Oncorhynchus kisutch — Coho Salmon

By Susan McDougall

The tiny salmon fry scope out little territories, defending their patch against siblings, feeding on small insects and larvae. Born a few weeks after their parents' autumn return to their natal stream, now once again the days shorten. Yet for the youngsters, there seems little rush to return to the sea. Sustained by the availability of food, they may delay the hazardous journey one more winter. Then, colored in different hues and patterns than those of their early days, the six-inch fish — now called "smolts" by human observers — move downstream with the springtime flow, relinquishing the security of their birth home for the wide, rich sea. It is a lure they cannot resist.

Also called the Silver Salmon, the name "Coho" is of unknown origin although is most likely indigenous. *Oncorhynchus* means "hooked snout" and the genus includes 16 salmon and trout species, most of them native to the northern Pacific, from the waters of Asia to North America. *Kisutch* is the Russian vernacular for the fish, a name dating back to 1792. *Oncorhynchus* species are members of the Salmonidae family, a medium-sized group of about 66 species which also includes graylings, whitefishes, and others. However, salmon are the most well-known among the Salmonidae members, both for their importance to tribes along the Pacific coast, and as a seemingly unlimited resource for exploitation by commercial and recreational fisheries. And of the several salmon species in the Salish Sea, for thousands of years the Coho played an important role for those who depended on its annual return. In more recent times, the Coho has been a desirable fish for the ever-growing human communities of coastal and inland homes alike.

Coho Salmon (*Oncorhynchus kisutch*)

The Coho is the third largest of the native Pacific salmon; both the great Chinook and the less well-known Chum are heavier and longer. Coho reach a maximum length of about 38.5 inches (97 cm) and a weight of nearly 31 pounds, but more commonly they tip the scales at 6 – 12 pounds, with the larger males approximately 28 inches (71 cm) in length and the female 23.5 inches (59.5 cm). In other words, this is a two-foot fish weighing in like a medium-size bag of flour.

During their years of maturation in the ocean, Coho are silvery on the sides, bluish gray above, with a white belly. They have small black spots above the lateral line and on the upper lobe of the caudal fin. The lining of the mouth is white, the body elongated, and the upper jaw extends beyond the eye. The body scales are large and sparse. This classic, beautiful fish is closely related to Chinook Salmon.

Coho are anadromous, returning to their natal stream to spawn and die, typically after one winter at sea. Occasionally, younger, smaller fish, known as "jacks," spawn after less than a year in saltwater and often survive to return to the ocean, only to swim upriver once again. Coho fry may spend two winters in their birthplace, eventually swimming downstream towards estuaries where they undergo physiological changes necessary for adaptation to saltwater. The adults return in autumn and are known to travel farther upstream than most other species, spawning in shallow waters of narrow creeks, or sometimes in larger rivers as well.

During their ocean residency, Coho typically remain near the continental shelf, migrating shorter distances than other salmon species. If they do migrate, fish that enter the ocean via the Strait probably move northward. This species is distributed from the Bering Sea to Monterey Bay, California, and across the Pacific to northern Japan and eastern Russia, including the Kamchatka Peninsula and the Sea of Okhotsk. Coho have also been introduced to the Great Lakes and other locations long distances from their Pacific home and are raised in fish farms and hatcheries alike. In the Salish Sea, they are present in all large rivers and most streams. Although historically numbering in the hundreds of thousands, today Coho is the second least abundant salmon species, not including sea-run trout such as Cutthroat.

When Coho begin their homeward journey, they must undergo a "reverse" adaptation, this time from saltwater to fresh. Such a change coincides with a transformation from their oceanic silvery color to warm hues, and the development of a hooked upper jaw and enlarged teeth, particularly in the male. The males are deep red, resembling a Chinook salmon, accented with greens and blues; females are more bronze in color with a paler dorsal surface. Both sexes retain their spots. Strong swimmers against the flow, they move upstream, seeking a gravelly site where the female digs a depression and deposits up to 3,000 eggs. These hatch in 5-12 weeks and remain in the substrate for a few more weeks. Most of the young fish spend 1-4 winters in the stream (northern populations tend to stay longer) before making their way in springtime to an estuary and eventually saltwater; there the juveniles tend to remain close to the coast, often hidden in kelp or eelgrass. They typically return after a winter at sea, although this sojourn can extend to as many as five years. Factors such as increased river flow and high tides promote upstream movement.

