Osmeridae — Eulachon (*Thaleichthys pacificus*)
Part 1

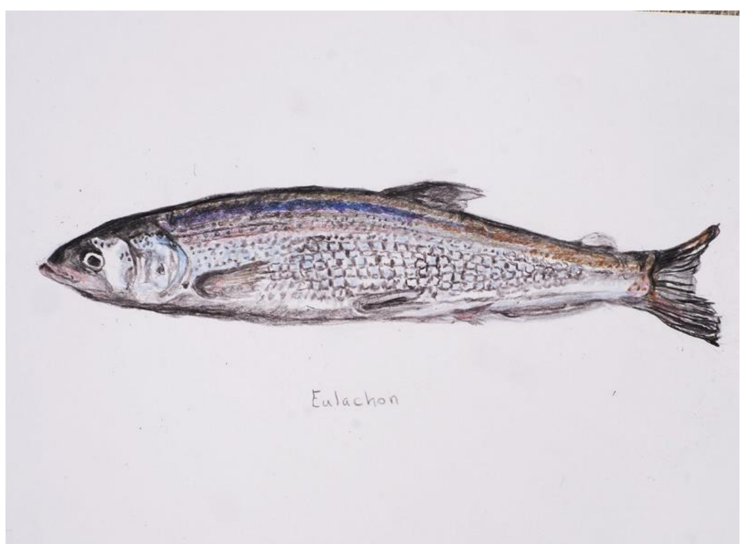
By Susan McDougall

The winter was exceptionally cold that year, and snow persisted on the coastal hills even as the days lengthened. The equinox had passed, but the leaves of sweet ephemerals remained tucked close to the forest floor and the dependable flush of new growth on the berry bushes seemed a forgotten dream. The rain came down and the last few of the great salmon, dried the previous year, would soon be consumed. The people watched the great river, their source of sustenance, but at times a very fickle provider. It was becoming the most difficult year in recent memory.

A young child burst into the settlement, dragging his large net behind. "They are here," he cried.

The length of a hand, they were mere shadows of a salmon, but as if in compensation for their small size, they came in great schools. The fishers welcomed them with thanksgiving in their hearts. The Salvation Fish had returned.

With many common names for such a little fish, "Eulachon" is thought to be derived from the so-called Chinook Jargon ("Tsinuk Wawa," a synthetic language that incorporates elements of French, English, and primarily Chinook. If the Eulachon's name did originate in that widely employed language, a literal translation closely matches a combination of oil ('heule,") and stick or candle ("chan"). The candle designation refers to another name for the Eulachon — Candlefish. The designation is an acknowledgement of the oil-rich flesh of this smelt, so concentrated that, like a candle, a dried fish will readily burn. Derived from the oil, a solid grease that melted easily was an important food item for indigenous people. But Eulachon flesh was also tasty. So thought Meriwether Lewis and William Clark, who, along with their tired crew of hungry men traveling down the Columbia River towards the Pacific Ocean in the autumn of 1805, where they had the good fortune to engage in trade with the native peoples. When the party reached the Pacific Coast and built Fort Clatsop for their winter quarters, a network was established with the local tribe for whom the fort was named. On February 24, 1806, a Clatsop chief visited the fort with Sturgeon and hats for trade. He also brought a small fish that had begun its return to the river. Lewis sketched a detailed drawing of the fish, described it, and prepared several by roasting them on a wooden spit. Enjoying his meal with his companions, Lewis declared that "They are so fat they require no additional sauce, and I think them superior to any fish I ever tasted, even more delicate and lussious than the white fish of the lakes." Lewis was both hungry and appreciative of the Eulachon.



Eulachon (*Thaleichthys pacificus*)

The Eulachon (*Thaleichthys pacificus*) ranges from southern Alaska to northern California and has historically been present throughout the Salish Sea. The fish spends most of its short life in the cold sea. Related to the Surf Smelt (*Hypomesus pretiosus*), also present in inland waters, both species are members of the small Osmeridae (meaning "odorous") family, a group of fish native to freshwater lakes, and the North Pacific and North Atlantic oceans.

