Taxonomy, Ecology and Life History of Bull Trout, Salvelinus confluentus (Suckley)

By Maxfield A. Fish

INTRODUCTION

Ask any angler or fish enthusiast, and you'll soon realize that no fish invokes the vision of speed, strength, and agility more than those belonging to the family Salmonidae. Salmonids all share a sleek body design, powerful swimming abilities and the presence of an adipose fin (a small fleshy fin on the dorsal side near the caudal peduncle.) One of the less understood members of this family is the bull trout, *Salvelinus confluentus.* The bull trout is a handsome char, possessing the typical salmonid body design with an olive-green to brown back, which fades to white on the belly (figure 1). The backs and sides are generally covered with pale-yellow to crimson spots, and the leading edges of the pectoral and pelvic fins are white. In addition to coloration, many other factors distinguish *S. confluentus* and will be addressed in the following paper, along with taxonomy, distribution, life history, diet and conservation.

Figure 1. Female (top) and male (bottom) bull trout during spawn, illustrating sexual dimorphism. (FBC 2004).

TAXONOMY

Bull trout were originally described by G. Suckley in 1859 as *Salmo confluentus,* and later Linnaeus gave the Char the genus name *Salvelinus*. The bull trout's species name (*confluentus*), which translates roughly from Latin to mean "flowing together," presumably refers to the larger rivers and streams which they inhabit (Moyle 2002). Contrary to their common name, bull trout are not actually trout, they are members of the Char (genus *Salvelinus*) subgroup of the family *Salmonidae.* In addition to bull trout, other char native to North America include the lake trout, *S. namaycush*, Dolly Varden, *S. malma* and the Arctic char, *S. alpinus*. Char differ from trout and salmon in that they lack teeth in the roof of their mouth; they possess light colored spots on a dark background (as opposed to dark spots on a light background;) and they lack dark spots on the dorsal fin. Another distinguishing character common to all char is that the leading edge of the anal fin is white (figure 2).

Figure 2. Bull trout; note white leading edge of anal and pectoral fins and straight posterior edge of caudal fin. Photo by Ernest Keeley.

Until relatively recently the bull trout and Dolly Varden were considered to be the same species, except that Dolly Varden were thought to be an anadromous form, whereas the bull trout were thought to be strictly resident. In 1980, after reviewing convincing evidence from Cavender's work of 1978, the AFS (American Fisheries Society) recognized the bull trout as a species distinct from the Dolly Varden. Now, through mitochondrial DNA analysis it has been determined that bull trout are actually more closely related to the white spotted char (*S. leucomaenis*) of Asia (Behnke 1989) than Dolly Varden (USFWS 2004).

IDENTIFICATION

Bull trout are a very distinctive fish, although they are commonly confused with Dolly Varden. The most reliable method of positively identifying *S. confluentus* is by examining and counting the pyloric caeca, which is unfortunately the least useful in most applications. Pyloric caeca are small out-pocketings of the anterior portion of the intestinal tract which aid in nutrient absorption and are common in many fish. Examination of the pyloric caeca is an invasive procedure and will result in the destruction of the specimen. This procedure may be applicable if the individuals are going to be killed anyway, but for general field identification this is not practical.

Bull trout can be identified in the field by readily apparent characters such as fin rays, gill rakers, body size, body shape, and life history. Bull trout are distinguished from Dolly Varden by their generally larger size, longer, broader head and the fact that their maxilla (upper jaw bone) extends significantly farther behind the eye than that of the Dolly Varden, which often just reaches the eye (refer back to figure 1). The bull trout have a more ventrally flattened body with a large broad head, whereas the Dolly Varden have a more cylindrical body shape with a less dominating head; specifically, the distance from the center of the eye to the top of the head is less than the distance from the center of the eye to the nostril in bull trout, but in Dolly Varden these distances are approximately equal (figure 3) (Cavender 1997). Dolly Varden typically have 10-15 anal rays, whereas the bull trout have significantly more. Bull trout generally have more branchiostegial rays (26-28) than Dolly Varden (21-23,) and a relatively larger adipose fin (Bull trout: adipose length=50-70% of caudle peduncle depth; Dolly Varden: adipose

length <40% of caudle peduncle depth) (Haas and McPhail 1991; Cavender 1997). Bull trout also have more stout gill rakers with formidable teeth on the inner margin, while Dolly Varden have more slender gill rakers with out any teeth on the inside (Nelson and Paetz 1992).