Maturing adults eat fish and invertebrates — squid is a particular favorite — and in turn are preyed upon by marine mammals, larger fish, and birds. And, of course, humans.

Feeding Humankind — Abundance and Loss

As with other salmon species, Coho were an important food source to Indigenous peoples for countless generations. With its firm flesh, it was not only sustaining but desirable for its taste. The species was abundant; in the early years of commercial fishing, the catch in the Columbia River alone reached 900,000 fish. By the 1930s, in part due to the construction of dams, that bounty was consigned to memory and until a growth in hatchery production, the catch remained low. Hatcheries had been constructed as early as the late 19th century specifically for augmenting the declining wild Coho population. On the Elwha River, dams built in the early 20th century contributed to reduced salmon runs, including the Coho, to the merest shadow of their former abundance, and in 1976 the Lower Elwha Klallam Tribe built a hatchery on the river to increase the Coho population.

In the past, Coho salmon supported fisheries in California, but with sharp declines beginning in the mid-20th century, by the early 1990s fishing this iconic species was closed throughout the state. First listed as "threatened" in 1996, in 2005 the Central California Coast Coho was relisted as an endangered Evolutionary Significant Unit (ESU). It is predicted by many that Coho will disappear from almost all California streams in the near future. Most of these small coastal waterways have fewer than 100 wild spawning adults. In 2023, a five-year review of the endangered central California ESU noted that while some threats, such as habitat loss, have eased, others have increased (climate change). It seems unlikely that this fragment will significantly increase; in fact, the opposite outcome seems to define its reality.

Declines in wild Coho populations have not been restricted to California. Of the seven Coho ESUs defined by the National Marine Fisheries Service (NMFS) in the three Pacific Coast states, four are listed under the Endangered Species Act (ESA), including one in the lower Columbia River. In the Strait, two Evolutionary Significant Units are defined; one west of Salt Creek (the Olympic Peninsula ESU), and the other east of the creek: that population is part of the Puget Sound/Strait of Georgia ESU and is considered a "species of concern." In general, ESUs are composed of both hatchery and natural (wild) Coho; however, for management purposes only the Dungeness and Elwha Rivers include hatchery fish. They are under the jurisdiction of the Pacific Salmon Treaty between the United States and Canada.

Today, the abundance of wild Coho in the past is lost in the reality of the present and future. Bred to support fisheries in the ocean and inland waters and hopefully contribute to preserving the wild runs, hatchery smolts number in the hundreds of thousands. These are fish that live along the outer coast, in rivers and streams, and in the Strait itself. As for the wild fish, restrictive management reflects the loss. Millions have been reduced to thousands, and in some years, those thousands are very small indeed.

2018 – The Strait's Wild Coho in Trouble

"*Optimum yield (OY) means the number of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account protection of marine ecosystems. It is prescribed on the basis of the maximum sustainable yield (MSY) from the fishery, reduced by any relevant economic, social, or ecological factors, and provides for rebuilding of an overfished stock, taking into account the effects of uncertainty and management imprecision***." – from the Pacific Coast Salmon Fishery Management Plan**

For the purposes of fishery management, which is the responsibility of both state and federal agencies, "overfishing" is defined as the contribution of several factors. There is fishing, which includes commercial, tribal, and sport taking of both wild and hatchery salmon. Other forces that contribute are predation by species other than humans, food availability at sea, ocean conditions (impacting marine survival), and more. For the Strait's wild Coho, overfishing is declared to occur if the 3-year geometric mean of spawning escapement (the number of fish that live to adulthood and return to their natal stream) falls below a specified percentage of the maximum sustainable yield (MSY), defined as the number of spawners that can be caught while sustaining a maximum production rate. The MSY is a particularly important concept for fisheries management; for the Strait Coho it has been estimated to be 11,000 spawning-age fish. The percentage of this MSY that defines overfishing is specified in the Pacific Coast Salmon Fishery Management Plan (FMP). First adopted as a regulatory requirement for the 1977 fishing season, this document was written in response to the federal Magnuson-Stevenson Act (MSA) of 1976. The plan has been modified through amendments extensively since that time. Among other specifications, the FMP defines the several Coho stocks of the west coast.

