Oncorhynchus nerka — Sockeye Salmon

From the tiniest sculpin to the platter-like sunfish to the dogfish shark, for someone who is fond of fish, almost any sighting will do. Yet it is always best to keep expectations in check, as these ancient creatures, although earthbound, can vanish as quickly as they appear. Theirs is a watery, viscous world, one that molds and sustains them. For air-breathing creatures, excursions into their realm are brief, and for most, the featureless waters are only viewed from above.

So, when you walk across a lakeside parking lot, casting about for flora rather than fauna along its edges, and just happen to come to a small but robust stream that flows into a deep, stunningly blue lake, and flashes of deep red seem to break the surface and stir the waters, then, from a fish encounter point of view, you know it is a really good day. For here, only a few feet away the narrow creek serves as a temporary home for kokanee, the land-locked freshwater form of the otherwise quite conventional Sockeye salmon.

Sockeye Salmon, the kokanee form in a crystal-clear stream

The place was Lake Chelan, located deep in the dry mountains of central Washington. Two hundred miles to the west, the kokanee's saltwater relative had begun its own transit through the cold waters of the Strait of Juan de Fuca, bound for a deep and swift river north of an international border of which the salmon was unaware. All that mattered was the keen sense of the direction to its natal home, where, hungry and spent, it would give all that was left to the next generation, and rest at last.

A fish with two names that reflect distinct although linked lifestyles, the Sockeye (*Oncorhynchus nerka*) is an ancient species with a genetic fluidity that enabled their adaptation to Pleistocene Ice Age dynamics. One form, named the "sockeye," is typically anadromous, spawning in streams and lakes and maturing in the sea, while the other — the "kokanee" — is strictly a freshwater fish. In particular, the kokanee lives in lakes, sometimes completely land-locked and isolated by physical forces such as climate change and geologic events. Stranded, the kokanee shares a common ancestor with the sockeye and research indicates that both are descended from the anadromous progenitor.

The "Sockeye" designation for both does not refer to the eyes, but rather is a Salish name. "Kokanee" means "red fish," referring to the deep warm color of the flesh. Anadromous sockeye are larger than the kokanee, but nevertheless rank as the second smallest salmon, greater in size than the Pink Salmon (*Oncorhynchus gorbuscha*) but much smaller than the three-foot-long Chinook (*Oncorhynchus tshawystcha*). The anadromous sockeye stretches to a maximum of 33 inches and a weight of 15.5 pounds, but the typical length is less than two feet and 3.5-8 pounds. By comparison, the kokanee is most often 8-15 inches in length, an indicator of a fresh rather than a richer marine diet.

Both forms of the Sockeye (the capitalized word refers to both the sea-run sockeye and kokanee in general) lack black spots as adults, although spawners can show some dark markings. The head is large,

and the mouth lining is black. At sea, the sockeye is bluish green above with silvery sides and white coloration below. Spawning sockeye are bright green to olive on the head with a contrasting red body; females tend to develop paler shades of red and green. As they approach their spawning grounds, males are most distinguished from females by their dorsal hump and hooked jaws lined with prominent teeth. As they mature to spawning age, the land-locked spawning kokanee also transform from silvery-blue to reddish hues.

The sea-run sockeye is the most range-limited of all salmon. A northern fish, they are distributed from Japan, across the Pacific to Kotzebue Sound near the Arctic Circle, and along the Pacific coast to southern California, although they are rare south of the Columbia River. Widely introduced in lakes throughout the United States, the kokanee is sought by anglers from Washington to Maine and along the Pacific coast. In the Southern Hemisphere, sockeye eggs were imported to New Zealand as early as 1902; populations there are land-locked, with most in decline. Sockeye have also been introduced in Patagonia.

Produced by several hatcheries, the more numerous anadromous sockeye is also stocked in rivers and streams, particularly in Alaska. In the Northwest, the largest "natural-origin" sockeye runs once numbered in the millions in Canada's Fraser River. This population is the most common sockeye in the Strait of Juan de Fuca: during spawning season they transit from southwest to northeast. Sockeye also return to their natal home via Johnston Strait, east of Vancouver Island.