As with its relatives, the Eulachon is a small fish, typically 6 – 8 inches (15 – 20 cm) in length. Within its upturned mouth are a set of large teeth. The anal fin is composed of many rays, and like salmon, this species has an adipose fin (this is the small fin that is clipped on hatchery salmon). Dark on their backs and silvery on the sides, with speckles, the Eulachon typically resides for 3 – 4 years in saltwater (sometimes as few as 2 years) before returning to their natal river or stream, or occasionally to a place previously unvisited.

An anadromous species, or technically "semelparous," meaning it dies after spawning, the Eulachon is considered a poor swimmer and thus spawns in slow moving waters, often in lower reaches of freshwater flows, although sometimes making its way upstream in rivers with long, flat deltas. Unlike salmon, the majority of which spawn in their natal waters, Eulachon do not always demonstrate site fidelity, but may move into neighboring streams and rivers, laying their small eggs in unknown waters,

Males arrive at their spawning grounds before the females, having acquired fleshy ridges along their bodies — "Thaleich" refers to this adornment. Laid at night on sand and gravel, the eggs are attached to the substrate with a sticky substance. There the eggs incubate for 3 – 4 weeks, and upon hatching are swept as larvae downstream to the sea where they disperse onto the continental shelf, feeding on plankton. As adults, Eulachon show a preference for euphausiids (krill), but also dine on fish eggs and other small prey.

Eulachon spawn between February and May, with the late spring migration to rivers and streams of particular importance to indigenous peoples. It is this delayed arrival that earned the Eulachon the name "Salvation Fish," a reference to its welcome presence at the mouth of the rivers, particularly during years of scarcity. Eulachon could be dried in large numbers, serving the tribes as a source of protein as well as for its oil, which is both nutritious and tasty.

However, predicting the time of a Eulachon run has never been straightforward. The month of spawning is not directly related to latitude*;* research indicates that peak run times are possibly timed to river temperatures. For example, in the Columbia River optimal water temperature is considered to be about 40 ° F (4.44 °C). Yet the range of spawning temperatures is approximately 32 – 50° F (0 – 10° C), and it has been suggested by researchers that the contrast, rather than the value, between river and ocean temperatures is an important factor.

Along the Strait of Juan de Fuca, it is known that Eulachon was harvested from the rivers that empty into the Strait, including the Hoko where Eulachon vertebrae have been identified in a rock shelter near the river mouth, occupied a thousand years ago. Thus, apparently abundant in the past, the fish essentially disappeared from the Strait's rivers and streams. Not until the 21st century would they be noted once again in the Elwha, where a study at the Elwha in 2005 concluded that the returning Eulachon were a "remnant" run, rather than one displaced from another river. This conclusion was in part reached by noting that adult fish were absent in the Dungeness River, one of the major rivers that empties into the Strait. Eulachon have a tendency to wander from their natal home, perhaps imprinting on an area rather than a specific river. Thus, the Dungeness River would be a candidate "home" for the Elwha fish; the lack of adults in that river indicates this source is unlikely. Preliminary genetic results also indicate a local source of the fish.

The small increase of the diminished run has also possibly been enhanced by the removal of two dams upriver, or perhaps signifies an increase of the populations in response to the "Threatened" status Eulachon listing in 2010.

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Today, concerns over dwindling populations of many species include acknowledgement of the tenuous status in the public eye of a small fish such as the Eulachon. More attention is given to salmon restoration, an acknowledgement of the precipitous decline of many stocks; it is fortunate that many species benefit from efforts to bring back the iconic salmon. Such commitment to restoration and conservation is vital to the health of the salt and freshwater living communities.

In 2010, the Designated Southern Population (DPS) of Eulachon, a population that ranges from the Skeena River in British Columbia to the Mad River in California was given "Threatened" status under the auspices of the Endangered Species Act (ESA). Such designation brought into play several requirements for the managing agency, the National Marine Fisheries Service (NMFS), and the state fisheries and hunting organizations as well — in Washington, this is the Department of Fish and Wildlife (WDFW). Documentation, based upon required investigation and research, would include a Management Plan, a Recovery Plan, five-year status reports, designation of critical habitat, and other measures. These would be written and implemented with the goal of restoring the DPS Eulachon run. Such a listing typically increases funding for research, surveying, and documentation, among other endeavors, but it is a big management task. Currently the southern DPS of Eulachon (hereafter referred to as "Eulachon") is given a time frame of up to 100 years for recovery. The restoration effort would be complicated by a combination of insufficient knowledge of this forage fish, the continuing human impacts of development, the impact of other fisheries, and, very importantly, climate change. Eulachon is a cold-water fish; understanding how it reacts to increasing temperatures may prove to be the greatest challenge of all.

