INTRODUCTION

LIFE STAGES

So what *did* come first, the chicken or the egg? Or, in our case, the fish or the egg?! However you want to look at it, the salmonid life cycle includes six distinct life stages:

The eggs are fertilized embryos, which need no parental care. Alevin are newly hatched salmonids with an attached yolk sac. Fry are young, free-swimming salmonids. Smolt are juvenile salmonids which undergo morphological adaptations to survive at sea. Young adult salmonids are adapted to live in the ocean. And sexually mature adults migrate back into freshwater to spawn, or reproduce.

For this learning module, we'll look at the life cycle beginning with the fertilized egg, and ending with the spawning adult. And while there are several species of anadromous salmonids (fish species that live in both fresh and saltwater environments) we'll discuss them as a whole group, with some references to individual species.

WHERE TO FIND SALMONIDS

You may be familiar with some of the species—Coho Salmon, Steelhead Trout, Chinook Salmon, Chum—but do you know where to find them? Upstream? In the ocean? On your dinner plate? The fact is salmonids can be found throughout the watershed depending on where they are in the life cycle.

The egg, alevin and fry stages are found in the upper tributaries of the watershed. But the fry will eventually head downstream to begin the next life stage.

Smolt are found in the brackish waters of the estuary. Since brackish water is partially salty, but not as salty as sea water, the estuary helps the smolt adjust its physiology to handle the waters of the open ocean, where it will move in its next life stage.

Young adults live in the ocean for a few weeks to years, depending on the species. But they all return to the estuary in order to prepare for spawning. Once the salmonid has adjusted to life in fresh water again, it will migrate back to the upper tributaries.

SO WHAT ARE WE TALKING ABOUT HERE?

Salmonids, like many other animal species, have specific requirements to ensure the completion of their life cycle. Habitat requirements include everything from cool, clean water to gravel substrates and protective vegetation. If environmental conditions aren't right, or if their habitat is unhealthy or destroyed, salmonids will have a very difficult time supporting future generations of their species.

One term you need to get to know is Limiting Factor. Limiting factors are environmental conditions within the habitat that limit the growth, abundance, or distribution of a species in an ecosystem. Limiting factors can be biotic or abiotic. So that means a predator—which is biotic—can be a limiting factor, but so can something like sunlight, which is abiotic. Limiting factors for salmonids, which can be natural or man-made, include temperature, stream flow, predation and disease, and migration barriers.

These are by no means complete lists! Let's look at the different life stages, what salmonids need to succeed, and what factors might inhibit their survival.

NAVIGATING THE MODULE

To view a particular life stage, click on the stage from the life cycle on the bottom left corner of the screen. The two links in the top right corner of the screen will take you back to the module's introduction *or* to a section that explains how you can help! These sections can be accessed at any time.

EGG

THE EGG STAGE

A redd is a nest of salmonid embryos, or fertilized eggs. Redds are buried 20-50 cm deep in gravel beds at the bottom of the stream. You will also see the word "redd" used to describe the adult salmonid's spawning site. But that will come later in the life cycle!

The eggs rely on the natural environment to provide healthy living conditions. Eggs need relatively cool water which has high levels of dissolved oxygen, or DO.

And food? The embryos get all their nutrition from the yolk of their egg!

Can you think of what might be a limiting factor for the salmonid at this life stage?

LIMITING FACTOR: STREAM FLOW

Low stream flows increase water temperature. Spikes in water temperature can cause a reduction of dissolved oxygen, or DO, in the water. This can lead to redd suffocation.

TAKE THE PLUNGE

Besides low stream flow, what else could cause an increase in water temperature?

- Removing vegetation from the stream bank increases the amount of direct sunlight.
- Sediment in the water absorbs heat from direct sunlight.
- Heated runoff from land surfaces enters the stream. Paved surfaces in a watershed heat source runoff before it enters the stream and this can significantly increase stream water temperature.

LIMITING FACTOR: FLOODING

High stream flows, or flooding, can lead to scouring.
Scouring is the washing away of gravel beds and the salmonid embryos.

TAKE THE PLUNGE

What other ways can flooding affect stream organisms?

- High stream flow allows the rapid delivery of food and nutrients.
- High stream flow may push organisms out of preferred stream segments.
- High stream flow cue migration and spawning in some fish species.
- High stream flow sort streambed materials and scour pools.