Sockeye salmon (*Oncorhynchus nerka*)

Sockeye hatch in about 2-6 months following fertilization, emerging at night. The fry mature in lakes for 1-3 years, although most usually depart by their second year. They remain in nearshore waters and migrate during fall and winter; typical residency in saltwater is two winters. They are known to move northward far offshore, often reaching Asian waters. Most spawning occurs in summer and fall, but returns can range across several months. Runs are typically earlier in the north, but in large freshwater rivers such as the Fraser, spawning occur from summer to late fall. It is not uncommon for the offspring of several populations to be present in the same lake.

A cold-water species, sea-run sockeye can tolerate temperatures as high as 59° F (15°C) but prefer waters that range from 37-48°F (2.5-9°C). Kokanee like slightly warmer conditions, but both do best in

cool waters. This makes the species particularly vulnerable to ocean warming, a consequence of climate change.

Most maturing anadromous sockeye forage in water depths from the surface to 44 feet (10 m) or less. Females produce 2,000-5,000 eggs, depositing them in several nests over a period of 3-5 days; spawning often involves more than one male. Although the typical spawning age is three years, some adults live as long as 8 years. Kokanee females lay from 200 – 1,800 eggs; their redd (nest) is sometimes located in deep lake water.

Anadromous and lake-dwelling fish may spawn at the same time in streams and rivers, and hybridization is known to occur between the two forms. However, high fidelity to spawning sites tends to minimize inbreeding. In their rearing lakes, sockeye and kokanee fry feed on invertebrates. At sea, the maturing fish consume a variety of prey, including zooplankton, small fish, and squid. Sockeye are sought by a variety of predators, such as other salmon and sharks, as well as seabirds, seals, and whales. For human consumers, this is primarily a sport fish that supports a commercial fishery throughout most of its range. In Alaska, hatchery fish provide most of the sockeye take, while in the Fraser River most are natural origin fish, unusual in the world of salmon fishing.

Evolution

Fifty million years ago, an ancient Sockeye relative occupied freshwater habitats in northeast Washington state and southern British Columbia. This was *Eosalmo driftwoodensis*, the oldest known member of the Salmoninae, a subfamily of the Salmonidae family, to which all *Oncorhynchus* species belong. At the time, much of British Columbia was subtropical, although upland lakes provided cooler waters for a variety of fish, including this extinct species.

In the early Miocene Epoch (15-20 million years ago), the Salmoninae split into the northern Pacific *Oncorhynchus* and the smaller *Salmo* genus, primarily an Old-World group of approximately 50 species, represented along the eastern coast of North America by the Atlantic Salmon (*Salmo salar*). Fast-forward another 30-35 million years and the *Oncorhynchus* species recognizable today had separated into the 16 northern Pacific species, with the divergence of the Pink and the Sockeye occurring most recently, possibly in response to topographical changes along the Pacific Rim region, including the Cascades. It is also noteworthy that modern salmon species had evolved before the onset of the Pleistocene Ice Age approximately 2.6 million years ago: it was apparently not the icy cloak that precipitated salmon diversification.

With the onset of the Pleistocene, Sockeye, as with other salmon, would have been confined to glacial refugia, most likely the so-called “Beringia,” located in the northern Pacific, and “Cascadia,” including the Columbia, and other more southerly rivers. Today, two major genetic groups, one that ranges from Kamchatca to northwestern British Columbia, and the other located south from the Fraser River to the Columbia are considered representative of the glacial refugia.

It is possible that the kokanee arose several times from the sea-run sockeye, most likely following deglaciation approximately 15,000 years ago. The derivation of kokanee from the larger sockeye is evident from the observation that kokanee populations are located within anadromous sockeye

distribution and have not dispersed beyond those boundaries. Research indicates that there were separate origins in different watersheds, giving rise to multiple colonizing events.

At least two questions come to mind when considering the evolution of the Sockeye lifestyles. Given that newly opened habitats became available as deglaciation began following the most recent Pleistocene maximum, regions that included ancestral lakes, why is the Sockeye the only *Oncorhynchus* to have adopted the two lifestyles? Certainly, such opportunities must have been present for other species. Second, although sockeye can be strictly riverine, most anadromous sockeye are dependent on lakes for reproduction. Kokanee and sockeye spawning takes place in streams and rivers near lake outlets, and fry occupy lake habitats for one to three years, feeding and growing until they reach smolt size. When sufficiently mature, sockeye then migrate downstream to saltwater. Thus, the young of both forms are often mixed. Why is there not more inbreeding between the two, given the mixture that naturally occurs?