Figure 3. Dolly Varden char, note the cylindrical body shape, more forked caudal fin and the much smaller mouth in relation to the bull trout. Photo by Ernest Keeley.

Although there are several qualitative characters that can be used to distinguish between *S. confluentus* and *S. malma*, the particulars of these characters vary with region. Thus, no one character will provide a reliable conclusion as to the definite identity. Instead the only proven way to distinguish these fish apart, without destroying them, is by using a multivariable LDF (linear discrimination function,) using variables such as anal fin ray numbers, branchiostegial ray numbers, and ratio of upper jaw length to standard length (Haas and McPhail 1991).

The most compelling argument for the distinction between *S. confluentus* and *S. malma* is the fact that they can coexist without excessive hybridization (Cavender 1978; Haas and McPhail 1991). Although to complicate matters further, Dr. Eric Taylor of the University of British Columbia has determined that bull trout and "Dollies" in the Frasier watershed are hybridizing and producing fertile offspring, which will make

differentiating the two an even more daunting task. If this is true, and the hybrids are in fact fertile, than it puts *S. confluentus'* status as a separate species in doubt. In the Skeena watershed, our area of interest, it has been observed that there are populations of bull trout and Dolly Varden living sympatrically. Cavender (1978) suggested that two specimens from lakes in the Skeena drainage were Bull-Varden hybrids, but unfortunately this was not verified because the ". . . lakes they came from were not readily accessible . . ." (Haas and McPhail 1991). Interestingly Haas and McPhail noted that in other regions that supported sympatric populations of bull trout and Dolly Varden, the Dolly Varden were consistently the dominant species. It is unknown whether the Dolly Varden are just more numerous in general or if they have some sort of adaptive advantage over the bull trout.

DISTRIBUTION

Bull trout historically occupied the mountainous rivers and streams of Northern California, and Nevada northwards to southern Alaska. Today bull trout are extinct from California, and have only a few relatively stable populations left in the entire United States. Although bull trout do exist in Nevada and Oregon, they are not abundant south of the Canadian border. This is probably due to the much lower human population densities and lower disruption rates in the Canadian watersheds. The bull trout's current range is bounded by a southern limit of 42°N, a northern limit of 61°N, a western limit of 133°W, and an eastern limit of 114°E (Haas and McPhail 1991). Bull trout were historically regarded as pests due to their voracious predatory behavior. It was thought that bull trout depleted populations of "more desirable" game fish by feeding on them at various life stages. In fact at one point there was a bounty placed on bull trout tails in Canada to encourage fisherman to rid the waters of this "Bully," which effectively eliminated them from certain watersheds.

LIFE HISTORY

Bull trout exhibit four distinct life history patterns: anadromous, adfluvial, fluvial, and resident. Anadromous populations spend the early portion of their life in streams, grow to adulthood in the ocean, and eventually return to the tributaries in which they

were born to spawn. Adfluvial populations spend between one and four years growing in their natal stream and then migrate to lakes. Fluvial populations spend about the same amount of time in their natal streams as their adfluvial siblings but migrate to larger rivers and streams instead of lakes. The resident populations are the runts of the litter, as they spend their entire lives in small, high elevation streams and generally do not reach very large dimensions. A 2 kg resident fish would be rare, compared to the U.S. record bull trout that weighed in at 15 kg.

A bull trout starts its life as a small pink egg (5-6mm in diameter) buried in gravel. After about 220 days of incubation in water that is ideally between 2°C and 4°C, the fry come to life and take approximately 65-90 days to absorb their yolk sacs. In warmer water juvenile growth rates are significantly reduced (McPhail 1996). After depleting their nutrient rich yolk sacs, the fry will spend up to three weeks developing parr marks and actively feeding on benthic and drifting aquatic insects before inflating their air bladder. Bull trout fry are very closely associated with cover and the river bed, and they almost never feed on terrestrial insects (McPhail 1996). The fry emerge from the stream bed at approximately 25-28mm total length and will continue to hold close to the bottom while foraging for benthic invertebrates during their acclimation to their new world. The world of the rearing juveniles is a benthic microhabitat of very low velocity water in which the fry can move about without confronting the swift mountain current (Rode 1988).