For the wild Coho, the FMP specifies the "SMSY as the number of spawners needed to produce the MSY," a theoretical concept. What its definition and use as a management tool means is that the population is believed to be sustainable indefinitely at this value. The minimum allowed threshold for spawners (MSST) is a proportion of that number. This has been set at 7,000 fish for the Strait's Coho. In other words, although the MSY is calculated at 11,000, exploitation is permitted that reduces the population below that number. However, if the estimated number of 3-year-old Coho (the spawning age) falls below 7,000 for three years, a Recovery Management Plan must be developed and implemented.

This is what occurred with the wild Coho of the Strait of Juan de Fuca in 2018. By that time, the maximum exploitation rate (ER) — that is, rate of adult spawners that can be caught in a season — had been set at 20 percent.

Prior to the acknowledgement of the "overfished" Coho status in the Strait, beginning in 2014 the ocean had been anomalously warm. In part, the elevated temperature could be attributed to the "Blob" that developed in the Gulf of Alaska in 2013, but other factors were unfavorable as well. The regularly oscillating Pacific Decadal Oscillation (PDO) was also strongly positive (warmer) during this time. By 2017, the postseason estimate of the Strait wild Coho population was less than 5,000. Ocean conditions had improved, an indication of possible recovery for Coho and other species as well, but the reality was an alarmingly depressed number of wild fish.

But prior to this proclaimed hope for natural recovery, what was the exploitation rate of the Strait Coho during the warm years?

In 2014, "total fishing mortality" of the Juan de Fuca (JDF) wild Coho was 2,327 fish; by 2016, the number was about a tenth of that value. That 2014 number represented an exploitation rate of about 18 percent of the estimated Coho cohort. By 2015 the returning spawner numbers had declined dramatically, although preseason estimates were still above the 11,000 MSY number. The exploitation rate remained about the same, although the catch was less; the reduced Coho numbers could not sustain the allowed take. By this time, the postseason estimate of ocean abundance was fewer than 5,000 fish. In 2016, actual mortality reflected this updated number, and fishing return was very low.

Clearly, the predictive methods for ocean abundance had failed, although it is interesting to note that in 2015 the number was getting close to the 11,000 MSY value. About two-thirds of the catch that year was sport fishing. The point is that a high exploitation rate continued because of the error in estimating the annual stock numbers, even though the catch was falling. And it was because of the low numbers from 2015-2017 that the Council was required to implement a recovery plan.

This Salmon Rebuilding Plan for the "Strait of Juan de Fuca Natural Coho" salmon is a lengthy document that considers the many potential impacts involved with recovery. Economic factors, overfishing status, regulatory specifications, environmental (habitat) considerations, and ultimately, recommendations (required for recovery), are all addressed in the plan. Finally, alternative actions are presented; in the end, "Alternative One," the status quo (or "no action) approach is selected.

In other words, the Strait of Juan de Fuca Coho were predicted to increase in number without changes to fishing regulations. In the Appendix (11) which describes this alternative, it is noteworthy (and expected) that this recovery plan would create no adverse effects on other environmental and economic considerations. This status quo alternative projected a 4-6-year recovery time frame.

Since 2019, what trends in the Strait of Juan de Fuca Coho are indicative of recovery? And what has been the escapement since the overfishing declaration? The answers are complicated.

In 2015 less than 4,000 spawning Coho were recorded, an exceptionally low number that was declared as related to low marine survival. That year the exploitation rate was approximately 18 percent. By 2017, numbers increased to 9,374 adult spawning Coho, and the exploitation rate was 7 percent. Fishing continued although the stock remained below the 11,000 MSY number.

Meanwhile, it is true that marine survival for the Strait's Coho has in general declined since the beginning of the 21st century. For those fish returning in 2022 the predicted survival was 4.5 percent. Nevertheless, in 2021 the predicted escapement was 20,000 wild Coho in the Strait, over twice the number in 2020. And in 2023, the wild Coho return is predicted at 23,562, a five-fold increase over 2019 when only 4,652 spawners returned.

Oncorhynchus kisutch — Coho Salmon

In 2022 a review of Salmon Fisheries states that the Strait of Juan de Fuca Coho is not overfished. The reasoning is that the exploitation rate does not exceed .6. This is the maximum fishing mortality threshold (MFMT) for all stocks. However, on December 12, 2022, the Federal Register of the United States declared that the Strait of Juan de Fuca coho salmon are still overfished.

