An argument for the local elimination of IHNV in hatcheries and aquaculture farms

By: Delaney Lawson

Abstract

IHNV, or infectious hematopoietic necrosis virus, is a virus that infects salmon and trout species. It has a high mortality rate in young fish and can therefore have a large impact on the revenue created from the rearing of these species in an aquaculture setting and the conservation efforts occurring at hatcheries. Due to the high mortality rates associated with infection and the damage infection can do in the aquaculture industry, I suggest that actions should be taken with the ultimate goal of local elimination of IHNV in aquaculture farms and hatcheries. Locally eliminating the virus is a long process that should begin with attempting to eliminate infection in aquaculture farms and hatcheries by practicing the disinfection of eggs and larvae, rearing fish in UV or ozone-treated water, immediately removing fish that begin to exhibit symptoms of infection, and more. The removal of IHNV from aquaculture farms and hatcheries will allow the virus to take its natural path in the wild while protecting a vital industry.

Introduction

IHNV, or infectious hematopoietic necrosis virus, is a virus that causes infectious hematopoietic necrosis in salmon and trout species, with the greatest effects on steelhead trout (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*; Yong et al. 2019). The steelhead trout is an anadromous form of the Rainbow trout, sharing the same species name (Hecht et al. 2012). IHNV was first observed in sockeye and kokanee salmon (*Oncorhynchus nerka*) in the 1950s (Rucker et al. 1953). These salmon are of the same species, but kokanee are non-anadromous, meaning they spend all of their lives in freshwater, and sockeye are anadromous, meaning they are born in freshwater, migrate to saltwater to grow, and return to freshwater to spawn (Rucker et al. 1953). IHNV was first observed in the state of Washington and is endemic to the Pacific Northwest region of the United States (Yong et al. 2019). However, it has since spread internationally through the importation of infected salmon and trout fish or eggs (MacLachlan and Dubovi 2017).

IHNV causes osmotic balance impairment, edema (swelling), and hemorrhaging (bleeding) in infected fish (OIE 2019). Osmotic balance impairment means that the fish can no longer regulate the concentration of salt and water in its body, which can lead to adverse health effects including death (Hvas et al. 2018). Edema and hemorrhaging are both considered destructive effects for fish (Velmurugan et al. 2007). IHNV infection can be identified through observation of darkened skin, pale gills, and a distended stomach coupled with lethargic behaviors with bouts of erratic or frenzied behavior such as spiral swimming and/or flashing (OIE 2019).

IHNV can be spread through urine, sexual fluids, and external mucus, but is present in largest numbers in the kidney, spleen, and other internal organs (OIE 2019). It is spread largely horizontally from juvenile fish shedding large amounts of the virus and others picking it up from the water column (OIE 2019). The entry point to the fish is thought to be through the gills and the bases of fins, although vertical transmission to offspring has occurred as well (OIE 2019). The virus can be spread from actively infected fish, as well as from cultured, feral, or wild fish that are not yet showing any symptoms (Ferguson et al. 2018).

Infection with IHNV can cause over 90% of fry, a young stage in the fish life cycle, to die (Ahmadivand et al. 2017). Due to the high mortality in young fish, this virus has serious effects on the profitability of the salmon and trout aquaculture industry (Dixon et al. 2016, Yong et al. 2016). Salmon and trout farming contribute $17.5 billion to the economy each year, so the impacts of this virus need to be addressed before it can cause irreparable damage (Dixon et al. 2016). From the years 1982-1989, 67% of total fish reared at the Dworshak National Fish Hatchery died from IHNV infection (Breyta et al. 2016). Then, in 2009, 50% of steelhead trout being reared there died from IHNV infection (Breyta et al.). Since then, methods such as delaying the exposure of young steelhead trout to river water have led to decreased death rates (Breyta et al. 2016). It is important that steps such as these be taken in order to decrease the severe impact that outbreaks of IHNV can cause on aquaculture farms and hatcheries.

IHNV should be locally eliminated in aquaculture farms and hatcheries as it has been shown to have many negative impacts on these fish communities (Breyta et al. 2016, Yong et al. 2019). Additionally, the presence of IHNV in aquaculture farms or hatcheries may increase the presence of the virus in the wild, resulting in harm to the fish native to the region. This has been observed in cases of several other parasites (Torrissen et al. 2013, Arechavala-Lopez et al. 2013). There have also been several attempts to develop vaccines, which could support the idea of local elimination of the virus (Yong et al. 2019). However, this virus should not be fully eradicated, as fish populations in the northwest of the Americas have been living with this virus for over 70 years now (Rucker et al. 1953). Natural fish populations have been able to survive well alongside this virus, and a plan for the full eradication of IHNV would cost a great deal of money that is likely unnecessary (Barnas Torpey 2016). The need for local elimination comes from the impact infection could have on the aquaculture industry, and from the possibility that increased levels of IHNV in an aquaculture or hatchery setting may lead to increased levels of the virus in the wild (Torrissen et al. 2013). This could have a severe effect on the natural population and would impact the naturally occurring balance between the natural fish population and IHNV.