ALEVIN

THE ALEVIN STAGE

Still buried in gravel beds, alevin need highly oxygenated, cool water—just like the eggs! And because the yolk sac is still attached to the newly hatched salmonid, alevin don't need an external food source.

This will all change, of course, as the alevin pushes its way out of the gravel and into the next life stage.

Low stream flow and flooding are still limiting factors for the alevin. What might some other limiting factors be?

LIMITING FACTOR: PREDATION & INFECTION

The greatest mortality rate in a salmon's life occurs during the egg-to-fry stage. Predators like birds and insects feed on alevin as they work their way up out of the gravel. Fungal infections also limit alevin survival.

LIMITING FACTOR: FINE SEDIMENT

Fine sediments can "clog" the water and reduce oxygen availability to the young salmonid. The sediments can also bury the alevin and prevent their passage into the water above.

THE DIRT ON SEDIMENT

Although sediment and its transport is a natural process in any stream, changes in sediment input and particle size can severely alter aquatic communities. Sediment can clog fish fills and suffocate eggs and aquatic insect larvae. Sediment interferes with recreational activities and aesthetic enjoyment of waterbodies by reducing water clarity. Sediment can aid in the transfer of pollutants and nutrients. Toxic chemicals can ride sediment particles as they wash into streams. And sediment absorbs heat from direct sunlight.

FRY

THE FRY STAGE

Now free from the gravel, fry move into shallow pools until they are big enough to swim in faster moving water. These newly emerged salmonids are usually about one inch long, but will grow to more than twice that within six months. Because of their size, they're sometimes called "Fingerlings"!

For the first time in its life, the young salmonid must catch its own food. Fry must establish a territory in the stream pool, competing with other fry for the preferred habitat. And what makes a good territory? There are several different factors to consider when scoping out fry real estate, such as riffles, riparian vegetation, and structural complexity.

Salmonids in this life stage have many limiting factors. Can you think of some issues that would limit a fry's chance for survival?

FRY TERRITORIES: RIFFLES

You can think of riffles as small rapids in the stream. The turbulent water, running over exposed rocks and cobbles, transports food from upstream locations to the stream pools fry inhabit. Moving water means moving prey, and this is important because fry are visual predators and they rarely feed on non-moving food items.

FRY TERRITORIES: RIPARIAN VEGETATION

Terrestrial insects, those normally found on land, are a major component of a fry's diet. In order for salmonids to take advantage of this food source there must be healthy riparian coverage, with overhanging vegetation that allows terrestrial insects to interact with the aquatic habitat.

FRY TERRITORIES: STRUCTURAL COMPLEXITY

The more large stones, woody debris, undercut banks, and hanging vegetation, the better! These structures create diverse habitat for a healthy macroinvertebrate population. Fry are opportunistic feeders so they'll change their prey preference depending on what's available. But the more options, the better! And since the fry isn't the only one out there looking for dinner, these corridor features also ensure that the fry have plenty of hiding places from *their* predators!

LIMITING FACTOR: SUNLIGHT

Not only can sediment in the water cause young salmonids to suffocate, but fine sediment can also reflect sunlight away from the stream which will limit plant growth in the water.

And while too little sunlight can be harmful, too much sunlight will raise the water temperature. Higher water temperatures mean lower DO levels. And you know what that means…

LIMITING FACTOR: PREDATION

Birds, mammals, fish (including older salmonids), and large invertebrates are all potential predators. This is why it is so important that fry have good stream habitat to provide hiding places from these predators. Camouflage also helps protect fry from predators. Parr marks are vertical stripes along the fry's silvery side, and these markings help them blend in with the streambed below.

SMOLT

THE SMOLT STAGE

In order for the salmonid to move into the saltwater as an adult, they must undergo smoltification, a process where physiological changes occur to the fish's body to prepare it for the move out of freshwater. As the smolt moves downstream into the estuary, it changes its gills and kidneys to cope with a saltwater environment. The estuary will be the smolt's home for several weeks to a year.

A healthy estuarine habitat is crucial for the smolt's survival. Estuaries are nurseries for many marine organisms, providing a place for juvenile fish and invertebrates to grow into adults. Many of these species are food sources for smolt, and are needed to support the rapidly modifying salmonid. And just as importantly, estuaries must provide shelter and protection from predators as the smolt prepares its body for the move into the ocean. So, actually, estuarine health is a limiting factor for the smolt.

