Fish Health News You Can Use

Brought to you by the Pacific Region Fish Health Program

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The National Wild Fish Health Survey Update

The FWs National Wild Fish Health Survey (FHS) was first funded decades ago as a response to the discovery of whirling disease in western trout populations. The goal of the Survey was to establish the geographic distribution of the whirling disease parasite so that measures could be taken to block its spread. As the years went by concerns about whirling disease diminished and the FHS was broadened to look at the geographic distribution of a long list of important fish diseases in all US watersheds. More recently, the FWS Regions have been more inclined to instead use their FHS funding to address specific fish health concerns important to the resources managed by the Service. For example, we have been using FHS funding to examine the role of the *C. shasta* parasite in poor survival of Chinook salmon traveling through the Deschutes system.

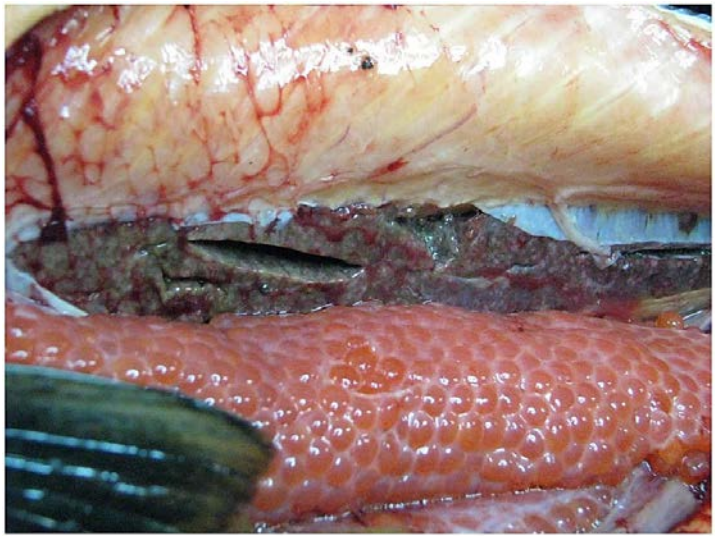

Figure 1: C. Shasta infection in a salmon kidney. Picture by Richard Stocking of the ODFW.

Beginning in 2017, the PRFHP began a new process to consult with our hatchery, FWCO, and ES colleagues to identify wild fish health concerns that could be addressed with our FHS funds. That list was then prioritized and a plan was made for the 2017 season that recognized both those priorities and the limitations of the FHS budget.

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Our FHS staff are now compiling a report describing the work that was accomplished in 2017. This winter we will be sharing that report and then using it as the basis of a new plan for 2018. We appreciate your help in 2017 and look forward to working with you again in 2018!

Amphibian Diseases, Who Cares?

There are more than 6,800 species of amphibians (salamanders, newts, frogs, toads, and caecillians) in the world today.

Figure 1.5: A caecilliian, Dermophis mexicanus. *Caecillians are limbless burrowing relatives of the salamanders.* None a*re found in the US. Photo by Franco Andreone - http://calphotos.berkeley.edu, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=5172445*

The United States has about 300 species of amphibians and the most diverse group of salamanders in the world. In the Pacific Region Tri-state area we have 24 species of salamanders, 14 species of frogs, 3 toads, and 1 newt. Some of the species common to all three states are Long-Toed Salamander, Rough Skinned Newt, Woodhouse's Toad, and the Columbia Spotted Frog.

Figure 1.6: The Long-Toed Salamander. http://www.californiaherps.com/noncal/northwest/nwsalamanders/images/amacrodp1105.jpg

Since the late 1980's the world has seen major declines in amphibian numbers and diversity. It is estimated that over 250 species have gone extinct, while 33% are considered threatened and 43% are declining. Of our Northwest species, 50% are listed by the states as species of concern, while 1, the Oregon Spotted Frog is federally listed. Although habitat degradation can account for some of the declines, amphibian diseases are a major contributor. One of the most devastating diseases is a fungal disease called *Batrachochytrium dendrobatidis, Bd* for short.

Bd is a primitive fungus in the chytrid family that affects keratin in the skin and mouth parts of amphibians. Because amphibians breathe through their skin, skin infections can easily cause death. Bd is unique in that it was the first chytrid fungus found to infect a vertebrate host and it is infectious to almost all species of amphibians. There are frogs that appear resistant to infection. They carry a bacteria on their skin that produces "violacium", an antibiotic effective against bacteria, viruses and fungi. Bd has been found on every continent where amphibians occur and it is present in the Pacific Northwest.

