglers per year in the Copper River, Gulkana and Tazlina river drainages combined, from 1990 to 1998 was reported as 138 fish (Taube and Sarafin, 2001). Most of these steelhead were caught in the Gulkana River system. As of December 2000, there has been no stock assessments on the Gulkana designed to estimate stock size or composition of rainbow trout/steelhead (Fleming, 2000). Stocking programs have given rainbow trout a wide distribution in Alaska. In relation to the Copper River, they may be found in Blueberry Lake, Worthington Lake, Sculpin Lake, Summit Lake, above the Chitina River, and in the Gulkana River drainage. Since rainbow trout have been planted in lakes around the Chitina drainage, it may be possible to find them in some of the clearwater tributaries of the Chitina and Nizina rivers.

Dolly Varden

Dolly Varden, Salvelinus malma (Walbaum), exist in both anadromous and stream dwelling resident forms (Figure 15). Little research has been done regarding the stream dwelling type, so most of the following information will apply to the more common anadromous forms. Dolly Varden utilize freshwater habitats for spawning and as overwintering grounds. These fish, like the Arctic charr, have adapted to living in extreme northern climates, where ocean waters

may freeze them to death in winters. Having no physiological defenses against freezing, such as the antifreeze proteins found in Winter flounder, Arctic charr and Dolly Varden move into the "warmer" temperature zones of freshwater streams to spend the winter.

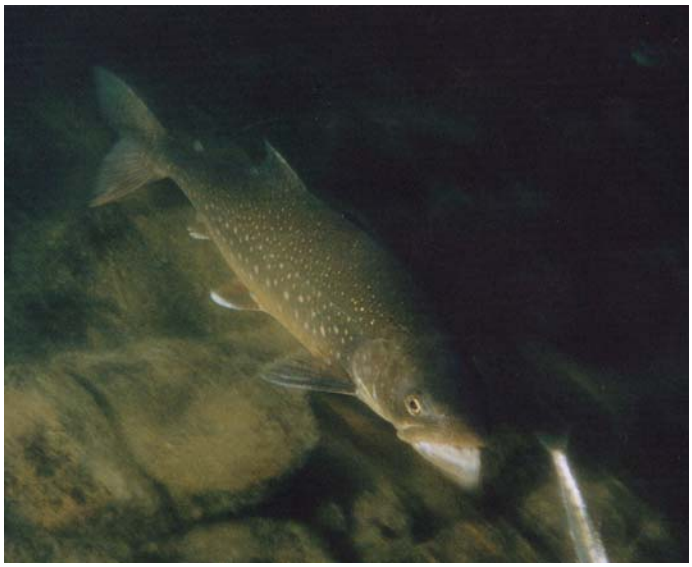

Figure 15. Dolly Varden chasing a sockeye smolt (Watson, 1999).

Spawning occurs in late August to November in the freshwater streams where Dolly Varden overwinter. This event is usually yearly for stocks in the southern end of the range, while northern stocks may only spawn every 2-3 years. Redds are dug in typical salmonid fashion in fairly heavy current. After the eggs hatch, alevins stay in the gravel to absorb their yolk sacs for 60-70 days before emerging. Young Dolly Varden feed on insects and later eat annelids, fish eggs and other small fish. Juveniles usually inhabit pools and slower areas of the stream. Freshwater residence can vary but usually lasts 4-5 years, followed by several years of migrations to saltwater feeding grounds. Dolly Varden smolts leave freshwater in spring, following older fish. They may stay in saltwater for as little as 3 weeks to as long as 7 months, before returning to overwinter (Morrow, 1980). Stream dwelling Dolly Varden may move downstream to deeper pools to overwinter, but usually don't enter major rivers.

Greatest annual growth takes place between May and September each year. Anadromous fish in the sea may double their weight in this short time (Revet, 1962). Ocean migration routes generally follow the coastlines closely, enabling a quick return to freshwater. Sexual maturity is reached between 4-6 years of age in southern stocks, and in 7-9 years in northern populations. Southeastern Alaskan Dolly Varden have been known to get quite old, reaching ages of more

that 10 and 12 years old. The return from the sea to freshwater begins in August, with spawners arriving first, and nonspawners coming in later. Dolly Varden may not necessarily return to their natal stream to overwinter. This may give them a great advantage by not having to make a long migration, allowing them more time to feed in the ocean before having to return to freshwater overwintering grounds. This may also provide a long term survival advantage if conditions in their natal stream were not suitable for overwintering. An estimated 70% of the males and 50% to 60% of the females die after spawning (ADFG, 2002).