Methods

The current strategies for preventing the spread of the virus include practicing early detection techniques and culling fish showing signs of infection (Yong et al. 2019). As no globally effective cure has yet been developed, the most efficient way to deal with the problem is to place the majority of effort into ensuring that fish do not get infected in the first place (Wade 2017). Methods to aid in this include placing bird nets above areas where fish are being reared, sanitizing boots, nets, and other gear in an iodine solution before interacting with fish, and using virus-free water for rearing (Wade 2017, OIE 2019). The use of bird nets is suggested because the arrival of fish-eating birds has been linked to an increase in IHNV infection (Chapman and Elmore 1995). Additionally, the placement of bird nets over outdoor ponds in combination with the rearing of young fish in virus-free water was observed to drastically decrease the effects of IHNV disease (Chapman and Elmore 1995). The sanitization of gear such as boots, gloves, and nets in an iodine solution is suggested because this kills 99.9% of IHNV present on the surface of the gear and decreases the risk of cross-contaminating different areas at the hatchery or aquaculture farm with the virus (Batts et al. 1991). Virus-free water includes river water treated with UV or Ozone, and water that has been kept in a reservoir or underground, without any exposure to fish and therefore IHNV (OIE 2019).

The use of virus-free water has proven to be the most effective for aquaculture farms and hatcheries working with salmon and trout species in the Pacific Northwest (Breyta et al. 2016, Chapman and Elmore 1995). Breyta et al. (2016) found that rearing steelhead trout in reservoir water for the first two months and then transferring them to river water resulted in significantly lower death rates from IHNV infection than when fish were reared in river water since hatching. The steelhead trout that were transferred to river water 2 months after hatching were infected by IHNV later than those immediately transferred to river water (Breyta et al. 2016). The later infection led to higher survival rates and is therefore an effective strategy to decrease the devastating impact IHNV can have on fish populations in aquaculture and hatchery settings (Breyta et al. 2016). Based on the results of this study, aquaculture farms and hatcheries impacted by IHNV infection should rear fish in virus-free water for at least 2 months before being transferred to river water (Breyta et al. 2016). This should be done in combination with all the other strategies mentioned in this report and will aid in limiting the death rate of fish at these places.

Another strategy is the disinfection of fertilized eggs with an iodophor solution, a disinfectant made of iodine and a surfactant (OIE 2019). The use of this disinfectant kills 99.9% of the IHN virus on the surface of the fish eggs and helps prevent pseudo-vertical transmission to the fish offspring (Batts et al. 1991, OIE 2019). Transmission is considered pseudo-vertical because the fish are not infected with the virus before they hatch, but the virus sitting on top of the eggs can infect them once they hatch (Wilkinson 1999). Therefore, the parasite is not transmitted directly from the mother to the offspring, but she plays a role in the transmission as her infected sexual fluid covers the eggs as they are laid (OIE 2019). This iodophor solution can also be used to disinfect boots and gear before and after interaction with the fish (Batts et al. 1991, OIE 2019).

Additionally, the virus is highly susceptible to heat, acid, and ether, and treatment with these things can kill the virus (OIE 2019). However, these are not methods used on live fish as they can have negative health impacts and cause harm to the individuals, including death (Pörtner and Knust 2007, Kroglund et al. 2008, Hale et al. 2001).

Another important step is preventing the virus from being released into rivers, the ocean, or any other body of water. The largest concentration of the virus is observed in internal organs such as the kidney and spleen (OIE 2019). Both of these are organs that get removed during fish processing (Ghaly et al. 2013). If processing plants are grinding up these parts of the fish and releasing them back into the water column, this could lead to the infection of many more fish. Finding an alternative way to get rid of these organs may aid in decreasing the prevalence of infection in an area. These organs could be disposed of by being fed to animals that cannot become infected or further transmit the virus, or by treating the organs with an iodophor solution before releasing them back into the water column. These solutions are surely not the only options, but ones that would decrease the amount of IHNV in the water columns near processing plants.

