BlueMentor

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Innovative Quality Mentoring program for development of a Blue Competence Framework in fin-fish production

Output 3
Fin-fish work based learning resources

D3.3 - Learning Resources and Pedagogy

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Summary

Overview

Learning resources have been developed to support flexible delivery of key salmonid aquaculture subjects, namely: Smolt production, Fish health and welfare, Salmon nutrition and feeds and Hatchery operations.

The resources are comprised of Flexible learning packs and Multiple-choice question banks. Their development complements resources developed under the previous "Ask for Best Practice" Erasmus strategic partnership, as the same style of presentation has been followed.

In the case of Fish health and welfare, a teacher resources pack has been developed adopting the same style as the Teacher resource packs developed under the previous "Ask for Best Practice" Erasmus strategic partnership.

The resources can be used to complement work based, facility based and blended delivery modes and could be used to support the mentoring of both husbandry operatives and site managers. Visual resources in the form of digital images are included. However, due to difficulties encountered with farm access during the pandemic, it has not been possible to source all the images required. Image boxes defining the image required have been placed in the text, to guide future users of the packs.

How to use these resources

The learning materials presented can be adapted to suit the needs of different learners and VET delivery modes. The images can be changed, and some need to be sourced by the VET provider. In addition, some instructional design notes have described how the delivery could be made more interactive via the use of courseware (such as Articulate) and the application of an up-to-date Learning Management system (LMS). To these ends, the Smolt production unit, includes Instructional video story boards which could be used to direct the development of instructional videos by a provider with access to a suitable smolt production facility.

The intention is to support interactive digital learning development through instructional design and the provision of exemplars to illustrate the methodology and could also be adapted video creation in an alternative facility.

There are banks of Multiple-choice questions (MCQs) for all three units and the Hatchery Operations Unit developed under the Ask for Best Practice Strategic Partnership. Feedback is provided in some case, allowing the MCQs to be installed within a sophisticated LMS in the future. They can be used to support the accreditation of prior learning (APL) or formative and summative assessment.

There are procedures included as exemplars for smolt production that are based on Scottish industry practices that may need to be revised to reflect practices on alternative farms in Norway and Iceland.

Table of content:

Learning Resources and Pedagogy

The learning packs have been devised to support customized VET delivery described below but can be adaptable to suit alternative delivery modes. Used according to the pedagogy described, they allow the learner to identify their weaknesses and focus their studies more effectively.

A typical VET delivery would be:

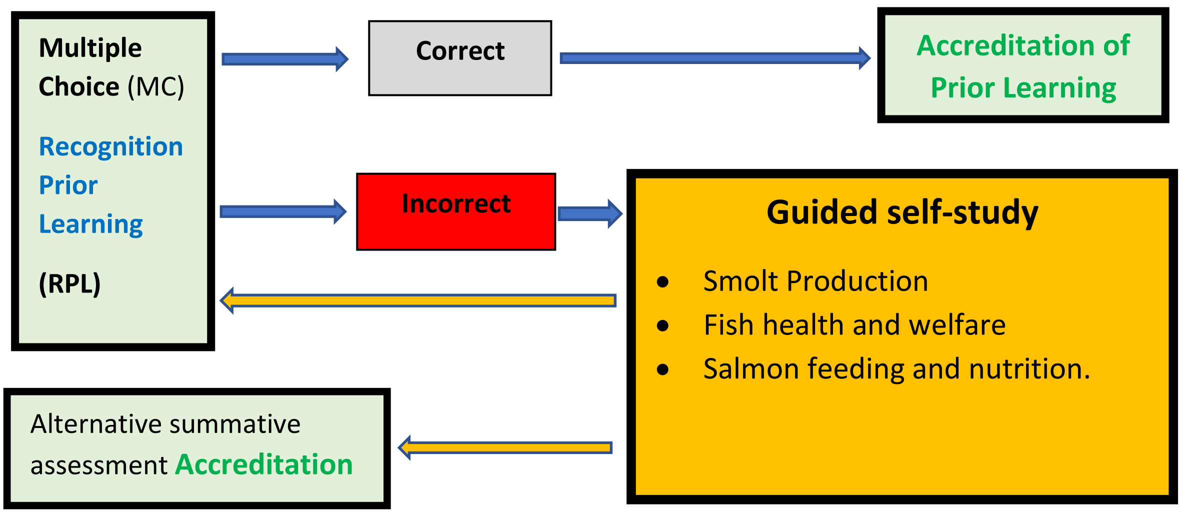
Step 1- Undertake multiple choice questions for the section.

Step 2 Automated RPL to determine which questions have not been answered correctly.

Step 3 (a) Automated documentation of correct responses for submission for accreditation of specific knowledge

Step 3 (b) **Self-study** guided by the RPL results and feed-back to address knowledge gaps

Step 4 Second Multiple Choice (MC) alternative questions (same topics and level) or alternative summative assessment leading to accreditation.



Graphic to illustrate recommended RPL/APL pedagogy.

Self-study (navigating learning materials and external resources)

The resources are designed to support interactive learning and to give the learner, starting with the 'Recognition of Prior Learning' (RPL). Icons that could be used in the margin to aid learner navigation are proposed.

Icons will flag learning resource components and activities to the learner.

Activity	Purpose	Icon
What do you know already? RPL/APL	Mandatory assessment of the learner's current knowledge. Can lead to accreditation for some Units (APL)	Finger raised to a thinking face
Main content	Text and image, providing context and more topic details.	No icon needed
Key points	Summary points expanded on in the main content (Mandatory knowledge assessed)	A key
Relevance to salmon husbandry	Short insert to make the topic relevant to the farm, with hyperlinks to web links etc. (Only used for fish science units)	Salmon in a net
Watch this**....**	Selected Youtube video clip	Film reel graphic
	Instructional video with story Boards home-produced instructional video based on typical farm procedures.	Film reel graphic
Learning Activity	May be a calculation or other activity, or formative assessment following a learning episode.	Icon to represent learning activity
The scientists say	Interesting insights and debates from the scientific community	Mad professor talking head
Typical procedure (Hatchery, RAS and Grow-out)	Task based SOPs that can be revised to reflect practices on the farm where the learners are based.	Clip board held in hand
Articulate Creative	A description of how the learning material can be made more interactive through course authoring software and LMS applications	NA

Unit Title:	Smolt production
Guided Learning hours:	**60**

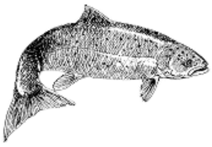
Unit level (EQF): 4

Introduction

The learning resources in this guide have been designed to support 'short episodes' of focussed learning' on a specific topic within the Smolt production following the Recognition of Prior Learning (RPL) using the multiple-choice question sets. Each episode has a title and number that relates it to a specific multiple-choice question or questions within the subject area.

The resources cover Atlantic salmon Smolt production operations, including feeding grading and photoperiod regimes. The aim is to provide experienced husbandry operatives with enough information, insight and understanding of the basics of salmon smolt production operations so as they can operate within a Smolt production unit with a full understanding and in compliance with all company Standard Operating Procedures (SOPs).

SP 1 Smolt production



Smolt production overview

In the wild, Atlantic salmon fry and parr (2 grams plus) seek to establish advantageous feeding positions within their nursery stream that offer an optimum flow rate and access to a natural food supply. Depending on their size, pebbles, stones and rocks on the stream bed can all provide shelter from the main force of the current. This allows the fish to maintain position without expending excessive energy and intercept natural food items in the stream drift. The competition for territory between the young salmon intensifies whenever the nursery stream is over populated due to multiple successful spawnings and a there is a scarcity of aquatic invertebrates.

Wild Atlantic salmon parr

The wild parr grow at a rate determined by the seasonally variable feed supply and water temperature regime for one to three years, before smolting. This physiological transformation in preparation for their ocean migration is triggered by lengthening daylight hours in the spring (the photoperiod trigger), typically once the fish reach 30 – 50 grammes in weight.

In a commercial salmon nursery all of the natural constrants the wild juvenile salmon face can be overcome. The population density and structure, food supply, flow rate, lighting and water temperature regime can all be controlled and optimised in order to maximise growth and control the timing of smoltification and size of smolt.

Many smolt production units are Recirculation Aquaculture Systems (RAS), with water quality monitoring and control according to a set regime, to optimise the key environmental parameters.

Disease free conditions must be maintained throughout to produce large healthy smolts of 100 - 200 grams for grow out.

1.1 Key environmental parameters

Most of the environmental requirements do not change as the fish progresses from parr to smolt, other than flow rates and high standards of hygiene remain paramount throughout. Water temperature, water quality, lighting, and flow rates, are important parameters to monitor and control, alongside feeding practices which remain important throughout the smolt production cycle.

1.1 Water temperature

The water temperature can be controlled within RAS and temperatures held within an ideal range of 11-14oC for the parr to smolt phase. The water temperature determines the feed rate and growth rate and a constant 12 oC optimum is often the target.

1.2 Water flow

Water flow rates should be sufficient to remove metabolic wastes and maintain oxygen level above 95% saturation in the outlet. A water flow pattern should be established in holding unit that eliminates dead areas. Flow rates should be measured with a flowmeter at the inflow to each holding unit.

- Hydraulic Retention Times (HRT) in minutes can be calculated.

Volume Tank(m3)/Flow (m3/hr)*60 min.

Commercial smolt Units recommend HRT minimum values 30-35 for parr and 40-45 for smolt to ensure that there is sufficient water exchange to remove fish metabolic wastes from the holding unit.

1.3 Oxygen

Dissolved oxygen is measured daily in the fish holding units at the outlet or the opposite side of water inlet in the fish holding units. A minimum level of 95% oxygen saturation and a maximum of 110% saturation in outlet water is a common target for parr to smolt.

1.4 Carbon Dioxide

Carbon dioxide is a waste product of respiration, and levels are indicative of the total metabolic activity. Excess carbon dioxide can cause pH reduction and levels should be maintained at <15 mg/L for parr and smolt. In RAS, measurements are taken in the sump, the make-up water and holding unit.

Key points

- Smolt production units provide a controlled environment (RAS) for fry to smolt rearing that replicates the conditions found in the Atlantic salmon's nursery streams.

- The production cycle from nursery transfer at 2 grammes to smolt takes 8 weeks for each batch at a water temperature of 12 oC

- Key environmental parameters (dissolved oxygen, pH, carbon dioxide, dissolved gasses, and ammonia) are monitored at well-chosen locations within the hatchery system and optimised.

1.5 Total Gas

Total gas should be measured daily, and whenever changes are made that have the potential to affect the total gas content, such as water temperature or flow adjustment. Nitrogen is the gas most often leading to supersaturation problems. This can be caused by leaks in pumps or couplings, negative pressure in pipes or heating of water without adequate ventilation. Although this is an unlikely event within a well-maintained RAS operation, it cannot be ruled out and vigilance is required. The upper limit for the parr and smolt stage is 105% saturation for total gas.

1.6 Water pH

The pH is an important water parameter that must always be carefully monitored. The acceptable pH range for parr and smolts is 6.8-8.0. At a pH below 6.0, there is a risk of metal ions in the water becoming toxic, but the application of sand filters can eliminate this risk. The pH can be controlled by adjusting flow rates and the addition of hydrated lime or bicarbonate.

1.7 Ammonia

Ammonia is a metabolic waste from the break-down of organic substances or protein catabolism. It is toxic to fish at low concentrations and removed by the nitrifying bacteria in RAS 'biofilters', initially converting it into nitrite followed by relatively harmless nitrate. The control of the pH levels within RAS is essential to limiting Ammonia toxicity. The Total Ammoniacal Nitrogen limit for parr to smolt is 10 mg/L and 0.015 Ammonia (NH_3).

1.2 The production process from fry transfer to smolt

Now watch this-

Video 1 Smolt unit guided tour

Aim: To provide a facility overview with audio.

Could support an introduction to the Unit showing all the main components and highlighting key features within the facility.

Could also highlight key challenges and 'mission-critical' stages of the nursery process, priming, but not replicating the more specific instructional videos to come later.

Go on the 'Nursery guided tour' for an introduction to the facility, equipment and technologies The main stages of the Nursery (parr to smolt) are as follows.

Articulate creative: Diagramatic facility layout to demonstrate each stage of the process from 2g fry receipt through to smolt.

1.This could be produced as an interactive diagram with hotspots on the diagram so as information drops down on point and click basis.The drop down box could provide an image of the fry, parr and smolt according to the specific production stage. The facility/equipment for that stage could also be shown.

Text and or an audio overlay could be included. This learning object would need to be story boarded and produced by outsourced multimedia technicians.

Learning activity 1

Arranging given stages of production process into the correct sequence, using LMS 'drag and drop'.

This activity could follow the video Nursery tour to consolidate learning, based on learners recollection only.

2. Hatchery process flow chart : Devised to illustrate each stage of the nursery process (2g fry to smolt) and illustrate which Instructional videos apply to each stage. This could be made interactive so as the Instructional appeared displayed to the right of the process chart 'on a point and click' .

The learner could go to the Instructional video immediately, if they chose to.

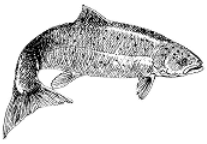
Water quality table summary

	Fry	**Parr/Smolt**	**Sampling frequency**	**Sampling equipment**
Size (grams)	**0.18-2**	**2-200**		
Water Parameter				
Carbon dioxide (CO_2) (mg/L) (measured)	<10	<15	Daily	Handly Probe
Ammonia (NH_3-N) (mg/L) not ionized	<0.0125	<0.0125	Daily	Lab
NH_3 (mg/l)	<0.015	<0.015	Daily	Lab

Ammonium NH4+-N (mg/l)	<1.0	<1.0	Daily	Lab
TAN (mg/L) pH<7.5	<5	<10	Daily	Lab
TAN (mg/L) pH>7.5	<1	<1	Daily	Lab
Nitrate (NO_3-N) (mg/L)	<25	<50	Daily	Lab
Nitrite (NO_2-N) (mg/L) at 0 salinity	<0.2	<0.2	Daily	Lab
Nitrite (NO_2-N) (mg/L) at 3ppt salinity	<0.2	<5.0	Daily	Lab
Oxygen (% saturation)	90-100%	95-110~~%~~	Hours	Handly Probe
Oxygen (O2) saturation (%) in the exit water (mg/l)	>90 (9.3)	>80 (8.2)	Daily	Handly Probe
Total gas pressure saturation (%)	100	105	Daily	Handly Probe
pH	6.8-8.0	6.8-8.0	Cont.	Handly Probe
Suspended solids (mg/L)	<10	<12	Daily	Lab

Smolt production workflow chart (To become interactive – see outline specification above)

Hatchery Operations (2) Nursery to smolt	Last updated 20.10.20	SOP		DAY		
Process	**Operation**		Prior to Day 1	1	2	3
Stock fry	Prepare nursery equipment					
	Batch weigh fry					
	Acclimate incoming fry					
Feed nursery stock	Set up feeders					
	Feed 2g fry to parr					
	Feed parr					
Maintain nursery holding units	Maintain holding unit hygiene					
	Adjust flow rates					
	Remove and record mortalities					
	Monitor nursery system water quality					
	Sample weigh nursery stock					
Grade and transfer nursery stock	Establish size range of the population					
	Grade fish					
	Count fish					
	Evaluate pre-smolts health status					
Control smoltification and smolt transfer	Transfer pre-smolts					
	Trigger smoltification (photoperiod)					
	Feed fish during smoltification					
	Assess smoltification					
	Transfer smolts					



Stock, grade, and transfer nursery stock

The fry are transferred from the hatchery to the nursery tanks at 2 grams, by which stage they have been feeding and growing for 6- 8 weeks, typically. They are grown on in the nursery from 2 to 30 grammes and the first grade is carried out at 10 grammes followed by a final grade at 30 grammes, prior to transfer to tanks with controlled lighting for smoltification. There are some systems that still operate using ambient light and use transition diets to trigger smoltification and prepare the fish for the marine phase. Fish welfare considerations are paramount during all fish movements, including, sampling, grading, and counting of fish stocks during the nursery phase must be conducted with care.

Hatchery fry pre-nursery transfer

Farm equipment should be selected that minimises physical handling and stress whilst getting the job done efficiently.

Grading in the early stages is important to split the fish population by size and remove and cull the 'runts'. The number of culls expected is built into the production plan and impacts on the number of eggs initially stocked into the hatchery system.

Grading should follow production plan timings, not only to achieve optimum fish size but to ensure tanks become available as the maximum biomass is reached. Sampling is essential to grade planning and for monitoring fish growth and performance throughout the freshwater phase.

Buying in salmon eggs of the highest possible quality at the start of the hatchery cycle reduces the need for as much culling of unviable stock.

2.1 Initial stocking

Between batches, all the equipment used during the nursery phase must be checked and maintained according to manufacturers' instructions, to ensure everything is in full working order. This includes holding units and screens as well as the equipment used for crowding, capturing, pumping, grading, and counting the fish during each fish handling activity and fish stock movement event.

Now watch this-

Instructional video- Fish reception

Story board 1

Are the fish graded at the hatchery before being transferred to the nursery?

Outdoor parr tanks

Typically, fish are transferred to the nursery from the hatchery at 2 grammes and batch and sample weighed to re-establish the transfer number. However, the fry are not graded before transfer but stocked into circular tanks, typically of 5 metres diameter with a regulated inlet and a screened central outlet.

Do the incoming 2 gramme fry need to be acclimatised on arrival?

Following the initial transfer from the hatchery to the nursery, the fish may take several hours to adjust to the new environment. Once they have had time to settle, the flow rate should be adjusted and maintained so as they are evenly spread and actively swimming against the current. If the fish are seen in group's not aligned with the tank flow the flow rate should be increased.

Is water quality monitored?

Standard water quality monitoring and RAS system management should be undertaken according to RAS SOPs. The key parameters should be kept within the water quality limits. (See App 1 Smolt unit water quality table)

2 Gram fry aligning with the current

2.1.1 Pre-transfer fish stock preparation

The transfer of fish from the hatchery to the nursery needs to be planned well in advance. The fry are prepared with consideration to the following.

- Starvation

The salmon fry are not graded before transfer, but are starved for 24 hours when being held at 10-12oC.

- Fish health evaluation

A fish health evaluation should be completed, typically two weeks before transfer. This is based on a sample of 60 fish (15 captured from each of 4 units) which are euthanized and sent to the fish pathology lab for viral disease analysis.

- Fish size distribution

Sampling fish stocks before transfer establishes the size distribution within the population and

Capturing fry sample

biomass, to inform feed particle size selection and feed rationing.

2.1.2 Nursery preparation

The nursery rearing system needs to be started up 4 weeks in advance of the fry arrival, to ensure a high-quality water supply can be delivered to each holding unit at a suitable flow rate.

- The RAS biofilters

Before the fish are stocked in a RAS facility the nitrifying bacteria in the biofilters must have been fully matured. This is so as they can convert ammonia from protein metabolism to harmless nitrates.

- Water quality sampling

A water sample should be taken from the holding units and sump, tested, and the results recorded. All water quality parameters must meet the company's water quality standards before transfer can be initiated.

Routine water quality sampling indoor parr tanks

- Water levels and flows

The holding unit should be set at a typical depth of 1.5 – 2.0 metres. An initial water flow measurement should be taken and measured routinely thereafter.

- Hydraulic retention

The water's residence time in each holding unit can be measured by calculating the hydraulic retention for each holding unit. This provides a useful indication of how long it would take for one complete water exchange. If too long, metabolic wastes can build up and the water quality deteriorate.

2.2 Fish transfer operations

All fish transfer pipes are connected and checked, and the fish pump adjusted according to the manufacturer's recommendations for the size of fish being transferred.

Typical procedure for fish transfer

a) Establish the water flow
The inlet hose is placed in the hatchery tank, covered with a net, and a continuous flow of water established.

Fish transfer by pumps to eliminate handling stress

b) Start the fish movement
The net is taken off the inlet hose to allow fish to enter, regulating the quantity in the pipeline to avoid overcrowding the fish stocks.

Overcrowding is a common cause of fish stress and must be minimised to maintain high standards of welfare.

c) Welfare sampling
Fish samples are captured every 15-20 minutes, or when anything unusual is noted, and the fish are carefully inspected in a glass vessel.

Why are the fish inspected periodically?

To be able to stop the fish movement operation any fish show signs of skin damage.

d) Activity record
The activity is recorded detailing the biomass of stock moved and the results of the inspections during the fish movement.

Why is an activity record necessary?

So as the manager can refer to the sampling records if the mortalities increase following the movement of fish.

e) Cleaning
All equipment and tools are cleaned after transfer to maintain the highest standards of biosecurity.

2.2.1 Post transfer transition
As the fish have been transferred from one rearing environment to another with a different water filtration system, water quality checks must be performed in the nursery unit where they arrive. This provides a log of the water quality parameters for the nursery system that can be referenced and compared to water quality in the hatchery unit where the fish originated from.

No sign of skin damage on this pre-smolt

The bottoms of the holding units are checked for mortalities, which if found, are removed, classified, and recorded.

- Stock acclimation

Following the transfer from the hatchery to the nursery, the fish normally adjust to their new within one or two hours. The transfer process is potentially stressful, and the new environment may not be offering ideal physical

Now watch this

Instructional video: Fish transfer

See story Board 2

conditions initially.

Once the fish have had time to settle, they should be spread evenly throughout the tank and swimming against the current. The flow rate should be increased if fish are seen in group's unaligned with the tank flow.

- Post transfer feeding

One to two hours after transfer, once the fish have settled, a reduced daily ration is fed. The fish's appetite is checked daily, and if strong with no waste evident on the base of the tanks, the feed input is gradually increased over the next 3-4 days to a full ration.


Two-gram fry aligned in the current

2. 2 Sampling

Sample weighing should be undertaken fortnightly during the nursery stage, to update stock records, including the average weight of the population, fish biomass and stock density. The correct recommended feed ration can then be calculated using up to date biomass data and with reference to the prevailing water temperature.

Sampling is vital to the planning of each grade. As a guideline, 250 individual fish should be weighed, so that the size range of the population can be assessed and tabulated. This will allow the grader settings to be accurately determined to split the population and remove any runts.

With reference to the numbers of fish in the tank, this data can be used with to establish the average weight expected for each grade.

2.2.1 Monitoring gill operculum

Routine sampling is often combined with operculum monitoring. The gill opercula can be inspected as an integral part of the sampling operation when the fish are 10-50 grammes in weight. Their condition is an important indicator of salmon parr physical health at the nursery stage. Some of the operculum protecting the delicate fish gill lamellae can be damaged in various ways, including aggression which intensifies if the fish have been underfed, and when fish being subjected to poor water quality.


Operculum in perfect condition (0)

There are four levels of operculum deterioration that can be identified.

0: No damage to the operculum

1: Loss of 25% of the operculum surface area.

2: Loss of 50% of the operculum surface area.

3: Loss of 100% of the operculum surface area.

Typical procedure for sampling

Waiting for anaesthetic to take effect

Weight sampling is conducted routinely every week when the fish are between 0.15 and 10 grams. The fish must be starved for four hours before sampling.

1. Set-up the scales

The scales are set up and electrical plugs covered in plastic if necessary to ensure that they cannot get wet during weighing. The scales are turned on and the calibration checked according to the manufacturer's instructions.

2. Prepare anaesthetic

An anaesthetic solution is prepared in a plastic bucket, according to chemical suppliers' instructions and company anaesthesia protocols. A recovery vessel is prepared with freshwater. The dissolved oxygen concentration measured in both containers to ensure company water quality standards are maintained throughout the anaesthesia process.

3. Capture sample

Using a small net, 30-35 fish are captured and placed into the anaesthetic solution. Once the fish are inactive and have lost their balance, they are ready to be weighed.

Individually weighing fish

4. Weigh fish

Fish are placed on the scale and weighed singly, recording each weight, and then placed in the recovery tank.

5. Return fish

Once the fish have regained their balance and are swimming normally (belly down), they are returned to their holding unit.

6. Change anaesthetic

The anaesthetic solution is changed during the sampling operation according to the manufacturer's instructions.

7. Sample weigh 250 fish

The next batch of 30 fish are captured and the process repeated until a total of approximately 250 fish have been weighed. On completion, sample weighing records are updated, and all surfaces and equipment cleaned.

Now watch this -

Instructional video – Sampling fish weight and smoltification

See Story Board 3

2.3 Capture, grade and count fish

Fish can be moved by net collection and transfer in buckets of water when small or by dedicated fish pump. At all times, limiting damage to the fish and maximising fish welfare should be the highest priority.

A well graded parr population has a small size range

In general, when netting fish only small volumes should be transferred at a time, so that the fish at the bottom of the net are not crushed. The transfer into buckets of water should be rapid and the fish moved with the buckets into the new facility as quickly as possible. Water should be changed between each transfer to ensure good levels of oxygen.

If high biomasses are being transferred, then oxygen diffusers should be placed in the buckets to ensure high oxygen levels maintained at close to 100% saturation.

Grading is carried out by pumping the fish to the facilities dedicated grader, with the rate of fish transfer appropriate to the specifications of the grader and associated fish counter.

Now watch this

You tube:

Faivre Grading system

https://www.youtube.com/watch?v=bV1etCWXVd4

Faivre Fish Pump

https://www.youtube.com/watch?v=lAUaFtaosH8

The grader is calibrated so that different numbers of fish will descend through each channel to achieve the planned population split. The setting is informed by sample weighing and the grade set according to the manufacturers' recommendations.

It is important at the start of grading and at intervals through the grade to check both the average weight of the grade and the numbers reported by the counters. This allows the grader to be adjusted during the grading process to ensure that the correct number of fish are achieved in each predetermined size category within the grade.

At grading, the fish should be counted through electronic fish counters.

Atlantic salmon parr

2.3.1 Grade strategy and planning

Grading in the early stages is important to split fish by size and to remove runts and 'slow growers' from the population so they do not transfer through to harvest. The number of culls expected is considered within the production plan and indirectly impacts on the number of eggs initially stocked into the hatchery system.

Therefore, grading should follow production plan timings, not only to achieve optimum fish size but to ensure tanks become available as the maximum biomass is reached.

The average weight and number of fish in each size category is established from interpretation of the sample data, including the weight and number to be culled.

A minimum of 250 individual fish must be weighed before each grading, so that the size range of the population can be assessed to determine the grader setting required to split the population and remove runts for culling.

The fish population structure can be described statistically by a 'normal distribution' and the associated 'bell curve graph. This means most of the fish are grouped around the mean, with relatively small numbers of small and larger fish. The company need to establish a policy for removal of a certain percentage of the bottom end of the size distribution, before determining how most of the population retained and grown on are to be split.

Typical procedures for grading

The grader is set up, adjusting the grill opening, according to the fish size distribution and grade plan requirements. If the grader settings are incorrect, fish welfare could be threatened, and the grade outcome may not meet production plan requirements.

Grader produces a 3-way population split

a) Position and calibrate equipment

The fish counter is positioned and calibrated according to manufacturer's instructions to ensure accuracy for the size range of the population to be counted. The % error increases as the fish size range increases but is generally less than 0.3% for the widely used Vaki counter.

b) Establish hose connections

All transfer hose connections are checked, and the pump adjusted according to the manufacturer's fish size recommendations.

Why? If the pump is not set correctly according to the size of the fish, there is a greater risk of physical trauma and stress during transfer.

c) Purge air from the system

A net is placed over the nursery tank inlet hose and a continuous flow of water to the grader is established, checking hoses for trapped air bubbles. If the net is not placed over the inlet hose fish will be drawn into the grader prematurely which could be detrimental to fish welfare if then captured and returned to the holding unit.

External vaki fish counter counting the grader output

d) Fish collection and grading

The net over the hose is removed, and the fish directed towards the hose inlet under control, to avoid overcrowding and they are carried to the grader for size grading.