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Fig 1.7: A Frog infected by Bd. Photo by Forrest Brem - From Riders of a Modern-Day Ark. Gewin V. PLoS Biology Vol. 6, No. 1, e24

Until recently Bd was the only chytrid fungus known to infect vertebrates, but a new fungus, *Batrachochytrium salamandrivorans*, (Bsal) was discovered in Europe in 2013 where it was causing high mortality in wild newts and salamanders. Bsal is closely related to Bd and infects the skin of salamanders causing skin lesions and then death. It is believed that Bsal was spread across Europe from Chinese Fire belly newts moved in the pet trade industry. Due to the devastating effect of Bd on wild populations of amphibians globally, the discovery of Bsal raised immediate concerns about its potential to impact salamanders in the US. In January of 2016 the FWS used the Lacey Act to prohibit the importation salamander and newt species known to be susceptible to Bsal. Many of the pet trade companies also voluntarily disposed of susceptible species they already had in stock.

USGS scientists believe that, if Bsal is introduced, our diverse salamander species and mild climates will be the perfect setting for a major Bsal epidemic. The USGS initiated a national survey to sample 10,000 wild salamanders in the USA and, thankfully, all samples that have been tested so far are negative.

The chytrid fungi are not the only disease challenge for our amphibians. There is a group of viruses, the aptly named ran aviruses, which are often able to move among fish, reptiles, and amphibians. The frog virus 3 (FV3) is the most common ranavirus infecting frogs, toads, and salamanders, and it has been found to be the cause of amphibian die-offs in the Pacific Northwest. Recently, FV3 has also been found causing mortality in Pallid sturgeon in the Midwest. The ranaviruses have not gotten as much publicity as the chytrid fungi, but the ability of these viruses to move between diverse groups of animals makes them a considerable threat.

While the Pacific Region FAC has no amphibian production or programs, the Pacific Region Fish Health Program has long been active in national and area efforts to protect amphibians from chytrid and the ranaviruses. The PRFHP represents the Service on national committees and panels and has the capability to provide diagnostic testing for chytrid fungus and FV3 when crises arise. We are proud of our involvement in efforts to protect our Regions amphibians. For more information on amphibian diseases or PRFHP involvement in amphibian health, contact Laura Sprague of the PRFHP.

Fish (Frog?) Factoids

The Pandominian Gold Frog *(Atelopus zeteki*) is highly susceptible to *Batrachochytrium dendrobatidi.* It is a species that has gone extinct in the wild, but is thriving in American zoos.

Figure2: Golden Frog. From http://amphibianrescue.org/category/partner-project/

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The rough skinned newt, common in the Northwest, is the only terrestrial animal that carries tetrodotoxin, the same toxin found in several fish species including the Japanese puffer fish.

Figure 3: the Japanese puffer (Fugu) From: http://www.straitstimes.com/lifestyle/food/restaurant-specialising-in-puffer-fish-offers-japanese-delicacy-all-year-round

The toxin is produced by bacteria growing on the newt and it is then sequestered in concentrations high enough to make the newts acutely toxic to predators. A single rough skinned newt produces enough toxin to kill 25,000 mice.

The common garter snake is one of the rare animals that can consume rough skinned newts safely. The predator and prey are in an evolutionary arms race that has led to the very high toxin levels in rough skinned newts.

Figure 4: A rough-skinned newt photographed on the watershed of the Eagle Creek NFH.

The worldwide average rate of a species extinction is one every 250 years, however, since 1989, it is believed that over 200 species of amphibians have gone extinct and more than 32% of the world's known amphibians have been listed as threatened or endangered. The last mass extinction of this magnitude was when the dinosaurs disappeared.

From the 1930's through the early 1970s, the leading test for human pregnancy was to inject African Clawed Frogs with human urine to see if it caused the frog to ovulate (frogs replaced rabbits in this role). Unfortunately, the African Clawed frogs are likely to have been Bd carriers and frog shipments for pregnancy testing may have led to the spread of Bd.

Figure 5: African clawed frogs being used for pregnancy testing. From http://www.todayifoundout.com/index.php/2016/06/time-rabbits-used-accurately-detect-pregnancy/

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Fish and amphibians share many diseases including infections by bacteria (*Aeromonas hydrophila*), fungi (saprolegnia, ichthyophonus), and viruses (ranaviruses, spring viremia of carp).

