Benchmark®
Genetics

ATLANTIC SALMON HATCHERY MANUAL

EGG TO FIRST FEEDING

Atlantic salmon eggs and alevins go through several stages and life-cycle events before becoming free-swimming fry. Each stage and event has its own characteristics and environmental requirements, which are covered in different sections of this manual.

CONTENTS

WHAT WE DO

Our business is based on more than 40 years of experience in delivering high-quality genetic material to the global Atlantic salmon market. Benchmark Genetics is a global breeding company operating advanced breeding programmes for Atlantic salmon, tilapia, and shrimp.

The company runs three nucleus programmes for Atlantic salmon in Norway, Iceland, and Chile supplying the SalmoBreed, StofnFiskur and SagaChile-strains, respectively, to producers around the world. Atlantic salmon are selected using a balanced breeding approach for improved growth, disease resistance and efficiency.

Achieving the genetic potential depends on farming practices and the conditions in which the animals are held. Sub-optimal conditions will reduce performance. The aim of this document is to describe good practice for Atlantic salmon eggs, alevins, and fry, allowing producers to develop best practice management procedures for their operation.

Information presented in this document combines data derived from internal researchtrials, published scientific knowledge with the expertise, practical skills and experience of the Benchmark Genetics technical service teams, and sister companies in the Benchmark Group. The information contained is consistent with standard industry welfare guidelines produced by industry bodies
— see *Further Reading*.

Ordering eggs

To place an order for eggs, please contact the local Benchmark Genetics sales manager. To provide the best customer service, please make contact as far ahead of time of delivery as possible. If you need to change an existing order, please notify the sales team as early as possible. This allows the incubation center supplying the eggs to make necessary adjustments.

The Benchmark sales team will follow up on orders both before and after delivery. Our experienced technical and sales teams are always available to assist you with any logistical, quality, and production-related issues that may arise.

USEFUL CONTACTS:

Benchmark Genetics Norway
Bradbenken 1
5003 Bergen
Norway

+47 553 33 790
post@bmkgenetics.com

Benchmark Genetics Iceland
Bæjarhraun 14
220 Hafnarfjörður
Iceland

+354 564 6300
iceland@bmkgenetics.com

Benchmark Genetics Chile
Santa Rosa 560
oficina 25 B
5550000 Puerto Varas
Chile

+56 65 223 2610
post@bmkgeneticschile.com

SECTION 1

ENVIRONMENTAL PARAMETERS

The requirements of the eggs and juveniles vary between stages. Water temperature, water flow, water quality, and lighting are important parameters for each stage, whilst feeding practice and feed quality become important at first feeding and beyond.

Temperature

Eggs are usually transported at a temperature range between 2-5°C.

The rate of embryo development and growth of alevins and fry depend upon water temperature, with slower development at cold temperatures and faster development at higher temperatures. Water temperature can be used to control the date of hatching as well as development.

Incubation temperatures above 8°C can result in an increased level of skeletal deformity (6°C in triploids) Alevins can initially be held in temperatures up to 7-8°C, although increasing temperatures can increase the risk of skeletal deformities. Time of development is measured in degree days. A degree day is defined as water temperature (°C) multiplied by the number of days:

Total degree days =
water temperature x number of days

Key events such as hatching and first feeding happen after a defined number of degree days as described in subsequent sections. However, at temperatures below 5°C, development is faster than predicted by the degree days, and key events may consequently occur earlier than predicted. For more information, see *Terminology* at the end of this manual or use our online hatching calculator (under *Further Reading*).

Water flow

Water flow rates should maintain oxygen levels above 80% saturation in the outlet and remove metabolites. The water flow rate should be regularly checked at several points in the hatchery to ensure that there are no dead zones (spots without circulation).

Oxygen

Oxygen should be measured daily at critical points in the system, especially in locations where deviations have a high risk of inducing stress to the eggs or fish. Each stage of the hatchery should be monitored for several days at full water flow before stocking.

