OPTIMIZING SALMON

INCUBATION OPERATIONS

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Introduction

Incubation is the process of turning a bag of chemicals into a living organism. This "miracle of life" transformation, the most profound event in the history of the universe, occurs every time an egg is successfully fertilized. While over 3 billion years of evolution has done a pretty good job of making the process fairly robust, fish culturists can still play an important role in giving each individual miracle its best shot at success.

Some points should be kept in mind when thinking of how to optimize conditions for incubation:

First, the process of incubation evolved with a number of assumptions about the environment in which it would occur, and is adapted to work well in that environment. For salmonids, this usually means the environment of fairly pristine mountain streams, and for Pacific salmon, it means cold, clear, high-oxygen, high-flow gravel beds. This is usually the kind of environment we try to mimic in fish culture facilities, using ultra-clean water and avoiding temperature extremes.

Second, this 'typical' environment is not necessarily 'ideal' for the incubation process. The reason that salmonids (a marine fish) sought out freshwater streams in which to lay their eggs probably had more to do with avoiding the abundance of predators in the ocean than that streams are a perfect incubation environment. (it is in fact the inhospitable-to-life nature of mountain streams, with their lack of nutrients, shifting substrate and cold temperatures, that is appealing to salmonids. Neither predators nor pathogens can survive in these locations during the long periods when salmon eggs are not available.

Third, optimization is an arrow that needs a target before deciding which way to aim the bow. Usual targets are perfect survival or maximum fry weight, but targets such as highest disease resistance or shortest swim-up timing might require aiming in a different direction. The fish culturist does not have to blindly follow nature's lead but has many options to manipulate incubation outcomes to serve whichever 'optimal' target is selected.

Fourth, while the water supply at every hatchery is undoubtably not 'optimal' for incubation, embryonic development is so efficient and low-key that it has little impact on the water used for it. Therefore, water supplies can be fairly inexpensively re-engineered to be more 'optimal' than what they were originally, using recirculation technology.

The incubation process starts off with the production of the eggs and sperm in the bodies of the broodstock, includes the stripping and fertilization of the eggs and their placement and care in incubation containers, and ends when the fry have swum up and started to feed. Each of these steps can be improved by improving the environment (physical and chemical) in which they occur, by removing deleterious effects (like pathogens or toxins) and by providing stimuli to accelerate (or decelerate) development.

Adult Holding

The role of the adult in incubation is to furnish the process with good-quality eggs and sperm, or more correctly, to take the best care of itself so that good quality eggs and sperm can be produced.. The role of the fish culturist is to take the best care of the adults so that they are in fit condition to produce good quality eggs and sperm.

The processes of egg and sperm production within maturing adults is a long and complex sequence of precisely timed and executed events. These events are signalled and triggered by a cascade of hormone releases that start before the germinal cells begin to undergo meiosis to produce gametes and are still going on while eggs and sperm are being shed from the adults' bodies.

We have to understand that the adult salmon has other things on its mind, in addition to procreation, while it is creating eggs or sperm, some of which, like survival, take precedence. The amount of energy that an adult puts into gamete production is dependent on the amount of energy that it has to spare. The fish culturist should seek ways to minimize the requirement for energy use for other things by the adults, to maximize the effort available for gamete production.

Some guidelines are:

Provide an optimal environment:

- Temperature - cool enough to keep oxygen levels high, metabolic rates low and reduce invasion by pathogens, but warm enough to allow thorough gamete development.
- Light - low enough to reduce excitement.
- Space - room enough to move and avoid rubbing against each other and the container walls but not enough to establish territories.
- Water Flow - enough for sufficient oxygen supply and waste removal.
- Chemical properties: ionic content of the water should be sufficient to minimize leaching of essential ions needed for egg development.

Protect from pathogens:

- Minimize handling to avoid the abrasions, stress and trauma that can encourage infection.
- Maintain physical separation between broodstock and sources of pathogens or toxins (birds, rodents, wild fish, people).
- Inject or bath with antibiotics to control pathogen growth on adults being held.

Stimulate development

- Manipulate degree of isolation from each other to stimulate or delay maturation, depending on the preferred timing of spawning.
- Inject hormones (e.g. LHRH) to stimulate final maturation and synchronize timing of egg-takes.
- Provide nutrients in food or water that will aid in gamete development.

Fertilization

The first requirement of successful fertilization is good quality eggs and sperm, which is mainly determined by how the adults were treated. Once removed from the adults, the gametes may or may not have all that is required to produce a living embryo. The fish culturist has many options available to make the fertilization process as near perfect as the quality of the eggs and sperm will allow.

Some guidelines:

Provide an optimal environment

Ensure that water temperature, oxygen content, other dissolved gas pressures and light are suitable at every stage of the process. Test the egg's environment with an oxygen probe and thermometer every minute during a typical (or extreme) egg-take procedure to convince yourself that the eggs (and sperm) are well taken care of at all times.

Manipulate the ionic content of the water used for fertilization, washing and hardening, to ensure that there is enough sodium, calcium and other ions for proper fertilization (Brown and Lyman, 1981) and hardening (Li et al., 1989). Such a small amount of water is needed for these activities that almost every hatchery could benefit from using a prepared mix rather than just using the available water (Rieneits and Millard, 1987).