Sea-run sockeye and kokanee are the same species, although in time they may diverge sufficiently for separation; they are considered by some researchers to be "actively" evolving. Inbreeding does occur, but variable run timing, and strong site fidelity tends to suppress genetic mingling. And kokanee are sometimes completely land-locked, often by migration barriers, preventing incursions into streams and rivers.

This development of the two Sockeye forms is certainly an intriguing occurrence in salmon evolution. As the ice melted Sockeye were poised to follow rivers and streams to newly formed glacial lakes. It may have been an unprecedented opportunity on both sides of the north Pacific. But for most researchers, the sea-run sockeye and the kokanee are considered as one, an acknowledgement of a recent, blink-of-an-eye separation.

Across the ocean, however, at least one descendent, confined to a single lake in Japan, has been designated as a separate, if closely related species.

Sockeye in the Strait

Except for the Fraser River sea-run sockeye that passes through the Strait, regional lakes that can support sockeye or kokanee are few. The terrain is steep, and most rivers flow rapidly from the mountains to the sea. Lake Sutherland is the only lake that discharges into the Elwha River, while Lake Crescent drains via the Lyre River directly to the Strait. However, a waterfall on the Lyre blocks migratory fish passage, thus preventing Sockeye from spawning in or near the lake. The Lake Crescent population is truly landlocked.

Both lakes support kokanee populations; origins of this smaller fish probably date to glacial retreat several thousand years ago. However, subsequent hatchery introductions have complicated the genetic mix of the Lake Crescent and the Lake Sutherland kokanee.

As the glaciers released their grip on land and sea, other dynamic forces altered the terrain. Approximately 7,000 years ago a landslide sliced an ancient lake that had drained to the Elwha via Indian Creek. Two lakes were created in this singular event, one eighty feet higher in elevation and much larger than the other. This was Lake Crescent, a 12 mile-long, deep body of crystal-clear water, now cut off from the Elwha River. The smaller lake — Sutherland — continued to drain to the Elwha.

With a maximum depth of over 600 feet, Lake Crescent is home to endemic forms of Rainbow Trout (*Oncorhynchus mykiss*) and Cutthroat Trout (*Oncorhynchus clarkii*), with record-holding members of both species that hint at a food source other than invertebrates. As it turns out, these large trout enjoy an excellent and expanded diet of kokanee.

With a mean depth of 57 feet (17 m) and a maximum of 80 feet (24 m), the mile-long Lake Sutherland is home to a mixed kokanee population. Prior to construction of the Elwha dams in the early twentieth century, these possibly shared habitat with an anadromous sockeye population that spawned in Indian Creek and spent their first year or two in the lake. In 1913, the completion of the Elwha Dam, located below the confluence of Indian Creek and the Elwha River, blocked sockeye access. At this time, the lake's kokanee became an essentially landlocked population (both dams on the river lacked fish ladders). Yet, as with Lake Crescent the background of Lake Sutherland kokanee is more complicated than the story of water access dynamics altered by natural forces, such as landslides, and human impacts, as with dams.

Between 1933 and 1964, approximately 7 million kokanee smolt were released into Lake Sutherland. These fish were sourced from four hatcheries, including one built on Barnes Creek, a stream that empties into Lake Crescent. Released to augment the population, primarily for recreational fishing, it seems likely that inbreeding between the resident kokanee, an isolated group that may have arisen thousands of years ago, and the introduced hatchery fish would occur. That the kokanee were present prior to hatchery augmentation has been confirmed from historic fishing accounts.

Today, ten years after the last dam removal, fisheries' managers hope for a return of Elwha River sockeye to Lake Sutherland or perhaps a reverse wandering of the lake's kokanee down Indian Creek.

However, one question about a potential saltwater incursion for the Lake Sutherland kokanee concerns its physiological ability to adjust to the different salt concentrations between lake and sea. At least one study that quantified the saltwater adaptability of kokanee, sockeye, and hybrids between the two, indicated that kokanee had a much smaller window for acceptable plasma sodium concentration, a measure of saltwater tolerance. For yearling sockeye, this number was considered sufficiently low beginning in late March, and extending through August, a fairly large window for the migrating fish. By contrast, for kokanee the lowest plasma sodium level was delayed until the end of May and exhibited a steady increase after that time.