Carbon dioxide

Carbon dioxide levels are an indication of the rate of metabolism in the system. Excess carbon dioxide can cause pH reduction. Levels measured at the outlet should be maintained at <6 mg/l for eggs and fry ≤5 grams, and <15mg/l for fry >5 grams.

Total gas

Total gas should be measured at least once per week, and whenever changes are made that may affect the total gas content (e.g., temperature or water flow adjustment).

Nitrogen is the gas that most often leads to supersaturation (caused by leaks in pumps or couplings, pipes that are in a negative pressure, or considerable heating of water without adequate ventilation). Reduced water depth during first feeding can often lead to changes in the water climate.

A total gas saturation over 100% can lead to bubbles forming in tissues with detrimental effects on affected eggs or fish.

pH

pH is an important water parameter that must be carefully monitored throughout the whole season. For example, eggs hatching in late summer may experience different water parameters compared to eggs hatching in winter.

Although salmon can withstand a higher range, the optimal pH for Atlantic salmon eggs and alevins is 6.6-7. pH can be controlled by flow rates and the addition of hydrated lime or bicarbonate. At lower pH values, there is a risk that metal ions can become toxic and potentially cause a harmful environment for the eggs and juveniles. This can be caused by adverse weather conditions such as snowmelt or heavy rain. The pH should be closely monitored at such times. Sudden changes in pH can also lead to an undesirable environment for the eggs and juveniles.

Suggested optimum water quality parameters are shown in Table 1.

Stocking density

High stocking density can have detrimental effects on welfare and performance. Optimum stocking density will vary between hatcheries depending on facilities, equipment, and other variables.

Eyed eggs can be stocked at 10,000 to 80,000 per m^2, without reduced hatching rates, depending on unit size and equipment. Care should be taken to ensure good welfare during hatching by monitoring important parameters, especially when increasing the stocking density.

For optimum welfare, alevins and fry should be stocked at less than 10kg per m^3 in the period after hatching and up to 1g of weight, although field results show that higher stocking densities can be used without effect on post-hatch survival.

Lighting

Eggs and Alevins should be kept in darkness or low-intensity light. Lighting can be increased as alevins begin to swim up to stimulate feeding behavior. Turning on and off lights should be done incrementally to reduce stress.

Water samples

Water samples should be taken daily from different parts of production. The samples should be kept stored and available in a refrigerator for 14 days for analysis in case tests become necessary due to problems.

Table 1. Suggested water quality parameters for Atlantic salmon eggs, alevins, and juveniles

Parameter	Eggs	Alevins/Fry (≤5 grams)	Fry (>5 grams)
Water temperature °C	1-8*	1-8**	2-14
Total gas %	100	100	100
Oxygen mg/ml	>7.0	>7.0	>7.0
Oxygen saturation %	>90	>80	>80
Carbon dioxide (CO_2) mg/ml	<6.0	<6.0	<15.0
pH	6.6-7	6.6-7	6.5-7.2

* Triploid eggs are liable to increased levels of deformity if incubated above 6°C.
** Water temperature can be slowly and incrementally increased to 10°C 10-14 days before first feeding.
Sources: RSPCA and Benchmark Technical team

SECTION 2

BIOSECURITY

Eggs and juvenile salmon are susceptible to many pathogens. Biosecurity is a set of procedures designed to prevent pathogens from entering the hatchery.

There should be a strict visitor procedure restricting entry of unauthorized personnel into the hatchery. Each biosecure area should require change of clothing, footwear, and hand washing and sanitization when entering and exiting the area. Clothing and footwear should not be moved between biosecure areas to avoid contamination.

Water should be filtered at entry to the hatchery. Water sterilization using UV or ozone can be used to prevent pathogens from entering the hatchery. Water sterilization procedures need to be defined for each hatchery and water source, and equipment manufacturer's guidelines need to be followed to ensure the effective operation of equipment without risk to eggs, fish, or operators.