Dolly Varden are distributed from the Arctic coast of Alaska to British Colombia on the eastern side of the Pacific Ocean. In the western Pacific, they reach the Russian coastline and south to Japan and Korea. Up the Canadian coast and round into south-western Alaska, most charr are considered to be Dolly Varden, but further north Arctic charr appear in the rivers and lakes, and the overlap between the two seems to be genetic as well as geographical (Watson, 1999). In the Copper River, Dolly Varden are present throughout the drainage in both resident and anadromous forms, except that none have ever been found in the Gulkana River system (Taube and Sarafin, 2001). Dolly Varden occur upstream of the Gulkana River system in the Chitina River system and in drainages downstream of the Gulkana. Taube and Sarafin (2001) state that there is no apparent explanation for the absence of these fish in the Gulkana River drainage. Dolly Varden are popular game fish in streams around Cordova, as well as in the Klutina and Tonsina rivers. Harvest of Dolly Varden in the Upper Copper River watershed from 1983 to 1988 averaged 4,687 fish, with the Klutina and Tonsina rivers contributing 50% and 21% respectively (Taube and Sarafin, 2001). Dolly Varden harvests have declined considerably in recent years, reaching a minimum of 1,092 fish in 1997. The harvest in 1999 showed an improvement, bringing numbers up to 2,398 (Taube and Sarafin, 2001). It is not clear whether the decline in Dolly Varden harvest is due to reduced fishing effort or stock decline.

Other Fishes of Note

Coastal Cutthroat Trout

Coastal cutthroat trout, *Oncorhynchus clarki* Richardson, make very short migrations to the sea, both in distance and duration. The cutthroat trout has distinctive orange marks on the underside of each lower jaw, as the name suggests. Small black spots are present over much of

the body, with sea-run forms taking on a more silvery appearance with less distinctive throat and body colorations (Fig. 16).

Figure 16. Cutthroat trout (Watson, 1999).

Movement into freshwater begins as early as mid-summer and peaks about September to October, concluding in November and December. Coastal cutthroat spawn from April to mid-May in southeastern Alaska (Baade, 1957). Again, like other salmonids, cutthroat trout exhibit the typical spawning behaviors. Females dig the redds while males chase other competitors away. Adult spawning fish may have better survival rates than steelhead, and can return to spawn again. Eggs hatch in about six or seven weeks. Emergence of the fry occurs between March and June.

Most young cutthroat do not go to sea until they are 2 or 3 years old, having spent at least a year or two in the stream. Coastal cutthroat populations are dominated by fish 4 to 7 years old (Morrow, 1980). Cutthroat smolt migration downstream takes place in late spring and early summer, peaking in late May and early June. Migrations occur mainly at night during times of moderate flows. Cutthroats stay at sea for 12 to 150 days in southeast Alaska with those migrating earliest staying out the longest (Morrow, 1980). Diets of cutthroat may contain insects, sticklebacks, fish eggs, and sculpins. While at sea, diets mostly include young salmon and amphipods. Generally speaking, the coastal cutthroat occupies the Pacific coast rain forest belt that extends from Prince William Sound of southern Alaska to the Eel River of California and inland to the Cascade crest. One might expect these fish to inhabit clear water tributaries of lower gradient in smaller drainages around the Copper River. Cutthroat trout have also been found to inhabit estuaries, making the Copper River Delta a suitable habitat.

Threespine Stickleback

The threespine stickleback, *Gasterosteus aculeatus* Linnaeus, although small, is very distinctive. It is easy to identify by it's thee prominent dorsal spines, and very narrow caudal peduncle (where the tail joins the body). Stickleback also lack scales, and have replaced them

with several bony plates, giving them a more ancient appearance (Fig. 17). Coloration varies greatly between populations, as do life histories. Marine, freshwater and anadromous forms are all in existence. Their varied life history strategies may contribute to their enormous success in colonizing many habitats.

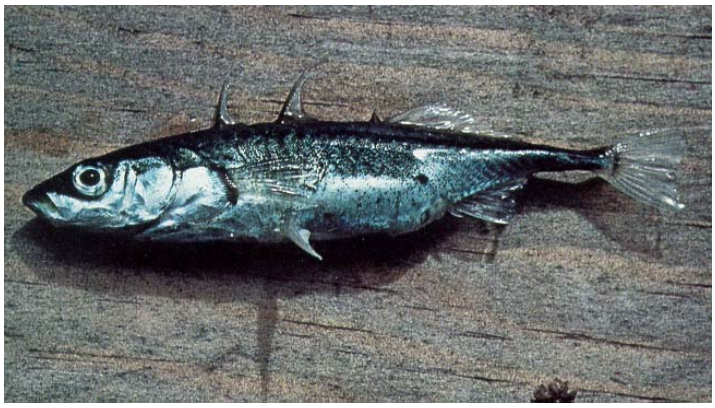

Figure 17. A typical threespine stickleback (Morrow, 1980).