The largest number of salamanders imported into the US is through Los Angeles California, with 420,000 a year. Of those animals, almost all are susceptible to Bsal infection.

Which Fish Diseases are Transmitted to the Next Generation within Fish Eggs?

In order to be successful, disease organisms (pathogens) must have a reliable method for transmission from host to host. One very successful strategy for fish pathogens is to move from one generation to the next through eggs or milt (vertical transmission). The pathogen must proliferate in the parent fish to a high enough level that it can colonize the eggs, but at the same time it must be careful not to compromise the parent's ability to spawn, the viability of the milt, or the survival of the eggs that are laid. It's a tricky balance, but many fish pathogens very successfully use this strategy.

One way for a pathogen to achieve successful vertical transmission is to simply stick on the surface of eggs and infect fry later as they hatch. At spawning the pathogen can be in the milt, ovarian fluid, or already associated with the egg surface. It then stays on the egg surface waiting for an opportunity to infect the developing fish. This opportunity may not happen until the egg hatches, but there is some evidence that mechanical damage to eggs during incubation increases the incidence of coldwater disease. We don't know if this occurs by 1) allowing coldwater disease bacteria from the parents to invade the egg (true vertical transmission), 2) allowing environmental coldwater bacteria to access the egg, or 3) damage to the egg surface that may allow better colonization by coldwater bacteria that then infect the fry when they hatch. Examples of diseases that we know are vertically transmitted on the egg's surface include bacterial coldwater disease, furunculosis, and the IHNV and VHS viruses.

The other strategy for vertical transmission is for the pathogen to make its way <u>into the egg</u> <u>before</u> <u>spawning</u>. This gives the pathogen an opportunity to propagate within the egg and to infect the fry before it hatches. Fish have evolved many effective defenses against pathogens that try to utilize this very advantageous route, so only a very few fish pathogens successfully use this form of vertical transmission. These are some examples:

<u>Herpesviruses</u>: Some virus groups, like the herpesviruses, cut strands of the host DNA and splice their own DNA into the gap. This means that the virus can sit quietly, be replicated along with the host DNA, and stay below the immune system radar for extended periods until conditions are suitable to emerge and produce an active infection. This trick works just fine with both eggs and sperm. Fortunately, while there is at least one very important herpesvirus of Pacific salmon, this virus (OMV) is not present in the Pacific Northwest.

<u>Microsporian parasites</u>: These parasites (like *Loma* in salmon) are very good at infecting the eggs of many kinds of animals. There is excellent evidence that some of the fish microsporians do infect fish eggs and that they remain at low background levels for months or years until conditions are right to propagate in mature fish and infect the next generation of eggs. For example, Ovipleistophora, a microsporian parasite of minnows, is vertically transmitted within eggs. It persists at very low levels in male and female minnows. Just before spawning it comes out of hiding, propagates rapidly, and infects the developing eggs. Interestingly, this happens only in female minnows, in males the parasite remains at low levels throughout the fish's life.

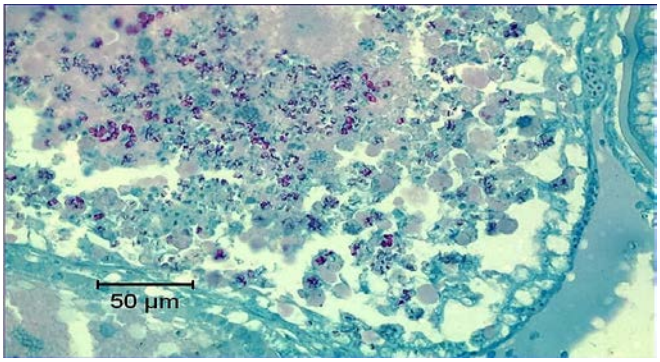

Figure 6: The microsporian parasite Ovipleistophora *(purple) inside the eggs of a shiner.*

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BKD: The Rhenibacterium salmoninarum bacteria that cause BKD are very effective at getting onto and into eggs before spawning and then successfully starting new infections in the next generation. There is even some evidence that the bacteria may employ two strategies two insure transmission 1) they cause disease in juveniles so that fish to fish transmission occurs, and 2) the lie low in some fish throughout their marine phase and then propagate to high levels just before spawning to insure the success of vertical transmission.

Figure 7: BKD bacteria on the surface of salmon eggs. Picture by Mary Peters, PRFHP.