Equipment

Like clothing and footwear, equipment should also be dedicated to each biosecure area. If equipment movement is necessary, then thorough cleaning and disinfection should be completed before use in another biosecure area. There should be thorough cleaning and disinfection of facilities and equipment between production groups.

Due to the nature of the hatchery cycle, each production section has an inactive period where equipment can be cleaned, repaired (if necessary), disinfected, and tested well before the eggs or juveniles arrive.

It is essential that the system is filled with water and run at operational flow rates for at least three days before egg reception.

Egg disinfection

Sanitary regulations require that eggs are disinfected after fertilization and before packing. Boxes and eggs can be disinfected upon arrival at the hatchery. Eggs are usually disinfected with an iodine disinfectant designed for salmon eggs, such as Buffodine, used in accordance with the manufacturer's instructions and within shelf life.

SECTION 3

EGG RECEPTION

It is very important that everything is prepared in advance of egg reception. It is also essential that enough trained employees are at the workplace, all necessary equipment is carefully cleaned, disinfected, thoroughly rinsed of all disinfectants and cleaning agents, and that a biosecure entry point for eggs is identified.

In countries where Benchmark is present, Benchmark sales or technical staff will attend the delivery and assist by checking the size and condition of eggs, delivery volumes, and temperature logs during transport. In other countries, Benchmark aims to attend the first official egg input and follow one egg delivery per year.

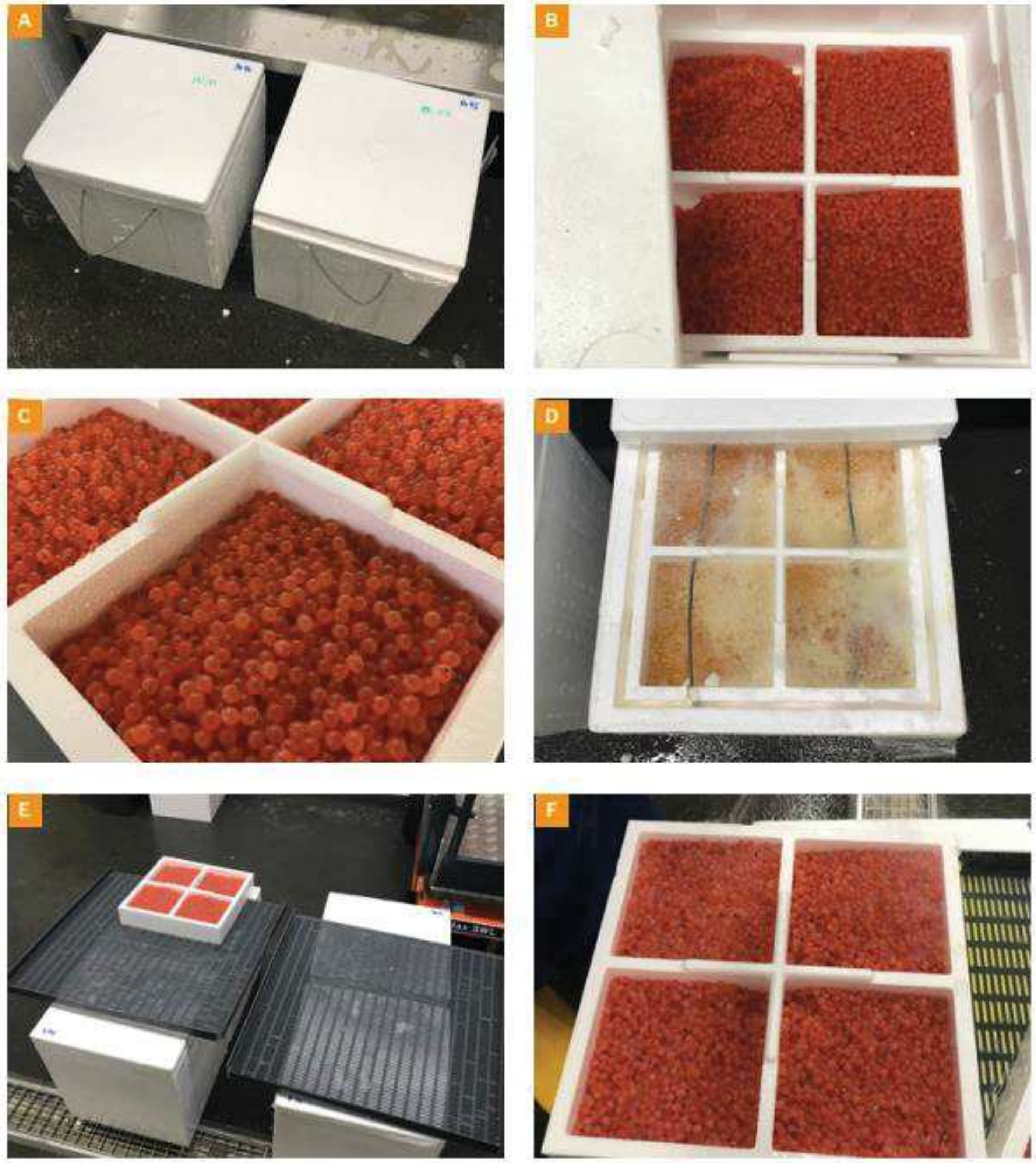
Transferring the eggs from boxes into incubators requires proper organization and should focus on minimal physical stress to the eggs. Care should also be taken to avoid temperature shocks to the eggs. It is good practice to check paperwork and make detailed records of the transferring process to ensure proper handling and following of procedures.