Constant vigilance is required during the grade, with particular attention to fish pump speed. If set too high, fish welfare could be threatened, resulting in mortalities following the grading operation.

e) Sampling

Samples of fish are taken routinely from the grader outlet in a hand net every 15-20 minutes for visual inspection, and whenever any abnormality is observed. The transfer operation is stopped immediately if skin damage is evident equipment checks made.

Most companies operate a 'zero tolerance' policy and at the first sign of any skin damage all the grading and fish transfer equipment is carefully checked.

The grade may be suspended, and the manager's decision will depend on the number and size of fish damaged. Sometimes an exceptionally large fish outside of the pumps size range setting will show signs of skin damage, whilst the rest are undamaged, and the grade can continue.

2.3.1 Post grade

There are important tasks to complete immediately after the grade. Nursery staff need to euthanize the culls and check for mortalities. For several days following the grade, staff must remain vigilant and observe the recently graded fish regularly.

Now watch this -

Instructional video – Grading

See Story Board 4

Typical procedure post grade

a) Accounting for culls

The smallest fish to be culled drop from the grader straight into a containment vessel containing well oxygenated water and with sufficient volume to hold the expected number culls in humane conditions. The fish are held in this vessel prior to being euthanised immediately following the grade. After euthanization, the mortalities from the cull are disposed of according to company procedures for mortality removal.

The Vaki counter provides data on the number, average weight and biomass of culls removed from the population during the grade. This allows accurate revised fish population numbers to be determined.

Disinfection

b) Disinfection

After fish transfer and culling, all tools and equipment are disinfected. Biosecurity is strictly applied to reduce the risk of disease outbreaks following any fish handling operation.

c) Inspection for mortalities

Immediately following the grade, the holding unit receiving the fish is checked for mortalities, removing, and classifying any found.

Significant mortalities should lead to a review of the grading operation with the staff who were involved. The cause should be established to reduce future fish welfare risks.

d) Ongoing observation

The behaviour of the fish is checked constantly after grading for several days, reporting any abnormalities to the manager. This could include erratic swimming behaviour, skin wounds, floating scales, fish gasping at the surface and bleeding gills. The mortality check and removal routine is repeated daily.

Any fish health and welfare issues during the grade can become apparent some days following, and the staff need to remain vigilant, immediately reporting any signs of stress.

2.3.2 Assess pre-smolt health status

The opportunity to form a barrier for pathogen transfer from the Nursery to smolt unit should not be missed. Before the movement of the fish from the nursery to the smoltification system measures are taken to identify any introduced diseases.

Pre smolt being sampled for health checks

A full raft of health checks should be undertaken at least two weeks before the transfer with a positive written approval obtained from a qualified fish pathologist for the fish's transfer into the smolt unit before they are moved.

The focus of these checks will be those viral and bacterial diseases identified as high-risk during fish health risk assessments of the facility and farming operation by a qualified fish pathologist.

This subject is covered in depth within the Fish health and welfare unit.

Learning Activities

1. **Stockman's calculations**: Average weight calculation exercises from given sample weight data

2. **Grade planning exercises**

Interpreting normal population distribution curves from given data, (mean, median and interquartile range)

Apply distribution analysis to given stock figures to predict the outcome of alternative grader settings. The sample analysis can be applied

Key points

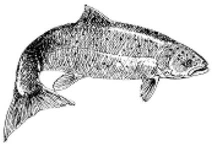
- Minimise crowding and eliminate handling during fish transfer operations and periodically check for skin damage during transfer.

  Stop the operation and check equipment and pipes attachments whenever damage is evident.

- Fish populations are routinely sampled to measure individual length and weight. The assessment of size distribution in the population is an essential part of grade planning.

- Prior to smoltification the parr are split into three pre-planned populations, large, medium, and smalls. Remove and cull the smalls (poor growers) with an anaesthetic overdose.

SP 3 Smolt production



Maintain and feed fish stocks

Once the salmon's appetite has fully developed in the first two or three weeks and the fry are well established on the feed, the feeding strategy remains unchanged. The fish are always fed to satiation to maximise their growth rate, whilst minimising feed wastage and maintaining high standards of tank hygiene.

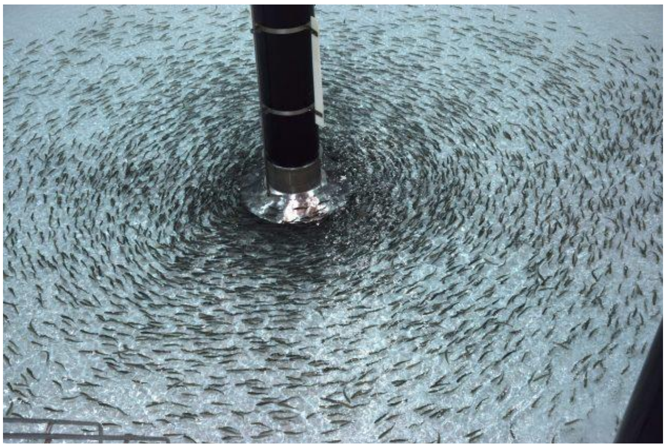
Throughout the nursery phase, although the tanks should be largely self-cleaning due to the increased water flow, they are checked twice a day. Any waste feed should be gently brushed towards the centre of the screen and flushed out of the central drain. Mortality removal, classification and recording established during the hatchery phase, should continue throughout the nursery and smolt phase.

Appetite is monitored routinely and recorded. This information alongside observations of waste feed during daily cleaning operations is used to inform decisions regarding daily feed ration adjustments.

3.1 Water supply

As with the hatchery, flow rates will need to be increased as the fish size and biomass increases. As the flow rate increases a vortex will form in the centre of the tank and needs to be controlled so that fish drawn towards the centre are not damaged on the central screen. The vortex can be controlled by managing the velocity of water entering the tank. A smaller orifice at the inlet will cause an increased circulation rate due to the higher water pressure. Conversely, the use of fixed baffles in the centre of the tank can reduce the strength of the vortex.

Vortex effect on salmon fry distribution



It is important that the water flow is adjusted to maintain tank circulation rates, ensuring that water quality criteria are met within the tank by flushing wastes, including faeces, waste food and metabolic wastes.

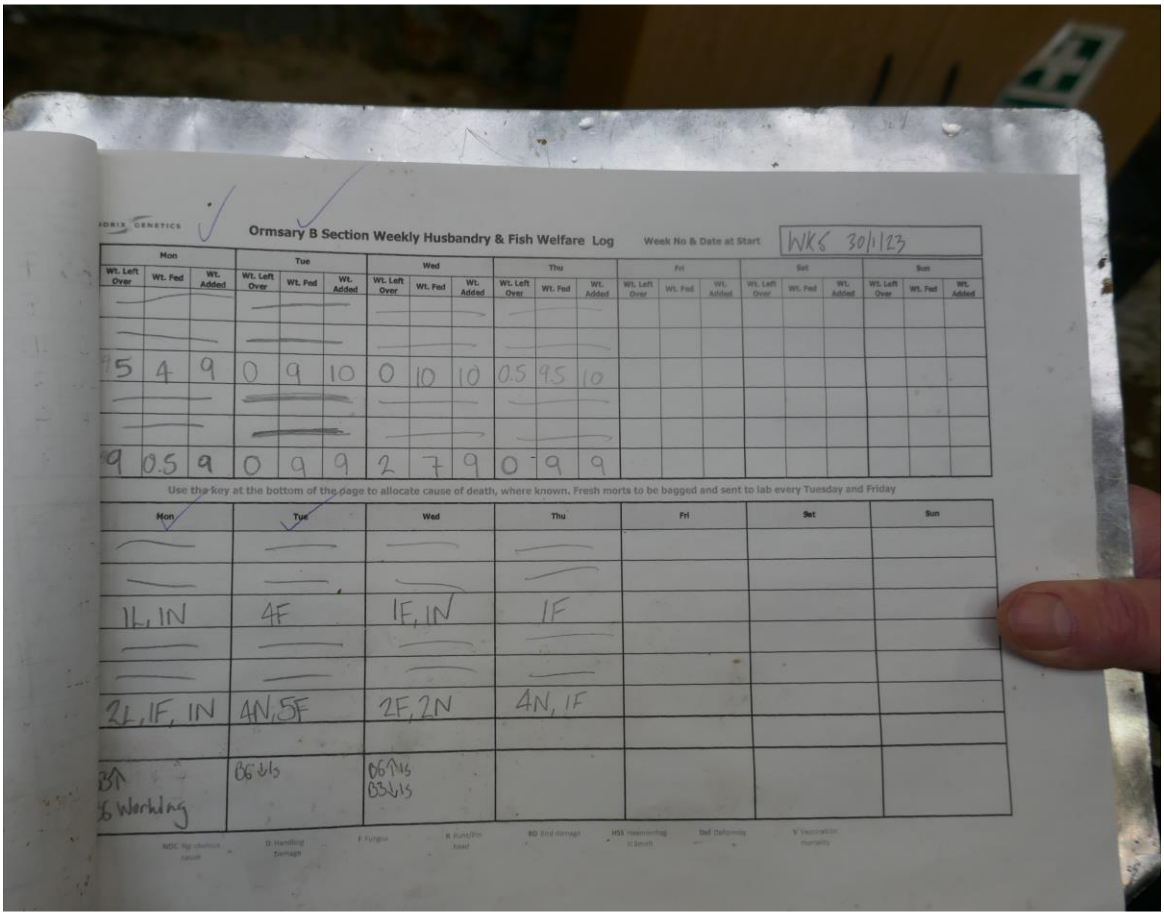
The flow of water also brings oxygen to the fish and removes carbon dioxide from the tank resulting from fish respiration.

The tank circulation rate is important in optimising fish swimming speed to maximize growth and efficient muscle building.

In general, the tank circulation rate should be maintained at 1 to 1.5 times the body length of the fish. Usually, the fish will swim into the current. If for any reason they are not aligned to the current flow, the angle of incoming water should be altered to maintain an even flow around the tank, drawing waste material to the central screen for removal.

3.2 Remove and record mortalities

Mortalities should be removed three times per day with accurate records maintained. Any increase in mortality over three or four days should be reported and action taken to establish the cause. The mortality removal should be undertaken twice a day at the pre-smolt stage (30-40g) with numbers recorded and monitored and any increase reported. It is important to keep accurate records of mortalities for future analysis, including the classification of the cause of death.



Mortality records including classification

The classification of mortalities should be systematic and applied consistently by each member of the husbandry team.

Mortality classification trends provide the farm manager information to determine causes of any unusual rise in daily mortalities.

When mortalities have no obvious cause, samples are often sent to an external fish pathologist to establish the cause.

Classification abbreviations

- NOC- No obvious cause
- D - Handling damage
- F - Fungus
- R - Runt/pinhead
- BD - Bird damage
- HSS- Haemorrhaging smolt
- Def – Deformity
- V – Vaccination mortality

Hand nets for fry

Procedures for the removal and recording of mortalities.

a) Routine mortality check

Mortality removal is a centrally important routine for managing holding unit hygiene and monitoring fish health.

At the start of every shift the dedicated hand nets and the mortality container are inspected to ensure they are in good working order, before each holding unit is checked for mortalities.

b) Remove mortalities

Mortalities are removed and placed in the mortality container, without splashing or displacing any potentially infected fluid, and ensuring no fish remain in the hand net.

Mortality container

Many systems have a side box for retaining mortalities, which reduces most of the need for hand nets once the fish have become sizeable parr.

Displaced fluid could contaminate work surfaces and lead to the transmission of infection.

c) Remove moribund fish

Any dying fish swimming near the water surface are removed for immediate euthanasia. Under no circumstances can they leave the fish rearing facility.

Moribund fish are a source of potential infection if not confined.


Euthanization of moribund fish

d) Euthanize moribund fish.

Moribund fish are placed into a pre-prepared vessel containing a solution of double strength anesthetic. It takes 15 minutes to overdose and euthanize them, before they can be placed in the mortality container.

Fish welfare must be safeguarded, including the use of euthanasia. This ensures that only dead fish are disposed of.

e) Collect up mortalities

The mortality containers of dead fish are taken to the mortality collection area directly, by following a prescribed route without pausing, deviating, or stopping.


Husbandry staff undertaking classification.

A prescribed mortality route minimises contact with surfaces and reduces the risk of pathogen transfer.

f) Classify mortalities

The dead fish are placed on a previously cleaned and disinfected surface. Mortalities from different tanks are kept separate, until counting and classification is complete.

What are the mortality records used for?

The mortality records for each holding unit must be accurate. This data is used by the manager for mortality trend analysis.

Mortalities are classified immediately by carefully examining the external appearance of each fish. The staff conducting the classification process will look for the following signs. (See images)


Mortality classification F - Fungus

The suspected cause of mortality is established using the company's classification system and recorded in the Nursery/Smolt Mortality Record.

g) A sample of any mortalities that cannot be classified and those showing potential disease symptoms, other than Saprolegnia fungus, are sent to an external fish pathologist for diagnoses.

Specimens are preserved and packaged according to the pathologist's instructions.

3.3 Mortality disposal

Every smolt unit must have procedures for mortality disposal. This is an important aspect of biosecurity that must be rigorously implemented and managed.

Procedures

Mortality disposal usually involves three steps.

a) Collection

Mortalities are collected into bags for disposal in the facility's mortality bins, which are dosed with disinfectant solution.

Bagging mortalities for transport and disinfection reduces the risk of pathogen transfer.

b) Transfer

The mortality bin is transferred to the mortality collection area for pick up. The final disposal can be conducted by ensiling or incinerating the mortalities.

The incineration or ensiling of mortalities ensures organic wastes are hygienically disposed of and any pathogens destroyed.

Floor cleaning brushes

c) Cleaning

All equipment and any surfaces in contact with mortality extraction are cleaned and disinfected after mortality processing and the dumpster truck is sanitised weekly.

The cleaning and disinfection of all equipment in contact with mortalities and the dedicated dumpster, is a central biosecurity procedure.

3.4 Feeding 2 gramme fry to parr

The manufacturers feed tables are referred to as a guide, but if the fish appetite enables feeding to continue beyond the recommended ration, the potential for increased growth should be exploited.

Parr actively feeding

At this stage, hand feeding has been entirely replaced by automatic feeders that must be well chosen and carefully set up in the tank to provide a well distributed food supply. There are a range of feeders in use in salmon nurseries, including clockwork belt feeders and the more commonly deployed automated feeding systems.

What kind of automatic feeders can be used?

Belt feeder: No power is needed to drive the belt, making this feeder easy to use anywhere, particularly in remote areas. Feed is slowly and evenly released to encourage high feed intakes faster growth, healthier fish, and lower mortality rates.

Clockwork belt feeder

The wind-up clock mechanism drives the feeding belt. The feeder is constructed of weatherproof corrosion resistant high impact plastic with a stainless-steel cover and inner components.

It is simple to use. The pull belt is pulled back and the clock automatically begins functioning. The required amount of feed is spread over the belt surface and process repeated the following day. There are 12- or 24-hour clock models available with either 3 kg or 5 kg capacity.

Now watch this -You tube video – Clockwork feeders

[FIAP profifeed BeltFeeder the most frequently deployed automatic feeder in pisciculture worldwide - Bing video - Search]

Automatic electric feeders: Electrically powered and automated feeding systems are more often chosen in modern Smolt production units. They are well made, robust and easy to operate. The height of the feeder can be easily controlled, along with feed distribution when coupled with an electric or pneumatic spreader underneath the doser unit.

Centralised automated feed systems have central feed silos, with feed distributed to the fish holding units by blowers and hoses. The silos can hold large amounts of feed which reduces the labour requirement for loading feeders. Sophisticated control programs and feeding software manage feed rationing and distribution to the fish, linked to a fish stock records system. Sophisticated and centralised systems are the most efficient way to deliver large volumes of feed and are often customised to suit the nursery operation.

Non-centralised feeders are available in a wide range of designs, and all are located at the tank with their own independent silo. A simple timer or control program determines when the feed is either dispensed, spread, or propelled to the fish depending on the design. The distribution of food to these silos is not easy as it is with the centralised system.

The replacement of hand feeding by automatic feeders reduces the labour requirement. However, the husbandry staff must remain observant and proactive as feeding salmon fry and parr is dynamic, and subject to change. There are several key considerations, and the approach taken is influenced by observations of fish behaviour and sample weighing results.

3.4.1 Setting up feeders

Feed distribution can be improved by locating the feeders close to the water surface. It remains important that the feed is distributed evenly around the tank by the water flow from the points of feeding.

Automatic feeder 'trickle feeding' fry

- Initially the fish are still not so actively looking for food and can be aggressive towards each other if hungry.
- Therefore, it is important that feed is distributed evenly around the tank and that the fish are fed to satiation.
- This is best achieved by constantly feeding throughout the 24-hour period with 24 hr Lighting to ensure that enough feed is distributed and that the fish are not hungry at any stage.
- If the fish are not well fed, they are likely to attack each other which can cause damage to opercula, fins, and eyes.
- Feeding to satiation ensures that the fish grow to their maximum potential and reduces the size range in the tank.
- Daily feed rates should be guided by the feed manufacturers feed table, increasing daily and with associated pellet size increases, and mixing for three days at each pellet size transition point.

The percentage of different pellet sizes in the mix should be determined by the size frequency distribution of the population.

The appetite of the fish should be checked daily, particularly when there is waste food evident, and adjustments made to maximise fish growth whilst minimising waste.

Learning activity-

Stockman's calculations
With reference to current fish stock records for 4 populations, and manufacturer feed tables, calculate the recommended daily ration in Kg for each stock.

Water temperature: 10 C.
Provide stock data 1 - 4

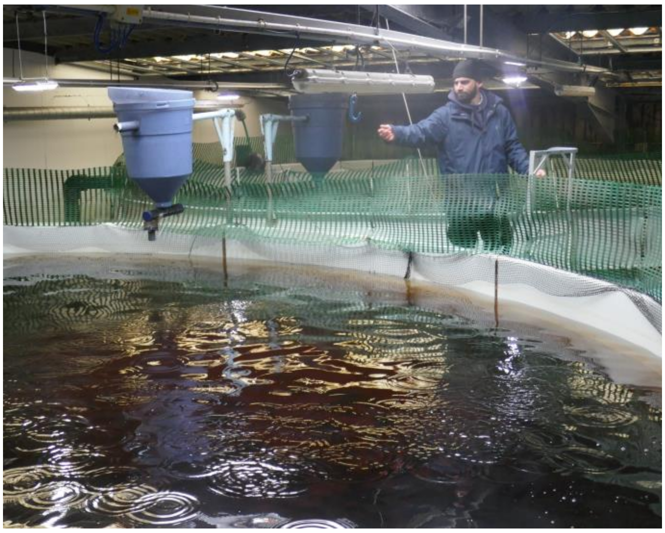
Are the fish fed a fixed daily ration?

The fish are always fed to satiation, according to their appetite. Feed ration calculations are conducted to determine the expected daily food intake. This is used as a starting point and guide only, with a willingness to deviate based on the fish observations made.

Feed charts are used to calculate daily rations as a guide to daily feed inputs.

How is fish appetite assessed when the automated feeders are being used?

A small amount of hand feed is introduced to assess appetite and any loss of appetite observed is reported. The assessment of appetite and the remediation in response to each 'appetite threshold' from vigorous to subdued are often standardised.



Hand feeding to assess fish appetite

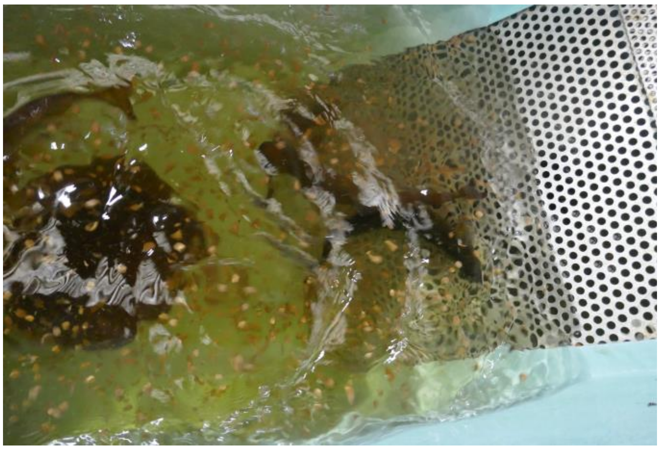
This removes subjective judgement to get consistency between the staff.

Whenever it is apparent that fish appetite exceeds the recommended ration, the opportunity to increase the feed input and therefore fish growth is taken, without wasting food.

Typically, the daily ration is:

a) Increased by 10-15% when fish are observed feeding very vigorously.
b) Unchanged when there is a moderate feeding response.
c) Reduced by 10-15% when the fish are subdued and showing little interest in the feed.

Are there any other signs as to whether the fish appetite is suppressed?



Waste feed evident in the side box

At the start of each shift the tanks bases are checked and cleaned if necessary. This provides an opportunity assess how much waste food is evident. The information is corelated to the appetite assessment to help inform the decision regarding whether to change the daily ration.

When is the daily ration changed?

Normally, the feed input is reduced, to minimise waste, whilst still maximising fish growth. This is achieved by re-calibrating the automatic feeding system.

Constant vigilance and good communication is required by observant and proactive husbandry staff to find the correct balance between tank hygiene and maximising feed intake.

3.4.3 Feed particle size and feeder calibration

As the salmon fry grow their mouth gape increases, and they can ingest larger food particles. By doing so, they expend less energy feeding. At each pellet size transition point, the different feed should be mixed for three days so as the entire size range within the population has access to food particles of a suitable size. The percentage of different pellet sizes in the mix can be determined by the size frequency distribution of the population established through sampling.

Feed labels provide pellet size data

On the fourth day onwards only the larger pellet size is provided in the feeders, as the transition is complete.

3.4.4 Feed distribution and meal frequency

The fish can be aggressive when hungry and may attack each other, causing damage to opercula, fins, and eyes. This can be remediated by 24 hours a day lighting and constant access to feed, so the fish are never hungry.

As with first feeding it remains important that the water flow evenly distributes feed around the tank from the points of feed input. Feed distribution can often be improved by locating the feeders close to the water surface (10-15 cm).

The planned frequency of meals can be programmed in the automatic feeder settings. Feeding frequency is determined from fish growth rates changes, fish biomass, feed particle sizes and life stages and temperature.

Feeder height can be adjusted

Automatic feeders can spread feed by deploying a system of rotating drums or spreader discs.

The Arvotec feeders are typical of the rotating drum design. Dosing feed cups are embedded externally around the dosing drums.

When are automatic feeders calibrated?

Re-calibration must be carried out whenever the ration, meal frequency or feed pellet sizes change. Once the feeder is calibrated with the required drum and pellet and the feeding speed is satisfactory, the same drum/pellet combination in the system can be inputted to each feeder. The smallest single meal dose starts ranges from 0.1g.

The Arvotec feeder has a variety of dosing drums from (100 microns up to 13 mm).

Now watch this- Arvotec robotic feeders

[Arvo-Tec Robotic Feeder - PAES W.A.T.E.R. Product Showcase - Bing video]

They have stainless steel springs and scrappers that keep the inner dosing drums clean, ensuring that each dosing cup (embedded externally on the drums), is emptied completely on each rotation.

Robotics have been introduced to Arvotec feeding systems, allowing a portable feed dispending unit to be transported on aerial rails to each tank to distribute feed to each stock.

3.4.3 Feeding operations

Watching the behaviour of fish feeding, to judge when they need more, or less feed, is a key husbandry skill that no automated feeding system can perform. In the absence of observant technicians, waste feed will collect on the tank bases, fish will be underfed, and feeders will malfunction.

Unlike today's salmon cage farmers, hatcheries do not have the advantage of camera surveilance and must rely on the constant observation, corrective action and monitoring by dedicated technicians working as a team.

4.3 Feeding parr

Husbandry procedures during this stage follow those of the Parr stage with changes to feed size, feed rate and water flow commensurate with the increasing fish size.

Key points

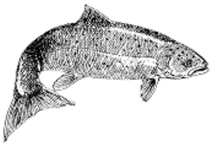
- Mortalities must be removed routinely and classified using a company system to standardise the process.
- Automated feeding systems save labour but must not lead to a lack of staff vigilance.
- Appetite checks by hand feeding should be performed daily and the ration changed in response to the vigour of the feeding response.
- Observations of waste feed must be corelated with appetite checks to help inform changes to the ration.

Learning activity

Stockman's calculations

Feed calculation exercises to calculate recommended daily rations, using given feed-charts for a fish stock/population

SP 4 Smolt production



Manage smoltification

In the wild, the timing of smoltification is determined by the growth rate of the parr. Depending on the food supply and fish population numbers it usually occurs following two to four years in the nursery stream when the fish have reached approximately 30- 40 grams in weight. The increase in daylight hours in the spring provides the natural trigger for the physiological and physical change as the fish smoltify in preparation for life at sea.

In commercial salmon nurseries, the feed supply and typically the light regime is controlled, and the entire smolt production process can be shortened. Instead of smolts being produced for spring transfer within in one or sometimes two years, (known as S1 and S2), as used to be the case, they can be produced in as little as 6 months and transferred at any time to suit the grow out production regime. To achieve this the fish are intensively fed to satiation from first feeding onwards with the highest quality feeds to accelerate their growth and subjected to photoperiod regimes on reaching their target weight. Smolts can be produced in as little as 6 months (known as S O.5), reflecting that they have been produced in under one year. It is also increasingly common for larger smolts to be produced, to reduce the length of the marine phase. This in turn reduces exposure to risks of overwhelming sea lice infestation.

A 9 M smolt tank

Smolt tanks are typically 2.5 metres deep with a central outlet and largely self-cleansing. Due to the higher water flows and the larger more active fish population they may require less regular maintenance than they did at the fry stage.

Once established, the pre-smolt population is grown on to an average weight of 50 to 200 grams, depending on the company production strategy. Once the company target weight has been reached the photoperiod regime is imposed to trigger smoltification.

4.1 Smoltification

Prior to transfer to the on-growing system the fish are normally subjected to a smolt inducing photoperiod trigger. However, there are still some facilities operating on ambient light and smolting fish seasonally, by feeding transfer feeds for 4-6 weeks pretransfer.

The objective of the smoltification process on a salmon farm is to adapt the fish for life in a saline environment. Irrespective of the importance of salt-water adaptation, the increased growth rate associated with smoltification is a major benefit.

Smolt transformation

Articulate creative: Set up a series of images to illustrate the change in appearance from parr to smolt every two weeks

A standard process should be established based on the temperature of the growing environment, light intensity, stocking density and day length.

Initially the fish are held on 24-hour light the lights will then be gradually reduced over a six-week period to 11 hours, with 13 hours of darkness to simulate the winter, before gradually increasing again to 24 hours to simulate the spring.

The photoperiodic stimulus from the photoreceptors in the eye's retina is conveyed to the brain-pituitary axis for processing which involves a pineal gland secretion. The activation of the eye-brain-pituitary axis stimulates a surge in neurotransmitters followed by high thyroid hormone and growth hormone levels. Morphophysiological changes are induced and provide a welcome boost to the fish's growth potential.

Is there independent control of the smolt tanks?

Each tank can be subjected to a chosen light regime, giving independent control over the smoltification process for each population. The lights are positioned above the tank and transmit white light on a timer controlled by the smolt unit manager.

Are the fish fed as normal during smoltification?

The fish are fed as normal, but in RAS production, carefully avoiding overloading the biofilters with excessive feed loads. When several tanks are undergoing photoperiod manipulation, the timing is often staggered, so that feeding events during the 11 hours of light occur in different periods of the day for different tanks, thereby avoiding extreme feed loading spikes. Appetite can be mor volatile during smoltification.

It would be expected that the fish will smolt within 4-5 weeks of moving on to 24 hours of light, following the short-day trigger.

Feeding operations

Many of the practicalities of automated feeding during the period of photoperiod manipulation are like feeding fry and parr. However, there are some different nuances due to the impact that smoltification can have on appetite. An additional level of vigilance is required

The feed requirements for each batch of smolts can be forecast, based on fish stock records, the prevailing water temperature and recommended feed rates.