Both forms displayed the highest adaptability in midwinter, a response to smolt development from parr-sized fish. Although this transformation is common to both the sockeye and the kokanee, researchers have questioned the possible energetic cost to the kokanee, the idea being that in their freshwater habitat, smolting may be unnecessary. It has been conjectured that this cycle reflects the genetic legacy of sockeye, but studies of kokanee isolated since the last glacial maximum also show this ancient ability to regulate sodium.

Given the reduced window for kokanee saltwater adaptation, another question concerning the kokanee's return to an anadromous cycle might consider whether this is, in a sense, a "reverse" evolutionary course. Researchers agree that kokanee developed from anadromous sockeye, and most often they are considered the same species. The tendency for Lake Sutherland kokanee to produce large eggs adds to the puzzle, hinting at a close connection with Elwha River sockeye before dam construction.

Perhaps the Lake Sutherland kokanee will at some point move downstream to the Strait. It remains an intriguing unknown.

Lake Crescent kokanee also have a complicated history. Prior to the ancient landslide, sockeye access to the lake involved a transit up Indian Creek. If the slide preserved the sockeye run, fish in the lake would have been isolated by the subsequent rise in its level, and the impassable waterfall on the Lyre River, their only connection to saltwater. Historically fished, with the construction of several state hatcheries, in the early twentieth century, supplementation with hatchery kokanee began in 1913 and continued until 1939.

As with Lake Sutherland, genetic mixing of natural origin and hatchery fish undoubtedly has taken place in Lake Crescent. Meanwhile, the blocked access to the Strait by the Lyre River waterfall ensures that natural origin sockeye will be denied access to the lake.

Following removal of the two dams on the Elwha it was hoped that Sockeye might return to Indian Creek and establish a spawning population near the outlet of Lake Sutherland. Expectations also included the possibility that the lake's kokanee, previously denied access to the Strait by the Elwha Dam, might follow the creek to the river and subsequently to the sea. Yet, more than ten years after dam removal, evidence of any new connections between the lake and the Elwha are absent.

In fact, studies of Elwha sockeye indicate that a small number in the lower river are strays from freshwater sources as far north as Alaska and, slightly closer, the west coast of Vancouver Island. Collected from 2010 to 2017, a period that included specimens both before and after dam removal, 45 adult sockeye were subsequently analyzed. This was made possible by use of a genetic database which provided the most plausible origin for the sampled fish.

All the analyzed adult sockeye were determined to be "strays" from other riverine/lake locations. Important to the question of local origins, none were from Lake Sutherland. Nearly half, sampled in 2015, were assigned to Vancouver Island, specifically to lakes that drain into Barkley Sound on the west side of the island. Of the remaining 23, initially 15 were identified as most closely related to the Stikine River sockeye; this Alaskan River is more than 620 miles (1,000 km) from the Elwha.

Such a distant assignment brought into question the accuracy of the genetic database, in particular the probability that stock identification is incomplete for closer sources. After considering this incompleteness, researchers believed it was likely that half of the sampled fish were strays from nearby rivers, such as the Dungeness, or rivers that terminate along the Washington coast. Only one specimen was from the Fraser River, a result that implies little straying from the sockeye that traverse the Strait.

Since riverine sockeye are believed to stray more than the lake form, it seems possible that a sockeye run may in time become established in the Elwha. Whether a connection will be made between the resident Lake Sutherland kokanee and the river is unknown. It is not a simple matter of swimming downstream or upriver. Origins, habitat, physiological responses, including but not limited to the transition to saltwater, and the availability of prey, among other factors, are important to the question of a spawning population of Elwha River sockeye.

Meanwhile, in the Dungeness River an exceedingly small run (6 or so adults) of spawning sockeye provide support for the idea that this salmon can maintain a population with a minimal number.

The Case of the Large Eggs — a Closer Look at the Lake Sutherland Kokanee

Kokanee are considerably smaller than anadromous sockeye, averaging less than a foot in length compared to the sockeye which is typically nearly twice as long. And, as expected, most female kokanee produce eggs much smaller than their cousins. There is, however, an exception, one that involves a population with a genetic history complicated by the mixtures of ancient, current, and hatchery fish. It turns out that, contrary to expectations, the smallish female Lake Sutherland kokanee deposits eggs of the same size as the anadromous, river-dwelling sockeye.