After a variable number of years (usually 1-4) in their natal stream, migratory smolt populations will travel downstream to the coast, a large river, or lake (depending on specific life history) to recruit to the adult stage. Adult individuals achieve sexual maturity at between four and seven years of age, although there has been little research on this aspect throughout much of their range, particularly on populations in the Skeena River drainage. Spawning is usually biennial, occurring only every other year or sometimes every three years, at which point the sexually mature adults fight the current back to the specific headwater in which they were produced to spawn. Several studies have shown a strong preference for spawning in small streams as opposed to larger rivers, although McPhail (1996) suggests that this may be do to sampling biases, due to the difficulty of sampling large swift rivers.

When water temperatures drop below 9°C, which tends to occur from mid-August to mid-October, spawning begins. Spawning typically occurs in August and September, although in recent years warm water has been persisting increasingly further into the year and effectively delaying the spawn (Baxter 1997). As with many Salmonids, bull trout exhibit varying degrees of sexual dimorphism. Sexual dimorphism refers to the changes in morphology and color that distinguish males from females during the spawn. Females do not exhibit significant changes during the spawn, but the males will develop bright red or orange sides and a kype (hooking of the lower jaw), although these distinctions vary from population to population (figure 1 and figure 4).

Figure 4. Spawning bull trout from the Attichika River (upper Peace River (Thutade Lake) drainage, BC). Two fish in foreground are females and the large fish in the background is a male. Photo by Ernest Keeley.

Bull trout are brood hiders, which means that their reproductive strategy is to hide their young from potential predators in the substrate instead of defending or protecting the young inside the mouth (mouth brooders) (Breder 1966). Once spawning commences the females will focus all of their time and energy into digging redds in the loose gravel substrate into which they will deposit their eggs. Bull trout prefer small gravel, usually digging their redds in areas dominated by substrate particles less than 20mm in diameter. Redds can range in water depth from 10cm to over a meter, and range in size from less than a meter in diameter to over 2 meters (McPhail 1996). While the

females are feverishly digging their redds, the males are busy trying to court the busy females while at the same time driving other competing males out of the area. Once the female is satisfied with her nest and her mate, she will release her eggs (up to 5,000) into the redd, closely followed by a male who will cover the eggs with his sperm. Once the eggs are fertilized the female will sweep pebbles into the nest to cover the eggs by undulating her tail while keeping the caudle and anal fins in contact with the substrate. Spawning seems to cease when water temperatures drop to about 5°C (Allen 1987). Unlike salmon, bull trout have iteroparity (the ability to spawn multiple times), so after spawning the adults will drift back downstream to their winter homes. Spawning is thought to occur biannually due to the fact that the fish survive spawning and need a year or so to recover afterwards.

DIET

Bull trout fry feed exclusively on benthic and near benthic drifting aquatic insects, zooplankton, and crustaceans. As they grow into juveniles, they begin to feed throughout the water column but still focus on foraging near the bottom. It is hard to generalize feeding habits of adult bull trout because much of their feeding habits depend on their specific life history. Migratory adult bull trout are primarily piscivorous (feeding on fish), and in some locations, such as the Flathead drainage in Montana, feed almost exclusively on mountain whitefish. Large aggregations of migratory bull trout awaiting their spawn will move into deep pools for the pre-spawn feast. The whitefish, which have a slightly earlier spawning period, migrate in huge numbers through these same rivers. As they pass, the trout rise and pick the numerous whitefish off with relatively little effort. Resident bull trout, in contrast, maintain a diet of primarily macro-invertebrates for the entirety of their life (McPhail 1996). Adult residents will fill a large portion of their diet with terrestrial as well as aquatic insects. Although there is much variability in the feeding habits among bull trout of different life histories, it is clear that all bull trout are fairly opportunistic predators as are most char, and in addition to insects, crustaceans, whitefish, sculpins, and other juvenile salmonids, they are known to feed on ducklings, snakes, frogs, and mice as well.