Growth and stock biomass predictions can be made with reference to feed rates and expected food conversion ratios (FCRs).

Typical procedures for feeding smolts

a) Identify feed requirements.

Each holding unit should be clearly labelled to show the type of feed and feed size to be fed. Typically, there are 3 sizes of feed used: 2.2-2.5 mm and 3mm.

b) Check for waste.

The tank bases should be checked for waste an hour after the lights come on, and clean if necessary to remove all organic matter. If feed waste is evident on the base of the holding unit, this is indicative of overfeeding!

c) Assess appetite at the start of the shift

Feed should be gently distributed by hand and feeding activity observed closely. If the appetite is weak, the daily ration should be reduced. If the appetite is particularly strong, the ration should be increased above the feed suppliers recommended rate.

Hand feeding pre-smolts at a through flow unit

How should staff respond if there is waste feed but a strong appetite?

If there is waste food and the appetite is strong, this could be indicative of inaccuracies in fish population numbers or an underestimation of fish biomass due to sample weighing errors. Once any necessary corrections have been made, the feed ration should be recalculated.

d) Load feeders

The automatic feeders are cleaned and loaded them with 90% of the daily ration. The other 10% is delivered by hand, typically spread over 2 hourly intervals, whilst taking note of the fish feeding response and appetite.

e) Increase appetite check regularity

Record fish appetite at least once a day, increasing to twice a day if fish behaviour changes become apparent during the last two weeks of the summer phase.

What is the advantage of increasing the regularity of hand feeding?

Regular hand feeding allows staff to maintain close contact with the stock. This becomes increasingly important as smoltification progresses, as appetite normally reduces and adjustments to the ration must be made.

f) Check water quality for any stocks with a depressed appetite.

The temperature, CO_2 and pH are measured with a probe to determine if any parameter is outside of the water quality standard. If a weak appetite and waste food are observed, the regularity of checks is increased.

g) Recalibrate feeders

Feeders should be recalibrated to correct any overfeeding and eliminate feed wastage, typically reducing the daily ration by 5-10%. Following a ration reduction, the tank is observed for several hours to see whether feed waste is still building. If so, a further reduction in ration may be required.

h) Check feeder operation

At the end of the shift, the ration 'actually' delivered to each unit is assessed by checking to see what feed is left in the feeder. A full feed description of the feed fed is recorded, including food specification, particle size and supplier. The automatic feeder records should be checked against these feed assessments to ensure that there is no need for feeder recalibration.

Why is this check necessary?

The actual ration can vary compared with the automated record.

i) Checking depressed appetites

For any stocks with a depressed appetite the feed particle size is checked against the fish size distribution and the feed supplier consulted if necessary

If the feed check does not lead to a resolution of depressed appetite, a full systems check is conducted.

Why? Because there may be a failure in the RAS and water quality monitoring and control system responsible for the suppressed appetite.

4.3 Monitoring smoltification

Smoltification should be undisrupted and synchronised, within a narrow smoltification window. A typical photoperiod regime would start with 5 weeks of short days (11 hours of light) followed by 6 weeks summer phase with 24 hours a day lighting. This regime provides the smoltification trigger. During this period smoltification progress within the population is monitored as the timing varies for individual fish

Darkened caudal fin margins are evidence of smoltification

The physical changes associated with smolting include silvering of the body, darkening of the fin margins and elongation of the body are all visually apparent to the fish farmer. Behavioural change can also be detected by husbandry staff.

Conversely, the adaptation of the animal's physiology for life in a marine environment is not visible but can be measured.

How can the fish's physiological status be measured?

The more practical farm-based methods involve subjecting a sample of fish to a saltwater challenge followed by measurement of blood chloride levels or gill sodium and potassium ATPase.

Some companies use the genetic analysis of gill tissue to determine the smolt's physiological readiness for transfer. The analysis measures the gene expression of various markers in gill tissues, which are directly associated with the fish's chloride cells and other physiological aspects of smoltification. During smoltification these genes will change, depending on what stage the fish has reached.

Now watch this - Instructional video Photoperiod smoltification

To cover photoperiod and feeding regimes as well as smoltification assessment.

Story board 5

By measuring these changes, a picture of what type of ATPase activity is about to dominate in the gills can be established. If associated with the ability of the chloride cells to act as 'chloride pumps', then this is indicative of the fish's readiness for transfer to more saline water.

Data from several genetic markers can be combined to provide a complete and more refined picture of the fish's smolt status.

Are there any alternative ways to assess physiological status?

The measurement of hormones can be useful for following smolt development and the effects of husbandry on growth and salinity tolerance. Thyroid hormones, cortisol, growth hormone, insulin-like growth factor I and prolactin have all been implicated in regulating the osmoregulatory changes that occur during smolting. These hormones, pancreatic peptides and others may also be involved in growth and metabolic changes associated with smoltification.

Salmon farmers rarely use hormone assays as they are expensive and not a commonly applied.

4.3.1 Preliminary smoltification monitoring

Whilst physiological testing can confirm the smoltification status, preliminary monitoring, the development of smoltification can be monitored throughout the photoperiod in other ways. There are several opportunities for husbandry staff within routine duties during the 11-week photoperiod. These include daily observations of fish behaviour, appetite, and weekly or fortnightly observations of physical appearance within routine sampling.

How does fish behaviour indicate the degree of smoltification?

As smoltification develops within the population, fish behaviour changes. Regular observations by technicians are essential, especially swimming behaviour. When fish start swimming with the current this is a smoltification indicator.

Although generally occurring during the summer phase, behaviour must be checked from the first week of winter (week 1), as some fish may smolt early. Observant staff can determine when smoltification has begun within a pre-smolt population.

Ideally, the smoltification of a salmon population should occur within a narrow window and be relatively synchronous. However, in practice the timing varies between individuals, and can be disrupted by light pollution incidents, caused by equipment failure or staff error.

How does the fish's appetite change during smoltification?

From the first week of summer phase some fish continue to swim against the current, whilst others appear disoriented and start swimming chaotically in several directions. In response, husbandry staff should appetite checks by hand feeding every 2 hours, and notify the manager of the fish's response.

More fish are expected to lose appetite towards the end of the summer phase.

How is physical appearance used as a smoltification monitoring tool?

The physical changes associated with smolting include silvering of the flanks, darkening fin margins on the dorsal and caudal fins, and elongation of the body.

Smolt showing typical physical characteristics.

Unlike the physiological adaptation for life in a marine environment, these signs are very apparent.

Systematically scoring fish samples for changes in skin colouration and pattern provides an indication of the level of smoltification within the population.

Skin appearance should be sampled periodically, taking particular care from week 5 of the photoperiod regime, as the skin becomes fragile, and scales lost more easily.

The company's sampling regime should prescribe the timing and frequency of smoltification sampling. The process is usually integrated with sample weighing for fish welfare reasons, to reduce the amount of fish handling and stress.

Individual fish are scored based on their physical appearance using a 1-4 scale. Once a total of 60-80 fish are scored and recorded, the degree of smoltification within the population can be assessed.

4.4 Transfer smolts

The final grade should take place at approximately 60g to establish graded populations for transfer to the main on-growing system.

Grading of the fish can take place at the end of the third week of the short-day photoperiod, if used. It is important that the fish are counted at this stage with numbers properly recorded.

Now watch this...Providers of genetic smoltification analysis services

Smolt Timer http://www.patogen.com/our-services/smolttimer/

Smolt vision https://www.pharmaq-analytiq.com/en/products/smoltification/smoltvision/

Smolt transfer preparatory procedures

The fish need to be prepared for transfer well in advance of the transfer operation, during the last 3 weeks of the summer phase.

a) Three weeks before transfer

Checking fish behaviour for signs of lethargy, stress or weakness, leading up to the transfer operation.

- Fish health analysis

A sample of forty fish is captured and euthanized for fish health analysis by a qualified fish pathologist to confirm the health status, before fish can be transferred to the post smolt unit.

b) Two weeks before transfer

Check fish behaviour and physical appearance from above the tanks. Fish swimming with the flow, a silver skin and dorsal and tail fins with black borders are signs of full smoltification. This is normally accompanied by a loss of appetite and daily feed rations will need to be reduced.

Checking smolt behaviour 2 weeks pre-transfer.

- Sampling

At the end this week, the fish should be sampled for weight and smoltification, and handled with particular care, as their skin is now at its most fragile and vulnerable to damage.

c) Final week before transfer

During the final week before transfer meetings with the post smolt unit manager enable the transfer operation to be planned. The post smolt unit manager must be confident that the fish have completed smoltification.

d) One or two days before transfer

Learner Activity - Stockman's calculations:

Analysis of population structure

One to two days before transfer the smolts are sample weighed to establish the population size distribution. This enables the post smolt manager to plan their feed requirement accurately.

If the physiological assessment indicates the fish population have not completed smoltification, the fish may have to be transferred to the post smolt unit and complete the process there.

It is better for the fish to stay in the smolt unit for another week, before transfer, if space in the facility is available.

- Prepare smolt transfer equipment.

The equipment for smolt transfer must be set-up and tested before the transfer operation can begin.

- Sample water

Water sample before transfer

Take a water sample from the smolt and post smolt system for laboratory testing, to ensure all water quality standards are met in both systems.

If water quality standards are not met, the transfer should be postponed until the water quality issue is resolved.

- Check the pump

Check fish pump components and accessories to ensure they are in working order.

If a faulty component is found during this check the operation is postponed until it has been repaired or replaced.

Procedures for transfer to post-smolt facility

a) Establish pump velocity.

Connect the fish transfer hoses and adjust the fish pump velocity according to the manufacturer's recommendations for the size of fish.

If the pump velocity is too high there is a greater risk of fish damage.

Now watch this –

Instructional video- Smolt transfer

Story board 6

b) Lower water levels

Lower the tank level as far as possible to make fish crowding easier and ensure sufficient oxygen.

If the tank level is lowered too far, there is a risk of stress due to overcrowding and physical damage to the fish.

c) Establish water flow.

Cover the end of the hose with an aquarium net before establishing a continuous flow to the post smolt units, ensuring no air bubbles are trapped in the hose.

If air bubbles are visible the hose connections need to be re-checked.

d) Crowd fish.

Crowd the fish to the fish pump inlet for entry and transfer to the post smolt unit. Carefully observe and regulated crowding throughout to provide a constant throughput of fish whilst minimising stress.

e) Check fish condition.

Check fish condition constantly by capturing samples with a net in the receiving tank looking for signs of skin damage.

If any fish skin damage is evident the transfer operation should be stopped immediately, and the tank base checked. Any mortalities found should be inspected and classified according to the and the transfer suspension recorded.

Checking fish skin damage immediately after movement

f) Observe fish behaviour

Observe fish behaviour throughout the operation, before and after transfer. Report any signs of stress and abnormalities to the manager.

g) Hygiene

Disinfect all equipment on completion of the transfer. Disinfection of all equipment after every fish handling operation is a central component of biosecurity.

4.4.1 Update records

Complete a transfer report, including the stock records and production history of the fish transferred. Fish production management is dependent on the staff always keeping comprehensive and accurate stock records.

4.4.2 Post transfer

Fish behaviour must be monitored for 2 weeks after transfer. The fish should show normal behaviour and colouration with no signs of damage or lethargy and no rise in mortalities.

Samples of fish are subjected to physiological smoltification assessment, and all data shared with the

Key points

- Most smolt units rely on photoperiod to trigger smoltification, using a 5-week winter of 11 hours a day lighting followed by a 6-week summer period of 24 hours a day lighting.
- Smotlification is monitored through close observation of swimming behaviour, appetite, and external physical appearance.
- The final confirmation of smoltification status is established by undertaking physiological tests, either a saltwater challenge followed by measurement of blood chloride levels /gill sodium or less commonly genetic analysis of gill lamellae.
- The fish are sampled during smolt transfer to post smolt units and the operation stopped if there is any sign of skin damage. The pumping equipment and pipe connections are checked before recommencing.

smolt unit manager.

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Story Board 1

Unit	Learning Episode	Instruction	Learning objective(s)
Smolt production	Stock, grade, and transfer nursery stock	Fish reception	To demonstrate fish reception routines

Sequence	Duration (Secs)	Media shoot and other resources	Audio
SB.1	12 secs	Health check fish stocks Footage: Operative catching sample. Cut to fish pathology lab team working in lab	*A fish health evaluation is completed two weeks before transfer. This is based on a sample of 40 fish which are sent to the fish pathology lab for IPN, BKD and ISA analysis.*
SB.2	10 secs	Fish size distribution Footage: Operative capturing sample of fish stocks.. Cut to individual fish length and weight measurement…	*The fish stocks are sampled before transfer to establish the stock biomass and size distribution upon which feed ration and particle size selection is based after transfer.*
SB.3	12 secs	Water quality checks Footage: Close up of biofilter… Cut to operative taking water sample from the sump…Cut to laboratory staff undertaking water tests	*The biofilters are checked after start-up, to ensure they are fully functional. A water sample is taken from the sump, tested, and the results recorded. All parameters must meet the company's Water Quality Standards before transfer*
SB.4	10 secs	Levels and flows Footage: Operative setting the unit depth…..Cut to water flow measurement using flow metre…Cut to manager working figures on PC.	*The holding unit depth is set at 2 metres and the activity recorded. A water flow measurement is taken with a flow metre and a 'mass balance' evaluation conducted. The hydraulic retention is calculated for each holding unit, based on the water flow rates recorded. Water flows are measured constantly.*

SB.5	10 secs	Prepare for transfer Footage: Operative connecting and checking hoses.. Cut to pump calibration… Cut to empty feeder close up inside.	*All fish transfer hoses are connected and checked, and the fish pump adjusted according to fish size recommendations. The fish are starved for 24 hours at 12 degrees Centigrade before transfer.*
SB.6	7 secs	Set up water flow Footage: Operative holding net over inlet and placing it in the tank…Cut to closeup of water flow…. Cut to operative checking for bubbles.	*The inlet hose located in the nursery tank is covered with a net, and a continuous water flow to the smolt tank started, making sure there are no air bubbles visible in the hose.*
SB.7	5 secs	Transfer fish Footage: Close up of net being taken of inlet pipe…. Cut to regulating crowding and flow of fish.	*The net is taken off the inlet hose and the fish transfer started. A constant water flow is maintained and the quantity of fish in the pipeline regulated to avoid overcrowding.*
SB.8	7 secs	Sampling Footage: Operative catching fish samples from outlet and placing them in glass vessel… Cut to closeup of fish in glass vessel	*Fish samples are captured and closely observed in a glass vessel every 20 minutes. Any signs of skin damage would lead to the transfer being suspended.*
SB.9	10 secs	Post transfer checks Footage: Operative taking water sample… Cut to operative scanning tank, leaning in with hand net to remove mortality… Cut to operative inspecting mortality… Cut to operative filling in mortality classification.	*Water quality checks are performed in the smolt unit and the bottom of the holding units checked for mortalities. Any found are removed, classified, and recorded.*

SB.10	10 seconds	Post transfer feeding Footage: Operative filling up feeder… Cut to operative hand feeding… Cut to fish feeding closeup.	*Two hours after transfer, the fish are fed a reduced ration, gradually building up to full ration over 40 hours, checking appetite at each stage. If the appetite is high between 16 and 32 hours, then the fish are put on full rations earlier, at 32 hours.*
SB.11	5 secs	Cleaning Footage: Operative cleaning all equipment	*All equipment and tools are cleaned after transfer and the activity recorded.*

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Story Board 2

Unit	Learning Episode	Instruction	Learning objective(s)
Smolt production	Stock, grade, and transfer nursery stock	Sampling fish weight and smoltification	To demonstrate procedures for sample weighing pre-smolts and smoltification sampling

Sequence	Duration (Secs)	Media shoot and other resources	Audio
SB.1	10 secs	Preparations. Footage: Closeup of fish in tank. Cut to operative setting up scales… Cut to plugs being protected with plastic.	*The fish are starved for four hours before sampling. The scales are set up ensuring that the extension cord is intact and electrical plugs cannot get wet during weighing, covering the plugs in plastic if necessary.*
SB.2	5 secs	Calibrate scales. Footage: Operative turning on scales and calibrating them.	*The scales are turned on and the calibration checked according to manufacturer's instructions.*
SB.3	10 secs	Prepare anaesthetic equipment. Footage: Close up of chemical on shelf.. Cut to operative measuring out chemical… Cut to chemical being added to a plastic bucket… Cut to recovery vessel being filled… Cut to operative monitoring DO in both…	*The anaesthetic solution is prepared in a plastic bucket, according to supplier instructions and the company anaesthesia procedure.* *A recovery vessel is prepared with freshwater, and dissolved oxygen measured in both containers to ensure water quality standards are maintained throughout.*

SB.4	8 secs	Capture sample and place in anaesthetic. Footage: Operative capturing fish sample… Cut to sample being placed in bucket… Cut to closeup of fish losing balance	*Using a hand net 30 fish are gently captured and placed into the anaesthetic solution. Once the fish become inactive and lose their balance, they are ready to be weighed.*
SB.5	7 secs	Weigh fish Footage: Operative lifting fish from the anaesthetic… Cut to close up of fish being placed on scale…Cut to weight recording, cut to fish return to recovery tank.	*The fish are placed on the scale and weighed singly, recording each weight and then placed in the recovery tank.*
SB.6	10 secs	Return fish Footage: Closeup of fish recovering…Cut to recovery tank full of upright fish swimming… Cut to anaesthetic being changed	*Once the fish have regained their balance and are swimming normally (belly down), they are returned to their holding unit. The anaesthetic solution is changed according to manufacturer's instructions.*
SB.7	5 secs	Repeat sample up to 200 Footage: Samples from previous footage… Cut to cleaning of equipment and surfaces	*The next batch of 30 fish are captured and the process repeated until a total of 200 fish have been sample weighed. Sample weighing records are updated and all surfaces and equipment cleaned.*
SB 2,3,4 and 6 above	5 secs	Smoltification sampling introduction Footage: Sample from anaesthetisation footage.	*Smoltification sampling is conducted during weeks 1,3,5 and 9 of the 10-week duration smoltification regime.* *On each occasion, the fish are starved for four hours before sampling. Once the fish become inactive and lose their balance, they are ready to be smoltification sampled.*

SB.1	6 secs	Smoltification score Footage: Show operative looking at scale and example images.	*The fish are scored for smoltification, using the company's standard visual scale (1-4) which indicates the degree of smoltification.*
SLIDES		Smoltification scale (1-4) A slide for each level of the scale	*The fish are individually scored using the company smoltification scales based on parr marks and the darkness of the tail fin edge.* *1) The fish has strong parr markings red and black spots, and a yellow belly colouration.* *2) The fish has weak parr markings, red and black spots, a deeper body shape and a pale cream belly.* *3) The fish has a darker tail and pectoral fins, less pronounced spots, faintly visible parr markings and less body depth* *4) The fish has a black edged tail and pectoral fins, silver colouration, no parr marks and the lean body shape of a smolt*

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Story Board 3

Unit	Learning Episode	Instruction	Learning objective(s)
Smolt production	Stock, grade, and transfer nursery stock	Fish grading	To demonstrate salmon pre-smolt grading methods and procedures

Sequence	Duration (Secs)	Media shoot and other resources	Audio
SB.1	10 secs	Sample fish Footage: Operative sampling… cut to weight frequency bar graph… Cut to manager considering data	*To plan the grading operation, the fish population must be sampled to establish the weight distribution frequency. They are starved for at least 2 days before sampling.* *The average weight and number of fish in each size category is established from interpretation of the sample data, including the weight and number to be culled.*
SB.2	8 secs	Fish pump and grading machine set up Footage: Operatives setting up grader… Cut to grader grill opening… Cut to operative making adjustment.	*The fish pump and accessories are set up along with the grader. The grader's grill opening is adjusted, informed by the weight distribution analysis and production plan requirements.*
SB.4	5 secs	Fish counter Footage: Operative setting up Vaky counter	*The Vaky counter is set up to reflect the population size range established to ensure accuracy.*
SB.5	10 secs	Check equipment and start the water flow Footage: Operative checking hoses and adjusting pumps… Cut to net being placed over hose and checking for air bubbles.	*Before starting the 'grading operation', all transfer hose connections are checked, and the pumps adjusted according to fish size recommendations.* *A net is placed over the inlet hose in the nursery tank, a continuous flow of water between holding unit and grading machine established and hoses checked for trapped air bubbles.*

SB.6	10 Secs	Grading Footage: Close up of hand net being removed…Cut to operative crowding fish… Cut to operative capturing sample, placing in glass beaker for inspection… Cut to tanks bases being viewed…	*Fish grading is started by removing the net and the fish towards the hose inlet under control to avoid damage. The condition of the fish is constantly checked in a glass vessel after capturing a sample and the base of the tank is checked for mortalities, removing, and classifying any found.*
SB.7	5 secs	Fish behaviour Footage: Operative looking in to tanks…Cut to close up of fish	*After the grade fish behaviour is checked, reporting any abnormalities to the manager.*
SB.8	7 secs	Condition sampling Footage: Sample capture… Close up of operative face as they inspect… Cut to close up of fish…. Cut to fish with skin damage signs.	*Fish samples are captured and closely observed in a glass vessel. Any signs of skin damage would lead to the transfer being suspended.*
SB.9	8secs	Culling Footage: Show culls being collected, euthanised and disposed of.	*Fish that have been graded out for culling because they are not viable stock are euthanised according to company procedures and the mortalities disposed of*
SB.10	5 secs	Cleaning Footage: Operative cleaning up and disinfecting tools	*After fish transfer and culling, all tools and equipment are disinfected*

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Story Board 4

Unit	Learning Episode	Instruction	Learning objective(s)
Smolt production	Manage smoltification	Smoltification process	To demonstrate smoltification procedures and techniques

Sequence	Duration (Secs)	Media shoot and other resources	Audio
SB.1	10 secs	Winter light regime (Weeks 1-4) Footage: Scanning the facility…. Cut to operative examining fish behaviour in the tank	*The winter light regime of 13 hours dark followed by 11 hours light is started at 7.00 am of the first morning after receiving the fish from the nursery. Fish behaviour is observed, especially their swimming direction. When they start to swim with the current, this is a sign of smoltification*
SB.2	12 secs	Automatic feeders Footage: Closeup of feeder sending out feed. Cut to hand feeding by operative to test appetite… Cut to fish feeding close up	*The feeders are set to deliver feed during the 11 hours of daylight starting at 8.00 am to allow 1 hour for daily routines. Appetite should be checked every hour and is usually strong. Following any signs of aggression, additional feed should be provided by hand, during automatic feeding intervals.*
SB.3	5 secs	Lights off Footage: Facility wide angle view as lights go off…Cut to operative checking tanks	*The lights are switched off at 6.00 pm by automatic time switch and the tanks are checked to make sure all lights are off.*
SB.4	10 secs	Branchial ATPase sample Footage: Operative conducting ATPase sampling	*From the end of week 4, the final week of winter, ATPase sampling is performed up to and including week 10 and the activity recorded. Values increase each week.*
SB.5	12 secs	Summer light and feeding regime from week 5	*The fish are subjected to 4 to 5 weeks of summer with 24 hours of light a day. The daily ration is delivered over the full 24-hour period. The appetite is checked when*

		Footage: Close up of lights over tank… Cut to hand feeding and operative looking at fish response… Cut to closeup of the fish in the tank feeding lethargically.	*needed in week 5 and twice a day and twice a day during weeks 6-8, as the fish will show a loss of appetite towards the end of this period.*
SB.6	15 secs	Morphological changes in the skin Footage: Operative catching and anaesthetising sample… Cut to operative checking fish… Cut to close up of scale loss	*The skin morphology is sampled during week 5-7 taking particular care from week 6, as the skin becomes more fragile and scales are easily lost.*
SB.7	10 secs	Fish health Analysis Footage: Operative catching sample… Cut to samples in the lab being prepared for despatch .	*A fish health analysis is performed 2 weeks before transfer to the post smolt unit in week 7*
SB.8	12 secs	Visual inspection over tanks in week 8 Footage: Operative looking into smolt tanks…. Cut to fish swimming… Cut to sampling operation	*Every morning in week 8 a visual inspection of the fish is carried out over the tanks to observe fish behaviour. The fish are sampled for weight and smoltification at the end of the week and handled with particular care, as the skin is at its most vulnerable.*
SB.9	5 secs	Transfer to post smolt unit (Week 9) Footage: Operative talking to manager	*The week before transfer, the manager is in close contact with the post smolt unit manager to plan the transfer. They must be confident in the ATPase level.*
SB.10	12 secs	Post transfer (2 weeks) Footage: Operative looking in to post smolt tanks…Cut to fish close up… Cut to ATPase sampling operation….Cut to phone call from office.	*Fish behaviour is monitored for 2 weeks after transfer. The fish should show normal behaviour and colouration with no signs of damage or lethargy and no rise in mortalities. The ATPAse levels are sampled, and all information fed back to the smolt unit manager for their records.*

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Story Board 5

Unit	Learning Episode	Instruction	Learning objective(s)
Smolt production	Smolt	Feeding smolts	To demonstrate smolt feeding

Sequence	Duration (Secs)	Media shoot and other resources	Audio
SB.1	10 secs	Feeding regime Footage: High perspective view of holding units….. Close up of feed being distributed by an automatic feeder… Cut to fish feeding.	*Salmon are visual feeders and are only fed when the lights are on. The daily feed ration is distributed over a 10-hour period daily during the winter light regime and throughout 24 hours during the summer phase.*
SB.2	10 secs	Feeding methods Footage: Operative cleaning feeder… Cut to feeder being loaded with the ration… Cut to hand feeding… Cut to fish feeding closeup.	*The automatic feeders are cleaned and loaded with 90% of the daily ration during darkness.* *The other 10 % is delivered by hand, so as the fish feeding response and appetite can be observed daily.*
SB.3	7 secs	Fish stocks and feed forecasting Footage: Close up of holding unit label… Cut to manager viewing records on PC… Show screen to demonstrate figures	*Each holding unit is clearly labelled to show the type of feed and feed size to be fed. Feed requirements for each batch of smolts are forecast, based on fish stock records, and recommended feed rates which are used to predict fish growth and biomass.*
SB.4	10 secs	Check for feed waste Footage: Operative checking tank looking for waste.. Cut to tank cleaning..	*Firstly, an hour after the lights come on, the bottom of each holding units is checked for waste food as a sign of overfeeding. If evident, the tank base is cleaned to remove all organic matter.*

SB.5	10 secs	Check appetite. Footage: Close up of feed… Cut to operative hand feeding.. Cut to operative's face (observing). Cut to fish feeding in tank	*After waste removal, hand fed is gently distributed and feeding activity closely observed. If the appetite is weak, the daily ration is reduced.* *Fish appetite is checked once a day, increasing to twice a day during the last two weeks of the summer phase, if any change becomes apparent.*
SB.6	7 secs	Recalibrate feeders. Footage: Operative opening feeders to check them… Cut to operative recalibrating settings	*To correct any overfeeding, the daily ration is reduced by recalibrating the feeders, to eliminate feed wastage.*
SB.7	10 secs	Automatic feeding Footage: Closeup of feed falling on water surface. Cut to operative looking into tank… Cut to waste feed on tank base….Cut to feeder height being checked… Cut to operative looking into tank again…	*Once automatic feeding has started, food should fall gently on the water surface. The tank base is checked after 2 hours and if waste feed is building up, feeder calibration and the height of the feeder above the water level are both checked, reporting any anomaly.* *The fish reaction to the feed is monitored constantly throughout the day.*
	5 secs	Automatic feeder check Footage: Operative opening feeder and checking feed inside… Cut to operative recording feed delivered in the feeding record	*Once per shift the automatic feeder records are checked against the feeder operation. At the end of the shift, the amount of food delivered to each unit is recorded along with a complete description of the feed. All activities are recorded in the feeding record.*
SB.8	5 secs	Water quality check Footage: Operative monitoring water in the tank with a probe… Cut to closeup of probe being lowered.	*For any stocks with a depressed appetite the water quality is checked. The temperature, CO_2 and pH are measured with a probe to determine if any parameter is outside of the water quality standard.*
SB.9		System and feed check	*If there are no water quality issues, then a systems check is undertaken. The feed is checked in relation to the fish size involving the feed company technical support.*

		Footage: Operative with checklist undertaking a full system check… Cut to operative inspecting feed.	
SB.10		Reporting Footage: Manager at desk looking at data on his PC… Cut to key board and hands working keys. Cut back to manager face	*The manager is responsible for reporting any changes in stock appetite. The monthly sample weights are checked against growth projections checking for deviations, and the incident report form completed.*

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Story Board 6

Unit	Learning Episode	Instruction	Learning objective(s)
Salmon production	Manage smoltification	Transfer smolt to post smolt	To demonstrate smolt transfer procedures and techniques

Sequence	Duration (Secs)	Media shoot and other resources	Audio
SB.1	5 secs	Prepare for the fish transfer. Footage: Operative lowering tank level by adjusting outlet pipe. Include closeup of components.	*The tank level is lowered as much as possible, and the water inflow reduced*
SB.2	3 secs	Release fish into distribution channel Footage: Operative releasing fish	*The drain valve is opened after making sure the fish have sufficient oxygen fish released into distribution channel.*
SB.3	5 secs	Crowd fish. Footage: Fish being crowded by operative. Include closeup of fish and their operculum.	*The fish are crowded through the distribution channel to the fish pump*
SB.4	10 secs	Setting up fish pump. Footage: Operative connecting hoses and adjusting pump velocity, holding net over. Cut to close up of operative checking for air bubbles.	*The fish transfer hoses are securely connected, and the fish pump velocity adjusted according to fish size recommendations.* *The end of the hose is covered with a net before setting up pump suction, creating a continuous flow between to the grading machine, ensuring no air bubbles are trapped in the hose.*
SB.5	10 secs	Start fish transfer.	*The fish transfer is started, and the condition of the fish checked constantly by sampling the fish in the receiving tank looking for any signs of skin damage.*

		Footage: Operative starting transfer operation. Cut to samples being taken and being examined for skin damage	
SB.6	8 secs	Stop fish transfer. Footage: Close up of skin damage. Cut to operative talking to manager, followed by operation being stopped. Cut to operatives looking into tank for mortalities.	*If any fish skin damage is evident the transfer operation is stopped immediately, and the bottom of the tank checked for mortalities.*
SB.7	10 secs	Classify mortalities. Footage: Operatives removing mortalities. Cut to closeup of damage. Cut to operative completing classification records.	*Any mortalities are classified according to the company Mortality Classification procedure and the transfer suspension recorded on the 'Fish Transfer Summary'.*
SB.8	5 secs	Check fish behaviour. Footage: Operative looking into the receiving tank… Cut to operative talking to manager	*Fish behaviour is observed, and any abnormalities reported to the manager.*
SB.9	5 secs	Conduct water quality sample. Footage: Operative taking water sample from the holding unit….	*A water quality sample is taken from the holding unit to check that all parameters are within prescribed water quality limits.*
SB.10	5 secs	Disinfect equipment. Footage: Operative disinfecting hand nets	*The fish pumps and hand nets used for sampling are disinfected when the operation has finished.*
SB.11	7 secs secs	Prepare fish transfer report.	*A fish transfer report is prepared to describe the population transferred to the post-smolt unit and its production history.*

		Footage: Operative in the office on the PC	

Guidance: Multiple Choice

This series of multiple-choice questions have been designed so as there is only one possible correct and complete response. This allows prior knowledge to be established through pre-testing.