With its inclusion under the ESA, the Eulachon joins several salmon populations that ply the waters of Washington, Oregon, and California. In all, 28 salmon groups are listed; these include those that live in rivers such as the Snake, as well as in salt water, such as the Salish Sea and oceanic habitats, and a coastal lake as well. Each is home to a Threatened or Endangered salmon group. The Eulachon is in good company, if it could be called that. Unfortunately, like the salmon, even a good year or two is not sufficient to determine the future status of the Eulachon. We are in for the long haul.

Eulachon Fishing — A Historic Overview

Eulachon fishing was important to many coastal tribes for thousands of years, as evidenced by the presence of bones in middens, known trade during pre-contact times, as well as oral traditions. The processing of Eulachon into a "grease" was particularly important; trade in grease was practiced along the British Columbia coast, with well-worn trade routes providing access to inland tribes.

In post-contact North America, newspaper reports place the first Eulachon fishing forays in the Columbia River to 1866. Commercial and recreational fishing records begin in 1888, while reliable data is available after 1936. Thus, Eulachon abundance is most often calculated or referred to from that time. Over the next 56 years (1936-1992) a yearly average of 22,000,000 fish were landed in the Columbia River subpopulation (one of four designated by the recovery plan); the Eulachon target recovery value of 20,000,000 fish today.

Data on the recreational sport dip net fishery is sparse, although a sampling program revealed that it was comparable to the commercial fishery, with a catch of about 22,000,000 fish per year. Combining the two for a total of 44,000,000 summarizes a Eulachon fishery in the Columbia River subpopulation that varied between 12,000,000 and 128,000,000 fish per year.

Sustaining a large fishery in the Columbia River alone implied a "substantially higher" total number of fish; in Canada, the Fraser River contributed 90,000 to 8,000,000 fish taken per year, and fishing was an annual endeavor in other Canadian rivers as well. The species was also heavily fished in Oregon and California.

Thus, the total number of the Eulachon population in the Columbia River prior to the twenty-first century numbered in the hundreds of millions. This large number contrasts with a population estimated at a mean value of 783,000 fish at its low point before listing in 2010.

This amazing collapse in the southern DPS Eulachon (it does not include Alaska) occurred in the early 1990s following the historical median annual commercial catch (1938 to 1992) in the Columbia River subpopulation of over 22,000,000 fish; f*rom 1993 to 2006 it was about 481,000 fish; this number reflects the ups-and-downs following collapse.*

Meanwhile, in the Strait of Juan de Fuca, by the 1970s the Elwha River Eulachon run was thought to be extinct.

The historic numbers of the Eulachon catch from the late 19th century to near the end of the 20th reveal that fishing in the Columbia River and its tributaries was cyclical, resembling a rough sine wave, but with a consistent high; a maximum take of over 60,000,000 fish during World War II was recorded, and the total was rarely below 10,000,000. In 1992, the number caught approached was about 41,000,000 fish. By 1996, this number was down to 102,000, and in 2005 it registered even fewer fish.

1994 – Collapse

The big undulations disappear, replaced by a flattened curve with the lowest numbers in the Columbia River occurring in 1994; only 200 pounds were harvested in the river that year (although it was much higher in the Cowlitz River). Meanwhile, to the north, the Canadian rivers, including the Fraser River, also were undergoing a collapse proportionately less but of sufficient magnitude to impel Canadian fisheries management to close the Eulachon fishery.

In the United States, a short recovery followed the low point of 1994, and in the Columbia a maximum of 158,800 pounds were landed. However, the Eulachon itself apparently had not increased enough to support such numbers and by 2005 the collapse was once more evident. That year all non-tribal fisheries took 2400 fish. It was the Cowlitz River where the decline was most evident, and interestingly, following listing, in 2016-2017 another abrupt decline was recorded.

Historic ups-and-downs continue today (in 2023 recreational fishing has been suspended), with notable increases after the listing in 2010 and again ten years later. Yet since the 1990s the number of Eulachon plying the sea and the rivers are a shadow of the past. This is easily seen in fishing numbers; always greater than 100,000 pounds, with highs of over a million in the late 1940s and early 1950s, this reflection of Eulachon abundance is relegated to memory.