The difference between in-the-egg and outside-the-egg vertical transmission is extremely important to our management of diseases in Pacific salmon. With most outside of the egg pathogens, iodine treatments during water hardening, and before and after transfer, are extremely effective in blocking vertical transmission. For example, the IHNV virus is very common in some broodfish populations but extremely rare in their progeny hatched from disinfected eggs and reared in virus-free water. On the other hand, pathogens that hide within eggs are protected from iodine and other disinfectants. If the iodine concentration in the eggs were to get high enough to kill the pathogen, it would also kill the developing fish within the eggs. For this reason, disease organisms that hide within eggs are very difficult to eradicate. With BKD in spring Chinook we are able to greatly reduce disease severity and prevalence in juveniles by reducing the bacteria load in eggs through culling or antibiotic injections, but the low levels of BKD bacteria still manage to sneak through and lie in wait hoping that some environmental condition will compromise the fish's immune system and provide the right conditions for a BKD outbreak.

The take-home message is that iodine treatment of eggs and good hatchery biosecurity are our main defense against many diseases with the potential to cause huge losses in populations of juvenile salmon. Even with diseases like BKD that hide inside fish eggs, iodine treatments kill additional BKD bacteria on the egg surface and reduce the likelihood of outbreaks in juveniles. The failure of an iodine treatment for a single tray of eggs can lead to disaster.

Circular RAS Systems and Disease Treatments

Agencies that are using circular Recirculating Aquaculture Systems (RAS) in the Pacific Northwest have not reported serious disease problems. There is the likelihood that the combination of raceway self-cleaning, gas equilibration towers, oxygenation, smooth tanks, laminar flow, protection from predators, and exercise are providing benefits that help fish resist disease. On the other hand, re-use of water means that disease organisms (pathogens) may build up to higher levels, that there may be water quality issues that compromise fish (for example, higher ammonia levels), and that there will be complications using fish disease treatments that have historically been successful in flow-through raceways. In this article we will look at the disease treatment side.

In RAS systems that re-use more than 70% of the water, biofilters are required as homes for the bacteria that detoxify ammonia excreted by the fish. The biofilter bacteria would be killed by most bath treatments (formalin, peroxide, chloramine-T) and may be harmed by the use of medicated feeds. Fortunately, the Pacific Regions is not contemplating these high-percentage reuse systems with biofilters (though we do have them on traditional raceway systems at Spring Creek and Kooskia), so we can focus instead on the complexities of bath treatments in re-use systems.

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In traditional raceways, we have laminar "plug flow". When a raceway is treated the treatment chemical is added to the raceway at the concentration needed to achieve the desired dose, and also added to incoming water to maintain that concentration. When the treatment is over, freshwater entering the head of the raceway pushes the treated water down the raceway and out the drain. Once the treatment is stopped, fish at the head of the raceway are out of the chemical almost immediately, and the treatment is gone once the freshwater reaches the drain (30 minutes in a raceway with 2 turnovers per hour).

In circular RAS systems, things are every different. As with a traditional raceway, the treatment can be added to the tank at the right concentration to achieve the correct dose and additional chemical can be added to incoming water to maintain the concentration during the treatment period. However, in circular RAS systems there are big differences in what happens once the treatment is stopped. The RAS systems are not plug-flow like traditional raceways. Instead they are completely mixed. This means that incoming untreated water does not quickly provide a chemical-free haven for the fish, and that the concentration of the chemical in the RAS drops slowly over time as a factor of the recycle rate and the turnover. Below is a comparison of a 150 ppm formalin treatment in a 100' traditional plug-flow raceway set at 2 water turnovers per hour vs. a circular RAS system with the 150 PPM same treatment and twice per hour freshwater turnover.

In the traditional raceway, 5 minutes after treatment stops the first 16 feet of the raceway are formalin-free. At 15 minutes the formalin is gone in the first 50 feet. After 30 minutes all of the formalin treated water has gone down the drain so the concentration is near 0 ppm throughout the raceway.

In a circular RAS, the concentration is the same throughout the tank. At 5 minutes after the treatment stops, the concentration of formalin throughout the system is still at about 140 ppm. After 15 minutes it is at 105 ppm, and at 30 minutes it is still at about 75 ppm. At an hour it is 37.5 ppm and at ***two hours post-treatment it is still at 19 PPM***. The reason why is that in a perfectly mixed system only part of the water going down the drain is the formalin treated water. The rest is the untreated fresh water that has been mixed in with the treated water.