Taxonomy: Bank number, Subject, Question title

An asterix (*) indicates the correct response(s).

Bank 1 Nursery operations

1.1 How long before the fish stocks are transferred from the hatchery to the nursery is the fish health evaluation conducted?

Select the CORRECT ANSWER from the options below:

a) 2 months

b) 4 weeks

*c) 2 weeks

d) 2 days

1.2 Who is authorised to conduct the fish health evaluation to confirm whether salmon fry can be transferred from the hatchery to the nursery?

Select AS MANY as you believe to be correct:

a) The facility manager

b) The team supervisor

c) A hatchery technician

d) The company fish pathologist

*e) The company's external fish veterinary pathologist

1.3 How many holding units contribute towards the sample for the fish health evaluation, conducted before salmon fry are transferred to the nursery?

Select AS MANY as you believe to be correct:

a) 12

b) 8

*c) 4

d) 2

1.4 Why are hatchery stocks sampled to establish their total biomass and size distribution before transfer to the nursery?

Select AS MANY as you believe to be correct:

*a) To determine their feed pellet size requirement

b) To determine fish growth rate

c) To evaluate fish health

*d) To enable a feed ration guideline to be calculated.

1.5 What depth of water is required in the nursery rearing tanks for the incoming fry?

Select the CORRECT ANSWER from the options below:

*a) 2 metres

b) 1 metre

c) 20 cm

d) 10 cm

1.6 Why is it important the biofilters have matured, before the fry arrive?

Select AS MANY as you believe to be correct:

a) To ensure pH is stable and in the acceptable range

b) To moderate carbon dioxide levels

c) To ensure organic solids can be broken-down

*d) To ensure toxic ammonia is converted into harmless nitrates

1.7 What does hydraulic retention measure?

Select the CORRECT ANSWER from the options below:

*a) The waters residence time in the holding unit

b) The flow rate of water going through a holding unit

c) The volume of water retained by a holding unit

d) The surface area to volume ratio of a holding unit

1.8 What is the impact of low hydraulic retention?

Select the CORRECT ANSWER from the options below:

a) The Total Gas Pressure could fall outside acceptable limits

b) The pH could fall outside of acceptable limits

*c) Metabolic wastes could build up and water quality deteriorate

d) The water flow rate may be too high for the salmon fry

1.9 How often should fish samples be taken to inspect for skin damage during transfer from the hatchery to nursery?

Select the CORRECT ANSWER from the options below:

a) Every hour

b) Every half an hour

*c) Every 15 minutes

d) Every 5 minutes

1.10 How should the supervisor respond to the first signs of skin damage in a fish sample taken during fry transfer?

Select the CORRECT ANSWER from the options below:

a) Carry on transferring fish for 15 minutes until the next sample is due for confirmation

b) Take a second sample 5 minutes later for confirmation

c) Immediately take a second sample for confirmation

*d) Immediately suspend the transfer operation and conduct an equipment check

1.11 How long will the fry normally take to adjust to their new environment following transfer from the hatchery to the nursery?

Select the CORRECT ANSWER from the options below:

a) Within 8-12 hours

b) Within 4-8 hours

c) Within 2-4 hours

*d) Within 2 hours

1.12 How should the salmon fry be distributed in the holding unit, once the fish are fully acclimated to their new environment?

Select the CORRECT ANSWER from the options below:

*a) Evenly spread, actively swimming against the current

b) Distributed in groups and not aligned to the water flow

c) More concentrated around the water inlet

d) More concentrated around the outlet screen

1.13 What action should be taken if the salmon fry are distributed in groups and not aligned to the water flow?

Select the CORRECT ANSWER from the options below:

a) Decrease the water flow rate

*b) Increase the flow rate

c) Reduce the water depth in the holding unit

d) Immediately start the automatic feeding system

1.14 What percentage of a full daily ration are the fry initially fed, after they have settled following transfer?

Select the CORRECT ANSWER from the options below:

*a) 25%

b) 50% hours

c) 75% hours

d) 100% hours

1.15 As a general guide, what should the flow rate be in 'body lengths per second' for salmon fry following transfer to the nursery?

Select the CORRECT ANSWER from the options below:

*a) 1.0-1.5

b) 1.5-3

c) 3-5

d) 5-7

1.16 How is the vortex in a fry holding unit moderated to stop fry from being forced against the outlet screen?

Select AS MANY as you believe to be correct:

*a) Fitting a larger orifice at the inlet

b) Reducing the inflow rate

c) Increasing the inflow rate

*d) Fitting baffles in the centre of the unit

1.17 Which of these water quality parameters are monitored in the nursery, by a hand-held probe?

Select AS MANY as you believe to be correct:

a) Heavy metals

*b) Dissolved oxygen

*c) Conductivity

d) Total Gas Pressure

*e) pH

1.18 What is removed when ‘flushing’ nursery holding units to maintain hygiene?

Select AS MANY as you believe to be correct:

*a) Waste feed

b) Fish mortalities

*c) Fish faces

*d) Metabolic wastes (carbon dioxide and ammonia)

1.19 How should a nursery technician respond towards moribund (dying) fish seen swimming near the surface whilst routinely removing fish mortalities?

Select the CORRECT ANSWER from the options below:

a) Leave them for future removal after they have died

b) Remove them and place them in a quarantine tank

c) Remove them and place them into in a mortality container

*d) Remove them for immediate euthanasia and subsequent disposal

1.20 Which fish mortality samples are sent to the company's external fish pathology service for confirmation of the cause of death, following mortality classification?

Select AS MANY as you believe to be correct:

a) Those showing genetic deformities

b) Those showing Saprolegnia fungal disease symptoms

*c) Those showing any disease symptoms other than Saprolegnia fungal disease

*d) Those that cannot be classified

1.21 What is the feeding strategy for salmon at the nursery stage?

Select ALL OF THE STAEMENTS BELOW that are consistent with the feeding strategy:

a) Feeding to a pre-determined daily ration calculated from feed manufacture tables

*b) Feeding to satiation whilst minimising feed wastage

*c) Calculate a feed ration using the manufacturer's recommendations for use as a guide

d) Feeding a restricted ration less than the fish's appetite, to eliminate feed wastage

*e) Increasing food input, whenever fish appetite exceeds the recommended ration

1.22 Which type of automated feeding system is most deployed in the nursery phase?

Select the CORRECT ANSWER from the options below:

a) Pendulum demand feeders located at the tank

*b) Automated feeders with central feed silos

c) Clockwork feeders located at the tank

d) Automated feeders located at the tank with their own silo

1.23 What is the main advantage of automated feeding systems?

Select the CORRECT ANSWER from the options below:

a) Low capital cost

b) Low maintenance requirement

*c) Reduced labour requirement for feeding

d) Sensitive to fish feeding response

1.24 What is the single most important disadvantage of all automated feeding systems that nursery staff must remain constantly aware of?

Select the CORRECT ANSWER from the options below:

a) Poor feed distribution

b) High maintenance requirement

c) Increased labour cost

*d) Insensitive to fish appetite

1.25 Why must the pellet sizes be mixed during each pellet size transition during the nursery phase?

Select the CORRECT ANSWER from the options below:

a) To compensate for inaccurate sizing by feed manufacturers

b) To provide a more complete nutritionally balanced diet

c) To stop pellets of a uniform size blocking the automatic feeders

*d) To ensure a suitable size of pellet is available for all fish in the size range

1.26 Why should salmon never be allowed to get hungry during the nursery phase?

Select AS MANY as you believe to be correct:

*a) To reduce fish aggression that can cause physical damage

*b) To exploit their strong appetite to maximise growth rate

c) To avoid increases in feed wastage

*d) To discourage an increase in the population size range

1.27 How can feed distribution be improved during the nursery phase?

Select AS MANY as you believe to be correct:

*a) By using feeders designed to increase feed spread

b) By increasing the flow rate in the holding unit

c) By lowering the holding unit water level

*d) By locating feeders closer to the water surface

1.28 How can feed intake be increased during the nursery phase?

Select AS MANY as you believe to be correct:

*a) By providing light 24-hours a day

b) By increasing the flow rate in the holding unit

c) By lowering the holding unit water level

*d) By recalibrating the feeders according to daily appetite checks

*e) By regularly checking and optimising water quality

1.29 What is the main visual sign of overfeeding that an observant technician should notice and respond to?

Select AS MANY as you believe to be correct:

a) An increase in fish mortalities

*b) A build-up of waste feed on the base of the tanks

c) An increase in the fish size range

d) Signs of physical damage due to fish aggression

1.30 What are the main reasons for sampling fish stocks during the nursery phase?

Select AS MANY as you believe to be correct:

*a) To monitor gill operculum as a health indicator

*b) To revise the fish stock records

c) To check for signs of smoltification

*d) To help plan fish grading operations

1.31 What does the manager need to know to revise the fish biomass after routine weight sampling?

Select AS MANY as you believe to be correct:

*a) The number of mortalities during the previous period

b) The weight of food fed to the fish

*c) The average weight of the fish population

*d) The initial population number at the start of the period

1.32 Why is the population size range assessed before grading?

Select AS MANY as you believe to be correct:

*a) To work out the size limit of the runts for culling

*b) To determine size threshold for splitting large from small fish

c) To assess the increase in biomass during the previous period *d) To determine the grader settings needed to achieve the grade objectives

1.33 Why are the smallest fish graded out and culled during the nursery phase?

Select the CORRECT ANSWER from the options below:

a) Because they are more likely to carry fish diseases

b) Because they consume a disproportionate amount of fish feed

c) Because they are aggressive towards the other fish

*d) Because due their poor growth rate they are unviable

Bank 2 Smoltification

2.1 How long before transfer from the nursery to the smolt unit are the fish sampled to establish their size distribution?

Select the CORRECT ANSWER from the options below:

a) 2 months

b) 4 weeks

c) 2 weeks

*d) 1 week

2.2 What size are the fish at transfer from the nursery to the smolt unit?

Select the CORRECT ANSWER from the options below:

a) 10-20 grammes

b) 20-30 grammes

*c) 30-40 grammes

d) 40-50 grammes

2.3 During the fish health evaluation by external fish pathologists, required for authorisation of fish transfer from the nursery, which fish diseases are analysed.

Select AS MANY as you believe to be correct:

*a) Infectious Pancreatic Necrosis (IPN)

b) Enteric Red Mouth Disease (ERM)

*c) Infectious Salmon Anemia (ISA)

*d) Bacterial Kidney Disease (BKD)

2.4 For how long should the fish be starved for before their transfer from the nursery?

Select the CORRECT ANSWER from the options below:

a) A week

b) 3 days

c) 2 days

*d) 24 hours

2.5 What depth of water is required in the smolt tanks for the incoming parr?

Select the CORRECT ANSWER from the options below:

a) 3 metres

*b) 2 metres

c) 1 metre

d) 50 cm

2.6 What checks should be performed after the parr have been transferred to the smolt unit?

Select AS MANY as you believe to be correct:

*a) Test water quality in the smolt unit

*b) Observe fish distribution and swimming behaviour after 2-3 hours

c) Evaluate fish stress by monitoring blood cortisol after 2-3 hours

*d) Check the tank base for mortalities

2.7 How long after transfer are the fish first fed?

Select the CORRECT ANSWER from the options below:

a) 2 days

b) 1 day

c) 12 hours

*d) 2 hours

2.8 How long after transfer can the fish consume a normal full daily ration?

Select the CORRECT ANSWER from the options below:

a) 1 week

b) 50 hours

*c) 32 hours

d) 12 hours

2.9 What factors have enabled the production time scale from first feeding to smolt to be reduced from one to two years to 6 months?

Select AS MANY as you believe to be correct:

*a) Improved diet formulations incorporating highly digestible fish meals

*b) Genetic improvement of farmed stocks

*c) Photoperiod manipulation of smoltification

*d) Control and optimisation of water temperatures

2.10 What are the benefits of the smoltification process of to the salmon farmer?

Select the CORRECT ANSWER from the options below:

a) The salmon is less aggressive following smoltification

*b) The salmon can osmoregulate on transferring to a saline environment, reducing stress

*c) Growth hormones are released and accelerate the growth rate

d) Smoltification strengthens the salmon’s immune system

2.11 How long is the winter period within a typical photoperiod regime?

Select the CORRECT ANSWER from the options below:

a) 6 weeks

*b) 5 weeks

c) 4 weeks

d) 3 weeks

2.12 How many hours of darkness are there each day during a typical 5-week winter photoperiod?

Select the CORRECT ANSWER from the options below:

a) 16 hours

*b) 13 hours

c) 10 hours

d) 8 hours

2.13 How long is the summer lighting period within atypical photoperiod regime?

Select the CORRECT ANSWER from the options below:

*a) 6 weeks

b) 5 weeks

c) 4 weeks

d) 3 weeks

2.14 When during a typical photoperiod regime is biochemical evidence of smoltification gathered through ATPase testing?

Select the CORRECT ANSWER from the options below:

a) From week 3 onwards

*b) From week 4 onwards

c) From week 5 onwards

d) From week 6 onwards

2.15 When are behavioural changes observed as evidence of smoltification

Select the CORRECT ANSWER from the options below:

a) In the final week 9 only

b) From week 4 onwards

c) From week 6 onwards

*d) Throughout the entire period from week 1

2.16 How long does the change from light to dark and dark to light take each day during the winter period?

Select the CORRECT ANSWER from the options below:

*a) 1 – 2 hours

b) 30 minutes

c) 10 minutes

d) It is instantaneous

2.17 How often should fish appetite be checked in the smolt unit?

Select the CORRECT ANSWER from the options below:

a) Every hour

*b) Every 2 hours

c) Every 4 hours

d) Every 10 hours

2.18 How should staff respond to signs of aggression, such as damage to the operculum or fins?

Select AS MANY as you believe to be correct:

*a) Hand feeding in the intervals between automatic feeding

b) Increasing the water flow rate in the holding unit

c) Reducing the frequency of feed delivery

d) Reducing the stock density by grading out the larger fish

2.19 The appetite of the fish in the smolt unit increases as the summer phase progresses.

TRUE or **FALSE**

2.20 During the summer period within the photoperiod regime, when there is 24 hours of light, food is distributed throughout the 24-hour day.

TRUE or FALSE

2.21 Why are feeding events 'staggered' so as they occur at different times of the day, for different fish holding units?

Select the CORRECT ANSWER from the options below:

a) To avoid a dangerous peak requirement for dissolved oxygen

b) To spread the fish monitoring workload more evenly over the day

*c) To avoid over-loading the biofilters

d) To avoid overloading the digital light control system

2.22 When should the holding units be checked for mortalities during the winter phase?

Select the CORRECT ANSWER from the options below:

a) Every 2 hours during the 11 hours of light for each holding unit

b) Twice during the 11 hours of light for each holding unit

*c) During the first hour of light for each holding unit

d) Every 8 hours during a 24-hour period

2.23 Typically, how much of the daily ration is distributed by hand in the smolt unit to check appetite?

Select the CORRECT ANSWER from the options below:

a) None

b) 5%

*c) 10%

d) 20%

2.24 What methods are used to monitor smoltification?

Select AS MANY as you believe to be correct:

*a) Fish behaviour observations

*b) Fish feeding response (appetite)

*c) Observations of physical appearance

*d) Fish physiological status

2.25 What fish behaviour changes are indicative of smoltification?

Select AS MANY as you believe to be correct:

*a) Fish swimming in a downstream direction

b) Crowding the holding unit outlet screen

c) Jumping at the oncoming water supply

*d) Fish swimming chaotically in several different directions

2.26 The salmon lose appetite later into the summer phase as smoltification progresses

TRUE or FALSE

2.27 What changes in the salmon's physical appearance are associated with smolting?

Select AS MANY as you believe to be correct:

*a) The flanks of the body become more silver

b) The number of red spots increases

*c) The caudal (tail) fin develops a black edge

*d) The body elongates and becomes more streamlined

2.28 The salmon's skin becomes increasingly fragile from week 5 of the photoperiod regime and scales can be easily lost

TRUE or FALSE

2.29 There are several ways the salmon's physiological status can be evaluated to assess the degree of smoltification?

Select AS MANY as you believe to be correct:

*a) Hormone assays

*b) Genetic analysis of gill tissue

c) Measurement of cortisol levels

*d) Measurements of ATPase following a salt challenge

2.30 What is the method of physiological evaluation of smoltification adopted by most of the industry

Select the CORRECT ANSWER from the options below:

a) Hormone assays

b) Genetic analysis of gill tissue

c) Measurement of cortisol levels

*d) Measurements of ATPase following a salt challenge

2.31 When does the final smolt grade take place?

Select the CORRECT ANSWER from the options below:

*a) During the winter phase at the end of week 3

b) At the start of the summer phase in week 5

c) At the end of the summer phase in week 9

d) Two days before transfer to post smolt during week 10

2.32 How can the smolt unit manager respond if the fish have not reached the required ATPase levels to indicate smoltification is sufficiently advanced?

Select the CORRECT ANSWER from the options below:

*a) Transfer the entire population to the post smolt unit to complete smoltification

b) Grade out the larger fish using the automated grader for transfer

c) Grade out fish that have smolted for transfer, based on their appearance

d) Keep the fish in the smolt unit an additional week if there is space

2.33 The smolts are sample weighed 2 days before transfer to the smolt unit to establish the population size distribution.

TRUE or FALSE

2.34 The smolt population size distribution data is used to inform a grade during the first week post transfer.

TRUE or **FALSE**

Unit Title:	Fish health and welfare
Guided Learning hours:	**60**

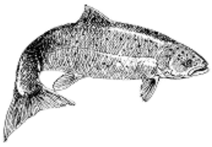
Unit level (EQF): 4

Introduction

The learning resources in this guide have been designed to support 'short episodes' of focussed learning' on a specific topic within Fish health and welfare following the Recognition of Prior Learning (RPL) using the multiple-choice question sets. Each episode has a title and number that relates it to a specific multiple-choice question or questions within the subject area.

The resources cover fish health and welfare with the emphasis on salmonids, welfare monitoring, disease diagnosis, prevention, and treatment. The aim is to provide experienced husbandry operatives with enough information, insight and understanding of fish health and welfare operations, so as they can operate within a salmonid production unit with a full understanding and in compliance with all company Standard Operating Procedures (SOPs).

FHW 1 Fish health and welfare



Fish welfare

The management of fish welfare is an important ethical consideration within fish farming. Research has indicated that fish are sentient animals that can experience fear and feel pain. The development of legislation and industry 'Codes of Good Practice' reflect societies expectation that farmed fish should have the same consideration as terrestrial livestock.

Fish farmers are obligated to review their farm practices and procedures impacting on fish health and welfare from egg to harvest and to mitigate, whenever fish welfare could be compromised.

The 'Five Freedoms' devised by the Farm Animal Welfare Council was first formulated in the early 1990s and are now reflected within many Aquaculture Codes of Good Practice.

What are the five freedoms?

The five freedoms are succinctly defined.

- Freedom from hunger
- Freedom from discomfort
- Freedom from pain, injury, or disease
- Freedom to express normal behaviour
- Freedom from fear and distress

Freedom from hunger, discomfort and injury are the easiest to interpret and remediate.

However, freedom from 'fear and distress' is more difficult, as this parameter can be subjective and difficult to observe in fish compared to other animals. Fish stress can be more easily observed by the farmer and measured biochemically.

Recently harvested salmon

Are consumers concerned about farmed salmon welfare?

Consumer buying behaviours are increasingly influenced by animal welfare perceptions, making welfare of central importance to the marketing of aquaculture products.

Poor fish welfare can also lead to lower flesh quality at harvest, providing an additional commercial 'consumer driven' incentive to maintaining the highest welfare standards.

There are many more fish welfare considerations than simply ensuring fish are humanely killed at harvest.

How can fish farmers ensure their stocks have the 'freedom to express normal behaviour'?

Due to considerable differences in the biology and behaviour of different fish species 'normal behaviour' can be easily misjudged.

Artic char held at high density

For example, the Atlantic salmon during its early freshwater phase exhibits territorial behaviour, but during the marine feeding phase it is a shoaling species.

Cage farms on-growing salmon provide high welfare conditions by limiting stock densities to 10Kg/M3.

In contrast to Atlantic salmon during grow out, if Arctic char were farmed at these low densities, they would become territorial. This would result in agitation, aggression, and stress. In the wild they live and feed together in densely packed shoals.

Therefore, to reduce stress the char farmer needs to maintain high densities and 50Kg/M3 is a comfortable norm.

What does the term stress mean when applied to farmed fish?

Stress is a term used to describe many situations and responses experienced by humans and animals and is often defined as a 'mental, emotional, or physical strain or tension'. It can result from a combination of chemical and physical factors that cause a physiological reaction and compromise an animal's natural defence against disease.

There are two types of stress that the salmon farmer should be aware of:

- Acute stress - short-term cause, although effects can have longer term implications.
- Chronic stress- long term cause and accompanying effects. The longer the duration of exposure to the stressor, the greater the risk of deteriorating health.

Stress in fish has a major influence on their susceptibility to pathogens and transmissible disease, as it weakens their immune system.

What happens to the salmon physiologically when stressed?

Fish, like all animals, will elicit a response known as 'fight or flight', and release stress induced hormones in preparation to react to a threat. A series of physiological reactions lead to energy being supplied to the muscles in readiness for 'explosive exertion'.

This includes:

- Release of cortisol
- Increased heart rate
- Increased blood pressure

These physiological changes are normal, as stress is linked to survival, enabling the fish to react to and evade life-threatening dangers.

In aquaculture, poor husbandry and poor stock management practices tend to be the more common stressors than the 'fight and flight response'. They are detrimental and need to be recognised and addressed as common causes of chronic stress.

Water sample to monitor water quality

What stressors are typical for farmed fish?

In any aquaculture production environment fish stocks can be exposed to a range of stressors at various stages of the production cycle.

- Water temperature fluctuations beyond the fish's acclimation capability.
- Water quality deterioration, such as decreased oxygen levels, pH fluxes, increases in dissolved toxic nitrogenous wastes and other chemicals, beyond the species tolerance limits.
- Fish handling increases the stress responses if the fish are out of the water for too long or overcrowded in nets.
- Grading can involve fish removal from the water with the potential for physical damage.
- Predator presence, activity and/or damage from predators
- Poor husbandry and hygiene practices.
- Group social interactions – aggressive fin/tail nipping due to overcrowding or underfeeding.
- Harvesting - inappropriate slaughter method and extended overcrowding.

How does stress normally first become apparent?

Stress can result in appetite suppression and decreased growth rate, followed by a deterioration in the fishes' immune response. This increases the risk of pathogen invasion and disease and increased mortality if not addressed.

What are the specific signs of stress in farmed Atlantic salmon?

The recognition of the early signs of stress is one of the most important husbandry skills. It is the essence of good stockman ship. This can be challenging, as the initial responses of fish to the stressors may be internalised and physiological.

The first visual indications to the husbandry staff that fish are stressed will normally be physical and behavioural signs, including:

- Hyper-activity
- Increased respiration rate (rapid operculum movement)
- Fish rolling at the surface
- Reduced appetite
- Poor growth

Reduced appetite and gill damage are the two key initial stress indicators during the fry to smolt stage.

How can stress be minimised on a salmon farm?

Some of the main practices that can reduce stress and improve welfare standards when adopted on the farm, include:

- Maintaining stocking densities at an acceptable level and never allowing the holding unit maximums to be exceeded.
- Water quality optimisation (including water temperature and dissolved oxygen levels). Water quality monitoring an important daily routine, therefore.
- Keeping fish stock biomass and densities within acceptable limits.
- Careful fish movement and handling, eliminating or minimising time out of the water.
- Starvation before any fish handling operation.
- Feeding a nutritionally balanced at a rate that is suitable for the species and life stage.
- Serviceable equipment and well-maintained holding units free from abrasive surfaces.

A relatively high stock density of healthy parr

How can a salmon farmer monitor their fish welfare standards?

Animals, including fish, are assumed to be experiencing good welfare when their welfare needs are fulfilled. Some of these needs go further than the relatively simple avoidance of stress.

Welfare indicators can be devised that link to specific welfare needs to provide early warning signs that the fish may become stressed and then more vulnerable to disease and other health issues,

The Atlantic salmon's welfare priorities change at each stage of its lifecycle.