Listing the Eulachon Southern DPS

On November 8, 2007, more than 20 years after the sharp decline in the southern DPS Eulachon, the Cowlitz Indian Tribe filed a petition with the National Marine Fishery Service (NMFS) requesting that the Pacific Eulachon populations of Washington, Oregon, and California be listed as threatened or endangered under the ESA. In their petition the tribe argued for the defining of the southern DPS as a distinct population and noted that the Eulachon had declined severely both in British Columbia rivers as well as American. Also included in the tribe's petition was the observation that the species had essentially disappeared in Oregon and California.

Interestingly, the Cowlitz Tribe petition emphasized local human interference with Eulachon runs, including sedimentation, in part as an aftermath of the Mount Saint Helens eruption that altered conditions in rivers, and subsequently inadequately stabilized. Other concerns were dredging activities and pollutants present in the fish. Also addressed was the bycatch issue. Global climate changes were also discussed.

After a review that included other data and publications, the NMFS ruled that sufficient scientific and commercial data had been provided to consider the petition. A decision on Eulachon status was required within a year. At this time, the boundaries for a discrete Eulachon DPS were accepted. Comments were solicited for a period of six months.

With the petition accepted, the process of determining whether the Eulachon should be listed as "threatened" or "endangered" began. The goal was (and is) to save the southern DPS Eulachon from extinction. However, the NMFS also had to consider whether it was even possible to implement programs to save this discrete population. Funding for such efforts was part of the process, and ongoing efforts were solicited. A listing would specify requirements to provide a framework for managing the Southern DPS Eulachon, not only to stop the decline but to rebuild it to at least a proportion of its former abundance. Among other items on the agenda, the question of "what happened" would be considered — how was it possible for an abundant fish decrease so rapidly.

On March 18, 2010, the Eulachon southern DPS was listed as "Threatened." Now a new set of documentation, including management and recovery plans, as well as regular status reports would be required.

Prior to the listing, the NMFS had convened a Biological Review Team (BRT), composed of scientists from several agencies and given the responsibility for identifying threats to the southern DPS Eulachon and making a recommendation for listing. In their report, the BRT identified four primary threats, presented in order of importance, while also recommending that the Eulachon DPS should be given Threatened status. The four threats would be of particular importance to the Eulachon Recovery Plan, a requirement for an ESA listed species. In particular, specific actions, such as surveying spawning, shrimp fishery observations, and other specific measures to access both threats to recovery as well as understanding current conditions would be recommended. Status reports were to be prepared at 5-year intervals.

The four top threats identified by the BRT were (1) Climate change, (2) Offshore shrimp fisheries bycatch, (3) dams and water diversions in the Klamath and Columbia Rivers, and (4) Predation. For purposes of evaluating these factors, the southern DPS Eulachon is partitioned into four subpopulations — the Klamath, Columbia, Fraser, and British Columbia.

Documentation, surveys, research — this is a big task for those ultimately responsible for the recovery of a once abundant fish now on the edge of extinction throughout a significant portion of its historic range. Underlying these efforts would always be the question of what had happened.

In the immediate future, one of the most important issues to be addressed was fishing, as Threatened species can be taken, both commercially and recreationally. What were the advantages and disadvantages of continuing this long use of the Eulachon for human needs and the pleasure of fishing as well. However, one immediate outcome of the listing was the closure of fisheries until 2014. Since that time Eulachon fishing has been permitted, with one abrupt cessation in 2019. Data collected from fishing contributes to knowledge of the population while more fishery-independent measures provide insight into possible recovery as well as more accuracy in estimates of Eulachon numbers. Specifically, spawning surveys would provide this measure; these, although indirect estimates, are considered the most consistent and best method in the absence of other survey methods such as collection of adults in their ocean habitat. And they would increase in scope and duration, adding to the knowledge of Eulachon spawning dynamics.

Unfortunately, as with so many things, the "recovery" of the southern DPS Eulachon is not straightforward. The increase in numbers after the listing, the leveling off, the restart of fishing, and the acknowledgement of the Eulachon as a "data poor" species, and in particular the specification of as many as 16 factors implicated in decline— all would play their role in recovery. Which, as would be evident in 2018, would not be smooth. Was it the rise in water temperatures prior to that year, given that the spawning cycle is typically three years? A climate oscillation? Whatever the combination of multiple factors, in 2018 the Eulachon in the mainstream Columbia River the Eulachon count was estimated at 400,000 fish. Recovery was, for that year, on hold.