The Juan de Fuca salmon had also reached a low point from 2006-2008. During this period, marine survival was low (approximately one percent), a value that was reflected in the numbers of 3-year-old spawning fish. As with the severe decline in 2017, fishing in the years prior to the low population of 2008 continued at a rate comparable to good years, at least until the fish were clearly in free fall. Then the exploitation rate increased, as there were fewer fish to be caught.

Although the news appears good for the wild Coho in the Strait for 2023, this number is based upon an expected survival rate of over 7 percent, a value that fisheries' personnel "in the field" say is optimistic. It must also be remembered that Coho, like other salmon species, vary in abundance, even in the absence of human impacts. Following a few years of such depressed numbers, the 2023 prediction should be regarded with as much caution as hope.

When salmon populations decline, the exploitation rate will eventually drop as well. If estimated spawning numbers are too low, the fishery can be temporarily halted, or the catch restricted in the following year as new estimates are computed and corrected. This is apparent from the data.

Thus, in 2013, the estimated wild Coho spawning number in the Strait was 8,458. Two years later the population had dropped to 3,859. In 2017, the preseason prediction of over 13,000 spawning Coho was more than twice the post season estimate.

Were the fisheries halted in those years? What were the fishery rules?

In 2015, wild Coho retention was allowed between October 1 and October 31. In 2017 recreational fishing was closed.

This is the reality when fishing rules are set by quotas based upon annual predictions of stock size and escapement. The management principle is to permit fishing that brings the population near the maximum sustainable yield but to permit exploitation that can reduce the number below that value.

The 2023 regulations published by the Washington Department of Fish and Wildlife will permit fishing of wild Coho between October 1-15 in selected areas such as Port Angeles Harbor, Sequim Bay, and Discovery Bay, as well as popular areas in the western Strait.

Processing the Data with FRAM — Fishery Regulatory Assessment Model

Suppose that you precisely knew the number of Coho smolts (juvenile fish) released from a hatchery located near a river that flows into the Strait. Perhaps it is a couple hundred thousand youngsters. Released from their pen, these little fish make their way towards the saltwater, undergoing physiological changes as they swim downstream, thriving on new food, and within a year or two, transforming into silvery-blue, white-bellied three-year-olds. Now mature, the adults embark upon the final stage of their lives, answering a compelling call to reproduce and thus ensure the continuance of their species. And so, they begin the arduous return journey, this time from salt to freshwater, back to the river where their lives began.

As the tired fish finally arrive at the hatchery, you can count them, dutifully recording how many have returned. Simple enough. Except, of course, somewhere in the vastness of the sea and the river, the lives of most of the smolts have been snuffed out. and even if they reach maturity, not all will succeed in the journey to the hatchery.

Not only that but the loss varies, sometimes widely, from year to year. And as a fisheries biologist, or perhaps an observer, you know many of the reasons why most smolts never become adults. You also know that understanding the causes behind the sometimes widely varying mortality is important not only to the continuance of hatchery fish, but to the species itself. Addressing the variables involved in successful maturation and spawning is in part the work of those now responsible for ensuring their continuance. The salmon's fate rests in human hands.

In the past, the return of spawning fish to their natal stream was also a concern for the peoples of the Strait who depended on them for life itself. The quantification of stock and the complexities of management may have been less, but expectation of the annual return was part of a cultural awareness and response that was quite different than today. Most people who fish (in particular, sport anglers) are not dependent on their catch for survival, and even commercial fishers can look elsewhere for employment or aid if their efforts do not earn a living.

This was not the case for those who needed fish (and many still do) for survival. And it would be a mistake to think that people who depended on salmon were not aware of the ups-and-downs of fish populations. The appearance of these great fish in a freshwater stream or river was an anticipated event, acknowledged with ceremony and thanks. Present for only a few weeks, the salmon provided sustenance for an entire year.

In the 21st century, salmon fishing has long been an "industry," one regulated by local and national agencies, subject to laws and international agreements designed to ultimately ensure species' survival, but most often applied to specific populations of those species. With a primary goal of providing fishing opportunities, such responsibilities are complicated and involve thousands of employees and impact millions of fish. Part of the regulatory process involves counting these mostly unseen animals, living beneath the surface of the water. Without that count, understanding the dynamics of the population is not possible.