They include:

- Ultimate needs (or basic needs) necessary for immediate survival and good health. Respiration and nutrition are examples.
- Proximate needs (or behavioural needs) necessary for long term success (including social contact)

Which welfare indicators are in common use by the salmon farming industry?

Welfare indicators (Wis) should be selected with care to reflect the husbandry routines and operations that apply during each phase of production. Most are based on are observations or measurements that provide information about the extent to which the animal's welfare needs are being met. They include:

- Observations of fish behaviour.
- observations of the environment, including farm infrastructure, and processes.

How are these indicators categorised?

Operational Welfare Indicators (OWI) are of practical use and can be readily applied on a farm.

The nature of farm operations from hatchery onwards determines the selection of OWIs

Whereas Laboratory based Welfare Indicators (LABWI) require access to a laboratory or other analytical facility. The range of indicators chosen should be those most relevant to the farm operations and integral to the farm's Fish Health Plan (FHP).

The OWIs and LABWIs have been developed for the salmon farming industry through scientific research. Their general suitability for aquaculture has been evaluated, including their relevance, practicability, and reliability.

Is salmon farming welfare quality assured?

Many companies enter a selected welfare standards assurance scheme which is audited, to prove their welfare commitment to their consumers. In general, standards are based on a combination of scientific, veterinary, and practical aquaculture experience. Numerous animal based Wis and indirect environment Wis are utilised.

There are five well established standards that promote more welfare friendly aquaculture. They all adopt and similar welfare principals. However, there are some significant differences in emphasis.

- Royal Society for Prevention of Cruelty to Animals (RSPCA)

Welfare standard for farmed Atlantic salmon.

"A comprehensive species and life stage specific welfare requirement covering all aspects of salmon production".

- World organisation for Animal Health

Aquatic Animal Health Code

"Primarily designed to ensure safety from infectious agents in international trade in aquatic animals. Also provides some general guiding principles on welfare."

- GLOBALG.A.P.

GLOBAL G.A.P Aquaculture standard

"Provides extensive checklists for ensuring that measures for maintaining fish welfare are in place. Fish farms must be inspected to be awarded the standard".

- Aquaculture Stewardship Council

Standard for

“Primarily aimed at limiting environmental impacts, but also has some criteria related to fish welfare. It demands regular visits from a designated veterinarian, health management plans, disease monitoring and limits for mortality”.

- Global Aquaculture Alliance

Guidelines for salmon farms

“Predominantly focuses on environmental responsibility, but also covers fish welfare. Provides a list of behavioural indicators, colour changes and morphological abnormalities that can be used to identify and mitigate against potential welfare problems”.

What determines whether an Atlantic salmon’s welfare needs have been satisfied?

When fulfilling these needs the salmon is rewarded by the release of opioids. This gives pleasurable feelings, to reenforce their positive actions. Conversely when their state of needs worsens, neurotransmitters are released to deliver unpleasant emotions.

The balance between positive reinforcement and negative emotions is what determines the salmon’s current welfare status.

1. Farmed Atlantic Salmon welfare needs.

Regardless of the specifics of each welfare standard, the farmed salmon’s welfare needs can be categorised as environmental, biosecurity, rearing operations.

1.1 Environment

Flaws in the design and construction of farm facilities and faulty operations must be avoided. They present a fish welfare risk as water quality can be adversely affected, particualrly in RAS production.

What are the important aspects of welfare for RAS producers?

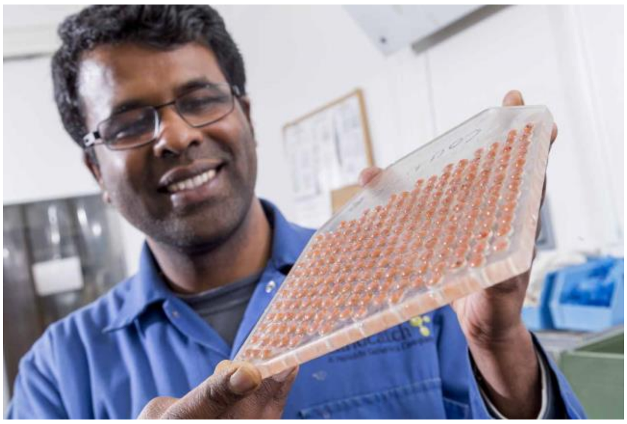
There are several:

1. Biofilter monitoring activity is essential as disruption of the nitrification process can lead to dangerously high concentrations of nitrogenous wastes (ammonia and nitrite nitrogen)
2. Production plans must be realistic and take account of the maximum feed loads that the system was designed for.
3. Optimal water quality must be provided to avoid long term chronic exposure to chemicals that can have clinical and sub-clinical effects and increase disease susceptibility.

Adequate monitoring of the RAS environment, well established routines, alarm systems and back up systems for emergency and well-trained staff reduce the negative welfare effects.

1.2 Biosecurity

Good biosecurity is a prerequisite for successful salmon farm operation. This is particularly important to RAS producers when incoming eggs and make up water are the main source of pathogens.



Incoming eggs must be certified disease free

In RAS, disease eradication is particularly difficult due to the potential impact any remedy may have on the biofilter.

Heath management often includes the seperation of different life stages, an 'all in all out' batch production and disinfection procedures.

Which pathogens have been commonly found in RAS?

Some of the pathogens that have been commonly found in RAS include the parasite Ichthyobodo sp. (Costia), fungus (Yersinia) and Infectious Pancreatic Necrosis (IPN).

1.3 Rearing operations

Many fish farming operation involve fish crowding, capture and/or handling. Although these are unavoidable activities on any commecial farm, they do represent a fish welfare risk. Measures must be taken to mitigate the impact.

Smolt vaccination is potentially stressful and must be conducted with attention to welfare at every stage

What effect do fish handling practices have on salmon welfare?

Fish handling sensitivity can be fish size dependent. Some research indicates that 450 g post smolts are more sensitive to handling and seawater transfer than 250g and 800 g post-smolts.

Large fish handling must be carefully planned, and sedation products containing PVP and EDTA used if the fish are to be netted.

2. Welfare assessment

Most animal welfare protocols use a combination of environment and animal Wis.

The environment Wis are addressed through water quality monitoring and management procedures on farm.

The animal WIs selected must be appropriate for detecting relevant welfare issues and affordable and practical to use.

Both are operational welfare indicators (OWIs) and can be defined as follows:

- Group Wis

The level of welfare within the population is scored, based on a set of indicators derived from data routinely gathered for a range of purposes.

- Individual Wis

The welfare of individual fish is scored, based on a set of welfare indicators that describe their appearance

2.1 Behaviour

Deviations in behaviour can be an early sign of sub optimal conditions. Since the advent of camera technology observations of cage farm salmon can be easilly made in clear water conditions most of the time.

These parr are difficult to view in turbid water even when swimming near the surface

However, the observation of fish in land based tanks can be more problematic. This is particularly true of RAS production where the land based rearing tanks are large, with fish held at high density and the water can be turbid. This restricts the effectiveness of camera-based monitoring.

Consequently, fish observations may only be possible at water surface. Alternatively, recently developed acoustic telemetry technology is showing potential for real time monitoring of swimming activity.

What are the behavioural warning signs of welfare issues?

Normal behaviour should be well understood and recognised by all husbandry staff. This makes it easier for them to recognise the more subtle abnormal behaviours.

Behavioural warning signs:

- Altered swimming due to sub optimal velocity (all salmon)
- Aggression and biting (salmon parr)
- Number of fish with dorsal fin damage (salmon parr)

Abrupt changes in the number of fish in a population with grey thickened dorsal fins is easily observed. Noting the number of fish that have dorsal fin damage is a ‘proxy’ for monitoring aggression in salmon parr. It can be done by eye and is less labour intensive.

Underfeeding will intensify aggression and is often the solution to fin damage issues in parr.There are other potential causes of dorsal fin damage, including fish handling and water flow.

2.2 Health

There is a progression of health related WIs, starting with those that provide early warning OWIs, followed by routine health monitoring and culminating in mortality removal and classification.

An emaciated salmon parr that eventually sucumbed to fungal disease

1. Emaciated fish

Often found isolated at the group's margins, near the surface and moribund. They are most common during the end of the freshwater and early sea water stages.

These fish should be graded out as culls, before reaching this weakened state, as they are experiencing very low welfare and acting as disease vectors.

Their occurrence should be monitored as they are a very early warning OWI.

2. Disease diagnosis

This is regularly and routinely monitored by fish health personnel. The prevalence of certain conditions in the population and the potential causes of mortality and morbidity should be determined.

Definitive diagnosis often involves tissue sampling and off-site analysis and is therefore classed as a LABWI.

Tissue sampling in the farm laboratory

However, some of the external signs of disease conditions posing a welfare risk can be diagnosed on farm, and a disease outbreak responded to more quickly.

Salmon diseases and their diagnosis are covered in other episodes within this unit.

3. Mortality

Mortalities are recorded daily on all farms. Each holding unit must have an efficient system for mortality collection. In sea cages the process of mortality capture and removal rarely presents any practical problems, so long as bad weather does not prohibit cage access. The inability to see the tank base in large land-based RAS tanks can make mortality removal challenging.


Packaged samples to be sent to the pathology laboratory.

Most companies have a mortality classification system. Any mortalities that cannot be classified and those suspected to have died from an infectious disease are sent to the pathology lab for analysis.

2.3 Fish feeding and growth

Accurate monitoring of fish appetite, growth and food conversion rations are standard practives on all salmon farms. This information in all very informative regarding fish welfare.

2.3.1 Appetite

Appetite can be an early warning sign for many welfare issues. Appetite monitoring is constant during the freshwater stage when feeding fry, parr and fish undergoing smoltification. The vigour of feeding response is typically monitored and evaluated by husbandry staff with reference to company standards. The aim to make the judgement of 'feeding vigour' less subjective.

What problems can arise due to reduced appetite?

Reduced appetite can lead to feed wastage overload and disrupted biofilter nitrification if the 'feed input' is not adjusted. Feed management optimisation should take full account of fish production performance, water quality and welfare considerations.

2.3.2 Growth

Growth can be affected by several factors, such as nutrition, diseases, social interactions, water quality and chronic stress.


Weight Sampling fry is a regular routine

The growth of Atlantic salmon parr and smolt in RAS can match flow through systems.

The growth rates of each stock can be calculated:

- Specific growth rate (SGR), or,
- Thermal growth coefficient.

The assessment of growth depends on accurately stock record keeping and representative sampling. Acute changes in growth rate provide an effective early warning system of potential problems.

2.4 Morphological indicators

A range of Individual based OWIs rely on morphological indicators and should be followed throughout the production cycle.

Pre-smolt parr

Articulate interactive - Explore the external features used as OWIs by exploring the pre-smolt. Whenever a part of the fish has been outlined, click for information.

Morphological indicators can be assessed through inspection with the naked eye. Simple scoring systems have been devised on a 1-3 scale to standardise evaluation by staff.

2.4.1Scale loss and condition

The presence, severity and frequency of scale loss and epidermal damage and wounds should be monitored regularly, especially as the fish approach smolt transfer.

2.4.2Eye status

Eyes are very vulnerable to mechanical trauma, leading to haemorrhages or desiccation during handling.

Exophthalmus ("pop eye") is often a non-specific sign of disease, while cataract or loss of transparency of the eye lens can be caused by number of factors. It is more frequent in later life stages, such as smolts and post-smolts.

2.4.3 Mouth/jaw wounds

Wounds can be caused by handling (crowding, pumping, netting) or from contact between the fish and the tank walls.

2.4.4 Vertebral deformities

Vertebral deformities may be due to malnutrition or temperature amongst other factors.

2.4.5 Opercular damage and gill status

Opercular damage includes, shortening, lack of opercula, warped opercula, and "soft" opercula. It is particularly applicable to early life stages in freshwater phase and can be caused by suboptimal rearing conditions and dietary deficiency.

Gill bleaching and gill status should also be monitored in relation to turbidity and TSS.

2.4.6 Fin damage

The effects of fin damage upon welfare are both fin- and life stage specific. When a salmon parr loses a pectoral fin, it can reduce their ability to hold station in the flow.

Relevance to salmon husbandry:

- Observant husbandry staff should be monitoring welfare constantly and intuitively. Any changes in behaviour, including appetite and growth, can be a sign that welfare has been compromised.

- Welfare monitoring systemises the process of fish behavioural and morphological observation and reduces the subjectivity.

- Welfare monitoring normally precedes disease diagnosis and can lead to a more focussed investigation of fish diseases in any stocks where welfare has been compromised.

There is a distinct relationship between biting and dorsal fin damage in parr. In smolts and post smolts, active fin damage can subject the fish to osmotic stress.

2.4.7 Smoltification state
Morphological changes related to smoltification can be scored according to existing operational scoring schemes

Staff should be aware that smolts tend to swim higher in the water column than parr and a small subsample of individuals taken from the upper part of water column to test smoltification status could underestimate the presence of individuals that are not completely smoltified.

2.5 Scoring welfare
An amalgamation of the injury scoring schemes used in the Salmon Welfare Index Model (SWIM) has been produced. This provides a unified scoring system for 14 different indicators

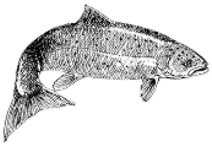
Key points:

- Salmon farm operations inevitably cause some degree of stress, but the selection of equipment and critical evaluation of practices to minimise handling can create a high welfare farm environment.
- Routine behavioural observations and farm performance monitoring data on appetite and growth, can inform key welfare monitoring parameters.
- A combination of Individual and group indicators are essential to any farm welfare monitoring system.
- Schemes have been developed by scientists to introduce consistency to the use of a range of morphological indicators and scoring systems.

The system has the following features:

- Dorsal, caudal and pectoral fins are the primary fins to monitor for fin damage.
- The Speilberg scale can be used for intra-abdominal legions
- Morphological schemes have been developed for diagnosing and classifying eye cataracts in Atlantic salmon
- Morphological schemes have been developed for diagnosing and classifying key external injuries

FHW 2 Fish health and welfare



Biosecurity

There has been a growing awareness within aquaculture globally of the importance of biosecurity in preventing infectious fish diseases. All fish farms need to define the range of preventitive actions and interventions within their 'Fish Health Plans' (FHPs) for combating the diseases most likely to threaten their farming operation.

Preventitive measures are particulalrly important when dealing with untreatable viral diseases, such as Infectious Pancreatic Necrosis (IPN), which is a common cause of mortality on salmon farms.

1. Biosecurity principles

How easily a specific pathogen can enter an aquaculture facility, spread from one fish rearing system to another and cause disease outbreaks, depends on the robustness of biosecurity policies, their implementation and the level of compliance achieved.

Effective aquaculture biosecurity has several aspects to consider.

1.1 Fish Stocks

Healthy stocks must be carefully sourced and their health and immunity optimised. Like all animals, if salmon are stressed, their immune system is compromised and they become more suseptible to disease. The best farms carefully evaluate their fish handling procedures, stock densities and the quality of the rearing environment for all stages of fish production, and make improvements where required.

Alevins hatched from disease free eggs

Welfare monitoring and scoring systems support the optimisation process which is influenced by:

- The water quality within the aquatic rearing environments.
- The life stage and condition of the fish stocks.
- The immune status and disease susceptibility of the species and genetic strain farmed.
- The husbandry practices fish stocks are subjected to throughout the production cycle

1.2 Pathogens

There must be strict barriers to pathogen entry and emergency measures for reducing or eliminating pathogens from spreading if they do manage to enter.

This is influenced by:

- The pathogen's behaviour and characteristics, including biology, life cycle, and vulnerability to chemicals.
- The pathogen's ability to survive on inanimate objects (equipment) and within the RAS infrastructure.
- Regulatory status, reporting obligations and legal treatment options for exotic and endemic diseases.

Within RAS production, as water is constantly recycled, pathogens can be provided 'safe harbour' within the RAS infrastructure, such as the sump and filters, which can act as 'reservoirs' for infection. In the event of a disease outbreak, the entire system must be cleansed, not just the fish holding units, as is often the case for 'water through flow' systems.

1.3 People

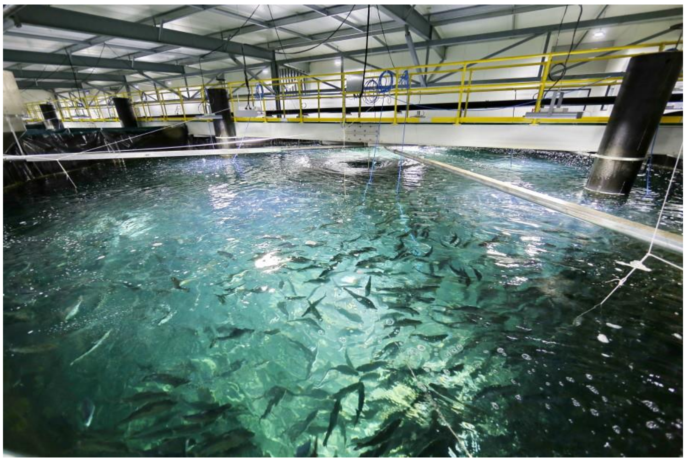
The risk posed by staff and visitors introducing and/or spread pathogens is influenced by their;

- understanding of biosecurity principles and company policies,
- compliance with company biosecurity protocols, and
- use of company boots, clothing and Personal Protective Equipment (PPE).

What additional biosecurity challenges do RAS producers face?

RAS production has some potential advantages and disadvantages regarding biosecurity, as compared with 'conventional' salmon farming (through flow and cage systems).

Advantages:



RAS salmon farm

- All stages of production can be controled and contained within the farm facility, with the exception of egg production.
- The transfer of pathogens from wild or other farmed stocks is impossible.
- The fish are held and reared in a controled aquatic environment, from egg receipt through to harvest, optimising conditions to reduce stress.

Disadvantages:

- High degree of dependency on the egg supplier's biosecurity practices.
- Fish stock densities are very high compared with conventional salmon farming, which could lead to increased stress and disease vulbnerability,
- The RAS could harbour pathogens that are hard to eradicate, once they have entered.

- A high dependency on water quality optimisation and monitoring to enable rapid remediation in the event of equipment failure.

2. Pathogen barriers

A full biosecurity 'risk analysis' of all aspects of production should be conducted. This includes movements of people, livestock and resources 'on and off site', anticipating all possible pathways for pathogen entry and transfer.

2.1 Geograpic zones and policies

It helps to 'zone' the site to provide a framework for specific biosecurity policies and the development of facilities.

Farm site boundary and signage

- Boundary

A facility which is geographically isolated from surrounding properties provides the first level of protection from pathoges. A defined property boundary and perimeter fence provides a physical barrier to preventing unauthorized entry of people and associated fomites.

Good signage helps to manage the flow of people vehicles and goods in and out.

- Prevention zone

Any facilities within the boundary fence where a higher level of biosecurity needs to be maintained must be identified to provide protection against pathogen entry,

These may be buildings used for storage and maintenance, the farm office, rearing units and water plant, including the area around any wells and effluent disposal areas.
Typically disinfection points are required:

a) Staff and visitors
b) Vehicles and trucks
c) Machinery and equipment

- Exclusion zone

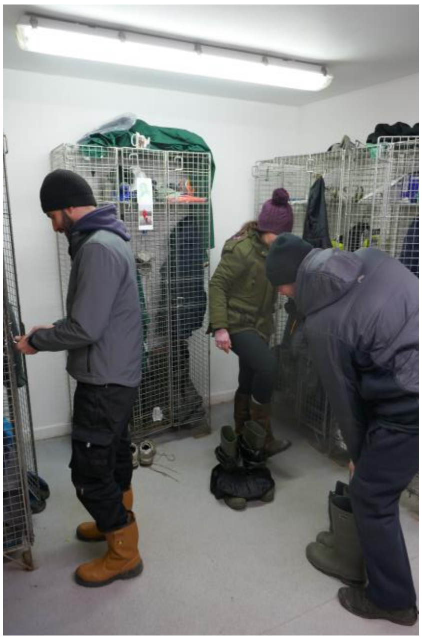
All fish rearing units and their water sources, including water plant and associated wells require a higher level of biosecurity. This is to ensure the complete exclusion of pathogens and these areas are subject to the following protocols:

- Staff are designated to specified work areas to restrict their movements
- Exclusive materials and equipment can not be moved from their allocated work area
- A unidirectional flow of staff, visitors and fish is prescribed
- The flow of fish feed and fish mortalities is defined and must be followed.

3. The management of people

The movement of staff, vistors, vehicles and resources within each farm facility should be controlled carefully. Staff and vistors can not access farms for at least 48 hours following their departure from any other farm they have visIted.

Everyone entering the production areas from outside the facility must follow company bio-security protocols at all times.



Changing into work clothing

3.1 Staff

Typically, staff must use the clothing and PPE resources supplied by the company to ensure they can not bring in or transfer pathogens.

- Staff can only enter their area of work by an assigned route and must normally remain there for the entire shift, except when taking a toilet break.
- Staff are often required to wear fresh set of personal clothes before arriving at the farm.
- Personal footwear is not permitted in any fish rearing areas.
- Staff have dedicated changing room in which they must change, putting on the company issue boots, clothing, and Personal Protective Equipment (PPE) appropriate to their role.
- Staff must sanitise their hands using the changing room hand wash and disinfect their boots in the foot bath before entry to their work area.
- Whenever leaving their work area staff must change out of coveralls/wet gear and footwear in the designated changing areas and sanitize their hands.
- Staff must follow the same procedures for re-entry to the work area during their shift as applied at arrival.

Can pathogens be transferred on personal clothing?

Sanitizing hands

There are a range of activities which risk transferring pathogens that could impact on fish health. This is why most companies insist on staff arriving in clean clothes and issue them the clothing they must wear appropriate to the work they will be doing.

The high risk activities include, but are not limited to:

- Water sports such as swimming or diving.
- Recreational or commercial fishing.
- Handling of fish or shellfish including pet fish.
- Handling birds, particularly waterfowl, including shooting and pet bird handling.
- Working in or having any contact with surface water (rivers and lakes)


Boot dip

- Visiting another farm, both terrestrial or aquatic.

3.2 Company boots, clothing, and PPE

Typically, staff all work clothing, footwear, and Personal Protective Equipment (PPE) appropriate to their area of work by the company.

Explore each of these items to see what they are used for.

- Dedicated boots

Boots provided by the company are waterproof and must be disinfected in the foot bath before entry to the work area

- Coveralls

Coveralls are worn in most work situations without any additional protection or biosecurity barriers.

- Wet gear

Wet gear must be worn over coveralls whenever conducting any fish handling exercise or removing mortalities. They are disinfected immediately after use.


Staff PPE for chemical handling

- Nitrile gloves

Nitrile gloves are worn to protect the hands during egg handling operations

- Disposable booties

Disposable booties are worn by visitors over the top of their personal footwear, but rarely worn by staff

- Aprons

Aprons are worn in the laboratory over coveralls, whenever handling or analysing fish samples.

- Safety goggles

Safety goggles are worn whenever handling, mixing, or applying chemicals.

- Full face respirator

A respirator is worn whenever chemicals are used that emit fumes or when handling chemicals in the form of a fine powder that can endanger human health.

3.3 Company dress policy

Staff must dress appropriately for their days work from a biosecurity and personal health and safety perspective.

Salmon farming company dress policy example

Role	Hatchery technician	Egg receipt	Laboratory (Fish work)	Smolt unit husbandry.	Fish handling task	Sea cage husbandry
Dedicated boots	✓	✓	✓	✓		✓
Coveralls	✓	✓	✓	✓		
Wet gear					✓	✓
Nitrile gloves		✓				
Aprons			✓			
Life jacket						✓

Dress Dag

Dag is getting ready for his day's work and has an unusually diverse range of tasks to attend to in one day.

Select each of these work areas in turn, to see what he needs to wear in each. samples

- Grow out
- Hatchery mortality removal
- Hatchery
- Egg receipt
- Lab fish pathology
- Cage site husbandry

Articulate interactive – Learning activity to follow reading dress policy table above. This could be a drag and drop activity, by putting images of the clothing and PPE on to an image of Nick.

Can staff ever move to another work area?

Whenever moving between units or work rooms and areas, clothes must be changed accordingly and undergo cleaning and disinfection.

The boots and clothing allocated to each work area can be made identifiable by their colour, so as the facility manager can be sure staff have changed when they should.

Whenever staff must move to another work area during their shift, normally, they should only move unidirectionally - hatchery to nursery to smolt production to grow out to harvest purge.

However, in exceptional circumstances, staff conduct activities in multiple buildings in a single day and are permitted to move against the flow. When this occurs, they must change clothing each time they enter a new work area.

3.3. Visitors

All visits must be pre-approved by the facility manager and follow the same biosecurity protocols as the staff. Entry by officials for inspection purposes are subject to company biosecurity policies, and must always be authorised. If an official has to take a sample of fish, a member of staff will assist them.

Coveralls for visitors

Visitors must not place their hands on or into any of the fish holding units, or handle fish feed and equipment and they must travel within the facility in the same direction as the fish flow.

3.4 Managing external visitors and goods arrival.

Company vehicles are cleaned and disinfected routinely every week. Whenever heavily soiled, company vehicles must be cleaned immediately and the activity recorded.

Staff and visitor's vehicles do not need to be disinfected to enter the perimiter fence.

Any vehicles entering the 'prevention zone' must have pre-approval from the facility manager. This includes all feed, oxygen and chemical delivery and mortality extraction vehicles as well as any staff driving their own vehicle.

All vehicles must be cleaned and disinfected.

In the exclusion zone, all company vehicles, such as fork-lifts should never exit the building, unless required for maintenance purposes.

3.5 Receipt of goods

Goods coming into the fish rearing areas pose a risk to fish health. Feed, vehicle fuel, gas, and chemical deliveries, are the main supplies which enter a salmon farm facility in containers or bags.

The loading floor area is coated disinfectant prior to offloading any goods.

Organic film

All goods are disinfected before entry into the facility by spraying with alcohol or virkon, including all chemical containers.

Feed is delivered on pallets wrapped in several layers of plastic. This is disposed of outside of the facility and only the bags of feed are permitted to enter the fish rearing areas, once disinfected.

4. Cleaning

Many surfaces in a land based salmon farming facility are in contact with water and can become contaminated with organic wastes, particularly fish faeces, and the growth of microorganisms forms an organic film. A wide range of equipment and chemicals are applied to routine cleaning operations within each type of farm facility, to achieve the highest standards of biosecurity.

Chemical storage (liquid)

Some organic wastes must be removed by physical cleaning alone. However, for those surfaces not in direct contact with the aquatic rearing environment, chemicals are used according to company policy.

4.1 Cleaning and disinfection policy

The salmon farming company should identify all surfaces, equipment and tools that require cleaning. How every item is to be cleaned, including the method, frequency, chemical (when used) and dose rate should be described precisely within Standard Operating Procedures (SOPs)

A wide range of equipment is used for cleaning waste food and organic residues.

A range of chemicals are used at the concentrations as recommended by the manufacturer to kill pathogens on those surfaces not in contact with the fish. The appropriate Personal Protective Equipment (PPE) must be worn for handling and applying chemical cleaning products.

4.2 Cleaning surfaces

Tank, and settler walls, screens, and components of automatic feeding systems, all provide a perfect substrate for fouling. Therefore, all surfaces must be regularly cleaned, to preserve their structural fabric and maintain general hygiene standards.

Image – Pressure washer floor cleaning

Some surfaces must be cleaned daily, as they are either integral to the fish rearing system or in proximity to the fish. This includes the feeders, any filtration equipment and piping.

Chemicals must all be held in labelled containers sitting in a large tray in a chemical store. Its volume must be greater greater than the total volume of the chemical containers held.

A pressure washer is used when a more vigorous deep cleaning action is required, such as RAS facility walls and floors. Teamed up with a foaming gun and spray bottles, foam-based disinfectants can be applied to surfaces.

4.3 Cleaning floors and work surfaces

The work environment must be cleaned and disinfected regularly, using either bleach or alcohol, to maintain fish health.