In both traditional plug-flow raceways and in circular RAS systems, the concentration of the chemical post-treatment is dependent on the turnover rate. In a plug-flow system there is very quickly a chemical-free refuge at the raceway head and one turnover displaces all of the treatment leaving all of the fish in chemical-free water. In a completely mixed RAS system, there is no chemical free refuge and the treatment concentration only drops by about half with each turnover.

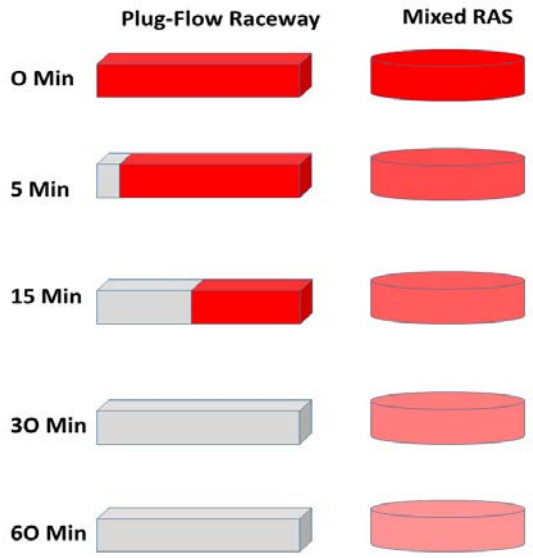

Fig 8: Chemical concentrations (red) in traditional laminar "plug flow" raceways (water entering from the left) and in a RAS system with the same freshwater turnover time.

The "News you can Use" is that we are going to have to re-learn treatment concentrations in mixed systems to allow for the longer half-life of the chemical post treatment.

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Fish Vaccines

The use of fish vaccines to prevent bacterial and viral diseases in fish has a long history of successes and disappointments. In some aquaculture, especially of Atlantic salmon, vaccines are standard practice. But for the rest of us...

- It is really hard to evaluate the effectiveness of vaccines in the field, even when they are working.
- Bath treatments with some killed vaccines (bacteria) are very effective, but others are not.
- Injected vaccines may be expensive to use so cost and benefits must be carefully assessed.
- Live attenuated vaccines are difficult and expensive to license so choices are few.
- The new generation of vaccines is largely based on recombinant DNA technologies.

So where are we at? First a bit of background:

Vaccines mostly fall into two broad regulatory categories. The first is FDA-licensed commercial vaccines that, like fish drugs, carry very specific labels detailing their legal uses by fish species and disease. Extra-label use is allowed under a veterinary prescription. The second category is "autogenous" vaccines that are made for very specific purposes with very major restrictions. In general, autogenous vaccines are killed bacteria derived from an isolate of the bacteria that was obtained from the same hatchery (or sometimes one nearby) in which the vaccine will be used. These vaccines must be made in a USDA licensed facility but the requirement for that facility are not difficult. The reason for requiring that autogenous vaccines are only used on fish from the same location that the vaccine isolate was obtained is to ensure that, if the vaccine still contains some live bacteria, the bacteria are not spread to new places. Autogenous vaccines must be used under the direction of a veterinarian.

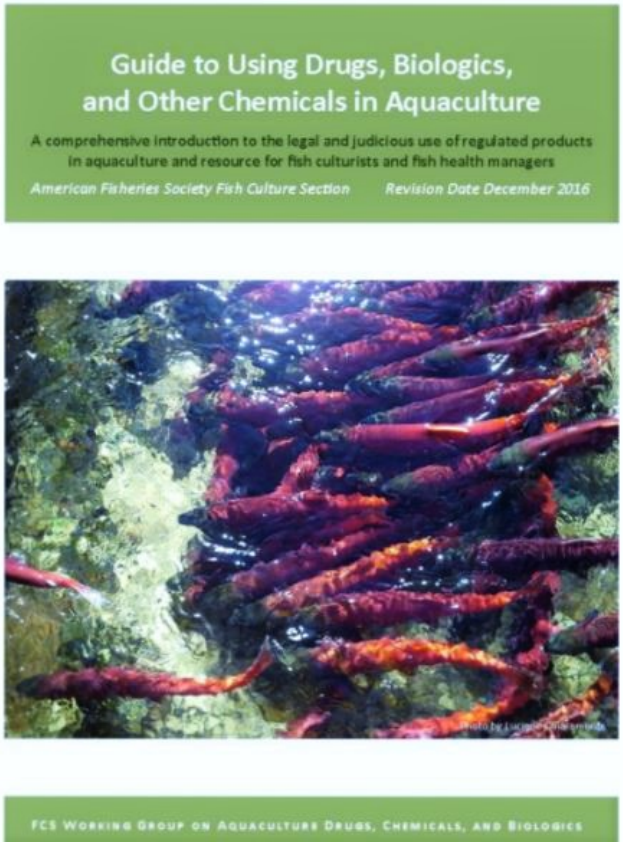

Figure 9: The AFS Guide to drugs Chemicals and other biologics contains useful information about drug, chemical, and vaccine use. https://drive.google.com/file/d/0B43dblZIJqD3Q2NqQkhfeV84emc/view