Use procedures that eliminate occurence of blood or broken eggs in the fertilization buckets. Use a bicarbonate soda wash (Wilcox et al, 1984) to dilute any cytoplasm (potassium) in the ovarian fluid, since it severely inhibits sperm activation (Morisawa et al., 1983).

Protect from pathogens

Use test kits to screen for known pathogens and eliminate carriers from the egg pool.

Select only those eggs that are at their peak of ripeness. Do not use eggs from over-ripe females with watery ovarian fluid, nor eggs that have had to be torn out of the skein. Test the fertilizability of eggs from different parts of the abdomen and taken from fish with different degrees of softness to determine the best time and procedure for extracting eggs.

Handle eggs and sperm carefully during extraction, storage and mixing to minimize physical damage.

Make sure that your wash water, fertilization water and hardening water are all sterile.

Stimulate development

Consider using an activator solution to stimulate or prolong sperm activity (Moccia and Munkittrick, 1987).

Manipulate the content of the hardening water content to see if you can provide essential nutrients (Ronnestad and Fyhn, 1993) or ions to the egg at the only time when it is taking in large amounts of external water. After hardening, the egg becomes quite impervious to movement of all but the smallest chemicals through the shell.

Egg and Alevin Incubation

Many of the fish culture procedures and criteria for incubation are determined by the containers in which the fertilized eggs are kept during the incubation period. Biologically, the choice of container should not make much difference to the fish, since every kind should provide the same kind of even, gentle flow that brings oxygen and removes wastes from the area around every egg. Care needs to be taken that a container or the way it is loaded does not crush or deform eggs.

The stages of development that an egg goes through after fertilization, from the combining of the sperm and egg haploid nuclei, through the first cell division and formation of the blastula, the gastrula, the neural fold, the eyes, etc. are incredibly complex (Velson, 1980) and are made up of, and controlled by, biochemical reactions that were pre-set, all ready to go, in the bag of chemicals (Hamor and Garside, 1977) that was produced by the female salmon (Brachet and Alexandre, 1986).

Provide an optimal environment

Ensure that water quality is kept at the highest standards, including oxygen, nitrogen and total gas pressures, ammonia, nitrite and carbon dioxide. Micro-environments within an incubation container can be very different from one another due to the pattern of water flow or stagnation within the incubation container.

Add ions to your process water if it is very soft or acid and soften the water if it is extremely hard (Gunn and Keller, 1980).

Keep the temperature within the metabolic limits of the fish (Weatherly and Gill, 1995), with the understanding that this is one area where the environment can be manipulated to suit your needs, since those of the fish are very plastic.

Minimize disturbance by keeping light and sound (vibration) levels very low.

Provide media for alevins to lean up against, reducing energy wasted in thrashing around.

Protect from pathogens

Thoroughly disinfect both the containers and the fertilized eggs at the beginning of incubation.

Start off with a clean water supply and make it even cleaner with disinfection.

Take every step possible to ensure a pathogen-free environment, including limiting work around and access to the incubation area.

Pick dead eggs out of the system as soon as possible. Pre-eyed picking has proven to be very useful in stocks with poor fertilization, if conducted extremely carefully.

Minimize handling and disturbance to only those events that are essential (Jensen and Alderdice, 1983). There are always a great deal of extremely complex biochemical events going on in eggs and, even though the egg is very robust much of the time, a perfectly healthy egg can be killed if the timing of a hard bump occurs at a sensitive period for only one of its millions of cells.

Stimulate development

While the egg is encased in its shell, it might be possible to provide it with some ions or nutrients that will aid in its development. Once the shell is gone, alevins are much more intimately connected with, and sensitive to, the water around it. Treatment with hormones at this stage can alter the sexual development of salmon and it is likely that other chemicals can be utilized by the alevin in its development.

Experiment with adding nutrients, hormones and ions to the incubation water to see if they direct development closer to the incubation target.

Recirculation

Many of the suggested improvements to the environment for adult holding and incubation listed above involve altering the basic characteristics of the water used in the hatchery. While this might be considered to be a shopping list for the type of water that would make up the perfect water supply (but impractical to implement in facilities that do not have the suggested type of water), most of the changes described above can be accomplished fairly easily at any hatchery using water recirculation technology. In fact, complete control of the incubation environment probably depends on the application of water reuse, since to alter the characteristics of any flow-through supply to such an extent would be prohibitively expensive.

The appeal of recirculation for incubation water is that it is much simpler to treat incubation waste water than it is to treat rearing waste water. During rearing, massive amounts of extraneous material is added to the system in the form of feed, and over half of the feed is not incorporated into fish flesh and becomes waste, mainly solids (uneaten food and feces) and ammonia (Timmons and Losordo, 1994). During incubation, no extra material is added to the system whatsoever, and only a very small fraction of the existing egg is excreted as waste, mainly ammonia. For a short period of time, the egg shells are shed and can be removed either as solids, or after they have disintegrated, as a foam fraction. This means that a recirculation plant for an incubation system needs to be much simpler, smaller and cheaper than one for a rearing system.

Conclusion

Fish culturists have the opportunity to make major improvements in the quality of incubation in salmon hatcheries. Any hatchery with a history of poor incubation success should take a more active role in the control of the physical, chemical and biological components that make up its system. Recirculating the incubating water can make such control relatively inexpensive.

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