Vaccines may seem like a good solution to the problem of IHNV infection, but it is not currently the most effective solution. First of all, 100% of fish must be vaccinated by injection (Alonso and Leong 2012). It would take an extremely large amount of time and labor to vaccinate every single fish being grown in an aquaculture farm or at a hatchery, and it is unlikely that these places will have the staff or resources to be able to execute this effectively. Additionally, affected fish become infected at a very young age, and are therefore extremely small (Ahmadivand et al. 2017, Shelbourn et al. 1973). It is likely that some of these fish will die from other causes before being harvested or released, so this furthers the idea that total vaccination would be a misuse of resources in this scenario (Aunsmo et al. 2008). Overall, vaccination does not currently seem to be the most efficient solution in this situation. However, if a different method than individual injection is developed, the idea should be revisited.

Aquaculture farms and hatcheries affected by IHNV should begin and maintain efficient practices of disinfecting eggs, larvae, boots, and nets, and using virus-free water to rear fish (OIE 2019, Breyta et al. 2016). If it is not possible to rear fish in virus-free water for the entirety of their life cycles (due to space or financial constraints), fish should be reared in virus-free water for a minimum of 2 months after hatching before being transitioned into river water (Breyta et al. 2016). Additionally, bird nets should be put up, checked, and replaced often because once birds can enter the area, the efforts being made will no longer be as effective (Chapman and Elmore 1995). People taking care of the fish should watch out for IHNV infection symptoms such as darkened skin, distended stomachs, and erratic behavior such as flashing (OIE 2019). If a fish begins to display any of these symptoms, they should be removed from contact with other fish and culled, and those that were in close proximity with the individual should be transitioned into virus-free water. These other fish should be closely monitored to determine if they are infected as quickly and efficiently as possible. It is extremely important that those working at aquaculture farms and hatcheries adhere to these steps well. Human error can play a large role in the spreading of a virus, and most times it is easily preventable. Ensuring that protocols are followed is just as important as the rest of the steps mentioned.

Conclusion

IHNV is a virus that infects salmon and trout and is prominent in aquaculture farms and hatcheries, as well as the wild (Yong et al. 2019). Infection in aquaculture farms and hatcheries can lead to a large percentage of infected fish dying and negative impacts on the revenue of fish farming (Dixon et al. 2016, Yong et al. 2019). I decided to suggest that you pursue a local elimination at the individual aquaculture farm and hatchery level. This decision was reached because wild populations have been living alongside this virus for over 70 years and have been able to survive its presence (Rucker et al. 1953, Barnas Torpey 2016). For this reason, it seems as though the best decision would be to allow the wild population to continue interacting and evolving with this virus, and to remove it from aquaculture farms and hatcheries for two main reasons. The first reason is that the presence of IHNV in those areas can cause mass-mortality events and significantly impact revenue from the aquaculture industry and conservation efforts from the hatcheries (Ahmadivand et al. 2017, Yong et al. 2019). The second reason is that elimination in these two areas will prevent the virus from accumulating to high levels that may be transferred into the wild populations and have negative impacts on those fish (Torrissen et al. 2013).

The effect of IHNV in aquaculture farms and hatcheries can be devastating (Ahmadivand et al. 2017, Breyta et al. 2016, Dixon et al. 2016, Yong et al. 2016). For this reason, we believe that action should be taken in order to locally eliminate and control the virus, but not to eradicate it from the wild. Thank you for your consideration in selecting me to advise you on this subject. I am looking forward to working with you all in order to solve the problem of infectious hematopoietic necrosis virus.

References

Ahmadivand S, Soltani M, Mardani K, Shokrpoor S, Hassanzadeh R, Ahmadpoor M, Rahmati-Holasoo H, and S Meshkini. 2017. Infectious hematopoietic necrosis virus (IHNV) outbreak in farmed rainbow trout in Iran: Viral isolation, pathological findings, molecular confirmation, and genetic analysis. Virus Research **229**: 17–23.

Alonso M, and J-A Leong. 2012. Licensed DNA Vaccines against Infectious Hematopoietic Necrosis Virus (IHNV). Recent Patents on DNA & Gene Sequences **6**.

Arechavala-Lopez P, Sanchez-Jerez P, Bayle-Sempere J, Uglem I, and I Mladineo. 2013. Reared fish, farmed escapees and wild fish stocks—a triangle of pathogen transmission of concern to Mediterranean aquaculture management. Aquaculture Environment Interactions **3**: 153–161.

Aunsmo A, Bruheim T, Sandberg M, Skjerve E, Romstad S, and R Larssen. 2008. Methods for investigating patterns of mortality and quantifying cause-specific mortality in sea-farmed Atlantic salmon *Salmo salar*. Diseases of Aquatic Organisms **81**: 99–107.

