SALMON AND STEELHEAD SMOLT MIGRATION TO THE OCEAN, TOTAL GAS SATURATION AND GAS BUBBLE DISEASE

By
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While spawning, raising, and transporting Salmon and Steelhead at Idaho Fish and Game (IDFG) hatcheries, for 36 years, I learned that there are many pieces to the puzzle of their life cycle.

The first piece is about a **<u>Tiny Window of Time in the life of Salmon and Steelhead smolts.</u>**

The word smolt may be new for some of you. It refers to a part of the life cycle of Salmon and Steelhead juveniles (Spring Chinook Ave. length 133mm and Steelhead Ave. length 182 mm). It is the time when they are ready to leave freshwater and migrate to the ocean.

After they have lived from 12 months to 3 years in Idaho waters or in an Idaho fish hatchery, the smolts begin the physiological transition preparing them to migrate to the ocean. This transition and instinctive urge to migrate downstream is referred to as smoltification. These changes start during the late winter and early spring (some begin in fall). As the daylight hours increase in the spring, physiological changes begin to take place both on the inside and outside of the young smolts. On the outside, their camouflage coloring changes to bright silver and their scales loosen. Sometimes, at the fish hatcheries, as smoltification and migration to the ocean became imminent, we could see the silvery scales in the water like glitter. On the inside, their swim bladder is slightly increasing in size causing them to ride higher in the water column as they travel downstream; kind of like wearing a life jacket. Another change will occur inside the smolts as their gills and kidneys reverse osmotic functions to accommodate the transition from freshwater to the brackish (mixture of fresh and salt) water of the estuary (where rivers meet the ocean) and eventually to the salt water of the Pacific.

Increasing daylight hours of spring triggers the start of these physiological changes in the salmon and steelhead smolts. At the same time their freshwater river environment is also changing. The snow pack in the mountains is melting and spring runoff is beginning in the Idaho Rivers. The rising water flow of spring runoff combined with the increased buoyancy of the smolts is the perfect balance to speed them on their way to the ocean. This increased buoyancy enables smolts to easily take advantage of the faster flowing water in the top three feet of water during spring runoff. The increased daily photoperiod of springtime, the physiological changes of the smolts, and the rising water flow of spring runoff in the rivers are perfectly choreographed with one purpose in mind :

"GET THE SMOLTS TO THE OCEAN IN 14 TO 21 DAYS SO THEY HAVE THEIR BEST CHANCE TO ADAPT TO SALT WATER!"

It is only in this tiny window of time that the organs and systems of the smolts can change from living in fresh water to living in salt water. This adjustment enables them to live 1 to 3 years in the ocean environment.

If the smolts arrive late to the estuary and miss this tiny window of time to adapt to salt water, THEY WILL NOT BE ABLE TO SURVIVE IN THE SALTY OCEAN ENVIRONMENT!

Travel timing of smolts to the ocean is only one of the many pieces of the puzzle of a successful anadromous (anadromous fish live as juveniles in fresh water, mature to adults in salt water and return to freshwater to spawn) fish life cycle.

The second piece is **gas bubble disease in fish**. This disease is not caused by infection or infestation of etiological (disease causing) agents but living in gas supersaturated water. When fish are living in water with a Total Dissolved Gas (TDG) saturation that exceeds 102 %, Gas Bubble Disease can occur.

> "Theoretically, gas bubble disease can be caused by any supersaturated gas, but in practice the problem is almost always due to excess nitrogen. When water is supersaturated with gas, fish blood tends to become so as well. Because oxygen is used for respiration, and carbon dioxide enters into physiology of blood and cells, excess amounts of these gases in the water are taken out of solution in the fish body. However, nitrogen, being inert, stays supersaturated in the blood. Any reduction in pressure on the gas or localized increase in body temperature can bring such nitrogen out of solution to form bubbles; the process is analogous to "bends" in human divers. Such bubbles (emboli) can lodge in blood vessels and restrict respiratory circulation, leading to death by asphyxiation. In some cases, fish may develop obvious bubbles in the gills, between fin rays or under the skin, and the pressure of nitrogen bubbles may cause eyes to bulge from their sockets.
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> Gas supersaturation can occur when air is introduced into water under high pressure which is subsequently lowered, or when water is heated. Water that has plunged over waterfalls or dams, water drawn from deep wells, or water heated from snow melt is potentially

supersaturated. Air sucked in by a water pump can supersaturate a water system.

All fish -- coldwater or warmwater, freshwater or marine species – are susceptible to gas bubble disease. Threshold tolerances to nitrogen supersaturation vary among species, but any saturation over 100% poses a threat to fish, and any levels over 110% call for remedial action in a hatchery. Nitrogen gas concentrations in excess of 105% cannot be tolerated by trout fingerlings for more than 5 days[....]"[1]

"Once a nitrogen bubble has formed in the tissue of a fish, following the exposure to TDG supersaturation, the bubble (gas embolism) will not easily reabsorb into the bloodstream. This condition causes a blockage in capillaries and will result in dead tissue in the effected parts of the fish."[2]

"The gas bubble disease can be detected by the formation of small gas bubbles under the epidermis which includes the formation of gas bubbles in the skin, the gills, and eyeballs causing exophthalmia. [Exophthalmia can be caused as Nitrogen gas escapes from the bloodstream of a fish in a gas bubble disease situation. Tiny bubbles build up behind the eyeball and cause it to "bulge out".] Gas bubbles may also form in extremities (fins), in the vascular systems where they often cause embolism and in their mouth opening. The gas bubble diseases may cause floating problems due to the excessive amount of gas in their bodies, ultimately leading to upside-down swimming and death."[3]

1. Fish Hatchery Management, pg. 9, Department of the Interior, U.S. Fish and Wildife Service. Piper, McElwain, Orme, McCraren, Fowler, Leonard; 1982

2. Dave Owsley, U.S. Fish and Wildlife Service (retired), Dworshak National Fish Hatchery.

3. Wikipedia, November 24, 2022; Gas bubble disease; Bohl, Gultepe,Hisar, Rucker, Hulst, Bouck; Accessed on January 19,2023.