Thus, an inventory of returning hatchery or wild Coho during the spawning season is a vital part of fisheries management. The problem is that counting is both difficult and always subject to available funds, the result being that consistency may be compromised, with many questions thus remaining unanswered. For example, suppose historical counts provide a baseline for estimating returning salmon numbers, both hatchery and wild. And then, for reasons not fully understood, the spawning fish one year are half of what was predicted. What has transpired? Surveying at the beginning and end of a salmon's life journey leaves many questions unanswered.

This variability in salmon mortality is an annual fact of life that must be dealt with by fisheries' personnel. Accurately quantifying salmon populations has become increasing necessary; without such measures, predicting the annual return is impossible and regulating the fishery an endeavor full of uncertainty. The fact that salmon are managed for fishing further emphasizes this need. Those involved with salmon management are tasked with the complexities of understanding their subject's life history.

What are the mortality factors that biologists attempt to quantify? To begin with, there is "natural" mortality; that is, the death rate in the absence of human predation. Although treated as a seasonally fixed number, this factor obviously is subject to fluctuations. The ocean is not a reproductive constant; each year the bounty of planktonic life upon which fish and other animals depend varies, sometimes widely. Juvenile fish may simply starve for lack of food. Abundance can be driven by seasonal weather fluctuations such the El Niño/La Niña cycles. The physics of the cycle may be understood, but the impact of temperature swings on ocean biota is difficult to quantify.

From the tiniest members of the food chain upon which the maturing salmon depends, the presence of larger creatures is also a concern. If another animal is bigger, it is a potential threat. This includes fish and marine mammals, swift and hungry creatures always on the lookout for a meal. And, of course, there is the human, a predator often concerned with more than food on the table.

All of these and more potentially reduce the salmon population. And the reality is that overall mortality is extremely high. The thousands of eggs laid by a spawning female will for the most part fail to mature into a returning adult. It is a statistical process.

Estimating predation by animals such as seals at sea may be difficult, but the impact of human fishing should be more tractable. Reporting the catch provides an estimate of population reduction and returning spawners, and such methods have been part of fishery management for many years. However, there is always the problem of both incompleteness and counting errors as well; these include the death of released fish, the incorrect retention of wild fish when releasing them is required, and the fishery catch mortality, including bycatch in other fisheries. How can such errors be quantified?

There is also the problem of stock mixing. For example, if you are fishing off the Washington coast, perhaps near the entrance to the Strait, how do you know which river a landed Coho came from? Coho do not migrate great distances, but they do move about in search of food. Thus, anglers and commercial fishers alike may catch salmon from multiple natal streams.

If, as well, you are concerned with the status and preservation of wild fish, what methods do you employ to ensure their separation from hatchery-bred fish. Hatcheries exist in large part because "natural" (wild) populations could not withstand decades of fishing pressure. And the continuance of wild fish concerns more than harvest — studies have demonstrated their vital importance to entire ecosystems. There is an emotional, historical appeal as well, and a worrisome uncertainty about the disappearance of wild fish. But the preservation of these runs poses questions that are at times difficult to answer, and treating hatchery fish as a one-to-one substitute for ancient runs is a mistake. There are inconsistencies in hatchery returns as well, and these fish, fed and grown in fabricated structures, are prone to problems and weaknesses associated with confinement. And, as always, there is the question of funding hatcheries while dealing with the reality of aging structures.

So, if you are a member of a fisheries group dealing with so many unknowns, how do you improve the accuracy of escapement prediction which includes variables such as smolt mortality and ocean productivity? Additionally, how do you stop the free fall of wild salmon, which, by law, you are required to do. And how do you distinguish the wild from the hatchery-bred fish?

One answer to the last question is to mark the hatchery fish, and as a response to the continuing decline in wild salmon populations, in the 1990s the Washington Department of Fish and Wildlife (WDFW) began marking Coho and Chinook hatchery fish. This was a simple enough procedure in which the small adipose fin was removed. Thus, distinguishing a hatchery fish from a wild one required a check for this small fin. If it was present, the fish would be wild and thus released. With this marking program the "mark-selective" fishery began, with seasonal rules restricting the wild catch to a few weeks. Along with proper management, this separation of the catch would in theory halt the decline of wild salmon.