Barnas Torpey K. 2016. SPS Abundance: Population data and references for the Salmon Population Summary (SPS) Database. NOAA Fisheries Northwest Fisheries Science Center.

Batts WN, Landolt ML, and JR Winton. 1991. Inactivation of Infectious Hematopoietic Necrosis Virus by Low Levels of Iodine. Applied and Environmental Microbiology **57**: 1379–1385.

Breyta R, Samson C, Blair M, Black A, and G Kurath. 2016. Successful mitigation of viral disease based on a delayed exposure rearing strategy at a large-scale steelhead trout conservation hatchery. Aquaculture **450**: 213–224.

Chapman J, and R Elmore. 1995. Niagra Springs Fish Hatchery: 1993 Steelhead Brood Year. Idaho Fish & Game **95**.

Dixon P, Paley R, Alegria-Moran R, and B Oidtmann. 2016. Epidemiological characteristics of infectious hematopoietic necrosis virus (IHNV): a review. Veterinary Research **47**.

Ferguson PFB, Breyta R, Brito I, Kurath G, and SL LaDeau. 2018. An epidemiological model of virus transmission in salmonid fishes of the Columbia River Basin. Ecological Modelling **377**: 1–15.

Ghaly A, Ramakrishnan V, Brooks M, Budge S, and D Dave. 2013. Fish Processing Wastes as a Potential Source of Proteins, Amino Acids and Oils: A Critical Review. Journal of Microbial & Biochemical Technology **5**.

Hale RC, La Guardia MJ, Harvey EP, Mainor TM, Duff WH, and MO Gaylor. 2001. Polybrominated Diphenyl Ether Flame Retardants in Virginia Freshwater Fishes (USA). Environmental Science & Technology **35**: 4585–4591.

Hecht BC, Thrower FP, Hale MC, Miller MR, and KM Nichols. 2012. Genetic Architecture of Migration-Related Traits in Rainbow and Steelhead Trout, *Oncorhynchus mykiss*. Genes|Genomes|Genetics **2**: 1113–1127.

Hvas M, Nilsen TO, and F Oppedal. 2018. Oxygen Uptake and Osmotic Balance of Atlantic Salmonin Relation to Exercise and Salinity Acclimation. Frontiers in Marine Science **5**.

Kroglund F, Rosseland BO, Telen H, Salbu B, Kristensen T, and B Finstad. 2008. Water quality limits for Atlantic salmon (*Salmo salar* L.) exposed to short term reductions in pH and increased aluminum simulating episodes. Hydrology and Earth System Sciences **12**: 491–507.

MacLachlan N, and E Dubovi. 2017. Rhabdoviridae. Pages 357-372 *in* N. J. MacLachlan and E. J. Dubovi, editors. Fenner's Veterinary Virology, Cambridge, Massachusetts, United States. Academic Press.

OIE. 2019. Infection with Infectious Haematopoietic Necrosis Virus. OIE - Manual of Diagnostic Tests for Aquatic Animals.

Pörtner H, and R Knust. 2007. Climate Change Affects Marine Fishes Through the Oxygen Limitation of Thermal Tolerance. Science **315**: 95–97.

Rucker R, Whipple W, Parvin J, and C Evans. 1953. A contagious disease of salmon possibly of virus origin. Fishery Bulletin of the Fish and Wildlife Service **54**.

Shelbourn JE, Brett JR, and S Shirahata. 1973. Effect of Temperature and Feeding Regime on the Specific Growth Rate of Sockeye Salmon Fry (*Oncorhynchus nerka*), with a Consideration of Size Effect. Journal of the Fisheries Board of Canada, **30**.

Torrissen O, Jones S, Asche F, Guttormsen A, Skilbrei OT, Nilsen F, Horsberg TE, and D Jackson. 2013. Salmon lice – impact on wild salmonids and salmon aquaculture. Journal of Fish Diseases **36**: 171–194.

Velmurugan B, Selvanayagam M, Cengiz EI, and E Unlu. 2007. The Effects of Monocrotophos to Different Tissues of Freshwater Fish Cirrhinus mrigala. Bulletin of Environmental Contamination and Toxicology **78**: 450–454.

Wade J. 2017. British Columbia farmed Atlantic Salmon health management practices. Fisheries and Oceans Canada, **61**.

Wilkinson. 1999. Bacterial ecology, antibiotics and selection for virulence. Ecology Letters **2**: 207–209.

Yong CY, Ong HK, Tang HC, Yeap SK, Omar AR, Ho KL, and WS Tan. 2019. Infectious hematopoietic necrosis virus: advances in diagnosis and vaccine development. PeerJ, **7**.