The marine forms move into shallow coastal waters to spawn in early spring, with spawning occurring in June and July. Male mating behavior is complex, and is a favorite subject of animal behaviorists. Males build a barrel shaped nest of various materials found in the environment glued together by a specialized kidney secretion (Morrow, 1980). After an elaborate courtship dance to draw a female's attention, the receptive female may enter the nest to copulate. Males then tend the nest, and exhibit a remarkable degree of parental care. The male closely herds newly hatched stickleback until they are large enough to swim off on their own. Stickleback may spawn several times in one season.

Freshwater stickleback spawn in much the same way as marine forms, but inhabit shallow, well-oxygenated waters. Aquatic vegetation is often an important part of suitable habitat for stickleback (Morrow, 1980). Anadromous forms spawn in similar fashion to marine stickleback, and can do so in either fresh or saltwater. Young anadromous stickleback then move out of estuaries into the ocean. Stickleback feed on a variety of insects and zooplankton.

There is little information in the literature to confirm that threespine stickleback inhabit the Copper River. However, judging by their range and habitat preferences, it is likely that they may be found in the system, especially in the lower stream reaches and in the Delta.

Round Whitefish

The round whitefish, *Prosopium cylindraceum* (Pallas), is found throughout mainland Alaska from the Taku River mouth to the Arctic coast. These fish are usually silvery in color, with bronze dorsal surface, and have a very narrow, pointed snout. Spawning occurs in late September, but not until November in some populations on the southern part of the range. Spawning beds are usually located on gravelly shores of lakes, or rivers and in shallow water. After hatching, young spend 2-3 weeks in the gravel until the yolk sac is absorbed. Young leave the spawning grounds soon after emergence from the gravel. Sexual maturity is reached in 5 years in the southern part of the range (Furniss, 1974). Migration is not common. Round whitefish feed primarily on insects, fish eggs and gastropods.

Round whitefish are resident throughout the Upper Copper River drainage (AKDFG, 2002). They may be found in most of the clearwater streams of the upper drainage, especially the Gulkana, Tazlina, and Klutina rivers and their associated tributaries. Some smaller populations of round whitefish may occur in the clearwater tributaries to the Chitina and Nazina arms of the Copper River as well.

CONCLUSION

Even though the Copper River system is largely a glacial system, which may be referred to as less productive than a large clearwater system, the Copper River still produces large numbers of salmon each year, and sustains several populations of resident fish. The situation appears to be a bit of a contradiction: why does this glacial system support five species of salmon as well as so many other type of smaller fish? The answer to this may lie in the combination of rich spawning habitats with productive offshore marine feeding grounds. This relationship may also explain why the anadromous life cycle is so dominant among the fishes of this system.

The Upper Copper River watershed contains the majority of the spawning grounds that maintain the famous runs of Copper River salmon. These spawning streams, such as the Gulkana, Tonsina, and Klutina rivers are all large clearwater systems ideal for salmon spawning habitat. In addition, many of these streams in the Upper Copper River system have large lakes associated with them, which provide critical rearing habitat for the large numbers of sockeye salmon that hatch in the streams each year. Chinook, sockeye and coho salmon all utilize these

tributaries in the upper watershed to spawn. In the lower river, the large intertidal zone provides extensive habitat to support the spawning runs of pink and chum salmon. The large estuary and Copper River Delta provide a rich environment in which juvenile salmon may rear before heading out to sea, increasing juvenile survival. The Copper River provides a number of different habitat types, which enables so many different salmon species to utilize the same system. The "unproductive" glacial river that connects the upper spawning ground to the intertidal zone may function best as a transportation route to facilitate the migration of these anadromous fish.

Anadromous life histories in the Copper River may dominate because of the inherently low productivity of the glacial system. The tributaries in the system work well for spawning and early rearing, but productivity in these glacial streams may be limited. The productivity of the ocean is substantial, so those fish that make the journey to the sea can reap its rewards. During the winter, when glacial streams may be very low in available food sources, migrating ocean fish can continue to find rich foods in warmer waters. When conditions become more favorable, anadromous fish return to freshwater and utilize spawning habitats to create the next generation. By combining life in freshwater and saltwater, anadromous fish are able to take advantage of differential habitats to maximize benefits at each life stage.

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