The Big Four

Climate change was specified by the BRT as the primary threat to Eulachon. Since this is a cold-water species, it can be expected that impacts on life processes, such as spawning, would be greater when salt and fresh waters alike warmed. Verification of the overall increase in sea surface temperatures has been historically quantified at several locations in the north Pacific. Other factors combine with this upward trend, including regular fluctuations of the El Niño/La Niña cycle, familiar to the public for many years. Although expected and observed, the intensity of this warm/cold water influx remains difficult to predict, particularly for its impacts.

Other important drivers of ocean temperatures and ultimately productivity are the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO). Identified in 2008, and probably less well-known to the public, the NPGO has been studied extensively for its effect on nutrients and their influence in phytoplankton production, as well as salinity, and sea surface height variability. Driven by winds and horizontal water movements, the NPGO is coupled with other cyclical physical processes.

These include both the well-known ENSO and the North Pacific Oscillation (NPO). All of these are strongly influenced by the "Aleutian Low" (AL), a dominant low pressure atmospheric phenomenon located near the Aleutian Islands in Alaska, where it is particularly intense during the winter. The PDO and NPGO are local oceanic expressions of this low-pressure system.

Influencing these two oscillations in the North Pacific, atmospheric warming due to increased carbon dioxide and other gas compounds drives temperatures upward. The processes are coupled in ways that are not — and may never be — fully understood.

Meanwhile, in 2020 the northeastern Pacific entered a "cool phase" PDO, implying decreased temperatures and lower sea level, for a period that may last 20-30 years. However, some scientists believe the oscillations are occurring more frequently although not necessarily increasing in magnitude.

As for the ENSO cycle? In 2023, it appears that a warm El Niño phase may be coming.

The second factor considered for its impact on the Eulachon is the Pink Shrimp (*Pandalus jordani*) fishery. Expanded in the 1950s because of the invention of an automatic shrimp peeler, the trawl nets that collect the inch-long invertebrates captured thousands of other creatures as well. This "bycatch" grew commensurate with the shrimp catch and historically included species that would abruptly decline, in part from the loss to the shrimp fishery. One of those heavily impacted fish was the Eulachon as well as others — rockfish, hake, bottomfish, and squid remain part of that unintended take.

In time, the possible impact on populations of sensitive species, many of them subject to fishing pressure from their own industry, would spur shrimp net alterations that reduced bycatch. Some of these introduced devices, such as grates that permitted escape of unwanted species, would become requirements. The most recent of these Biological Reduction devices (BRD) is LED lights, positioned on the net; these provide enough contrast between sea floor and net to enhance escape.

Not surprisingly, shrimp fishery bycatch, and in particular that of the Eulachon, increases and decreases with the number of Pink Shrimp caught. Some fluctuations have been more pronounced than others. But the numbers caught and discarded are not insignificant, and in the past, when good estimates were not available, they were undoubtedly very high. Prior to the mandated use of BRDs, in Oregon alone 32-61% of the shrimp fishery was bycatch. The possible role of bycatch in the decline of the Eulachon seems clear. And even after listing, bycatch can number in the millions of fish. This, of course, occurs in good years for the Eulachon and the shrimp fishery as well, but it points to the importance of continuing efforts to reduce the numbers of non-targeted vertebrates and invertebrates as well.

Eulachon is considered a “data poor” species. Until more is understood, caution seems in order. Reducing bycatch is considered a priority in the Eulachon Fish Management Plan (FMP). However, the plan does not include specific restrictions on the shrimp fishery, such as closure or reduced hours, when a specific bycatch limit is reached, although such decisions can be made by management. By contrast, the British Columbia management plan has a Eulachon Action Level (EAL) for the west coast of Vancouver Island. If the bycatch reaches 4 metric tons (8818 pounds) the shrimp trawl season is closed.

The third contributing factor to the Eulachon decline is dams and other diversions, of particularly on the lower Columbia River. Although the Eulachon is typically observed to spawn in lower river reaches, the fish does travel upstream; historically, Eulachon are known to have spawned nearly 100 miles (164 km) up the Columbia. Recent surveys have found larvae near the Bonneville Dam, 40 miles (64 km) inland from Portland, Oregon. Spawning fish have constituted a large historical run in the Cowlitz River, the Sandy River, the Kalama, and the Lewis as well.