A standardized procedure should be developed for each hatchery depending on layout and equipment. This procedure should follow general steps to ensure a biosecure transfer of eggs into the hatchery.

The following list is an example of a procedure for disinfecting boxes and eggs (see figure 1 on the next page):

1. Remove tape and lid.
2. Carefully lift out top tray of ice and discard residual ice. Note if there is no ice present.
3. Replace top tray.
4. Clamp top tray to outer box either by pins or spring clamp to prevent the trays floating when the disinfectant is added.
5. Ensure that eggs, disinfectant, and water for rinsing are at the same temperature to avoid temperature shock to the eggs.
6. Slowly fill the box with 10 liters of diluted disinfectant prepared according to manufacturer's instructions allowing air to escape. Leave eggs in the disinfectant solution for 10 minutes, unless otherwise specified for your delivery.
7. Lightly press down on top tray and remove clamps/pins.
8. Slowly lift out trays by lifting evenly from the center.
9. Place trays onto a raised mesh and gently rinse off disinfectant using fresh water.
10. Pour remaining disinfectant through a sieve to retain any ova and add to tray.
11. Once comfortable with the procedure, start each box at 5-minute intervals.
12. Replace disinfectant solution according to manufacturer's instructions.

Figure 1. Unpacking and egg disinfection procedure on arrival at the farm.
A. Styrofoam boxes placed in the disinfection area. **B.** Lid removed revealing the first egg tray. **C.** Ideal condition of eggs during unpacking on site. **D.** Disinfectant is added to the styrofoam boxes. **E.** Egg trays placed onto a raised mesh following disinfection. **F.** Gently rinse using fresh water.



SECTION 4

INCUBATION OF EYED EGGS

Temperature

Water temperature in hatching trays or troughs should be adjusted as close as possible to the transport temperature (usually 2-5°C). Water temperature can then be slowly adjusted to increase or decrease the rate of development and advance or delay hatching in the range 2-8°C (2-6°C for triploids). Water temperature should not be adjusted by more than 1-2°C per day. The increase should be done in an incremental manner.

Sudden temperature increases can induce premature hatching.