CONSERVATION

Bull trout are particularly vulnerable to perturbation due to their dependence on pristine habitat. Bull trout are considered a habitat-quality indicator species because of their intolerance of disturbance and pollution. Bull trout require clean, cold streams that are relatively free of small particle sediment and silt. Much of this reliance on rocky substrate is indirect due to the lifestyle of the trout's prey items. Juvenile bulls feed primarily on benthic crustaceans, insect larvae and other invertebrates that utilize the porous nature of the coarse substrate for cover. Larger individuals feed on sculpins and other small benthic organisms, which also need cobble substrate to survive. Bull trout also require a silt-free stream for procreation. Eggs that become covered in sediment due to excessive riparian erosion face a bleak future. The accumulation of sediment starves the buried eggs of oxygen and also prevents the fish from emerging if they were to survive long enough to hatch. It is this unusual sensitivity that placed the entire population of *Salvelinus confluentus* in the lower 48 on the federal ESA's threatened species list on November first of 1999 (FPC 2004).

The effect of excess sedimentation was exemplified by a lab study conducted by Weaver and White (1984), who determined that when the percentage of fine grained sediment (<6.35mm) reached 30%, only 15% of the eggs survived. An even larger factor in spawning success is temperature. *S. confluentus* is unusually sensitive to temperature, and only thrives in cold mountain streams. Between 8°C and 10°C only 0-20% of the eggs survive, while at 6°C the egg survival rate jumps to 60-90%, and at 4°C the egg survival rate reaches 80-95% (Rode 1988). Bull trout of any age are almost never found in watersheds whose temperature rise above 15°C for prolonged periods of time (McPhail 1996). Due to both local and global thermal pollution (global warming), the bull trout may retreat further north and further upstream to take refuge in colder waters.

The combination of these factors posses a far greater threat to the population than any harvesting pressure. With aggressive logging practices and the constantly increasing temperatures, bull trout production can decline to a fraction of its potential. Over several generations this can lead to an extinction spiral and the end of a population. These are the reasons that the bull trout require urgent active habitat management throughout its current range. Dams have severed migration routes to spawning sites, mining operations have left

traces of chemical contamination in the water long after they are closed, and erosion resulting from clearing the land has filled the streambeds with fine sediment. It is important to preserve this beautiful and yet vulnerable species now, while we still have a chance to ensure the continuance of this species.

SKEENA RIVER

Throughout British Columbia, it is not uncommon to find both Dolly Varden and bull trout coexisting in the same rivers and streams. Across northern and west-central British Columbia, the bull trout generally exhibit an adfluvial life history, whereas Dolly Varden are typically permanent stream residents (Bustard and Royea 1995; McPhail personal observations). The Skeena River lies entirely within the area of overlap between Dolly Varden and bull trout distribution (figure 5), which means that during our study will we be faced with distinguishing the two species, and possibly encountering hybrids as well. It will also be interesting to note the prey items of the bull trout. In areas of sympatry, bull trout will feed on not only sculpins, whitefish and insects, but on Dolly Varden as well (McPhail and Keely in prep.). Recent accounts suggest that bull trout may inhabit the waters of the Skeena drainage in very large numbers, and they may in fact be the dominant species over much of the watershed. This is contrary to the findings of Haas and McPhail (1991), which showed that Dolly Varden generally dominated sympatric locations. The apparent success of bull trout here could be due to many factors. One obvious factor is that the Skeena is one of few remaining unregulated and unpolluted rivers in the bull trout's range. The fact that it is still a clean cold-water river makes it a desirable refuge for all life-stages. Bull trout may have an adaptive advantage over other resident salmonids, such as Dolly Varden, since neither are protected and they experience harvesting pressures equally.