The Management Plan calls for gathering more information about the impacts of dams and channel-spanning water control structures, suggests actions for dam management, and other generalities. Dams and other alterations to river flow are considered of “moderate” impact in the Columbia and Klamath rivers, but not of concern in British Columbia.

The fourth most important factor impacting the four Eulachon subpopulations is predation; this factor is considered of “moderate” effect. Although perhaps not as significant to Eulachon recovery, nevertheless increased monitoring and analyses is specified in the Eulachon Recovery Plan, particularly concerning juvenile fish. Implicated predators include other fish, birds, and pinnipeds, both in freshwater and marine habitats. Specifically, it has been observed that harbor seals, California sea lions, and Steller sea lions move into the Columbia River during the winter, feeding on Eulachon. Spring spawning runs also are subject to predation. Harbor seals have been seen 45 miles upriver; this mammal numbers in the thousands and is believed to have consumed Eulachon in the past by the millions. In the late 1980s when commercial fishing was at a high level, it was estimated that Harbor Seals played a significant role in the catch, consuming as much as 50% of the Eulachon take. Today, when commercial fishing is at a low level, seals continue unrestrained to prey on the population.

As for fish, the Spiny Dogfish and Pacific Hake are known to consume large numbers of Eulachon, particularly in the Fraser River subpopulation. It is expected that Pacific Hake, a cold-water species, will increase in more northerly waters as the seas warm in response to climate change. This movement will include a potential shift in spawning populations; young hake consume prey (euphausiids) also preferred by Eulachon. Thus, the impact is two-fold.

Although not considered as significant as climate change and the pink shrimp fishery, the increasing presence of Eulachon predators and the small numbers of the population are cause enough for concern.

Research and Documentation

As part of restoration efforts for a listed species, the ESA stipulates that a Recovery Plan be developed and implemented, with measures of success, research, and ongoing concerns summarized in reports at five-year intervals. Published in 2017, the plan was preceded by a "Federal Recovery Outline," made available in 2013, as well as a draft recovery plan in 2015. Interestingly, this transpired during a time of another sharp decline in the Eulachon population.

This document includes a Priority Number which, on a scale of 1-10, was given a 7; in other words, the risk of extinction is considered to be moderate. Recovery would be high if fishing remained closed and habitat was protected. This was problematic, however, as economic interests call for other approaches. Another consideration to the "moderate extinction" risk was the fact that threats are not well understood for the Eulachon.

Nevertheless, even given the limitations of scientific knowledge and the ongoing concerns about possible extinction, the goal was clear and ambitious — the outline would specify a plan intended as a guide to a "Healthy, self-sustained, biologically viable sub-populations of eulachon exist throughout their historic range… . " The concept of what constitutes viability is one of the key words here.

Yet given the statement and acknowledgement of data limits, understanding, ongoing threats, and conflicts, the plan would be the primary guide for agencies, general in some respects but also with specific actions directed. These include several activities, such as spawning stock biomass surveys, development of models, expanded research, and studying climate impacts, among others.

Other measures in the outline included proposed regulations directed at shrimp fisheries, work with various agencies such as the Bonneville Power Administration and the U.S. Army Corps of Engineers, and support for the removal of the Klamath River dams. Coordination with other groups and agencies, such as the tribes, and various NOAA divisions are specified; basically, this is a directive for increased collaboration.

The publishing of the Recovery Plan in 2017 constituted a very important milestone in the goal of recovery for the Eulachon. Here were laid down the factors that contributed to the Threatened status of the species, and the specifications of a program that included formation of a Recovery and Implementation Team, naming research priorities, and a close look at threats. The formation of the team, the estimates of costs — all these specifics and more in theory would lead to recovery of the species. The time frame? 25 to 100 years.

Modeling the Bycatch

Quantitative modeling of a physical or biological process is a common approach to combining information about what is known with that which is difficult to obtain in the present, although future input might become possible. From airplane navigation to Stock Market dynamics to changes in fish populations, confidence in this approach and verification ultimately lies in the data. Sometimes the predictions are difficult to assess, but modeling is an increasingly common approach to understanding fish dynamics and predicting outcomes of events and processes. Such “answers” as the model produces are often used to validate an approach to quantifying a system. High speed computing, funds for modeling research, availability of new or updated data — all contribute to the increasing use of prediction and verification with a modeling approach.