The tendency towards large eggs indicates a possible anadromous background for the Lake Sutherland kokanee, perhaps even prior to the landslide that separated the shallow lake from Lake Crescent. The population may have been modified by sockeye influx via Indian Creek. It may be as well that planted fish were not only kokanee but also included anadromous stock. Another possibility is that the kokanee are the descendants of a very ancient population. Such conjectures add to the mystery of the lake's fish.

Fishing the Sockeye and Its Landlocked Form

Commercial and recreational fishing of the Fraser River sockeye that pass through the Strait on their spawning run is not presently permitted south of the international border. The run itself is the largest natural occurrence in the northeast Pacific, consisting of millions of fish that after migrating to Alaska, return to the Fraser along both sides of Vancouver Island. The number in the Strait during the survey of 2010-2017 was estimated at 1.88 million fish.

The size of that return depends on annual conditions both north of Vancouver Island, and within the migratory route to Alaska. Fraser River salmon are known to undertake this long route northward, perhaps following cold water. Their return route as well may depend on water temperatures.

Kokanee are not currently supplemented with hatchery fish along the Strait, but hatcheries at Lake Ozette contribute to the ESA-listed "threatened" stock there. And while the Fraser River sockeye is primarily a natural run, increased supplementation programs have been instituted for sockeye blocked access to their spawning sites by a landslide on the river in 2021.

On the peninsula, Lake Sutherland provides an opportunity for anglers seeking kokanee for their dinner plate. Open from April to the end of October, fishing is permitted prior to spawning: the kokanee population of the lake varies between an estimated 4,000-6,000, most of which spawn in November near the Falls Creek inlet.

As with other Salish Sea species, fishing for sockeye dates back thousands of years, with indigenous fishers employing methods later adapted by American settlers. Since the late 19th century, the take increased, in part because fishing was linked with cannery processing, an industry that during seasonal salmon runs could produce thousands of cans each day. For the sockeye, this capability was particularly evident in the rich fishery of the so-called "salmon banks," located on the Strait in shallow water offshore from the San Juan Island. The fisheries and canneries were created to take advantage of the autumn Fraser River sockeye run and, during that season, nearly frantic activity awakened the quiet island.

In 1792, Spanish explorers noted the seemingly limitless sockeye numbers and other salmon species as well. By the end of the 19th century, native tribal fisheries had been essentially supplanted by much

larger operations. Forty years later, the resource had declined to the extent that making easy money had become hard.

Today, the Salmon Banks are occasionally fished, but sockeye are no longer a commercial target within its shallow boundaries. The rich industry has died, but the numbers taken during its heyday give some indication of how numerous the sockeye really were. For example, in the summer of 1900, on average nearly 2,000 fish were processed daily from July through August. This number could vary widely; in 1917, a high of over 28,000 fish in one day dropped to 134 two days later. Overall, in 1917, over 45,000 sockeye were trapped and processed in canneries conveniently located nearby. Those facilities provided work for many, including immigrants and local people as well, and were places of nearly frenetic activity during the sockeye run.

As with other such concentrated fisheries, the Salmon Banks sockeye bonanza could not last, and in this case a natural event beyond human control contributed to the decline. The production of 450,000 cases of Sockeye in 1913 marked a high point in the cannery industry, yet coincidentally, less than six months later year a rockslide at Hell's Gate on the Fraser blocked access for spawning sockeye, and the numerical free fall, coupled with legislation banning traps, effectively spelled the end of the fishery dependent on the huge Fraser River sockeye run.

The large population in the Strait is attributable to the migration dynamics of millions of sockeye smolt that exit the Fraser River estuary each year. Originating high in the Canadian Rocky Mountains, the river is 854 miles (1,375 km) in length and drains nearly one quarter of British Columbia. Major tributaries add to the flow as the river passes through climatic zones that range from high mountains to dry interior regions to the salt waters of the Salish Sea. Home to seven salmon species, many lakes within the Fraser River watershed provide excellent spawning and rearing habitat. For management purposes four runs are recognized, ranging in timing from early summer to late fall.

Mitigation of the Hell's Gate rockslide began within a month as rubble was removed, and fish were transferred in nets over the blockage. Yet despite ongoing efforts to remove the fallen rock, salmon numbers plummeted. Prior to the rockslide, the Fraser River sockeye population averaged more than 10,000,000 annually, with high points of 40,000,000 fish estimated at the turn of the twentieth century. Following the slide the run fell to less than a million, with recovery averages measured at less than half of the former numbers, at least until the latter part of the 20th century. By that time, concrete "fishways" transported fish around the slide, and in 1985 spawning channels were constructed. By 1990, recovery looked promising as sockeye numbers trended upward, at least for a time.