Temperatures above 7-8°C (6°C for triploids) during egg incubation can increase the risk of skeletal deformities.

At temperatures below 5°C, development is faster than predicted by the degree days, which can lead to the time of hatching being accelerated

— see *Terminology* at the end of this manual or use our online hatching calculator (under *Further Reading*) to obtain a more accurate hatching date.

Water flow and incubation

It is good practice to observe the development of all eggs during incubation. In most cases, this will require placing fewer eggs in each incubator than the maximum limit indicated by the manufacturer. This will also make the removal of dead eggs and cleaning easier.

The optimum flow rate of water in the incubation phase is 1 liter water/minute/liter of eggs. Slower flow rates may result in reduced survivability due to poor gas exchange. Higher flow rates can produce excessive turbulence that will disturb the eggs, causing reduced survivability.

Lighting

During the incubation phase, eggs should preferably be kept in darkness or dim light.

Hatching environment

Eggs are usually placed on a screen or grid, which has holes that are big enough for the newly hatched alevins to swim through and access the substrate at the bottom of the hatching system.

SECTION 5

HATCHING

The hatching embryo is vulnerable to several environmental factors. It is important that hatching eggs experience stable temperature, light, and water quality to minimize stress resulting in high survivability.

Temperature

Atlantic salmon eggs will typically hatch between 480-520 degree days and hatching will last for 3 to 4 days.

The hatching date and duration will be affected by water temperature during the incubation period. In cold water (1-5°C), hatching can often commence up to 50 degree days earlier and can be extended over a longer period (the temperature can be increased to approximately 7°C when hatching starts to avoid a long hatching period)
— see *Terminology* at the end of this manual.

Suboptimal water quality and fluctuations in water temperature and oxygen level may result in a premature and stress-induced hatching period.

Water quality

Foam derived from protein in the water can present a challenge during hatching (especially in a system that reuses water). It is very important to keep the incubator screens clear to ensure optimal and stable water exchange.

Total gas

Total gas should be measured regularly during hatching, and flow rate should thus be adjusted if problems occur. Total gas values above 100% can cause problems for alevins. Total gas is especially important to monitor in facilities that reuse water.

Light

Newly hatched alevins are sensitive to light. Darkness or subdued light is recommended to minimize stress during this phase

SECTION 6

ALEVINS TO PRE-FEEDING

Alevins are sensitive to stress and handling. A balance must be struck between handling frequency and duration (which causes stress to the alevins), and hygiene (removal of egg debris and non-viable hatchlings).

Deformed and dead eggs/fry should be carefully removed at least twice per week to prevent the development of fungus. More frequent removal may be required in cases where there is lower hatchability.

Sub-optimal water quality and stress can cause deformed, distended, and/or cracked yolk sacs characterized by orange fat droplets on the water surface. Alevins affected by this will not survive.

Mechanical damage (handling, fast water flow, etc.) is often associated with white spots in the yolk sac due to coagulation of yolk.

Alevins should be held in a water temperature range of 2-7°C to control development. Groups held at the lower end of this range may impact the synchronization of the group. The temperature can slowly be increased to approximately 10°C the last 10 to 14 days leading up to first feeding (maximum 1-2°C increase per 24 hours). This increase promotes optimal growth and fry activity.

SECTION 7

FIRST FEEDING AND FRY

An effective first feeding phase plays a crucial role in the future growth and health of a stock. Establishing a good appetite and feeding-response makes feed management more effective at later stages.

Close observation of fish behavior in the days leading up to first feeding will indicate when the population is ready to begin feeding. It is common to move the alevins to larger tanks at this point, and feeding should begin immediately after transfer.

The fry is usually introduced to feed between 850-920 degree days after fertilization (370-440 degree days after hatching). Feeding can be initiated when yolk sacs are almost empty. A rule of thumb is to initiate feeding when 90% of the alevins have absorbed 90% of the yolk sac.