A second question concerning both wild and hatchery salmon was how to separate the stocks. By doing so, the impact of fishing and other factors could be more clearly quantified. Indian treaty rights could also be more accurately addressed, and hatchery success understood in more detail. Fortunately, the development of a coded-wire tag (CWT) program, begun in the 1960s and implemented in hatchery fish in 1971, provided a means for enumerating individual fish, including recording their origins. In time, implementation of the program would result in the tagging of millions of juvenile salmon. Dollar investment was likewise (and continues to be) in the millions. Since its initial inception, improvements in the tags have provided increased accuracy and new codes are added each year. Although not all fish are tagged, recoveries number in the hundreds of thousands.

Tagging and marking programs have enabled fisheries' personnel to assess population dynamics for marked hatchery releases, and unmarked wild fish as well. Currently, Coho salmon populations are divided into 123 groups, consisting of marked (tagged, hatchery fish) and unmarked components. Thus, in total there are 246 Coho stocks. The number of surveyed Coho fisheries is 198, including pre-terminal and terminal fisheries (terminal fisheries are those that are directed towards spawning fish returning up rivers and streams, whereas pre-terminal refers to fishing distant from the natal stream).

Handling the Data

Improvements, such as the implementation of electronic tag detection, easier-to-read tags, and faster methods for injecting the tiny wire with its code, are part of the ongoing efforts to use CWT to count returning fish and to increase knowledge of individual stock dynamics. Yet the recording of potentially thousands of numbers creates a new problem. How do you save the data for processing? Fortunately, a data repository provided by the Regional Mark Processing Center (RMIS) stores millions of numbers. As for processing that data? Computers — the ultimate (to date) high speed machine — provide the means.

Given that reduction in time and the mind-boggling work for handling thousands of entries provided by electronic computing, the question now becomes of what to do with it all. How is the data to be interpreted? What do you know about the “system” represented by so many numbers?

This is where modeling, in this case of fish population dynamics, offers an answer. The method has a long history. Many systems, from airplane navigation to traffic flow, have been and are continually interpreted and improved in understanding by modeling. In that sense, the dynamics of fish populations can be considered a system to be modeled. And, like an airplane where data input, and the mathematical implementation of relationships between physical variables, enables prediction of the “state,” so too with fish, at least in theory. As with most other systems, however, fish dynamics are a stochastic process; that is, the variables that define the system are randomized.

Many stochastic models depend on knowledge of the statistics of known errors, such as sensor errors (for example, radar, or GPS). In the case of fish, such information may be lacking or rudimentary. Hence, a simpler approach to modeling the system is a linear, deterministic method, where errors are specified as constants, and the data is compared to a base period, consisting of variables collected over a designated time frame.

For airplane navigation, you want to know where you are going; for fish stocks, understanding what will transpire THIS YEAR, if certain parameters are assumed and incorporated into the calculations, is the goal. The output of such a model? How many fish will escape (that is, survive the many pitfalls that can and will decrease their numbers, permitting completion of their life cycle) given the starting population (always an estimate) and the modeled impacts on that initial salmon number.

Designed in part as a response to Indian fishery rights litigation in the 1970s, FRAM (Fishery Regulation Assessment Model) is a deterministic, time-step model (five time-steps for Coho) used to evaluate proposed fisheries impacts for a single management year. Over the years, the model has been modified and made available for personal computers. It is simplistic in concept, with user input of fishery errors (such as retaining of wild fish in mark-selective fisheries), and other errors as well (treated as constants), and, most importantly, exploitation rate. This parameter is set as a percentage, a quota, a "ceiling," or a value determined for terminal fisheries.

The input of a FRAM run includes estimated stock abundances for the year as well as the fixed error values. Initial stock numbers are independently derived by fisheries biologists and include such factors as jack-to-adult relationships, smolt production, marine survival rate, and consideration of historic ocean abundance. This estimated starting value is multiplied by a constant and applies only to age-3 mature Coho. FRAM calculates predicted escapement for the current year, but it can also be used "backwards" to ascertain the accuracy of this value against the actual stock prediction. This is done by using the (current) yearly Coded-wire tag (CWT) data.

The importance of FRAM is in part its historical use as a predictor of annual escapement. Like all models, it depends on user input, including the predicated initial starting population and the exploitation rate. Ultimately, permitted fishing depends on that number and its relationship to the concept of maximum sustainable yield discussed above. In other words, if fish numbers are predicted to be high, so, too, is potential exploitation rate. This application of exploitation percentage is evident when studying fishing charts and graphs.