This includes:

- Floors that live or dead fish can contact and which must be disinfected with a bleach solution immediately after the activity, and
- laboratory work tops which are disinfected with bleach or alcohol and cleaned daily.

Now watch this-

Instructional video

Cleaning floors and work surfaces

4.4 Cleaning RAS components

In a recirculation system, water is in contact with all surfaces, including the fish holding units, pipes, and filters where micro-organisms can become established.

Now watch this-

Instructional video

Cleaning surfaces

All components must be cleaned using sodium hydroxide after any contagious disease outbreak, including the biofilter, as it can harbour pathogens.

Chemicals are applied at the dose rates recommended by the manufacture.

Relevance to salmon husbandry:

- The consistent implementation of well-designed biosecurity policies provides the foundation to fish health and welfare management for at all stages of production.
- The management of people is necessary to stop the unintentional introduction and spread of fish pathogens.
- Staff must wear appropriate clothing and PPE for the job that they are undertaking and always comply with and promote biosecurity.
- The farm infrastructure (walls, floors and holding units) must be cleansed by pressure washing to deter the build-up of biofilm which can harbour pathogens.
- Equipment is disinfected after use and mortality buckets and hand nets specific to each holding unit.

Key points

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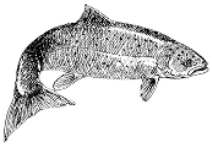


Transmissible diseases

Infectious diseases are attributed to a range of pathogenic organisms. The term pathogen is the collective name for those micro-organisms causing infectious disease, which are fungi, viruses, and bacteria and some parasites.

The way fish are farmed and the environmental conditions in which they are held, plays a major part in both the cause and prevention of transmissible diseases.

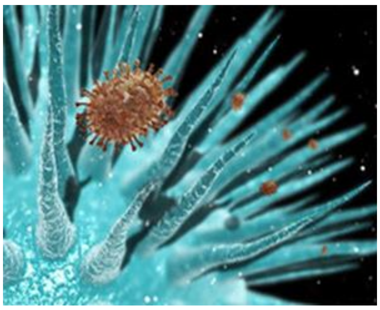
1. Viral diseases of Atlantic salmon

A virus is a small infectious agent, 10 to 100 times smaller than bacteria. They can only replicate inside the living cells of their host to fulfil their life cycle. They rely on their host's cellular mechanisms for survival as 'obligate pathogens', which makes viral diseases the most difficult to treat.

Viruses can be spread vertically from parents to offspring (which is why egg suppliers must be chosen with care) as well as horizontally from fish to fish within the same population.

The virus's structure is composed of a nucleic acid core (either DNA or RNA) surrounded by a protein coat. The central core of the nucleic acid is called the genome, and the surrounding protein coat the capsid, which can form an elaborate and complex structure. It is resilient enough to survive outside of the host for several days.

Image- Virus external structure



There are a few viral fish diseases that can infect farmed Atlantic salmon, in both the freshwater and marine environments.

1.1 General symptoms of a viral disease

The first stage of disease diagnosis is the observation of behavioural changes, which although non-specific, must not go unnoticed or unreported.

Infected fish may isolate themselves and show signs of nervousness. They may be seen swimming near the surface, or at the edges of the unit, showing external darkening and a poor feeding response. An increase in mortalities may follow.

1.2 Disease specific behavioural symptoms

Some behaviours are disease specific, such as the bursts of spiral swimming during periods of lethargy seen in salmon suffering from Infectious pancreatic necrosis (IPN).

Long periods of low-level mortality are a reliable indicator of Cardiomyopathy Syndrome (CMS).

In both examples the observation, recording and reporting of behaviours and mortalities by staff will determine how quickly samples can be sent to the lab for confirmation. They are vitally important early warning signs.

Image - Darkened skin symptom

1.3 Physical and pathological symptoms

Some disease symptoms are physical and visible to the naked eye. Others are internal and only evident from microscopic examination.

Some physiological symptoms, such as a ‘darkening of the skin’ are non-specific and shared by most of the viral and bacterial diseases that salmon can suffer from.

However, other symptoms are specific, such as the swollen endocardial cells in the heart of fish suffering from CMS but require microscopic examination by a fish pathologist to confirm.

2. Viral diseases of Atlantic salmon

Site specific disease risk assessments by external veterinary services are often used to identify the most significant in terms of the likelihood of infection.

2.1 Viral haemorrhagic septicaemia (VHS)

Historically, VHS was mostly associated with freshwater salmonids in western Europe and is still a major concern for many European fish farms. Consequently, it is being monitored by the European Community Reference Laboratory for Fish Diseases.

2.1.1 Transmission

VHS can be spread from fish to fish through water transfer, as well as through contaminated eggs. Survivors of the disease can become lifelong carriers of the virus, contaminating water with urine, sperm, and ovarian fluids.

2.1.2 Symptoms

Fish that become infected experience haemorrhaging of their internal organs, skin, and muscle. Some fish show no external symptoms, but others show signs of infection that include bulging eyes, bloated abdomens, bruised-looking reddish tints to the eyes, skin, gills, and fins.

Image – VHS symptoms

There may also be a nervous form of the disease where fish are constantly flashing and showing abnormal behaviour.

2.1.3 Gross pathology

VHSV is a haemorrhagic disease, meaning it causes bleeding. Internally, the virus can cause petechial haemorrhaging (tiny spots of blood) in internal muscle tissue, and petechial or severe haemorrhaging in internal organs and other tissues.

Internal haemorrhaging can be observed as red spots inside a dead fish, particularly around the kidney, spleen, and intestines, as well as the swim bladder, which would normally have a clear membrane. The liver may be pale, mottled with red hyperaemic areas, the kidney unusually red and swollen, as is the spleen and the digestive tract may be empty.

2.2 Infectious haematopoietic necrosis (IHN)

The Infectious hematopoietic necrosis virus (IHNV), is a negative-sense single-stranded, bullet-shaped RNA virus that infects salmonids.

2.2.1 Transmission

Clinically infected fish and covert carriers among cultured, feral, or wild fish are reservoirs of IHNV. Viruses are shed via urine, sexual fluids, and from external mucus, whereas kidney, spleen, and other internal organs are the sites where the virus is most abundant during overt infection. Insects, annelids, and crustaceans may act as viral vectors. The potential for epizootics is highest at 10 °C and the disease does not occur naturally above 15 °C. Some fish become covert carriers of the virus if they survive infection.

2.2.2 Symptoms

Clinical signs of infection with IHNV include abdominal distension, bulging of the eyes, skin darkening, abnormal behaviour, anaemia, and fading of the gills. Infected fish commonly haemorrhage in several areas - the mouth and behind the head, the pectoral fins, muscles near the anus, and (in fry) the yolk sac. Diseased fish weaken, eventually floating “belly-up” on the water surface. Mortality is remarkably high in young fish.

2.2.2 Gross pathology

Necrosis is common in the kidney and spleen, and sometimes in the liver.

2.3 Infectious pancreatic necrosis (IPN)

The IPNV mainly infect young salmon and trout that are less than 6 months old. Adult fish can carry the disease asymptomatically.

2.3.1 Transmission

IPNV can be transmitted in fresh and salt water, on equipment. It is a very resilient virus and can even survive in silage waste and in the gut of birds and mammals, allowing it to be transmitted in faeces.

2.3.2 Symptoms

A swollen abdomen or eyes, darkening of the skin, spiral swimming and faecal casts trailing from the vent characterised the disease.

2.3.3 Gross pathology

Internally there may be pancreatic necrosis, a catarrhal exudate in the intestine and haemorrhages in the visceral organs.

As an Aquabirnavirus its presence can be confirmed by isolation in tissue culture and identification by Enzyme Linked Immuno Sorbant Assay (ELISA), antibody neutralisation or Polymerase Chain Reaction (PCR)

2.3.4 Control

Movement of equipment from infected sites should be avoided, and mortalities and other wastes should be regarded as highly infectious.

IPNV may be vertically transmitted from parent to progeny. Consequently, it is recommended that any broodstock originating from infected farms should be tested for the virus at time of stripping, and eggs from infected parents should be destroyed.

2.4 Infectious salmon anaemia (ISA)

Affects Atlantic salmon farms in Canada, Norway, Scotland and Chile, often causing severe losses. ISA has been a notifiable disease within the World Organisation for Animal Health since 1990 and is classified as a non-exotic disease by the EU.

2.4.1 Transmission

The virus is spread by contact with infected fish or their secretions and can survive in seawater. A major risk factor for any uninfected farm is its proximity to an infected farm.

The sea louse (Lepeophtheirus salmonis) attacks the salmons protective mucus, scales and skin and can carry the virus passively on its surface and in its digestive tract.

Image- Pale gills

2.4.2 Symptoms

The fish can develop pale gills and swim close to the water surface, gulping for air. Alternatively, they may show no external signs of illness and maintain a normal appetite, until suddenly dying. The disease can progress slowly throughout an infected farm. In the worst cases, mortality may approach 100%.

2.4.3 Gross pathology

Post-mortem examination of the fish has shown a wide range of causes of death. The liver and spleen may be swollen, congested, or composed of partially dead tissue. The circulatory system may malfunction, and the blood become contaminated with dead blood cells. Many of the living red blood cells burst easily, and there are increased numbers of immature and damaged blood cells.

2.5 Cardiomyopathy Syndrome (CMS)

Cardiomyopathy syndrome (CMS), is a severe heart disease of Atlantic salmon was first reported in Norway in 1985 and since diagnosed in several countries, including Scotland, Ireland and the Faroes. It is causally linked to the Piscine Myocarditis Virus (PMCV), closely allied to the Totiviridae. The disease can have a major economic impact as it primarily affects large fish and therefore brood stock are also susceptible.

2.5.1 Transmission

The PMCV is presumed to transmit extracellularly and have extra protein-coding sequences that have been suggested to encompass all or some of their cell entry machineries. This is a feature not shared with the official Totiviridae members which transmit to new cells during cell division, sporogenesis or cell fusion.

2.5.2 Symptoms

Atlantic salmon will normally suffer CMS during their second year at sea but can succumb shortly after sea transfer. Typically, CMS occurs in the biggest, fastest-growing fish that never go off their feed. The disease may appear as an outbreak, with sudden mortality without prior clinical signs from fish that have stomachs full of pellets. Alternatively, it can have a chronic manifestation with prolonged moderately increased mortality.

2.5.3 Gross pathology

Gross lesions include exophthalmia and other changes expected with a failing heart, especially zonal hepatic pallor/congestion. Common internal signs are ascites and dark coloured liver with fibrinous casts.

The lesions of CMS start with swollen endocardial cells, an influx of inflammatory cells into the spongy myocardium layer. Necrosis can be so severe in the atrium that it can rupture leading to a blood-filled pericardial sac or even peritoneal cavity. The compact layer of the ventricle is largely unaffected.

It is important, therefore, to ensure that the fragile atrium is not lost at sampling during necropsy, or in subsequent processing.

2.6 Identifying viral diseases.

As symptoms may be shared by several viral diseases, whilst others are more specific, it is important to take account of all visible behavioural and external symptoms as well as internal symptoms, during diagnosis.

The symptoms of common viral diseases of Atlantic salmon are shown in the table below.

Symptom (Note: Y = yes evident, and S = sometimes evident)	VHS	IHN	IPN	ISA	CMS
Behavioural symptoms					
Lethargic fish showing bouts of frenzied activity			**Y**		
Low level mortalities over a prolonged period					**Y**
External and visible physical symptoms					
Protruding eyes (exophthalmia)	Y	Y			
Blood spots in the eyes				Y	
Darkening of the skin	Y	Y	Y		

Lethargic fish showing bouts of frenzied activity		**Y**			
Haemorrhage at the base of the fins		Y			
Gills appear pale and anaemic	Y	Y		Y	
Swollen abdomen		Y	Y		
Internal symptoms					
Severe anaemia				**Y**	
Swollen endocardial cells (heart)					**Y**
Myocardium loss of striations and necrosis (heart)					Y
Empty myocardial "tubes" filled with inflammatory cells (heart					Y
Infiltration of lymphocyte-like cells onto the pericardium					Y
Pancreatic necrosis			**Y**		
Fluid accumulation in the abdominal cavity (ascites)			Y		
Internal haemorrhages - liver, pancreas, pyloric caecae, swim bladder, lateral musculature surfaces			Y	Y	
Darkening of the Liver				Y	

2.7 Treating viral diseases.

Viruses in fish are the most difficult pathogen to control, and as a result many of them are listed as 'Notifiable Diseases'.

Vaccinating smolts

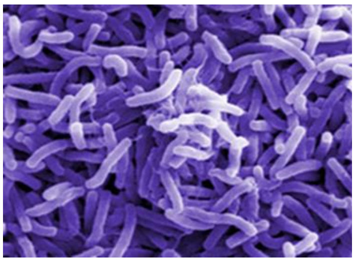
The most important way to control any disease pathogen including viral infections is by prevention and eradication. As some viruses can survive outside the host for considerable time periods, awaiting an opportunity to infect a host, this can be difficult.

There are vaccines available to the aquaculture industry that can prevent outbreaks of some viral diseases, such as IPN and ISA, but they are not available for all viral infections.

Prevention of viral infection is the key, achieved by following strict bio-security policies, quarantine of stocks, routine monitoring, and general good husbandry.

3. Bacterial diseases

Image – Rod shaped bacteria



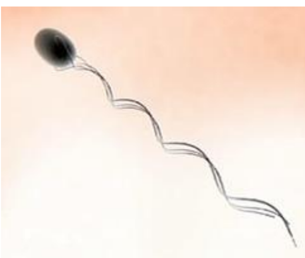
If an infection is caused by bacteria, there are often medications available as effective disease treatments. Bacteria are single celled organisms, but much larger than viruses, with some being 'opportunistic' whilst others are 'obligate' pathogens.

It is also important to note that some bacterial infections can be spread vertically (from parents to offspring) and horizontally (from fish to fish within the same population).

3.1 Bacteria structure

Bacteria are a type of cell surrounded by a cell membrane made primarily of phospholipids. This encloses the contents of the cell and acts as a barrier to enable nutrients, proteins, and other essential components of the cytoplasm to be held within the cell. They reproduce by asexual methods and unlike a virus, do not need a host to survive.

Image – Flagellate bacterium



Typically, a few micrometres in length, bacteria have several shapes, ranging from spheres to rods and spirals. Some have flagella and are motile whilst others are immobile. They are part of a large group of prokaryotic microorganisms.

3.2 Bacterial diseases of salmon

There are a few bacterial fish diseases that can infect farmed Atlantic salmon, in both the freshwater and marine environments. The gross external pathology of bacterial diseases is variable and ranges from a complete lack of clinical signs to visible external and internal symptoms.

3.2.1 Furunculosis

Aeromonas salmonicida is the causative agent of furunculosis and is very contagious to fish of all ages. It can lead to high mortality in salmonids, and some other fish species are also susceptible.

It occurs in freshwater and marine salmonid aquaculture in all countries except Australia and New Zealand. It is one of the most commercially significant salmonid diseases.

3.2.2 Transmission

Although typically occurring at temperatures above 10C, in very young fish outbreaks can occur at temperatures as low as 24C. Natural physiological changes (smoltification and spawning), and environmental factors (temperature fluctuations and poor water quality) are stress factors that commonly trigger the disease.

Horizontal transmission occurs within the aquatic environment and through direct fish-to-fish contact and animal vectors (birds and invertebrates such as sea lice).

Susceptibility to the disease increases with damaged mucous and skin, due to netting and handling. Fish surviving disease outbreaks can infect the remaining population without themselves showing any outward signs of infection

3.2.3 Symptoms

Fish may also show lethargic swimming or swimming just below the surface, loss of appetite, respiratory distress or jumping from the water.

Furunculosis develops very rapidly and causes high fish mortality, with death coming a matter of days after symptoms first appear. In addition, sudden death, accompanied by slight exophthalmos (popeye) can be observed.

Furunculosis gross pathology-furuncule

3.2.4 Gross pathology

Very visible boils, known as furuncles, involving skin and/or muscle, progress to ‘crater lesions’ and give the disease its name.

There are a multitude of other visible external signs, including, haemorrhages on the skin, mouth and fin bases, a darkening body colour, pale gills, bloody discharge from nares and/or vent and exophthalmos (popeye).

They are commonly accompanied by Internal haemorrhages in muscle and internal organs, enlarged spleen, liver necrosis and a stomach filled with mucus, blood, and sloughed epithelial cells.

Death without any clinical signs other than darkening of the skin can occur in juvenile salmon.

3.3 Enteric Redmouth (ERM)

Enteric redmouth disease (ERM) is most commonly a freshwater disease of salmonids, though seawater cases are occasionally reported and may be rising. The disease is caused by the pathogen Yersinia ruckeri, a gram-negative bacterium adapted to the gastrointestinal tract.

Image – ERM symptoms

It has become a major constraint to the expansion of salmonid culture worldwide, affecting both Atlantic salmon (Salmo salar) and rainbow trout (Onchorhynchus mykiss).

3.3.1 Transmission

Transmission of the disease is mainly by direct contact with infected fish. It is thought that asymptomatic fish may also carry the bacteria in the lower intestine leading to disease outbreaks when stressed. Infected fish directly shed bacteria through their faeces, which can survive several months in surface biofilms, leading to recurrent infections. Therefore, high standards of facility hygiene are essential to reducing the bacterial load.

3.3.2 Symptoms

The ERM symptoms are not specific. Typically, an increase in mortalities, is accompanied by fish swimming near the surface or at the sides of the unit, showing darkening and poor feeding response.

3.3.3 Gross pathology

The presence of vascular lesions around the mouth are classic signs of this disease, although these are uncommon. More frequently exophthalmos (pop-eye) with blood spots in the eye is found, accompanied by haemorrhagic congestion of fins, pale gills, and a distended vent.

3.4 Bacterial Kidney Disease (BKD)

Bacterial kidney disease (BKD) is a chronic condition, first identified in wild Atlantic salmon populations in the 1930s in the Scottish rivers the Spey and Dee. More recently, BKD has been reported in both wild and farmed salmonid populations in North and South America, continental Europe and Japan. The causative agent is a small, non-motile, Gram-positive rod-shaped bacterium 'Renibacterium salmoninarum' that usually occurs in pairs.

3.4.1 Transmission

Transmission can be vertical via eggs or sperm, or horizontal by direct contact with infected fish or water. The most effective method of control is prevention of live fish movements as there are no licensed vaccines or antibiotic treatments. Infected farms are placed under fish movement restrictions and must enter an eradication programme.

3.4.2 Symptoms

Outbreaks can occur throughout the year but tend to be triggered by rising water temperatures in the spring. Infection can result in significant mortalities in both wild and farmed salmonids, and nearly all age groups can be affected, although very young fish are rarely infected. Losses are generally chronic, occurring over an extended period.

Image - BKD gross pathology of kidney

3.4.3 Gross pathology

The gross external pathology of BKD is variable and ranges from a complete lack of clinical signs to fish exhibiting protruding eyes (exophthalmia), darkening of the skin and haemorrhage at the base of the fins. The gills may appear anaemic, and fluid may accumulate internally in the abdominal cavity.

The kidney may be enlarged, covered by an opaque membrane, and, in some fish, cream or grey nodules may be present. Similar nodules may be observed on the liver, spleen, and heart.

3.5 Vibriosis

Vibriosis is one of the most prevalent fish diseases and normally caused by Vibrio anguillarum in salmon. It is of major importance to salmonid fish culture industry and known as ‘Red pest’ of eels. It is a gram negative curved and rod-shaped bacterium with a single polar flagellum.

Image – Vibriosis internal haemorrhaging

In addition, Vibrio salmonicida, which mainly affects Alantic salmon and trout, causes cold water vibriosis and is generally confined to freshwater.

3.5.1 Transmission

Transmission in sea water can occur by direct contact and probably by contact with faecal casts. Disease outbreaks can be influenced by water quality and temperature, the strain and virulence of the Vibrio bacteria and the amount of stress imposed upon the fish. The osmotic stress of sea transfer can trigger an outbreak.

3.5.2 Symptoms

The symptoms of vibriosis are very similar to furunculosis, general haemorrhagic septicaemia, external lesions, haemorrhaging of the fins,

and bloody discharges from the vent.

3.5.3 Gross pathology

Image – Vibriosis bleeding skin legions

The external signs of the vibriosis are characteristic red spots, swollen and dark lesions on the skin that bleed and ophthalmic changes. However, some acute and severe cases die without any clinical signs.

Also known as haemorrhagic syndrome, V. salmonicida is evident from haemorrhaging in the integument surrounding the internal organs. The fish are anaemic and fry show splenomegaly, cataracts, and cranial haemorrhage.

3.6 Pathological symptoms of bacterial diseases

Although observations of the gross and microscopic pathology are a necessary step in the process, they are not normally sufficient to confirm a specific diagnosis. This is required to prescribe the correct treatment and management of the disease.

The most distinctive bacterial disease symptoms are highlighted in large red font in this table

Symptom (Note: Y = yes evident, and S = sometimes evident)	Furunculosis	ERM	BKD	Vibriosis
furuncles (or boils) involving skin and/or muscle, progressing to crater lesions	**Y**			
protruding eyes (exophthalmia)	Y	Y	Y	
darkening of the skin	Y	S	Y	Y
haemorrhage at the base of the fins	Y	Y	Y	Y
Haemorrhage on skin or mouth	Y			Y
haemorrhages at vent	Y	Y		Y
gills appear pale and anaemic	Y		S	
fluid accumulation in the abdominal cavity (ascites)		Y	S	
enlargement of the kidney			**S**	
reddening (subcutaneous haemorrhages) of the gill cover, corners of mouth, gums, palate and tongue		**S**		
loss of appetite		Y		

swollen abdomen		Y		
pinpoint haemorrhages on liver, pancreas, pyloric caecae, swim bladder, lateral musculature surfaces	Y	Y		Y
cataracts and cranial haemorrhage (in fry)				Y
enlarged, friable black spleen		Y		
enlarged spleen	Y			Y
focal necrosis of liver	Y			
distended mucoid and necrotic intestine				Y
inflamed lower intestine with thick yellow fluid.		Y		
stomach filled with mucus, blood and sloughed epithelial cells	Y			
Congested intestine	Y			
Bloody discharge (nares or vent)	Y			

4. Parasitic diseases

If an infection is caused by parasites there are medications available for use as disease treatments.

Parasitic diseases of fish include a diverse range of species from single celled organisms (protozoa, which are similar in size to large bacteria), up to more complex vertebrate species such as lampreys.

Most parasites that infest fish are motile (can swim or move through the water) and are categorised into the following groups.

Parasite group	Parasite example
Protozoans	Single celled organisms e.g. Costia
Trematodes	Flukes, flatworms
Cestodes	Tape worms
Nematodes	Round worms
Hirudinae	Leeches
Acanthocephalans	Thorny headed worms
Crustacea	Crustaceans e.g. Sea lice
Molluscs	Larvae of freshwater mussel e.g. Glochidial infestation

4.1 Amoebic Gill Disease (AGD) (Marine)

The marine amoeba 'Neoparamoeba perurans' causing AGD was first discovered in Tasmania in the mid-1980s. It continues to be a challenge, despite the well-established control methods in place. Today, AGD is recognised in most marine salmonid farming regions including Chile, the USA, France, Ireland, Scotland, Spain and Norway. It results in poor performance and mortalities.

4.1.1 Transmission

The free living and parasite can colonise gill tissue and cause a dramatic cellular reaction in the fish, resulting in proliferation and fusion of the gill anatomy. Consequently, the disease is often referred to as Proliferative Gill Disease (PGD). The amoeba can lie dormant at low temperatures but proliferate exponentially when temperatures rise.

4.1.2 Symptoms

In the early stages the symptoms are not obvious, although fish do normally lose appetite. As the condition develops, signs of respiratory disease can be seen, including flared operculae and gasping and fish are often found higher in the water column than normal.

Image - AGD

They lose their ability to control salts, fluids, and blood gases and will die if left untreated. More subtle gill changes may compromise the fish when crowding them for disease treatments or fish movements, especially if accompanied by low oxygen or high-water temperatures.

Some recent research has indicated that the main challenge may be acid-base disturbances due to the increased mucus on the gills impairing carbon dioxide excretion from the gills, as opposed to respiratory failure.

4.1.3 Gross pathology

Mucoid patches appear on the gills as pale grey/white spots, and legions develop in more advanced cases. Gills should be monitored and scored weekly, wherever AGD has been identified as a risk.

4.2 Ichthyobodo sp (Costia)

The genus Ichthyobodo is one of the most pathogenic flagellate protozoans in salmonid culture and causes significant mortality in, especially in smaller juvenile fish. In the hatchery it must be removed by chemical treatment, generally formalin. It is commonly known as whitespot.

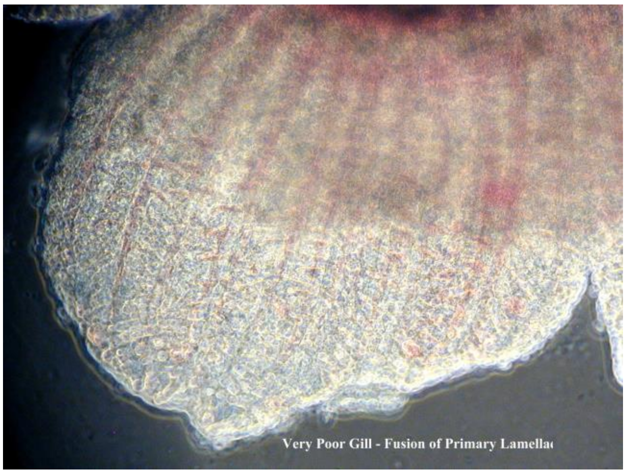
4.2.1 Transmission

Ichthyobodo is horizontally transmitted from fish to fish and sub clinically parasitised fish act as reservoirs for the parasite. Ichthyobodo reproduces by asexual longitudinal fission where one cell produces 2 motile daughter cells, each with 2 flagella, that parasitise the same or different host. Motile forms attach by means of a flat disc with two small microtubules extending into the host cell but retain flagella. Infestation of a host must occur within one hour after division or the parasite dies.

4.2.2 Symptoms

Fish infested with Ichthyobodo are often anorexic and listless and commonly exhibit flashing behaviour.

Fused gill lamellae resulting from Costia



4.2.3 Gross pathology

A blue-grey film appears on the surface of fish In

advanced cases, caused by increased mucus production and general hyperplasia of epidermal epithelium.

Gill hyperplasia and lamellar fusion (clubbing) can occur if gills are infested commonly accompanied by secondary bacterial and fungal infections.

4.3 Gyrodactylus salaris (Freshwater)

This tiny leech-like monogenean ectoparasite, commonly known as salmon fluke lives on the body surface of freshwater fish. It has devastated wild Atlantic salmon populations in the Norwegian fjords.

Gyrodactylus salaris is notifiable disease in many countries that must be reported to appropriate animal health authority.

4.3.1 Transmission

The parasite attaches to the host by the posterior attachment organ, or 'opisthaptor' and feeds using glands at the anterior. It is viviparous, producing live offspring nearly as big as themselves. A further generation is already growing inside the neonates.

Gyrodactylus salaris

They infect the skin, gills and fins of fish and are capable of rapid multiplication that can cause serious physical damage to Atlantic salmon parr.

4.3.2 Symptoms

Heavily infected parr appear greyish, with excess mucus, and possibly concurrent fungal infections.

4.3.3 Gross pathology

The parasite can be seen with low power magnification and a good hand lens can suffice.

Morphological examination can lead to the identification by a trained morphologist, but the main method for identification and confirmation is the use of molecular techniques involving PCR, sequencing, and phylogenetic analysis

4.4 Trichodina sp

Trichodina is a saucer-shape cilliate, 40-60 um in diameter and moves along the surface of the skin, fins, and gills of fish by means of its cilia. It feeds on the detritus and other debris found on the surface of the fish using tooth-like structures called denticles.