But it is only as good as the mathematics and the data. Approximations of unknown parameters are part of the process; in fact, it is the specification of such unknowns that drives a modeling approach. Some may be set at a constant value, a number derived from other determinations; others are varied, the purpose being to evaluate the model output.

A good example is provided by models developed to estimated Eulachon bycatch in the pink shrimp fishery. In part because of the inclusion of onboard observers, logbook entries, and other data sources, “output” data is available, such as the approximation of the bycatch itself. What is desired is to determine its dependence on various factors and hopefully predict the impact of the fishery on the Eulachon.

Such a model currently employed examines parameters such as the area fished, the percentage of Eulachon taken by a particular fishing apparatus, including new regulated devices to reduce bycatch, the area used by Eulachon itself, the proportion of Eulachon caught in a fishery net sweep, and the proportion of Eulachon that perish because of encountering the net, among others. These are “set” at a few values, and the outcome on Eulachon (the bycatch) calculated from the modeling equations. The results depend on the accuracy in estimating the parameters, and the mathematics itself.

Modeling has become an important approach in predicting Eulachon bycatch. Output is also used as an advisory in setting regulations, promoting more research into BRDs, and explaining the fluctuations in bycatch. In that sense, the model takes on a role in the recovery of this threatened fish. Since bycatch from the shrimp fishery has been determined as the second most significant cause of the Eulachon decline, modeling takes on added significance.

Fishing

In its specification of factors that most affect Eulachon population fluctuations, the “threat assessment” of the Eulachon Recovery Plan, places recreational harvesting in position 13 and commercial harvest in position 15. While this placement may reflect the predicted role of fishing after listing, Eulachon numbers in the past were estimated at a mean value of 186,000,000 fish. In 2017, the number was 8,148,600. Even given the fluctuations in forage fish populations, such as that of the Eulachon, this is an enormous decline.

What, if any, impact could fishing have contributed to the sharp decline of the Eulachon in the 1990s? Research suggests that overfishing has historically been a factor in the collapse of forage fish populations. Here “collapse” implies a sudden decline at a certain percentage (25 percent and less) of biomass. The important factor when considering fishery impact is the observation that fishing continued at a high level *even as the signals were present that a collapse had begun. In other words, the impact on a species whose numbers were in sharp decline continued until the collapse itself.* Reproduction could not compensate for the removal by fishing which did not cease until the population reached a point low point and was considered a candidate for listing. And, in heavily fished forage fish populations, in which collapses are a periodic natural phenomenon, heavy fishing until collapse surely contributes to the low numbers and the frequency of occurrence.

Is it possible that this happened with the Eulachon? A close look at fishery numbers during the early 1990s provides some insight.

At its highest point since the 1940s, in the first three years of the 1990s, the Columbia River Eulachon landings, including the tributaries, weighed in at more than 2,775,000 pounds per year, reaching its high point in 1992, when 3,673,800 pounds of Eulachon were caught, the vast majority in the Cowlitz River. Using 11.19 fish per pound as an estimate, this number translates to over 41,000,000 fish. Yet apparently unknown to managers and fishers, the collapse was already in progress. Reflected in the catch, by 1994, the total poundage was 43,400, again most of it in the Cowlitz, or more than 485,000 fish.

The collapse may not have been foreseen as it can be very difficult to determine forage fish dynamics. But the numbers caught in the Columbia and its tributaries were definitely at a high point, suggesting that continued fishing pressure contributed to the very sharp decline in Eulachon numbers. Fishing would, of course, essentially cease. The fish were not there.

Yet in 2001 fishing increased once again, to levels more common in the early 1980s. What happened after that increase (listing did not occur until 2010)? In the Cowlitz River alone, where the catch is typically highest, the average catch from 2000 – 2009 was approximately 11,000,000 fish. After listing fishing ceased for three years, resumed again in 2014, and halted in 2019 because of another sharp decline; fishery numbers alone reveal this downward trend. In 2022 the catch in the Columbia was about 307,000 fish. Meanwhile, on the Cowlitz, recreational fishing will not be permitted in 2023.