Vaccines fall into three major types: There are killed vaccines where bacteria or viruses are completely inactivated. There are attenuated vaccines that still contain live, but weakened, versions of the disease organism. And, there are DNA vaccines that consist of DNA molecules that are put into the fish where they are used by the fish as a template to make proteins that resemble fish pathogens and trigger immunity.

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There are also three possible routes of vaccine administration: With bath vaccines, the vaccine is added to the water along with the fish. This works well with live vaccines that can still invade the fish host, but less well with dead or DNA vaccines. There are injected vaccines that are put into the fish. They often work well even with killed vaccines. The injection gets even dead organisms into the fish where the immune system can see it, and these vaccines can contain "adjuvants" that trigger a stronger immune response. The third route is oral. Oral vaccines are top coated onto feeds and fed directly. Experimental oral vaccines have worked with ESC in catfish (a bacterial infection that often starts by invasion through the intestine).

Fig 10: Atlantic salmon vaccination by injection.
http://www.euro-fish.co.uk/photo-gallery/

The type of vaccine and route of administration have a big impact on how vaccines work. For example, injected vaccines trigger a response from different parts of the immune system than do bath vaccines. Both the location and the nature of the response to a later infection are different. In addition, live vaccines trigger a different part of the immune system than do killed vaccines. Some trigger production of antibodies while others trigger the production of white blood cells that seek out and destroy bacteria or virus infected cells. None of the vaccine types have been effective against parasites, even single celled invaders like ich. The type of vaccine and the route of administration must be considered when vaccines are used.

So what is available for steelhead and Pacific Salmon? There are commercial bath vaccines for furunculosis, enteric red mouth, and columnaris. There are injectable vaccines for furunculosis, BKD, ISA, and coldwater. There are also non-FWS hatcheries in the Northwest using autogenous vaccines for bacterial diseases. There are no recombinant DNA vaccines licensed for fish in the US, but there is a popular IHNV DNA vaccine that is widely used in Canada.

So, do they work? Absolutely, but not all of them, not all the time, and none of them provide 100% protection. In addition, while a commercial label provides strong evidence of safety, there are commercial vaccines that don't appear to work well in the field. As with all vaccines, a good fish vaccine decreases the probability of major losses from a specific disease, but they will not make up for major problems in husbandry. We must also keep in mind that efficacy can be very hard to determine in the field. If you expected 75% mortality and only lost 30% of the vaccinated fish, you might be very pleased. If you instead expected 10% mortality and lost 30% of the vaccinated fish, you might be upset. The important thing to keep in mind is that it was 30% mortality either way, but your evaluation of the vaccine efficacy is entirely dependent on your expectations!

So why don't we use vaccines in the FWS Pacific Region? Probably because there is a general perception that injectable vaccines are expensive, labor intensive, and require extra handling of fish. Likewise, there are widespread doubts about the efficacy of killed vaccines used as baths.

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Should we be using vaccines? Yes, **if** there is a hatchery program where 1) there are major annual impacts from specific bacterial or viral diseases, 2) biosecurity and the best husbandry have not solved the problem, 3) there are commercial vaccines or possible autogenous vaccines available, and 4) where the cost of the vaccine is outweighed by the magnitude of the fish losses or fish welfare concerns, **then** it is worth consulting with your veterinarian and other fish health professional about vaccine use.

Biosecurity on Fish Hatcheries

Biosecurity encompasses all of the methods that we use to prevent the introduction and spread of diseases on our hatcheries, and it is a critical part of protecting the health of both wild and cultured fish in the Pacific Northwest. For the FWS trout hatcheries with captive broodstock, biosecurity is straightforward and the need is obvious, but for our Pacific Region Hatcheries with open water supplies and anadromous broodstock, *life is somewhat more complex*. We don't have much control of our water supplies, especially where there is passage above the hatchery, and we can't do much about the disease organisms that return from the ocean in and on our broodstock. That's frustrating, but there are still some important things that we can do.