4.4.1 Transmission

Transmission is direct from fish to fish or from organisms in the water originating from a sub clinically infested reservoir host. Reproduction is by binary fission whereby daughter organisms either attach immediately to the original host or seek a new host in the water column.

4.4.2 Symptoms

Fins are generally frayed and fish exhibit flashing behaviour by scraping their bodies against hard surfaces. If the gills are heavily infested opercular movements may be laboured.

4.4.3 Gross pathology

Fish parasitized by Trichodina often have white patches and/or mottling of the skin and fins. Excessive mucus is produced causing a white to bluish sheen of the skin.

4.5 Sea lice

Sea lice are naturally occurring ectoparasite copepods that live in the marine environment and can be found on wild fish including migratory salmonid species during the marine phase of their lifecycle. There are many species of sea lice but the ones most referred to in salmon aquaculture are *Lepeophtheirus salmonis* and *Caligus elongatus*.

Sea lice have caused major problems for the salmon farming industry by impacting on fish welfare, public relations, and the economics of production. Due to the potential for impact on wild fish stocks, the control of sea-lice is a controversial issue.

An adult sea lice

Sea lice do not normally cause significant damage to adult fish, unless infestations are particularly severe. However, they can cause high mortalities among young salmonids, particularly those in the smolt stage during heavy infestations.

4.5.1 Transmission

Sea lice are crustaceans that have a multi-stage life cycle. The larval phase is pelagic with two stages; the nauplii stage are newly hatched larvae that cannot swim and drift with the currents. The copepodids stage larvae have a limited swimming ability but are still able to spread from fish to fish.

Once they find a host they attach and feed on the fishes mucous and soft tissues and start to grow. They start to move around the fish to find a mate and reproduce. Female sea lice can produce hundreds of eggs at a time in long strings.

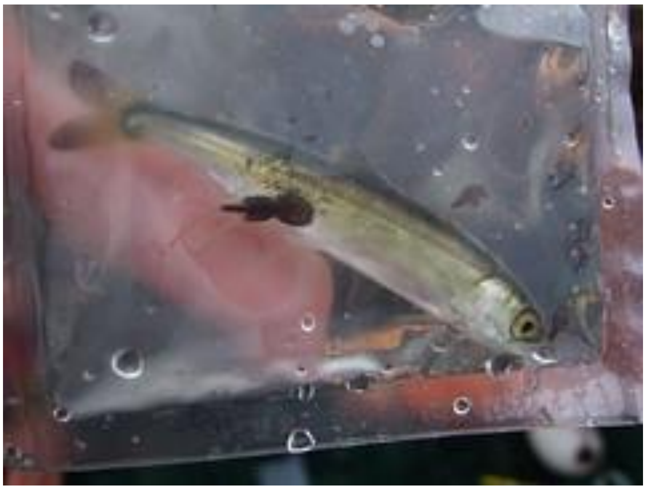
4.5.2 Symptoms

The most obvious symptom of a sea lice infestation is the presence of the parasite. This will be observed during the routine sea lice checks carried out on each site. As the parasite irritates the fish this leads to behavioural change, such as an increase in jumping, flashing, and scraping on the sides of the cage net.

4.5.3 Gross pathology

Whitish spots will be visible around the dorsal, head and gill area when *Lepeophtheirus.salmonis* have been feeding on a salmon. When infestations are high there may be evidence of skin lesions and open wounds.

As the fish's defensive mucous layer, scales and skin have been compromised this will place further stress on the fish, including secondary infection from bacterial and fungal pathogens and a deterioration in the fishes' ability to osmo-regulate efficiently.



Sea Lice are much more damaging to young fish such as this Pacific salmon (Coho) smolt

If left untreated this combination of factors will result in the death of the fish.

4.5.4 Treatment options

There are a range of treatments to combat and control sea lice.

It is in the interest of aquaculture companies to ensure that lice burdens on contained fish stocks are kept to a minimum.

This can be achieved using a range of approaches, including,

- site fallowing (within farm area management plans),
- stock management practices that avoid mixing year classes,
- using licensed veterinary medicines under prescription and
- using cleaner fish where appropriate.

Many salmon farming companies cooperate using Farm Management Area Plans to co-ordinate the control of sea lice. This involves companies and farms in the same area coordinating their sea lice treatment operations to synchronise the treatments at each site to not only treat the lice problem on that site but also reduce the risk of re-infestation locally.

How do the salmon farmers know when to treat for sea lice?

Site technicians as part of their routine monitoring will carry out visual lice counts at least once weekly. They will have agreed minimum standards on the numbers of lice per fish that are acceptable and sampling regimes (how many fish should be checked) for their Farm Management Area. Company standards may exceed must cannot fall below these standards.

The site technicians will look for all life stages of the sea lice when recording their counts, for assessment by the site managers and veterinary specialists. This information will be used to plan the timing of the next sea lice treatment.

Bath treatments involve reducing the holding unit size by enclosing the fish in a tarpaulin and adding a chemical such as azamethiphos or hydrogen peroxide to the enclosed area (bath) for a defined period. Using this method any attached sea lice will fall from the fish and die, but there are risks.

Are there any risks associated with chemical treatment for sea lice?

The fish being treated may be overexposed to the chemical and as they are already in a weakened state, deoxygenation of the enclosed space during treatment will stress them further. All of which can be prevented through good management and monitoring practices.

There is also a danger of non-target species in the aquatic environment being exposed to the chemicals introduced, unless the site has good flushing to dissipate and dilute the chemical once the treatment has been completed. Although the effects of the chemical bath treatment are instant, there is always the risk of reinfection soon after, hence the need for a coordinated 'Farm Management Area' approach.

Lump fish are effective cleaner fish at low water temperatures and are produced as 'cleaners

The infeed treatment involves including a prescribed chemical dose in the fish feed. Unlike the bath treatment, an infeed treatment has a more gradual effect that may be longer lasting than the bath treatments. This treatment makes it difficult for the lice to remain attached to the fish and they will fall off and die. There is a risk that some of the treated feed may fall through the cage with the potential to affect non-target crustaceans. Consequently, the prescription and administration of all chemicals used is closely regulated.

How effective is the cleaner fish alternative?

There are two commonly used Wrasse species and Lumpfish. In both cases the cleaner fish are stocked with the salmon in the cages and feed by picking sea lice off the skin of the salmon.

This method is common and often combined with other methods to reduce chemical usage and combat sea lice when they become chemically resistant. Lumpfish tend to be used in low temperature conditions and wrasse at higher temperatures. It helps if the nets are kept clean as this deters the cleaners from grazing algae to keep them foraging lice more actively.

5. Fungal diseases

If an infection is caused by fungi there are medications available for use as disease treatments.

Most fungi obtain energy from dead and decaying plant or animal materials, but some are parasitic and can infest the living tissues of plants and animals. There are very few fungal pathogens of fish but most of the ones that will infect fish are parasitic fungi made up of tubular filaments called hyphae.

Parasitic fungal infections in fish are normally a secondary external infection following physical damage to the fish which weakens external defences (mucus, scales and skin). Fungal infections in fish grow as the hyphae spread through the host animals' tissues creating a mat with a cotton wool appearance. There will be a host of fungal infections that can affect farmed Atlantic salmon and their ova, but two can cause problems for farmed fish. One is commonly found in freshwater and the other can survive both the marine and freshwater environments.

The most common fungal infections that can affect farmed Atlantic salmon and their ova are:

- Saprolegnia sp (Freshwater)
- Exophiala sp (Freshwater and Marine)

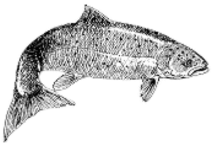
The range of medicinal treatments available for use against fungal infections in fish are limited and are usually administered as bath treatment.

Pre-smolt mortality with saprolgenia infection

The most important way to control any disease pathogen including fungal infections is by prevention and eradication of the fungi. Prevention of a fungal infection is key which can be achieved by following strict bio-security policies, quarantine of stocks, routine monitoring and general good animal husbandry including the immediate removal of dead and dying stocks to reduce the potential reservoir for fungal growth.

Some fungal infections can be internal and usually be attributed to a dietary issue. This can be prevented through improved feed management and hygiene.

FHW 4 Fish health and welfare



Non transmissible diseases

There are some diseases which are not transferred between fish stocks and do not involve disease pathogens. They are classed as non-transmissible and generally categorised as:

- Nutritional
- Genetic
- Water quality (environmental)

4.1 Nutritional diseases

Feeding fish on a nutritionally imbalanced diet that is low or deficient in some essential nutrients can lead to disease problems among fish stocks. Diseases caused by poor nutrition are rare in modern aquaculture as high quality and nutritionally balanced diets are the norm. There may however be occasional nutritional problems caused by poor feeding practices and feed quality deterioration due to poor storage. The diseases attributed to nutritional deficiencies are usually chronic and poor food conversions and growth are often the first signs, which can progress to changes to skeletal structure and outward appearance. If this is not addressed there will be a slow but steady increase in mortality.

Which nutrients are essential to fish health?

Most nutritional diseases can be attributed to a deficiency in one category of dietary components. Each category has been exemplified below:

- Vitamins – a deficiency in vitamins such as vitamin C (ascorbic acid) is linked to skeletal deformities, fin ulcers and reduced healing. This is an essential nutrient that is sensitive to temperature changes and easily oxidised in storage.
- Minerals - a deficiency in minerals such as Phosphorous (P) can lead to reduced growth, poor feed efficiency and skeletal problems
- Fats – a deficiency in Essential Fatty Acids (EFAs) such as linolenic and linoleic acids, which are important for cellular structures, and are linked with fin damage such as erosion and pigmentation problems.
- Proteins - a deficiency in Essential Amino Acids (EAAs) such as Methionine can lead to reduced growth rate and the development of eye problems such as cataracts.

Vitamins and minerals are needed in fish diets in relatively small quantities and are called 'micro-nutrients'. Proteins and fats are needed in higher quantities and are called macro-nutrients.

What are essential Amino Acids and Essential Fatty Acids?

Amino acids are the building blocks of protein and ten of them are essential in the diet, as they cannot be manufactured by the fish or substituted. If just one of these essential amino acids is low, even if the other nine are at the required level, fish growth will still be restricted.

The same principle applies to the Essential Fatty Acids which make up the fat content of the diet. The Omega 3 and Omega 6 fatty acids are essential to the normal development of cellular membranes.

How can nutritional diseases be avoided?

Due to strict diet formulation, it is very rare for nutritional diseases to occur in manufactured salmon feeds. However, once the feed arrives on the farm it must be kept in top condition to avoid the loss of the more sensitive essential nutrients.

To avoid feed and nutrition causing health problems for fish stocks the following should be observed:

- Fish should be fed high quality diets which are formulated and balanced to meet the nutritional requirements of the species and life stage.
- Fish should be according to the manufacturers feed rates for the species, life stage and environmental conditions.
- All food should be stored in a dry cool environment that is free from pests and vermin.
- Any feed showing signs of deterioration and/or mould should be discarded immediately.

4.2 Genetic diseases

There are a few genetically induced diseases that can occur in farmed fish stocks that are also found in wild stocks. The prevalence of genetic diseases is higher in farmed stocks due to the increased potential for inbreeding limiting the gene pool. Genetic diseases become more noticeable in farmed stocks as such fish survive longer than they would in the wild.

This farmed Atlantic salmon has a sever jaw deformity.

Examples of genetic diseases in fish include:

• Snub nose – the fishes top jaw is shortened giving the head an unusual shape.
• Spinal deformity – the fishes' spine does not grow properly and results in deformities such as scoliosis.
• Shortened body – fish have a stumpy shape to the body that is much shorter in length than normal.
• Siamese twins – two fish co-joined at the head or tail, most notably observed in juvenile fish at the alevin and fry stages.

How can genetic diseases be prevented?

Most genetic diseases can be prevented or minimised by improving stock management procedures.

- Brood-stock management – selection of brood-stock free of signs of any deformities.
- Outsourcing – in addition to good brood-stock management, new stocks should be routinely introduced to the gene pool to reduce the effects of inbreeding.
- Hatchery procedures - comprehensive hatchery record-keeping and individual brood-fish tagging can assist planning and control of spawning. Controlling the brood-stock used at each egg fertilisation event will reduce the risk of inbreeding.

4.3 Water quality related diseases

Water quality is critical when considering fish health and welfare. In an intensive aquaculture environment, it is important that water is supplied by a reliable source of a suitable quality and routinely monitored and maintained at the highest standard. Any deterioration that is not dealt with promptly increases the risk of fish becoming stressed, then infected with an opportunistic disease pathogen.

Water quality can deteriorate for various reasons.

- low dissolved oxygen (often the result of respiration by aquatic biomass (fauna and flora),
- water temperature flux (high or low due to climatic changes, or technical RAS equipment failure)
- pH flux - high or low (due to biological activity and/or acidifying land uses) and
- increases in the concentration of naturally produced toxic substances such as ammonia and carbon dioxide.

If the deterioration in water quality is severe, the fish stock will show symptoms and catastrophic mortailities arise if there is no remediation.

What non- transmissible water quality diseases can occur on a fish farm?

The water quality conditions in a holding unit can deteriorate through stock husbandry and management failures, such as overstocking or overfeeding which increase the levels of toxic ammonia. This can be rectified by reducing the stocking density and/or feed rates.

Routine pH monitoring with a probe is more typical than litmus paper.

Poor water quality is particularly problematic if it occurs during the hatchery stage, as the fish are less robust and more susceptible to disease problems. There are specific problems associated with the use of ground water supplies by hatcheries, despite the water's purity. 'Gas bubble disease' represents a real risk, if not addressed.

The trend towards closed recycled aquaculture systems (RAS) addresses this issue by constant monitoring and control of water quality using mechanical and biological filtration that removes solid and dissolved organic wastes. However, RAS systems failures can also bring catastrophic mortalities.

There are some general and more specific symptoms of water quality related diseases.

4.3.1 Low DO

Large fish are affected more readily. Hypoxia leads to gasping at surface, flared gills, skin darkening, and can result in catastrophic mortality.

4.3.2 Ammonia toxicity

Ammonia toxicity is determined by water pH.

Un-ionized ammonia >1 mg/L at a pH >8 can lead to lethargy, anorexia, convulsive spinning, darkened skin, and catastrophic mortality.

4.3.3 Methemoglobinemia

Caused by RAS biological filtration failure leading to inhibition of the conversion of nitrite into nitrate. Nitrite builds up to toxic levels, as opposed to being converted to relatively harmless nitrate.

4.3.4 Nephrocalcinosis

This is a common problem in RAS systems caused by increased carbon dioxide build-up. Levels of CO_2 >40 mg/ can result in fish lethargy at the water surface.

Excess CO_2 can also cause Acidosis/Alkalosis.

4.3.4 Gas bubble disease

Nitrogen supersaturation is the common cause of gas bubbles in gill capillaries which can lead to catastrophic mortality.

The symptoms are lethargy, buoyancy problems and fins show bubbles when viewed with a microscope.

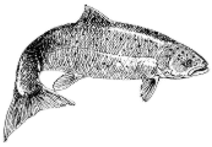
It is most common in hatcheries reliant on ground water supplies. It can also occur in RAS systems due to pumps and pipe leakages drawing in excess nitrogen.

How can non- transmissible water quality diseases be prevented?

The following routines prevent water quality related diseases:

- Monitor all main water quality parameters routinely, including oxygen, pH, water temperature, salinity, and ammonia.
- Prompt adjustment of any water quality parameters outside prescribed limits, or borderline for the species and life stages being farmed.
- Maintain stocking densities appropriate to the holding units and at a level that will allow for fish growth and prevent overstocking.
- Ensure mortalities are removed daily to prevent accumulation that would allow an increase in nitrogenous wastes such as ammonia and nitrite.
- Feed high quality digestible diets that are carefully rationed to reduce the level of organic wastes from fish feed and excreta.
- Apply water quality control technologies such as degassing equipment and filtration- Recirculation Aquaculture Systems (RAS)

FHW 5 Fish health and welfare



Disease monitoring and diagnosis

Disease sampling and identification follows routine welfare monitoring. The OWI scores can provide an early warning of impending fish health issues which normally leads to disease sampling and diagnosis.

Disease identification usually requires input from external fish pathologists for confirmation.

Disease diagnosis is an 'evidence based process', starting with observations of fish behaviour as early warning signs. It then moves to the gross pathology of infected fish, followed by microscopic examination and finally laboratory analysis and confirmation by an external fish pathologist.

Each step of this process narrows down the possible causes and the final step provides the singular cause upon which disease treatment and management can be based.

1. **Disease diagnosis process**

The first stage of disease diagnosis is the initial observations of behavioural changes, which although non-specific, should become evident from analysis of routine OWIs.

Infected fish may separate themselves from others and show signs of nervousness. This may be followed by an increased rate of mortalities, fish swimming near the surface or at the edges of the unit, showing external darkening and a poor feeding response.

Farm staff should be routinely observing their fish stocks as they go about their daily routines. Subtle changes in behaviour may become apparent. They are an early indication of a health problem.

These observations should always be reported as they could lead to a disease diagnosis and early intervention.

1.1 Gross pathology

Routine OWI monitoring includes comprehensive observations of fish morphology. This can reveal a range of gross pathological disease symptoms visible with the naked eye.

However, the 'gross pathology' is rarely definitive, as there are many 'shared' symptoms across a range of different diseases.

Salmon smolt furuncle

A minority of gross pathological symptoms are typical and distinctive and can help to diagnose the disease based on the initial visual inspection. For example, this furuncle is symptomatic of the bacterial disease, Furunculosis.

Unfortunately, some of the most distinctive and confirmatory symptoms are not always so evident.

When the fish is dissected, the gross pathology of internal organs can be observed and help to narrow down suspected pathogens.

1.2 Microscopic pathology

A high prevalence of clinical signs, compromised welfare, or increased mortalities are indicative of a salmon population with health issues.

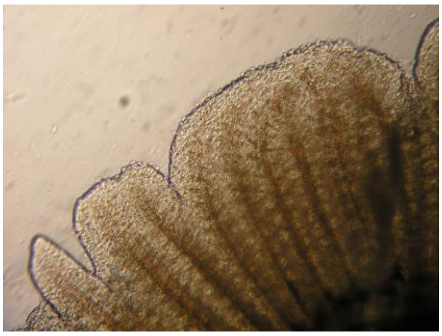
A representative sample of fish then undergo an in-depth assessment of their health status, and the gross pathology is followed by microscopic examination.

Lab health technician examining a mucus sample for parasites.

When a symptom can only be revealed through microscopic examination, it is known as 'microscopic pathological'.

Some companies have fish health specialists on site trained to undertake microscopic examinations. Independent fish pathologists in an offsite laboratory are used to confirm all on site diagnoses.

For example, the fusion of the gill lamellae due to necrosis of the epithelium may be revealed through microscopic examination. This is a common symptom of furunculosis.



Fused gill lamellae

1.3 Routine disease sampling

Disease monitoring routinely can help with the detection of disease during the early stages of an outbreak. Each fish from a captured sample is subjected to a comprehensive disease sampling procedure. This includes checking for parasites, bacterial and viral pathogens, and a histology tissue sample.

The fish sample collected must include:

- Moribund or fish showing clear signs of disease
- Freshly dead fish (if moribund unavailable)
- Healthy fish from the same population for reference

Healthy gill lamellae

Dissect mortalities to assess the presence of internal signs of disease and food in the stomach/intestine.

When dealing with moribund fish:

1. Prepare a bath with an anaesthetic overdose to humanely cull the fish before sampling.

2. Take the samples as soon as possible after the fish's death to avoid autolysis compromising diagnostic interpretation.
3. Note any clinical signs observed for each individual fish to support the diagnosis.
4. Determine whether a bacterial or viral disease is suspected with reference to the risk assessment gross morphology and clinical signs.

2. Fish examination procedure

The fish must be examined, and tissue sampled in a particular order, to avoid the risk of contamination of one part of the fish anatomy with pathogens from another.

a) Bacteriology

If a bacterial infection is suspected, samples for bacteriology should be taken before the rest of the samples to avoid contamination.

- Dissect the fish by opening the abdominal cavity to expose the internal organs.
- If a specific pathogen is suspected, take samples for molecular analysis.

b) Parasitology

The presence of parasites is assessed by,

a) taking a scrape of skin mucus with the scalpel and

b) a very small gill biopsy.

c) Routine histology

The gills, heart, liver, pyloric caeca (and pancreas), spleen, kidney, skin and muscle are routinely sampled.

- Take a piece of each organ (max. 1cm x 1cm) and place them into a container of 10% buffered formalin for preservation.
- If lesions are present in different organs, for example the eyes, skin, or fins, they should also be included for histology.

c) Virology

If a viral infection is suspected or viral screening needed, samples for virology isolation are taken.

- The fish do not have to be killed to take blood samples but must be anaesthetized.
- Blood collection and serology sampling is conducted according to company procedures.

3. Fish disease diagnosis tasks

Farm managers, supervisors and husbandry staff are expected to do all they can optimise fish health.

Those dealing with salmon husbandry day to day should be the first to recognise and report any changes in fish behaviour. This includes feeding, appetite, lethargy, and general activity.

The tasks to be conducted within disease diagnosis are:

a) Removal, counting, recording, and classification of mortalities.
b) Capturing fish samples for fish disease diagnosis.

c) Observation of the gross pathology and selected micro pathology of infected individual fish.
d) Conducting mucus scrapes and gill squashes to identify commonly occurring parasites.
e) Dissection of individual fish from the sample to expose internal organs.

Observing a sample of pre-smolt gross pathology.

f) Taking bacterial samples and conducing initial agar plate culture and assessment.
g) Dissecting and preparing histology samples for sending to external fish pathologist.
h) Taking blood samples from anaesthetised fish and centrifuging them to prepare blood serum.

Whenever taking and preparing samples for disease diagnosis, the staff must follow company procedures (SOPs) for each activity.

Bacterial diseases of Atlantic salmon pathological symptoms

There are a wider range bacterial diseases that infect Atlantic salmon farmed in sea cages compared to RAS. The RAS farms are more at risk from a limited range of 'opportunistic' bacteria.

Opening the abdomen

The symptoms of the bacterial disease most significant to RAS are highlighted in in this table.

Observations of symptoms, including the gross and at times microscopic pathology are necessary steps in the process. However, the specific diagnosis must next be confirmed so as disease treatment and management can be prescribed.

The procedural details are provided for each science discipline.

3.1 Bacteriological sampling

Bacteriology requires samples to be taken from a fish that is suspected to have a bacterial disease and cultured on an agar plate. Any growths can be analysed leading to an identification.

Typical procedure

Once the fish being examined has been euthanized the abdominal cavity is opened to expose the internal organs.

a) The head kidney or spleen are sampled with a sterile loop.
b) Agar plates are inoculated by wiping the loop over the plate to form a series of stripes.
c) The plate is closed and sealed and incubated at room temperature (18℃) or within an incubator.

d) Growth is assessed every 12 hours for haemolytic or pigment-producing colonies.

Instructional video - Opening the abdomen

e) If growth is present, colonies are selected individually and replated according to external fish pathology lab instructions

f) Plates are sent to an external fish pathology lab for pathogen identification.

g) <Instructional video> Bacteriological sampling

3.1.1 Bacteriological laboratory analysis

Confirmation requires laboratory bacterial cultures from infected tissues to be tested for an identification of the specific pathogen.

Agar culture plate

Once established, a bacteria culture can be subjected to a series of chemical tests. 'Gram staining' determines whether they are gram positive or gram negative and allows binary categorisation.

As an example, this information alone is enough to differentiate the gram positive 'Renibacterium salmoninarum' (Bacterial Kidney Disease - BKD) from the gram negative Aeromonous salmonicida (Furunculosis) or Vibrio salmonicida in the table below.

However, typically, bacteriologists apply molecular/PCR sampling to confirm which bacterium is acting as the causative agent (pathogen).

3.1.2 Molecular/PCR sampling

Molecular/PCR sampling is a laboratory technique for assessing and quantifying the presence of a specific pathogen in a tissue.

The organs to be tested are chosen according to the suspected pathogen. Fish pathologists keep certified assays for many representative and common pathogens.

Typical procedure

a) Euthanize the captured salmon.
b) Disinfect forceps and scalpel before taking the sample.
c) Dissect the salmon by opening the abdominal cavity to expose internal organs.
d) Take a small piece (max. 5mm x 5mm) of the selected organ.
e) Place the sample in the PCR tube and close it, ensuring that the tissue is completely submerged.
f) Label your sample so as different samples can be tracked to the same individual fish.
g) Store samples at between 4-15 C or in a freezer unit.
h) Send samples to external pathology lab within 1 week (15C°) or 1 month (4C°) or at any time if frozen.

3.2 Parasitology

When infection by external parasites is suspected, the examination of a well-prepared skin scrape can confirm the organism responsible.

Skin mucus scrape procedure

Image - Skin mucus scrape

a. Scrape a clean scalpel blade in the direction of the scales, across the skin above the lateral line.
b. Take a scrape from behind the pectoral fin towards the caudal fin.
c. Place the skin mucus removed in the centre of a slide and add a drop of water.
d. Place a coverslip on top of the mucus sample and press to ensure the sample is fixed.
e. Immediately view the sample under the microscope at low magnification (4x/0.10)
f. Strip search systematically starting from the top left and finishing at the bottom right.
g. Look for movement and increase the magnification as and when necessary to complete any identification (10x/0.30 to 40x/0.75).

3.2.1 Gill tissue biopsy

The gill lamellae are only one cell thick, rich in blood and vulnerable to infection by external parasites. The gill can be examined by conducting a gill biopsy.

Instructional video - Skin mucus scrape

Gill biopsy procedure:

1. Using a clean scalpel or scissors, remove a small sample of gill lamellae
2. Place the sample on the centre of a slide, remove any cartilage and add a drop of water.
3. Place a coverslip on top of the tissue sample and press to ensure the sample is fixed.

Image – Gill squash

4. Immediately view the sample under the microscope, starting at low magnification (4x/0.10) and increasing to (10x/0.30 to 40x/0.75) when suspecting something.
5. View systematically looking for movement by starting at the top left and finishing at the bottom right.
6. Gill condition (congestion/swelling) can also be assessed.

3.3 Histology sampling

Histology is the study of the microscopic anatomy (microanatomy) of cells and tissues. It can determine the presence of pathological changes in tissues.

This technique is undertaken by specialist fish pathologists in an external laboratory.

Samples are taken for histological analysis routinely when identifying bacterial and viral diseases.

Histology sampling procedure:

a) Euthanize the fish.
b) Open the abdominal cavity to expose the internal organs.

Instructional video - Histology sampling

c) Identify each organ routinely sampled, examining its colour and texture, and noting any abnormalities.

d) Take a section (max. 1cm x 1cm) from each and place each into a sampling pot containing 10% buffered formalin.

e) Ensure a ratio of formalin to tissue of 10:1.

f) If lesions are present in other organs, take sections from them and place them into a sampling pot.

Image -Removing opercula from parr

The procedure for tissue sampling varies according to whether the fish are large or small.

- Fish less than 3cm in length can be placed directly in fixative.
- For fish between 4-10cm, make a slit along the abdomen, remove the opercula and place directly in fixative.

3.3.1 Packaging tissue samples

Tissue samples must be sent to the company’s external pathologist immediately they have been taken so as they arrive in top condition.

The samples must be labelled clearly so as they are identifiable, with the fish number, date, and serial number.

Tissue samples ready for despatch

They must be packed separately from culture plates and surrounded with absorbent material.

Before despatch

- keep samples cool, and
- check that sample container lids are secure and seal rim with paraffin tape.

Instructional video Preparing histology samples.

3.4 Viral sampling

Sampling is undertaken to assess a specific virus's presence (and isolation) in a tissue.

The sampling protocol for virology varies according to the aim. The tissues targeted, and the number of fish sampled are determined by whether,

Opening a smolts abdominal cavity

• a suspected viral disease is being confirmed or

• the population is being fully screened.