Small groups of alevins can be observed in the tank or tested in suitable containers for feeding and swimming ("swim up") behavior. A rising temperature profile (<13,5°C) after transfer and during first feeding, can be used to develop appetite.

Temperature can be increased by 1-2°C at transfer, followed by 1°C per day as feeding behavior develops up to a maximum of 13,5°C.

During the first feeding phase (maximum 5-7 days), it is a possibility to retain some substrate from the hatching phase to allow alevins to exhibit natural sheltering behavior during the transition to active schooling and feeding. This can reduce stress and prevent the fry clumping around the screen outlet. As feeding behavior develops in the group, the hatching substrate can be removed, allowing proper tank hygiene procedures to begin.

Be advised that use of hatching substrate will have an adverse effect on the water quality in the tank when the fry show high feeding rate. A flat screen on the tank bottom may need to be surrounded by a barrier or "hat" until all the fish are feeding. The hatching substrate should be removed as soon as the fish do not require it for shelter to allow optimum water quality.

Feeding

- Hand feeding allows observation of individual groups in early stages of appetite development to ensure that each group is feeding well before moving to automated feeding systems.
- It is particularly important to observe the fish carefully during the first 3 weeks of feeding. During this period, the fish's appetite is changing rapidly, and underfeeding can lead to aggressive territorial behavior, resulting in damaged eyes, shortening of the gill covers (operculum), and/or fin damage.
- It is important to properly spread the feed in the tank. This can be achieved with good water flow, with focus on speed and direction controlled by nozzle jets. Uneven distribution in the tanks can lead to aggressive behavior.
- First feeding pellets should float on the surface before sinking gently with minimum amounts of fragmentation. Drop height and angle of the pellet when it meets the water are also of importance for an even feed distribution in the tank.
- The amount and type of feeders can be adjusted based on the size and shape of the tank.
- Feed suppliers should be prepared to provide suitable pellets giving optimal nutrition, feeding, and feed management for first feeding fish.

Stocking density

As feeding behavior develops, the alevins move from resting on the bottom or in substrate to active shoaling and feeding. Stocking density should therefore initially be managed by surface area and then by volume, taking welfare and performance into account. Fry can be stocked at approximately 10,000 per m^2 without loss of performance depending on equipment. As stocking density is increased, care should be taken to not compromise welfare.

Water exchange

During first feeding, it is important to have control over the water exchange rate. An exchange rate of 100 minutes (minimum 60% per hour) should be adequate for first feeding at the stocking densities described above. Water quality (O_2 and total gas) should be monitored to control exchange rate.

Temperature

Optimum growth rates for fry are usually between 11-13,5°C.

Health challenges

Fry can be exposed to various pathogens including bacteria, viruses, and parasites. Each producer should work with their veterinary adviser to establish health monitoring and specific management plans for each site.

TERMINOLOGY

Development and degree days

Development and growth in fish embryos (i.e., eggs), juveniles, and adult fish is temperature dependent. Degree days allow development to be monitored when temperature varies:

Degree days = temperature (°C) x day

Example: 7°C x 10 days = 70 degree days

Degree days are also used to calculate the hatching time for Atlantic salmon eggs.

Biological development in Atlantic salmon eggs at temperatures lower than 5°C is quicker than the degree days would suggest. Observations in hatcheries have shown that the biological degree day at temperatures below 5°C is related to the actual degree days as shown in Figure 2.