- Use iodine treatment, protected water supplies, and isolation during incubation to prevent the vertical transmission of important diseases.
- Clean and disinfect equipment and raceways between production cycles.
- Clean and disinfect equipment before it is moved between hatcheries.
- Whenever possible, move disinfected eggs between hatcheries, not juvenile fish.
- Work with your fish health folks to monitor populations for infections or signs of disease.
- If fish appear to be sick, strictly limit movements of people and equipment between that pond and other culture units.
- If husbandry is good and fish are strong, a pathogen accidentally introduced is unlikely to get a foothold.

The steps above are among the most practical and effective biosecurity measures, but there are other steps that you can take to protect your fish and avert a disaster. Hatcheries should work closely with their fish health specialist to develop practical and effective biosecurity measures and see that they are followed. Remember to deal with the small steps that make big impacts first. Once those are all covered, then you start looking at the possible benefits of measures that are more difficult or expensive to achieve. The best way to kill staff buy-in for biosecurity it to get bogged down in things that are a big hassle with minor benefits when big things are still not addressed. For example, worrying about moving dip nets between raceways may not be worthwhile if birds and otters are traveling freely among the tanks and back and forth from natural waters nearby. Sort out the predator problem, then worry about the hassles of dip net disinfection.

PRFHP Updates – New FWS Policy

For 2 years the fish health programs from throughout the FWS have been working to revise the FWS Fish Health Policies (703 FW1-5) and the associated Handbook chapters. At long last, there is a new draft. The new policy has just two chapters and it is very different from the previous version. My favorite change is a departure from the previous "one size fits all" requirements (that often didn't fit all!). The new draft policy has "Aquatic Animal Health Management Teams" (with the same membership as our current HETs) that have broad flexibility to develop a fish health plan for each hatchery. As part of that plan, the Team will be able to develop an inspection strategy that makes sense for the hatchery and mandates testing only when it is either 1) required by other regulators, or 2) provides important information that will impact management decisions. **The draft new policy has many other changes, (including a drug and chemical use policy and reporting system) that will affect hatchery operations. Roy is sending the draft to hatcheries, FWCOs, and the AFTC for review. It is imperative that you read it carefully and get your comments back to Roy by the deadline.**

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PRFHP Updates – The PRFHC Reorg

In the Pacific Region, we regard fish disease testing (the lab work) to be a support function for our true mission, the prevention and management of fish diseases on federal and partner hatcheries. As we have described in previous editions of the Fish Health News, the Pacific Region has determined that the most efficient and cost effective approach to that supporting lab function is to contract the testing out to a fully accredited third party laboratory. The request for bids from suitable laboratories is currently in the hands of our Contracts and Grants folks and we anticipate that it will go out on bid by the end of December 2017. If we are successful in that contracting effort, we anticipate that we will start moving our testing to the contract lab during FY 2018. Remember, the same fish health experts that serve you now will continue to be on your hatcheries helping you to manage fish diseases. The only change with the new system is that the testing will be performed in a different lab. From the hatchery side fish health will look exactly the same except that our fish health folks will now be able to focus more on the field part of our work.

New Science

Scientists have used new DNA technology to look at the prevalence of infection for 46 fish pathogens in out-migrating juvenile Pacific salmon. The new technology has lots of interesting applications. In this study one of the things that they showed is that 100% of the Chinook leaving the Columbia River were infected by the parasite C Shasta.

http://www.npafc.org/new/publications/Documents/PDF%202017/1718(Canada).pdf

For a quick read, the paper below describes the impacts of viruses on marine ecosystems. Not just fish diseases, but viruses that effect the entire food chain including plankton.

http://www.mdpi.com/1999-4915/9/10/302/htm

Cataracts are sometimes a problem in Pacific salmon living at hatcheries. A leading theory for the cause of cataracts is a histidine deficiency. Histidine is metabolized into N-acetylhistidine which plays an important role in osmoregulation in the eye lens. Poor osmoregulation leads to cataract development. A new paper looking at cataracts in lumpfish provides convincing additional support for this theory.

http://onlinelibrary.wiley.com/doi/10.1111/jfd.12664/full

Scientists have found a way to transfer substances into unfertilized salmon eggs using liposomes (microscopic fat droplets). This technology could be used to deliver DNA, antibiotics, or nutrients. (Contact me if you want a full reprint).