Although intervention could reduce the impact of slides such as occurred at Hell's Gate, the natural fluctuations of sockeye populations coupled with the consequences of both increased fishing pressure and natural events such as landslides and climate fluctuations would within a few years prompt a cooperative approach between Canada and the United States. Twenty-three years after the slide, the first sockeye management plan between the two countries was ratified: the purpose was to restore the Fraser River sockeye run. Thus, was born the International Pacific Salmon Fisheries Commission and with its formation the first serious scientific studies began on the Fraser River sockeye. In 1985, a treaty designed to protect five salmon species was signed by the two members and the name of the regulatory body changed to the Pacific Salmon Commission (PSC).

Reporting to the PSC on a yearly basis, the Fraser River Panel (FRP) was formed in 1985 with the directive of managing the Fraser River sockeye and pink salmon fisheries. Each year, panel members recommend a fishery allowance based upon statistical and modeling approaches to the Fraser River salmon populations. The panel is also responsible for developing preseason management plans. They are involved with details, not just broad generalities, including run size predictions, reports on the status, escapement goals, modeling results, and comparisons between forecast and return at the season's end.

The FRP meets several times throughout the season to evaluate the ongoing fishery. New estimates of the four Fraser River runs are often followed by adjustments to the catch allotments for both countries. These efforts are an aid to evaluating the accuracy of predictions and the fishery impacts on the Fraser sockeye.

The numbers are large and so is the potential catch. Unfortunately, the forecast error can be large as well. In 2022, the pre-season forecast season 9,775,000 sockeye; of this number, nearly 550,000 sockeye were allocated to the United States; of this number 67.7% was specified for Tribal Treaty fisheries. An upper limit of 2,172,000 was granted to Canadian fisheries. The final seasonal estimate was 6,936,000 fish, in part because of the small numbers of two Fraser River runs. The final tally yielded 7,009,000 fish with an exploitation rate of 23%. This return was the smallest since 1990 and less than three-quarters of the preseason prediction.

With the reality of the difficulties of modeling the Fraser run, and the unknowns associated with issues such as climate change, the FRC carries a heavy responsibility. The future of the Fraser River sockeye lies in large part on approach, mathematical accuracy, and response to concerns and environmental dynamics. Accurate predictions are hard to achieve, and securing the sockeye's future, one always subject to unknowns, has become more difficult in a world of climate change realities and pressures from other sources.

The object of human legislation and worries, mature sockeye answer an unavoidable internal demand to return to the Fraser, responding to external clues in complex ways barely understood. As smolts they had migrated north to Alaskan waters, where most of their lives were spent. Returning southward towards the tip of Vancouver Island, they continue along the coast of the island, with the majority following the coldest waters. For those fish that swim the open waters of the island's west coast a turn northeastward takes them through the Strait of Juan de Fuca for the first and last time. Exhausted, they enter the Fraser River's fresh waters, continuing ever upstream on to their birth home. There they will spawn and die.

The run predictions of 2022 were not the only ones to miss the mark. In 2019, a run size of 4,795,000 fish was estimated; the final total was 571,000 fish, the smallest since record keeping began. This number may have been a result of the warm water "blob" in the northeastern Pacific, but such a conjecture is considered by managers to be simplistic, given that the impact is not consistent across species. Whatever the cause, the numbers were exceedingly low yet followed a relatively good year of approximately 10,864,000 fish in 2018. However, this encouraging number was less than the pre-season estimate of about 22%.

Unfortunately, the news continues to be negative in the third decade of the 21st century. Some of the decline in Fraser River sockeye has been attributed to the Big Bar Slide of 2018. Located 40 miles (64 km) north of Lillooet, BC, this landslide created a 49-foot (15 m) waterfall, blocking the upriver sockeye

return. It is estimated that 63% of the total sockeye run must pass this site to reach their spawning grounds. Following the slide, mitigation processes such as transporting salmon with helicopters around the slide and enhancing the population with broodstock eggs, were part of the approach to aiding salmon runs. However, the outcome of the slide, coupled with other factors such as delayed snowmelt that led to excess water flow during the summer, further exacerbated the problem of spawning salmon; thus, many did not travel beyond the lower river.