What might be some other limiting factors for the smolt as it moves from the stream corridor down into the estuary?

IT'S NOT EASY BEING A COHO SMOLT

Coho smolt must complete all their physiological changes at a predetermined age. This means that if environmental conditions aren't good—such as a drought—the coho smolt will die before smoltification is complete. A steelhead trout, however, is able to wait another year to undergo smoltification, if necessary, while waiting for environmental conditions to improve.

LIMITING FACTOR: PREDATION

There are numerous salmonid predators during this life stage, particularly the great blue heron and the kingfisher. But the list doesn't stop there! Mammals like seals and otters feed on smolt, as well as numerous bird species and other fish species. A fellow salmonid will even dine on Junior!

LIMITING FACTOR: MIGRATION BARRIERS

Artificial barriers like flashboard dams can block downstream migrations. Droughts cause barriers by drying up stream passages, and man-made diversions also contribute to blocked migration.

ADULT: OCEAN

ADULTS IN THE OCEAN

As the smolt enters the ocean, its adult life stage begins. Adult salmonids will spend months to years at sea. Coho typically stay at sea for two years, while steelhead trout vary between a few months to three years at sea. During this time they may travel thousands of kilometers before returning to their natal stream, the stream where they were born.

Salmonid navigation at sea is not fully understood. Receptors in the salmonid may detect changes in the earth's magnetic field, helping to identify locations. Navigation by stars may be another way for salmonids to navigate.

Do you think there are limiting factors for salmonids, even as adults?

LIMITING FACTOR: PREDATION

Salmonids are preyed upon by numerous marine species while at sea. Young adult salmonids protect themselves with special coloration called countershading. Dark bluish backs and whitish bellies camouflage them in the shades of the ocean, protecting them from predators. As the adult sexually matures, the protective coloration is lost and differences between the male and female develop.

LIMITING FACTOR: UMAN IMPACTS

Salmonids have few defenses against human beings. Human predation has been extreme off the western coast of North America since the early 1900's. Pollution from human development has increased disease pressure on adult salmonid populations as well. And warming ocean temperatures, believed to be linked to global warming, are disrupting the salmonids' food supply at sea.

TAKE THE PLUNGE

Can you name four predators of ocean salmonid adults?

- Sea Lion
- Harbor Seal
- Human
- Killer Whale/Orca

ADULT: ESTUARY

ADULTS IN THE ESTUARY

Adult salmonids return to the estuary to prepare for spawning. The estuary is familiar territory. Juvenile salmonids underwent smoltification here, and now the adult will undergo changes to prepare for its journey upstream and into freshwater.

And by the way, this is the same estuary the salmonid was in before. The adult will always return to the same stream to spawn.

What factors in the estuary could affect the adult salmonid's ability to move upstream?

MAPS NOT INCLUDED

The act of returning to the natal stream site is known as homing. Chemical memory guides adult salmonids, as they can detect minute quantities of chemicals (including pheromones) in the stream water. They are also thought to depend on their olfactory senses (sense of smell), the acoustico-lateralis system (inner ear receptors that perceive movement and sound), celestial patterns, light sensitivity, and genetics.

LIMITING FACTOR: WATER QUALITY

Temperature, salinity, and pollutant levels can all impact the adult's ability to prepare for migration upstream. The health of the estuary is vital to the success of the salmonid life cycle.

TAKE THE PLUNGE

Can you name 3 pressures that can affect the health of estuaries?

- Toxins from industry and agriculture become locked in estuarine sediments and negatively impact water quality.
- Coastal developments cause a loss of intertidal habitat.
- Expanded industry, commerce, and navigation can have a deleterious effect on the life in and around estuaries.

ADULT: MIGRATION

MIGRATING ADULTS

Once they enter freshwater, salmonids focus on one thing, and one thing only—getting upstream. This upstream migration is known as a run, and a salmon run may take weeks to months before the entire population has reached the spawning ground.

The run will not begin until environmental conditions are appropriate for each species. Salmonids depend on specific water and air temperatures, as well as stream access and flow, to increase their odds of survivorship.

A heterogeneous stream environment provides the best habitat for salmonids at this stage. Migrating salmonids will be forced to swim through extremely shallow water (sometimes only inches deep!), over rocks and physical barriers, and other difficult terrain. Streams with pools and riffles allow salmonids a sheltering habitat for resting between migration efforts.