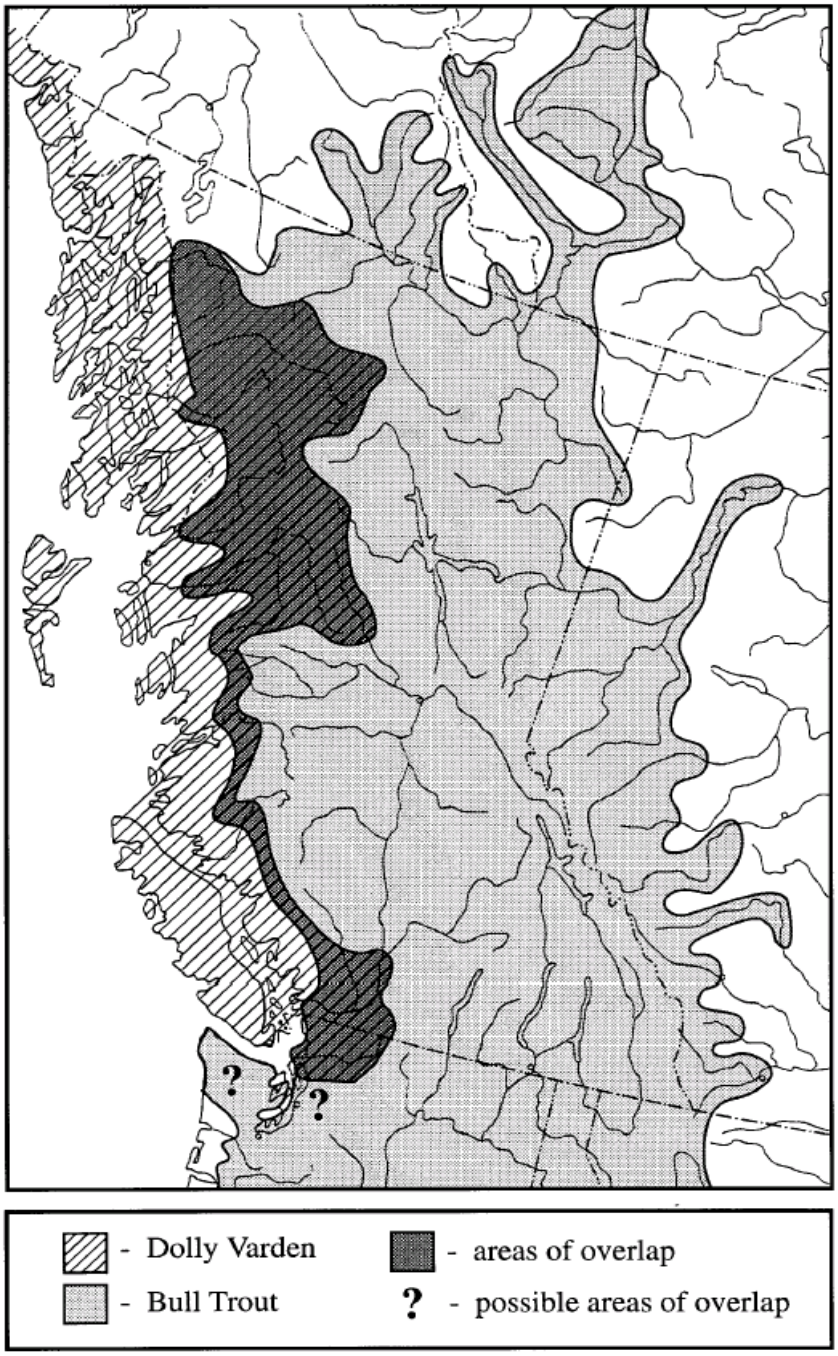

Figure 5. Approximate British Columbia distribution of bull trout (Salvelinus confluentus) and Dolly Varden (Salvelinus malma) showing areas of overlap (McPhail 1996).

CONCLUSIONS

Salvelinus confluentus is a unique fish whose dwindling numbers serve as an indicator of the increasing number watersheds that have and continue to face severe degradation. Reintroductions of bull trout have generally failed due to the fact that most of the causes for extinction persist (temperature, silt, barriers, etc.). Unless changes occur within the watershed to reduce temperatures, limit silt and remove barriers, reintroductions will continue to be unsuccessful (Moyle 2002). Further studies that increase our knowledge of this species will aid in more efficient and successful proactive conservation measures in the future, hopefully ensuring the existence of the bull trout for many generations to come.

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