How well does FRAM perform? If the pre-season prediction of stock abundance is fairly accurate to begin with, the calculated escapement also tends to come close. However, if the initial salmon stock is incorrectly calculated, and especially if it is estimated significantly above "truth," the model, being in a sense regressive, performs poorly.

What is most unfortunate about this discrepancy between reality and prediction is that permitted fishing will result in a high exploitation rate as the stock declines (because it is a percentage of a smaller number), meaning that there is a lag in correcting the original inaccuracy of the estimated abundance.

For example, in 2004-2007 when Coho populations fell dramatically, the exploitation rate was high. FRAM runs with predicted rates were very inaccurate, although by the following year, estimates of the Strait's Coho population were adjusted to reflect the poor year. Meanwhile, FRAM runs would be made on data that in 2008 was almost 600% over forecast. Similarly, during a subsequent decline from 2017-2019, one of sufficient severity that "overfished" status as defined in the Fishery Management Plan (FMP) was declared in 2018 and a rebuilding plan written and implemented as required. Interestingly, it was known that factors for salmon survival three years prior (2015) were poor. Marine survival rates declined to just .01 in 2015. Nevertheless, the exploitation rate reached 18 percent in 2015; the following year the number was 2.8 percent. The decline in exploitation rate was reflecting reality, but by that time the damage had been done.

Nine years prior to this decline, in 2006 the preseason abundance was predicted at 26,100 fish; the postseason estimate 4,600. The ratio is 5.65. In 2017, the preseason was 13,100 the postseason 5,900, the ratio being 2.24.

The impact of incorrect forecasting of stock populations can drive numbers downwards at a rapid rate. The rebuilding plan itself acknowledges management errors in designating the fishing season from 2014-2015.

By using data from the current season, postseason FRAM runs compute the results of fishery regulations. This approach can quantify the model's performance in estimating initial stock abundance. In other words, this is a postseason evaluation, calculating that season's escapement after quotas have been set. The backwards FRAM number can also be used in the analysis of preseason abundance.

Meanwhile, in 2023 the Juan de Fuca Strait wild Coho abundance forecast by the WDFW is 23,562, approximately three times that of 2022 when the estimated abundance was 8,280; in 2021 the marine survival was predicted to be below 2%, and the Coho population was calculated at a low rate of 5,152 fish. For 2023, the marine survival rate is predicted at over 7 percent. The forecast of more than 23,000 fish permits an exploitation rate of 40 percent. Since an El Niño event has begun in the Pacific this year, it will be interesting to follow the status of the Coho in the Strait of Juan de Fuca. The season for wild Coho fishing is set for October.

Strait of Juan de Fuca Wild Coho – the Future

In the 21st century, sharp declines in wild Coho populations in the Strait of Juan de Fuca have occurred at least twice, with the second event sufficiently severe to invoke a requirement to "rebuild" the stock. The fish of the eastern Strait are considered a "species of concern" in the Federal Register; however, that status is not recognized by the WDFW. In 2010, a petition to list the Coho as Endangered or Threatened in the Puget Sound region was declined by the National Marine Fisheries Service (NMFS). And, as one of the hardest to estimate and most important impacts on Coho, marine survival is strongly influenced by oceanic conditions. The cyclical nature of this factor has always been difficult to predict. The reality of climate change is equally hard to quantify. A more conservative approach might be advisable, but that does not seem likely. High exploitation rates permitted by the Fishery Management Plan depend on estimated abundance; additionally, pressure from many of those involved with the salmon fishery is always intense. Also, certain numbers, such as the maximum sustainable yield (11,000 Coho) are treated as constants — they do not necessarily reflect the annual reality. Finally, fish are managed for exploitation.

Thus, Coho and other salmon species will never be what they once were, nor is that the goal. The hope is that better knowledge of the dynamics of the Coho and other salmon as well will continue to boost the population. It seems that once "listed," recovery is extremely difficult.

One possible answer, if not the most desirable, to what one researcher calls "sputtering" Coho populations, is that hatchery production of Coho salmon will increase in the future. Yet with the reality of climate change and other factors as well, hatcheries also must deal with declining returns that are not well understood. The hope that hatchery fish will contribute to sustaining wild populations may be difficult to realize. Raised for the purpose of fishing, hatchery fish will never be a replacement for the wild fish, whose former abundance is consigned to memory. Has the wild Coho reached a perilous state, always on the edge?

As goes the fish, so goes the ocean. All of us are dependent on the sea, a reality that we would be wise to consider.