As if it isn't hard enough to migrate, there are more limiting factors for salmonids moving upstream. Any ideas?

SOARING STEELHEAD

Salmonids are capable of overcoming great obstacles to reach their spawning grounds. Prodigious jumpers, coho have been seen jumping vertically more than 6.5 feet (2 meters)! And steelhead, even stronger jumpers, are thought to be able to jump as high as 10 to 11 feet!

LIMITING FACTOR: MIGRATION BARRIERS

Like the smolt moving downstream, adult salmonids may encounter natural and man-made barriers as they travel toward their spawning ground. Culverts pose a particular problem because of the elevation gain, small "take off" pools, and high velocity water flow.

LIMITING FACTOR: PREDATION

A variety of predators exist for migrating salmonids. These include humans, otters and bears.

LIMITING FACTOR: POLLUTION

Besides negatively impacting the overall water quality, certain chemical pollutants, such as diazinon (a general-use insecticide) may interfere with normal olfaction and possibly impair salmonids' homing abilities.

ADULT: SPAWNING

SPAWNING

After battling upstream, adult salmonids reach the spawning site. Females may spend several days excavating nest sites. This involves pulling sediments away from the streambed by alternately flexing her tail and body. Redds, or spawning sites, can get fairly large. An average coho redd spans 9 square feet!

A female will protect her redd against other females. Meanwhile males will be competing for *her* attention! Eventually one male will take the dominant role. He will swim closest to the female during spawning, which gives him better odds of fertilizing the eggs.

All this work to get back upstream to spawn…What other environmental factors might limit spawning success?

LIFE AFTER SPAWNING

Both males and females are able to spawn at multiple sites with multiple partners. When "spawned out", the female will use her tail to dislodge upstream sediment to cover the newly fertilized eggs. Females may remain near the redd to protect it from other spawning females.

Coho salmon reproduce once and die, usually within days of spawning. Steelhead trout can be repeat spawners and complete the ocean-to-stream migration multiple times. However, the majority of steelheads at the spawning grounds are first time spawners, with second and third time spawners making up significantly smaller percentages of the returning steelhead population.

TAKE THE PLUNGE

The number of eggs a Chinook salmon produces.
Answer: 2,000 to 17,000

The number of eggs a Coho salmon produces.
Answer: 1,500 to 5,700

The number of eggs (out of 100) that will make it to the fry stage.
Answer: 15

The number of eggs (out of 100) that will ultimately make it to the ocean.
Answer: one

LIMITING FACTOR: SPAWNING SITE

A successful spawning requires the right kinds of sediment to secure and protect the redd. The stream habitat needs not only to have acceptable environmental conditions like cool temperatures and good stream flow, but also adequate size in order to support the spawning population and the next generation as well!

SO WHAT CAN I DO TO HELP?

FOR THE FUTURE

We as a community are beginning to recognize that something needs to be done to ensure that future generations will be able to witness a salmon run, make a great catch offshore, or simply enjoy the natural beauty of a healthy and diverse riparian ecosystem. There are many conservation efforts underway to help restore and protect salmonid populations.

HOOK, LINE, AND SINKER

Fishing regulations being enforced limit both the number of salmonids that can be caught, and the time of year. This can help build a larger population of sexually mature salmonids who can participate in spawning activities. Minimum water quality standards are also being enforced to reduce water pollution in streams and rivers.

"FREE TO GOOD HOME"

Captive breeding programs have been developed to supply streams with fry and fingerlings. Now, the question is, will the young salmonid return to its natal stream, or its "adopted" stream? Young salmonids learn to recognize the natal stream as early as the egg stage in a process known as imprinting. Salmonids will naturally "stray" from their original birth site if environmental conditions are better elsewhere, or to colonize new habitat. But studies are being done to see if salmonids are more likely to stray when they have been outplaced through hatchery management, and if this is negatively impacting the salmonid population.

STREAM CORRIDOR RESTORATION

We can all participate in stream corridor restoration! Whether it's cleaning up litter or planting native plant species, we can help make sure stream corridors are healthy enough to support generations of salmonids. Bigger projects might include removing dams to open migration routes, or building fish ladders or dam diversions to provide safe passage for migrating salmonids. But big or small, every bit helps. So get involved. Salmonids will thank you for it!