The great days and years of Eulachon fishing are over. For the fish and all concerned with its existence, hope for recovery remains.

Eulachon in the Strait — Loss and Reappearance

Present in the past, the Eulachon spawned in the major rivers and smaller streams alike, providing food for the tribes who lived along the Strait. Yet by the 1970s if a remnant Eulachon population remained in the Elwha River, a great waterway much altered in the twentieth century by two dams, no one seemed to know of it. The Eulachon appeared to be locally extinct.

And then, allmost magically it seems, the little fish would reappear.

Although fishery biologists cannot be certain without more analyses, it is thought that Eulachon collected in the Elwha during the last decade are likely members of a remnant population that spawned for countless centuries in the still waters of the river.

In 2020 and 2021, research on spawning in the Elwha, Dungeness, and Lyre Rivers was undertaken by the Lower Elwha Klallam tribe. The sampling of juveniles confirmed the presence of larvae, and preliminary data does support the idea that the Eulachon in the Elwha are part of a remnant population. The lack of adults in the Dungeness would seem to preclude the possibility that Elwha fish were “strays” from that river. Interestingly, the Lyre River had the highest count of larvae; however, this could be due to the smaller flows and thus more numbers in the concentrated collection.

Meanwhile, adults are present in the Elwha, raising the question as to whether measures undertaken since the Eulachon listing, whose recovery efforts are concentrated in the Columba River, are related to possible recurrence in the Elwha.

Osmeridae — Eulachon (*Thaleichthys pacificus*)

With the removal of the two Elwha dams, a project completed in 2014, the river, now flowing freely throughout its valley, carried sediment from two former lakes towards the mouth, depositing it along the river channel, and changing, or in a sense restoring, the riverbed, the banks, the degraded side channels, and other habitats altered by the dams. What did this mean for the Eulachon, a species that most often spawns in lower river reaches?

Because of the trapped sediment behind the dams, the riverbed between the two and to the mouth was essentially "scoured," rendering a vastly altered habitat throughout much of its length. Although Eulachon are poor swimmers that do not typically travel far, they are quite particular about spawning habitat. Preferences include sandy/gravelly substrate, often in side channels where water flow is reduced and sediment present. Thus, deposition of sediment to the river bottom following dam removal would provide better spawning opportunities for the Eulachon.

Today the fish has increased in small but recordable numbers in the Elwha. These fish could represent a continuance for which hope was nearly lost. To witness a spawning event would be exciting indeed.

Eating the Eulachon

When offered the Eulachon in 1806 by local tribes Meriweather Lewis extolled the virtues of a fish long known for its tasty appeal and sustaining qualities by the native peoples of the Pacific Northwest. The "grease" prepared from the Eulachon is rich in several vitamins and healthy fatty acids as well. For some tribes, the oil was as important as the flesh. Fresh preparation of the freshly caught Eulachon included roasting them or smoking them for future consumption. Preparing the oil involved placing the Eulachon in large vessels (including canoes) where the oil would be released as the fish rotted and were then cooked. The oil reportedly had a strong smell and a golden color. It could be used as a butter-like addition or as a dip for various foods, and for preservative of various fruits and other foods. It also was valued for medicinal purposes and as a paint when mixed with other ingredients.

Such an important dietary item to Northwest tribes implied significance beyond consumption in the form of various rituals, ceremonies such as those honoring the first seasonal catch, an event marked by ritualistic recitations and the welcoming of neighbors to the festivities.

Today, recipes vary for use of the fish and its oil. Culinary advice includes placing the cleaned fish in an overnight brine and then smoking it. They can be coated in flour and smoked as well. Other preparations specify cleaning and deboning the fish, following deep fat frying, and then placing it in a marinade made from vinegar and soy sauce. As for the oil, not as widely used as in the past, it is both nutritious and tasty and renders the dried fish flammable. Strike a match and the name "Candle fish" applies.

It is said that in the past some rivers "ran black" with Eulachon. What a wonder it would be to witness such an event once again. Unfortunately, at the present time, it seems unlikely. Nevertheless, there is hope for these little fish that ply the ocean waters during the early years of their lives and return to their freshwater birth homes to ensure their continuance. Someday, if management succeeds with its hopeful goals, and society exhibits its will for recovery, the Strait of Juan de Fuca, and the great rivers that flow into it, may be home to thousands once again. This is the vision.