http://www.sciencedirect.com/science/article/pii/S0044848616309632

Proliferative Kidney Disease (PKD) is caused by a parasite in the same family as *C. shasta*. The PKD organisms is present in the Pacific NW. A new paper shows that in Europe, the range of the parasite is moving northward and the authors hypothesize that climate change is the driver.

http://www.int-res.com/articles/dao2017/125/d125p073.pdf

A Hot Science Tip

If you want to read a solid and reliable description of any fish disease, the AFS Fish Health Section Blue Book is on-line and free.

https://units.fisheries.org/fhs/fish-health-section-blue-book-2016/section-1-diagnostic/

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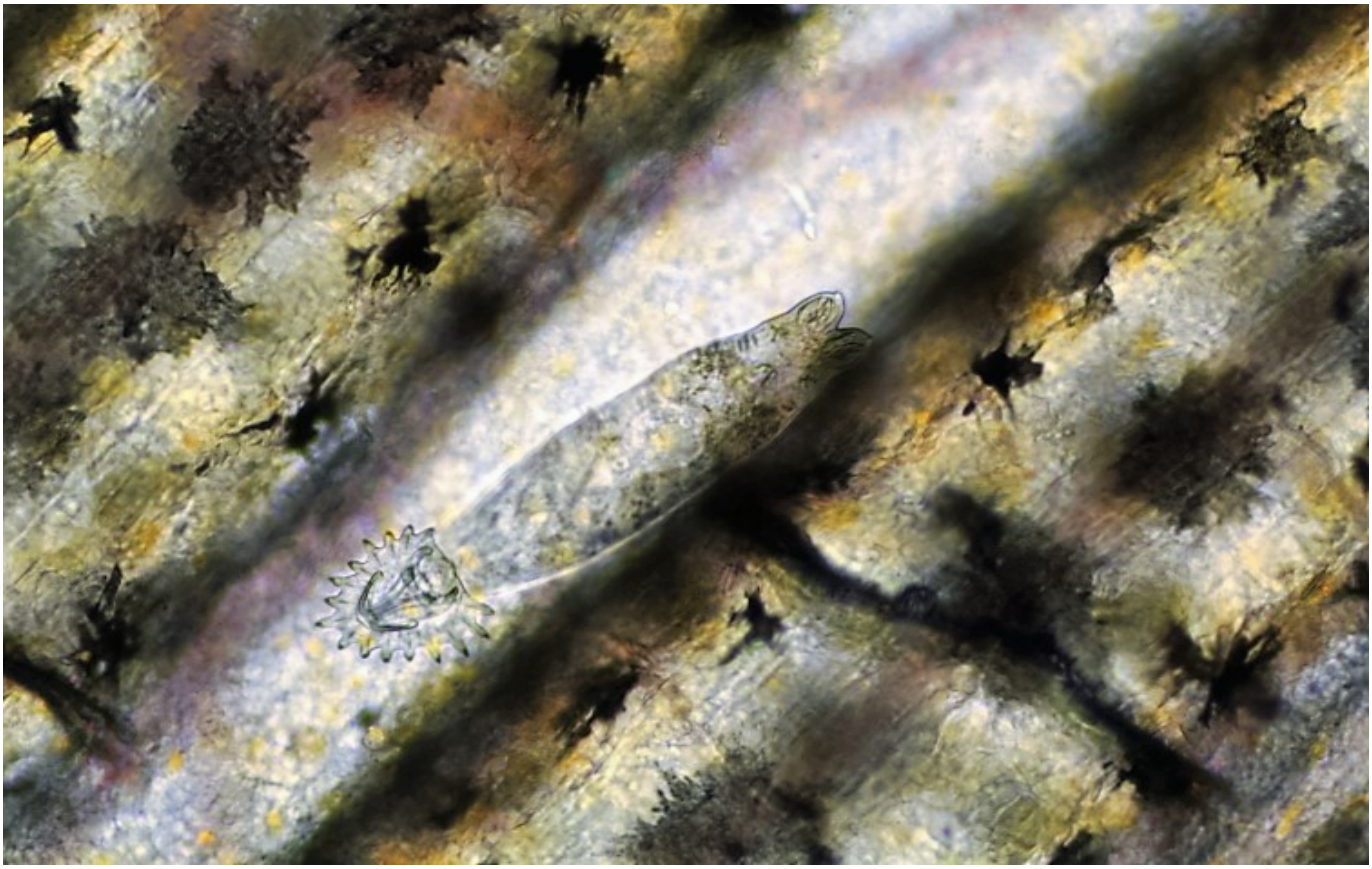
Mystery Parasite of the Day



Answer