While stationed at Rapid River Fish Hatchery in Riggins,Idaho, 1980 to 1983, I also performed duties at Lower Granite Dam as a member of the Idaho Fish Transport Oversight Team (F.T.O.T) during spring smolt outmigration. A part of my daily duty was to examine fish collected for barge transportation. I examined them for percentage of descaling, hatchery fin marking, and signs of gas bubble disease. One of the worst days for signs of gas bubble disease occurred when the TDG of the tailrace (river immediately downstream of the dam) was 118%. Bubbles could be easily seen between the fin rays and in the gills of Steelhead and Chinook smolts.

The newly approved increase for the allowable TDG concentration created in the river by Lower Snake and Columbia River dams is 125%. This is only 2% less than a lethal concentration (127%) and 9% higher than my observation in the early 1980's.

When I spoke with supporters of the increase of allowable TDG to 125%, they claimed that the smolts would dive deeper to protect them from gas bubble disease. The action of diving deeper as the smolts travel to the ocean would be against the natural instincts of the smolts to ride higher in the water column taking advantage of the faster water current near the surface. It would also be fighting the additional buoyancy they experience naturally during the smolting process. And the TDG of 125% will add even more buoyancy to the smolt from the higher concentration of nitrogen in their bloodstream as earlier stated in the Wikipedia article by Rucker et al [3]. You would have to ignore these three increased buoyancy factors to believe that all of the smolts will simply dive deeper and be protected from gas bubble disease.

When the TDG, in the Snake River arriving at Lower Granite Dam, is 108% and above the TDG will remain at an unhealthy level as the smolts travel 300+ miles downstream to the estuary. [4]

The timing of smolt migration to the ocean and exposure to TDG super saturation in the migration corridor of the Lower Snake and Columbia Rivers are two important pieces of the smolt migration puzzle.

In an effort to assure the smolts move quickly through the slow moving water of the eight hydro-projects and protect them from the TDG super saturation the Army Corps of Engineers have designed and constructed super tanker barges to transport the smolts safely to the ocean. These barges supply a constant flow of fresh water through the onboard degassing towers. These degassing towers reduce the gas saturation in the river water to a level safe for the juvenile Salmon and Steelhead. The smolt's barge ride downstream is approximately 300 miles and lasts two to three days.

4. John McKern, Army Corps of Engineers, Walla Walla District, (Retired

For greater details of the smolt barging operations I refer you to the barging article "Dams and Fish Barging Transportation" written by Dan Caldwell included on the website.

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EDUCATION

B.A., Biological Sciences, May 1979. Northwest Nazarene College; Nampa, Idaho, 83686

Principles of Aquaculture and Survey of Aquaculture Production Methods, June to December 2013, Kentucky State University.

Coldwater Fish Culture. December 1983. U.S. Fish and Wildlife Service, National
Conservation Training Center. Twin Falls, Idaho

Introduction to Fish Health . February 1982. U.S. Fish and Wildlife Service, National Conservation Training Center. Lacrosse WI.

EXPERIENCE

Clearwater Fish Hatchery Complex Supervisor, Idaho Department of Fish and Game (IDFG), Ahsahka, Idaho , December 2010 to January 2016

Fish Hatchery Manager 2, Idaho Department of Fish and Game (IDFG), Clearwater Fish Hatchery and Satellite Trapping and Spawning Stations, Ahsahka, Idaho 83520, June 1994 – December 2010

Fish Hatchery Superintendent 3, Idaho Department of Fish and Game, Clearwater Fish Hatchery, Ahsahka, Idaho 83520 1991 to 1994

Fish Culturist, Idaho Department of Fish and Game, McCall Summer Chinook Hatchery, McCall Idaho 83638 1984 to1985

Fish Culturist, Idaho Department of Fish and Game, Rapid River Fish Hatchery, Riggins, Idaho 83549, January 1,1980 to 1984

Crew Foreman/ Sales Manager, Allen's Apiaries, Payette, Idaho 83661, June 1979 to December, 1979 and July 1975 to June 1978

Owner/Operator, Rocky Mountain Taxidermy, 1969 to 2019

HONORS

2010 U.S. President's Volunteer Service Award , Lifetime Service Award 4,000 hours of Volunteer Community Service.

2009 U.S. President's Volunteer Service Award , Silver Medal.

2009 Idaho Hunter's Safety Hall of Fame 29 years of service.

2006 Idaho Hunter Safety Instructor, Twenty five year service award.

2005 Station of the Year Award from U.S. Fish and Wildlife Service, LSRCP (Oregon, Idaho and Washington).

2003 Idaho Fish and Game Employee of The Year Award, Fish Hatchery Manager.

2001 Fisheries Outstanding Service Award; In recognition to outstanding service to Idaho fishery resource.