In 2018, the catch was 3,699,400. In 2019, the year after the Big Bar slide, the number was 94,400 returning Fraser River sockeye.

While there are short timescale events (the Big Bar Slide) that can unleash a freefall of salmon numbers, more long-term dynamics such as warming oceans, competition from hatchery fish, disease, increased predation, runoff timing, and other factors make future run estimates more difficult. One certainty, however, is that the overall trend for the Fraser River sockeye has been downward, with low points in 2020 when the count was 291,000, the lowest recorded since record keeping began in 1893. During the 20th century and continuing into the 21st, highpoints of over 25,000,000, a rare maximum coupled with the free fall of the 2016 number characterize broad swings in the oscillating nature of the sockeye population. Dismaying to managers, commercial fishers, anglers, and tribes a bright future for the Fraser River sockeye relies on informed human endeavors.

In 2024, the Fraser River sockeye forecast is approximately 567,000 returning fish. Acknowledging this prediction, at a meeting on March 1, the Washington Department of Fish and Wildlife (WDFW) proposed closure of specific Marine Areas, including, among others, the east Juan de Fuca Strait (Area 6) and the San Juan Islands (Area 7) fisheries.

Listing the Sockeye

It is unfortunate that Lake Ozette, a lovely, isolated lake within the boundaries of Olympic National Park, near on the coast, is located within a decades-long active logging industry. Prior to restrictions on streamside and lakeside tree removal, the impact on tributary streams was significant, with sediment loads that muddied the gravel in streams and the lake as well. This factor alone contributed to unsuitable substrate for salmon spawning; additionally, encroachment by vegetation led to the reduction of spawning habitat. Further complicating the lake's status, sediments have increased, while the mercury level peaked in 1990 at one of the highest levels in the state. Nine years later the Lake Ozette sockeye Evolutionarily Significant Unit (ESU) was listed as Threatened under the Endangered Species Act.

At the time of the listing, the recovery goal for the Lake Ozette sockeye was set at 31,250-121,000 spawning fish. It was also noted that to reach such goals an increase of 1.02 to 1.03 percent per year would be necessary. Unfortunately, this goal has to date proved unreachable, as over the past four decades the numbers have ranged from 4,398 to 12,829, with measurable downturns reported in the five-year review, initiated in 2019.

A few hundred miles southeastward, in the desert-like landscape of Washington state, the Snake River sockeye struggle to maintain a viable population. Listed as endangered under the ESA in 1991, in 2022 the National Marine Fisheries Service (NMFS) recommended retention of that status. The Snake

River run was historically decimated by dam construction, and surveys indicate little change. A five-year NOAA review in 2022 confirmed the natural origin sockeye low returns, never topping 500 in the 21st century. This is a population augmented by hatchery salmon, increasing the number to approximately 1,500 at a maximum. The Snake River population remains at high risk of extinction.

Yet sockeye can apparently maintain runs of small numbers, and in the Strait, they benefit from restoration projects primarily aimed at other species. The removal of the second Elwha dam in 2014, offered more hope for the Olympic Peninsula Sockeye. And although the return has been low and the fish that enter the rivers are often strays from distant places, it can be hoped that these sockeye will increase in numbers and lead to a sustainable population.

Unlike its very distant human relatives, the sockeye is consistent in its behavior, returning to its natal stream or lake, only to offer its life force to a few thousand eggs. Bright red bodies deteriorate as starvation sets in, but theirs is a life of admirable determination. Physical objects may stop them, biological forces prey upon them, but the goal is never lost. They will always strive for their birthplace.

And what other salmon likes lakes, saltwater, and rivers alike? The ice of a million year's duration provided opportunity, while the sockeye offered flexibility.

As for me, I would like to see the bright red bodies and the grass-green heads of the spawning sockeye once again. Perhaps it would be in a small stream, or a lake where territory is precious in its shallow waters. It would be a memorable experience to witness the efforts of a returning wild fish, its dedication and destiny both inflexible and in some sense, quite pure.

It need not be large numbers, as the less-than-ten size of the Dungeness River spawners can attest. Encouragement evident in the robust nature and fidelity of this unusual species is most welcome at a time when so much seems lost. Visions of millions of sockeye dance in the mind, while hope for the future rests in humanity, with its predictive models, its surveys, and its attempts to understand, all contributing to the goal of continued existence of the red salmon.