At temperatures above 5°C, actual degree days will be the same as the biological degree days.

pH

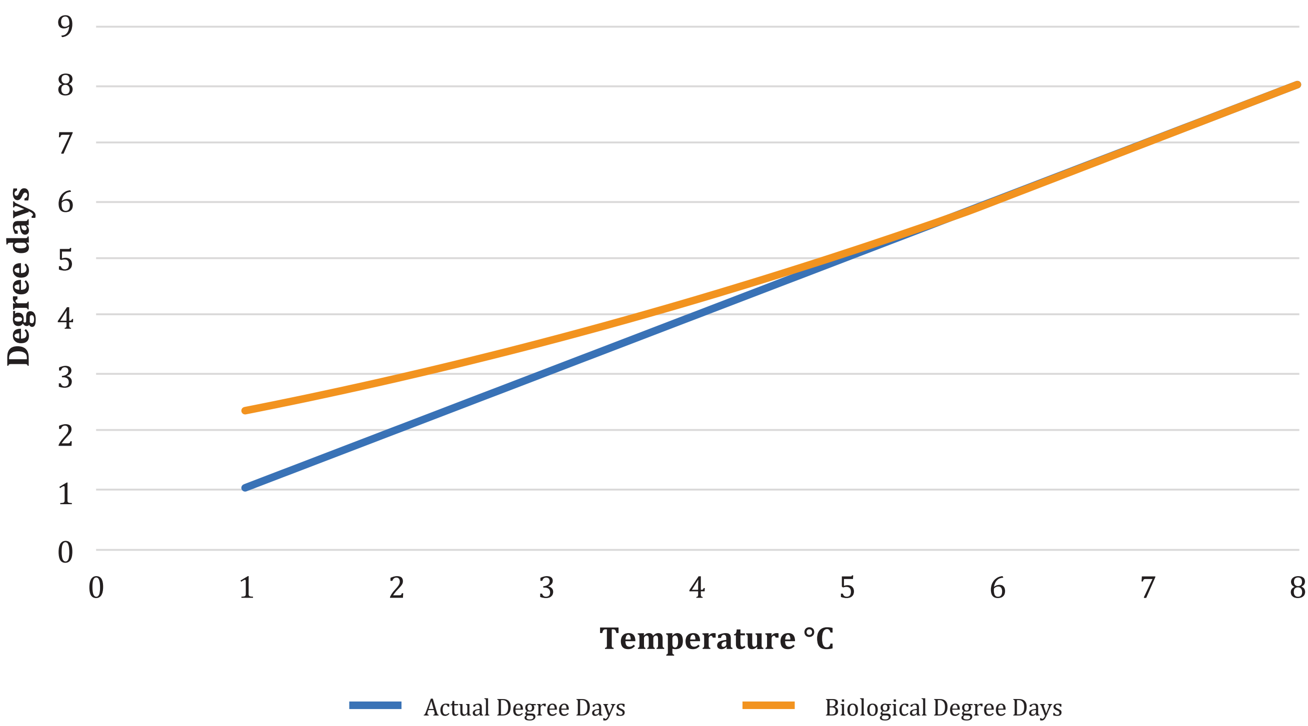
A measure of the acidity of water. Observed changes in pH can indicate changes in water quality due to biological or environmental changes.

Total gas

Total gas shows the measured sum of all gases dissolved in water using a total gas meter.

Total gas should not exceed 100%. This can lead to gas overload and form gas bubbles in the blood of the fish (supersaturation) and increased disease susceptibility

Figure 2. Relationship between actual degree days and biological degree days of Atlantic salmon eggs at temperatures between 1 and 8°C



FURTHER READING

Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare. Noble et al. (2018).

(http://hdl.handle.net/11250/2575780)

RSPCA welfare standards for farmed Atlantic Salmon.
RSPCA, February 2021.

(https://science.rspca.org.uk/sciencegroup/farmanimals/standards/salmon)

Atlantic salmon – guidelines for order and egg delivery procedures

(https://www.bmkgenetics.com/library/)

Hatching Calculator

(https://www.bmkgenetics.com/hatching-calculator/#/)

Disclaimer

Every attempt has been made to ensure the accuracy and relevance of the information presented in this document. Despite this, Benchmark Genetics accepts no liability for the consequences of using this information for the management of Atlantic salmon or for any other purpose.