The sampling protocol is devised on a case-by-case basis by the external laboratory when consulted.

Typical viral sampling procedure:

1. Once the fish is euthanized, dissect it by opening the abdominal cavity to expose the internal organs.
2. Tissue samples are placed and transported in viral media.
3. Viral media are inoculated onto cell lines for viral isolation in the external laboratory.

3.5 Blood sampling

When blood sampling the fish are kept alive after blood collection as the technique is not lethal. However, to ensure that fish health does not deteriorate after blood collection, it is highly recommended that the total volume of blood taken does not exceed 1% of the total body weight of the fish.

Image – Exposed internal organs.

Blood is sampled for a wide range of reasons, including to assess

- the presence of a pathogen and/or antibodies against a pathogen after exposure,
- metabolic disturbances and specific enzymatic activity,
- issues affecting bloodstream such as anaemia,
- smoltification and
- markers for stress and maturation.

3.5 Blood sampling procedures

Sampling has a broad set of protocols, due to the diverse size range of fish that may be sampled and the different aims of the sampling.

Image – Taking a salmon blood sample

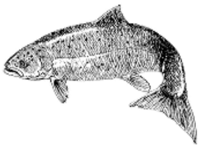
Specific protocols for different scenarios are agreed upon with external fish laboratory pathologist as and when needed.

a) Anesthetize the fish and place it on a flat, wet, secure surface.
b) Select a needle and syringe appropriate to the size of the fish. (25G needle and 1mL syringe for fish <100g or 21G needle and 2.5mL syringe for fish >1kg)
c) Collect blood using either a ventral or a lateral approach to the caudal vein.
d) Centrifuge blood sample to separate serum/plasma from blood cells (optional).
e) Transfer the serum /plasma extract into a new clean Eppendorf tube.
f) Send the blood or serum/plasma extract to a designated external pathology laboratory.

In the laboratory pathologists may test for:

- viraemia,
- viral isolation or
- presence of antibodies for different viral pathogens

B6 Fish Health and welfare



Disease prevention and treatment

All living organisms, including humans and other animals, will experience ill health during their life. This can normally be attributed a range of pathogens, which is a collective name for the micro-organisms and parasites causing transmissible (and infectious) diseases. Fish are no different from other organisms and are susceptible to infection from a range of pathogens, but they do have defences to help them fight off potential infections.

The first defence in the fishes' armoury is the mucous layer, scales and the skin. These defences are known as non – specific, which means they will defend against all potential threats from the external environment.

The next line of defence is the fishes' immune system, which will defend against recognised pathogens, this is known as a specific defence. It is the specific defence that is activated when administering vaccines. Vaccination introduces the fishes' body to an inactive sample of the pathogen to which the fishes' immune system will respond. If the fish encounters the pathogen in the future the immune system will recognise it and produce an immune response that will combat the pathogen.

It is therefore important that not only should the disease be treated, but the underlying cause and potential factors causing stress to fish stocks should also be addressed.

Prevention is always better than cure!

The prevention of disease is always easier to implement than managing a disease outbreak as disease prevention is the most cost effective and form of disease control and maximises fish welfare.

This can be achieved through good stock management practices which can involve; good biosecurity, good stock handling, correct nutrition, monitoring and maintaining water quality, quarantine procedures and the prevention of overcrowding.

If prevention has failed, there are a range of treatment methods the fish farmer can use. The medicine or chemical treatment of fish stocks can either be administered internally or externally.

1. **Disease treatments**

External treatments can include the addition of liquid chemicals, chemicals in powder form which must be added to water, or liquid medicines such as immersion antibiotics. The following steps describe how to calculate the correct amount of chemical/medicine to be administered:

- Follow the manufacturer and veterinary instructions for the treatment
- Calculate the water volume of the holding unit being treated
- Calculate the chemical quantity required for that treatment

The most common forms of external treatments are:

1.1 Bath

During a bath treatment a chemical is added to the holding unit for a prescribed time and dose rate e.g., Formalin bath to treat a Costia infestation at a dose rate of 200ppm for 30 minutes.

1.2 Flush

During a flush treatment a chemical is added to the holding unit near the inlet and allowed to flow through the unit at a prescribed dose rate e.g. Chloramine T flush to treat Bacterial gill disease at a dose rate of 2 ppm

It is important to take measures to ensure good even mixing of the chemical throughout the water body, otherwise a hotspot of highly concentrated chemical will enter and leave the holding unit, leaving some of the stock relatively untouched by the treatment.

1.3 Internal treatments (addition of chemicals to the feed)

1.3.1 Orally (medicated feed)

A prescribed medicine is added to the fish feed and fed to the fish stocks over a prescribed time. For example, an antibiotic treatment for a bacterial infection at a dose rate of 80mg/kg of fish/day for a total of 10 days

Internal treatments can include the addition of antibiotics, sea lice treatments and booster supplements to fish feed. For large quantities this is normally carried out by the feed production companies, however small batches can be mixed on fish farm sites by suitably qualified and trained staff.

The following steps describe how to calculate the correct amount of chemical/medicine to be administered:

- Calculate the total biomass (kg) of the stock in the holding unit being treated
- Follow the manufacturer and veterinary instructions to select the appropriate dose rate
- Calculate the total quantity of medicine required for the recommended treatment period
- A reduced feed rate should be calculated for the recommended time period to ensure the stocks consume all the treated feed
- Medicine should be added to the feed and mixed thoroughly
- Feed should be stored appropriately and whole treatment administered to the appropriate stocks over the recommended time period.

1.3.2 Vaccination (injection and immersion)

A prescribed medicine is administered to the fish using either a direct injection or immersion in a bath containing dilute vaccine. The latter technique is commonly used as a preventative treatment (prophylactic) administered to the fish before a disease becomes a problem.

What records of disease treatments does the fish farmer need to keep?

It is important to note that all treatments administered to any fish stocks should be accurately recorded as part of good management practices and as a legal requirement. This is important as some chemicals or medicines used will have withdrawal periods that must be observed before fish can be harvested for human consumption.

What is a withdrawal period?

If fish have been fed a diet containing a medicine such as antibiotics there is a prescribed time that has to pass before any fish destined for human consumption can enter the food chain.

Withdrawal periods in fish are normally described using the term ‘degree-days’.

When a treatment has finished there will be a minimum number of degree days that must pass before the fish stocks can be considered safe for human consumption.

How are degree days calculated?

Example: An infeed medicine (antibiotic) has a withdrawal period of 600-degree days after the treatment has finished.

The water temperature currently averages 10^{0}C.

How many days will it be before these fish can safely be considered fit for human consumption?

600 degree days / 10^{0}C = 60 days (after the treatment is finished)

To ensure accuracy - the water temperature should be taken and recorded daily and degree days calculated as a cumulative total.

How is the impact of chemical treatments on the aquatic environment regulated?

As with all other types of farming the use of chemicals and medicines is regulated not only from an animal welfare perspective but also to ensure human health is not adversely affected. The relevant water or environmental monitoring authorities in any country will be required to authorise aquaculture enterprises to use certain medicines and chemicals. This will be detailed in the consent to abstract and/or discharge into the aquatic environment.

2 Disease treatment calculations

2.1 Adding chemicals to the water.

Calculating chemical treatment quantities is straight forward but does require a series of calculations to be conducted accurately. In most aquaculture facilities the calculations will be completed by farm control software or specialists fish vets. However, it is useful for all fish farmers to understand how the chemical quantities are calculated.

2.1 External treatments

Require either the addition of a liquid or powder to a holding unit for a bath or flush treatment. The first calculation we require is the volume of the water in the holding unit being treated.

It is important that it is the volume of the water and not the volume of the holding unit that needs to be calculated! Rarely will the holding unit be filled to the top and so to a calculation of the holding unit volume would give an incorrect answer. In most cases prior to treatment the water level will be dropped to reduce the volume of water in the holding unit which consequently reduces the amount of chemical required.

2.1.1 Treating a stock of fish held in a raceway

To calculate the volume of water in a rectangular raceway unit you must first measure the length, breadth and the depth of water. All measurements should be made and recorded in metres.

The volume of the unit can then be calculated using the formulae: -

- Volume (m^3) = Length (L) x Breadth (B) x Water Depth (D)
- The volume calculated in this way will be expressed in cubic meters (m^3)

- It is important to note:
- $1m^3$ = 1 000 litres or 1 000 000 millilitres

Example 1

The rectangular raceway to be treated has the following dimensions:

- Length = 6 metres
- Breadth = 1.2 metres
- Depth = 1.5 metres

Raceway volume = 6 metres x 1.2 metres x 1.5 metre raceway depth

= 10.8 m^3 x 1000

= 10 800 litres x 1000

= 10 800 000 ml

Remember this is the tank volume and not necessarily the water volume.

Example 2

To demonstrate how an error could be made we will look at the following example.

- Length = 6 metres
- Breadth = 1.2 metres
- Water Depth = 0.8 metres

Raceway volume = 6 metres x 1.2 metres x 0.8 metre water depth

= 5.76 m^3 x 1000

= 5 760 litres x 1000

= 5 760 000 ml

In both examples 1 and 2 above you will notice the raceway unit is 6 metres long but in example 2 we have used the actual water depth in the calculation. This gives a very different water volume of 5.76 M3 as opposed to 10.8 M3. This type of error can result in the wrong chemical dose being administered.

How do we calculate the actual quantity of chemical required?

Once you have the volume of water in the holding unit to be treated you next need to know the dose rate of the chemical being administered. This will either be on the manufacturers label or in the written veterinary advice provided with the chemical.

If we use both calculations in the above examples, you will notice the difference in chemical quantity between them is significant. If the calculations are incorrect there is a danger of over/under dosing the chemical, which can cause damage to the fish, cause mortalities, be ineffective against the pathogen and pollute the environment unnecessarily with the excess chemicals.

The chemical we are using in this example is Chloramine T which has a prescribed dose rate of 2 parts per million (ppm).

- Example 1 has a tank volume of 10.8 m^3.

To calculate the total quantity of Chloramine T required for example 1:

$10.8\ m^3$ x 2ppm = 21.6 = 21.6 grams of Chloramine T required

- Example 2 has a water volume of $5.76\ m^3$

To calculate the total quantity of Chloramine T required for example 2:

$5.76\ m^3$ x 2ppm = 11.52 = 11.52 grams of Chloramine T required

It is obvious to see that getting the volume calculation wrong at the start can make a significant difference to the amount of chemical required, which in this case made a difference of 10.08 grams of Chloramine T.

2.1.2 Chemical treatments added to water (circular tanks)

Calculating chemical treatment quantities is straight forward but does require a few calculations to be accurately conducted. In most aquaculture facilities the calculations will be completed by farm control software or specialists fish vets. It is useful for all fish farmers however to understand how the chemical quantities are calculated.

External treatments will require either the addition of a liquid or powder to a holding unit for a bath or flush treatment. The first calculation we require is the volume of the water in the holding unit being treated.

Note, it is the volume of the water and not the volume of the holding unit that is being calculated! This is important because very rarely will the holding unit be filled to the top and to calculate the holding unit volume would give an incorrect answer. Normally the water level is dropped to reduce the volume of water in the holding unit which will reduce the amount of chemical required.

How do you calculate the volume of a circular tank?

To calculate the volume of water in a circular unit you must first measure the Diameter (or radius) and the depth of water. The diameter is then halved to give the radius e.g. a diameter of 4 metres = a radius of 2 metres. All measurements should be made and recorded in metres.

The volume of the unit can then be calculated using the formula:-

Volume (m^3) = πR^2 x D

- π =3.14
- R = the radius (in meters)
- D = the depth (in meters)

The volume calculated in this way will be expressed in cubic meters (m^3)

It is important to note:

$1m^3$ = 1 000 litres or 1 000 000 millilitres

Example 1

The circular tank to be treated has the following dimensions:

- Diameter = 5 metres
- Depth = 1.5 metres

To calculate the tank volume we half the diameter to give the radius; 5 metres /2 = 2.5 metres

Tank volume = 3.14 x 2.5 x 2.5 x 1.5 metre tank depth

= 29.44 m^3 x 1000

= 29 440 litres x 1000

= 29 440 000 ml

Remember this is the tank volume and not necessarily the water volume.

Example 2

To demonstrate how an error could be made we will look at the following example.

- Diameter = 5 metres
- Water depth = 1 metre

To calculate the water volume in the tank we half the diameter to give the radius; 5 metres /2 = 2.5 metres

Tank volume = 3.14 x 2.5 x 2.5 x 1 metre water depth

= 19.63 m^3 x 1000

= 19 625 litres x 1000

= 19 625 000 ml

In both examples above you will notice we used the same 5 metre circular tank but changed the tank depth for the actual water depth. This gives a very different volume, 19.63 m^3 as opposed to 29.44 m^3, which can result in the wrong chemical dose being administered if not calculated correctly.

How do we calculate the actual quantity of chemical required?

Once you have the volume of water in the holding unit to be treated you next need to know the dose rate of the chemical being administered. This will either be on the manufacturers label or in the written veterinary advice provided with the chemical.

If we use both calculations in the above examples, you will notice the difference in chemical quantity between them is significant. If the calculations are incorrect there is a danger of over/under dosing the chemical, which can cause damage to the fish, cause mortalities, be ineffective against the pathogen and pollute the environment unnecessarily with the excess chemicals.

The chemical we are using in this example is formalin which has a prescribed dose rate of 200 parts per million (ppm).

Example 1 has a tank volume of 29.44 m^3.

To calculate the total quantity of formalin required:

29.44m^3 x 200ppm = 5888 ml/1000 = 5.888 litres of formalin

Example 2 has a water volume of 19.63m^3

To calculate the total quantity of formalin required for example 2:

19.63m^3 x 200ppm = 3926 ml/1000 = 3.926 litres of formalin

It is obvious to see that getting the volume calculation wrong at the start can make a significant difference to the amount of chemical required, which in this case was 1.962 litres of formalin.

2.2 Calculating bacterial disease treatments

Calculating treatment chemical quantities is straight forward but does require a few calculations to be performed accurately. In most aquaculture facilities the calculations will be completed by farm control software or specialists fish vets. It is useful for all fish farmers however to understand how the chemical quantities are calculated.

When the treatment to be administered is an infeed treatment the volume of the holding unit is not required to calculate the quantity of chemical required, unlike external treatments. The information that is necessary however is the total biomass (weight in kg) of the stock being treated, the daily dose rate of the chemical being added to the feed. It is important to use the correct units of measurements when calculating any infeed treatments. If the calculations are incorrect there is a risk of either overdosing the treatment, treatments being ineffective through underdosing and an increased risk of bacteria building a resistance to the antibiotic treatment.

Step 1

How do we calculate the biomass of the holding unit to be treated with antibiotics for a bacterial infection?

Biomass = Total number of fish in holding unit x Average weight in grams/1000 = Biomass (Stock Wt) Kg

20 000 fish x 60 grams average weight/1000 = 1200 kg biomass

How do we calculate the actual quantity of antibiotic required?

- Infeed antibiotic quantity required = Biomass (kg) x Daily dose rate of antibiotic/kg of fish/day
- 1200 kg x 80 mg = 96000 mg/1000 = 96 grams of antibiotic/day
- The treatment is administered daily for 10 days so the total amount of infeed chemical required for this example = 96-gram x 10 days = 960 grams total antibiotic over 10 days

The quantity of antibiotic required would normally be added to the feed as a batch that would be fed to the stocks being treated. To ensure that all the treated feed is consumed the daily feed rate for the treated stock will normally be reduced e.g. by 50% for the whole 10-day treatment period.

Step 2

The stocks being treated should be fed at a daily feed rate of 2% of the biomass/day.

- Biomass - 1200 kg x 2% = 24 kg of feed/day for the treatment period of 10 days = 240 kg of feed
- The treatment daily feed rate should be reduced, in this case by 50% to ensure all the food (and therefore antibiotic dose) is consumed.
- Biomass – 1200 kg x 1% = 12 kg of feed/day for the treatment period of 10 days = 120 kg of feed

For this example, 960 grams of antibiotic would be premixed with 120 kg of feed for the whole 10day treatment.

It is standard practice to order the feed pre-treated by the feed manufacturers, especially when dealing with large quantities of feed as is the case on Atlantic salmon on growing sites.

Can medicated feed be produced by fish farmers themselves?

On site mixing of treated feed would only be considered when dealing with a small batch as in the example shown here. When applying antibiotics to feed on the farm dry gelatine can be mixed to the medication before mixing it with a feed. The gelatine acts as an adhesive agent to stick the medication to the external surface of the feed particles. This is a less precise process than having the antibiotic added during the feed manufacture process and is only used on small farms lacking access to a commercial supplier to make up the medicated feed.

3. Notifiable diseases of salmon

What is a notifiable disease?

Notifiable' diseases are diseases that you are legally obliged to report to the relevant government authorities, even if you only suspect that a human, animal or plant may be affected.

Notifiable diseases can be:

- Endemic – this means it is already present in a country
- Exotic – not normally present, but poses a significant risk

It is important to note that some diseases can be passed between animals and humans, which means they are zoonotic. This can make them a danger to human health if not dealt with promptly and appropriately.

Fish, molluscs and crustaceans are protected by various pieces of legislation within the jurisdiction of each country. In Scotland this protection is provided by the Aquatic Animal Health (Scotland) Regulations 2009. This Regulation places a responsibility on the owner of aquatic animals, including others who may be involved with the animals to report the symptoms of certain diseases to the Fish Health Inspectorate in Scotland.

The reason some diseases in aquaculture are classed as notifiable diseases, is they are generally those are considered to have the potential for significant economic consequences to aquaculture or could cause detrimental environmental effects to wild species and the wider environment.

Diseases are caused by pathogens, but what are they?

A definition of a pathogen is:

"An agent causing disease or illness to its host, such as an organism or infectious particle capable of producing a disease in another organism."

http://www.biology-online.org/dictionary/Pathogens

Pathogen is a broad term to describe a group of agents that cause disease. The disease-causing agents that most people will know of, are as follows:

- Viruses
- Bacteria
- Fungi
- Parasites (internal and external)

Now we know what a pathogen is and that they cause disease, what is a disease?

A definition of a disease is:

“A pathological condition of a part, organ, or system of an organism resulting from various causes, such as infection, genetic defect, or environmental stress, and characterized by an identifiable group of signs or symptoms.”

(http://www.thefreedictionary.com/disease)

A **disease is a condition caused by a pathogen**, so which diseases are commercially important to aquaculture?

There are many diseases important to aquaculture, particularly when the diversity of species being farmed globally is taken into consideration.

Some of the diseases of importance to salmon aquaculture in Scotland, for example, include;

- Amoebic Gill Disease (AGD)
- Bacterial Kidney Disease (BKD) - Notifiable
- Enteric Redmouth (ERM)
- Furunculosis
- Infectious Pancreatic Necrosis (IPN)
- Pancreas Disease (PD)
- Saprolegnia
- Sea Lice Lepeophtheirus salmonis
- Viral Haemorrhagic Septicaemia (VHS) – Notifiable

There are also other diseases which are of concern but have not been observed in Scotland to date, and include,

- the viral disease Infectious Haematopoeitic Necrosis (IHN) and
- the external parasite Gyrodactylus salaris.

Gyrodactylus salaris a gill fluke has wiped out wild salmon stocks in entire river systems in Norway. It is not found in the UK but if ever found it is ‘notifiable’.

The viral disease Infectious Salmon Anaemia (ISA), has been observed in Scotland in the past but has been successfully eradicated and this remains a notifiable disease.

Blue Mentor Multiple choice question banks- Fish health and welfare

Guidance: Multiple Choice

This series of multiple-choice questions have been designed so as there is only one possible correct and complete response. This allows prior knowledge to be established through pre-testing.

These questions have been devised for use within a learning management system (LMS) with feedback to learners provided.

Taxonomy: Bank number, Subject, Question title

Bank 1 Fish welfare

1.1	What are the terms used to describe the types of stress that can impact on farmed salmon welfare? Select AS MANY as you believe to be correct. a) Mild b) Acute c) Severe d) Chronic Ans b,d Feedback: You should have selected b) and d) as the correct answer. Answers a) and c) are incorrect as these terms are not used to differentiate different types of stress.
1.2	What is the correct definition of acute stress? Select the CORRECT ANSWER from the options below. a) Stress that leads to mass mortality b) Long-term stress that can causes fish disease c) Stress that causes severe pain and suffering. d) Short-term stress that can have a major health and welfare impact Ans d Feedback: You should have selected d) as the correct answer as all other answers are incorrect.
1.3	What is the correct definition of chronic stress? Select the CORRECT ANSWER from the options below. a) Stress that leads to mass mortality b) Long-term stress that can causes fish disease c) Stress that causes severe pain and suffering. d) Short-term stress that can have a major health and welfare impact

	Ans d Feedback: You should have selected b) as the correct answer as all other answers are incorrect.
1.4	What can cause farmed Atlantic salmon acute stress? Select AS MANY as you believe to be correct. a) Being graded b) Sampling with a Vaki frame c) Sub optimal water quality d) Overcrowding prior to grading Ans a,d Feedback: You should have selected a) and d) as the correct answer. Answers b) and c) are incorrect as they are not causes of acute stress.
1.5	What can cause farmed Atlantic salmon chronic stress? Select the CORRECT ANSWER from the options below. a) Grading b) Harvesting c) Sub optimal water quality d) Overcrowding prior to grading Ans c Feedback:You should have selected c) as the correct answer as all other answers are incorrect.
1.6	How does the Atlantic salmon respond to stress physiologically? Select AS MANY as you believe to be correct. a) Cortisol release b) Increased heart rate c) Increased appetite d) Increased blood pressure Ans a,b,d Feedback: You should have selected a), b) and d) as the correct answer. Answers c) is incorrect as appetite is reduced and not increased in response to stress.
1.7	Which of the following actions would stress in farmed Atlantic salmon? Select AS MANY as you believe to be correct.

	a) Increasing stock density b) Fasting before handling c) Reducing stock density d) Minimising time out of the water e) Minimising handling Ans b,c, d, e Feedback: You should have selected b), c), d) and e) as the correct answer. Answer a) is incorrect as increasing the stock density is likely to increase stress.
1.8	How can environmental welfare risks be remediated for RAS farmed Atlantic salmon? Select AS MANY as you believe to be correct. a) Reducing fish biomass b) Use of prophylactics c) Optimisation of biofiltration d) Adherence to water quality standards Ans a, c, d Feedback: You should have selected a), c) and d) as the correct answer. Answer b) is incorrect as the use of prophylactics is not a recommended response to any environmental welfare issue.
1.9	Which water quality parameter data should never be interpreted in isolation? Select AS MANY as you believe to be correct. a) Water temperature b) Ammonia c) Dissolved oxygen d) Carbon dioxide e) pH Ans b, e Feedback: You should have selected b) and e) as the correct answer. Answers a), c) and d) are incorrect as data on these parameters can be interpreted without reference to other parameters.
1.10	Which water quality parameter must be measured to determine the toxicity of ammonia? Select the CORRECT ANSWER from the options below. a) Water temperature b) pH c) Dissolved oxygen d) Carbon dioxide

	e) Nitrate Ans c Feedback: You should have selected b) as the correct answer as all other answers are incorrect.
1.11	Which water quality parameter influences the Atlantic salmon's tolerance to nitrite and nitrate? Select the CORRECT ANSWER from the options below. a) Chloride b) Temperature c) Dissolved oxygen d) Carbon dioxide e) pH Ans a Feedback: You should have selected a) as the correct answer as all other answers are incorrect.
1.12	Why is a 24-hour feeding day with regular small meals often recommended by RAS designers? Select the CORRECT ANSWER from the options below. a) To reduce Dissolved Oxygen consumption b) To improve water clarity c) To reduce metabolic waste peaks d) To reflect natural feeding behaviour Ans c Feedback: You should have selected c) as the correct answer as all other answers are incorrect.
1.13	What are the main sources of potential disease pathogens in farmed Atlantic salmon RAS? Select AS MANY as you believe to be correct. a) Salmon feed b) Incoming water supply c) Incoming air supply d) Incoming eggs Ans b, d Feedback: You should have selected b) and d) as the correct answer. Answers a) is incorrect because salmon feeds are subjected to great heat and pressure during

	manufacture which kills any disease organisms. Answer c) is incorrect as there are no airborne salmon diseases.
1.14	Why are chemical disease treatments best avoided in RAS? Select the CORRECT ANSWER from the options below. a) Because RAS farmed Atlantic salmon are less responsive to chemical treatment b) Because the biofilter is vulnerable to damage by chemicals in the water c) Because the chemicals are caustic and can damage the water pumps d) Because they are a threat to the water quality standards Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.
1.15	What determines the Atlantic salmon's sensitivity to fish handling? Select the CORRECT ANSWER from the options below. a) Its genetic origin b) Dissolved oxygen levels c) Water temperature d) Its size Ans b Feedback: You should have selected d) as the correct answer as all other answers are incorrect.
1.16	What is the maximum time Atlantic Salmon are allowed to be out of the water? Select the CORRECT ANSWER from the options below. a) 40 seconds b) 20 seconds c) 10 seconds d) 5 seconds Ans c Feedback:You should have selected c) as the correct answer as all other answers are incorrect.
1.17	Which of these behaviours are indicative of acute welfare concerns? Select AS MANY as you believe to be correct. a) Gasping b) Burrowing c) Flashing

	d) Lethargy e) Refilling swim bladder Ans b, d Feedback: You should have selected a), c) and d) as the correct answer. Answers b) and e) are incorrect because these behaviours are indicators of mild discomfort and not indicative of acute stress.
1.18	What is an increase in thickened grey dorsal fins indicative of in farmed Atlantic salmon parr? Select the CORRECT ANSWER from the options below. a) Sub optimal pH b) Nutritionally deficient feeds c) Parasitic disease d) Aggression/underfeeding Ans d Feedback: You should have selected d) as the correct answer as all other answers are incorrect.
1.19	Where are emaciated fish most likely to be found in a farmed Atlantic salmon population? Select AS MANY as you believe to be correct. a) Near the water surface b) Near the tank base c) Evenly distributed within tank d) At the periphery of the group Ans a, d Feedback: You should have selected a) and d) as the correct answer. Answers b) and c) are incorrect because emaciated salmon are not found near the tank base or evenly distributed.
1.20	For which stages of the Pure Salmon production cycle is ‘Routine Welfare Monitoring’ conducted? Select AS MANY as you believe to be correct. a) Yolk sac alevins b) Fry c) Smolt d) Post smolt e) Grow out Ans a, b, c, d, e

	Feedback: You should have selected a), b), c), d) and e) as the correct answer as all stages of the production cycle are subjected to routine monitoring.
1.21	When is ‘In Depth Welfare Monitoring’ normally conducted? Select AS MANY as you believe to be correct. a) Yolk sac alevins b) Fry c) Smolt d) Post smolt e) Grow out Ans a Feedback: You should have selected a), b), c), d) and e) as the correct answer as all stages of the production cycle are subjected to routine monitoring.

Bank 2 Biosecurity

2.1	What are the three foundations of aquaculture biosecurity management? Select AS MANY as you believe to be correct. e) Fish stocks f) Farm design g) People h) Pathogens Ans a,c,d Feedback: You should have selected a), c), and d) as the correct answer. Answers b) is incorrect as although good farm design supports biosecurity management, it is not one of the three pillars.
2.2	What influences whether farmed Atlantic salmon contract an infectious disease? Select AS MANY as you believe to be correct. a) Holding unit water quality b) Husbandry practices c) Choice of feed supplier d) Disease susceptibility of the stock Ans a,c,d Feedback: You should have selected a), b), and d) as the correct answer. Answer c) is incorrect as all feed suppliers’ offer nutritionally complete feeds with no detrimental effect on the immune system.

2.3	What determines the degree of risk a specific pathogen poses to farmed Atlantic salmon? Select AS MANY as you believe to be correct. a) The pathogens vulnerability to chemicals b) The pathogens biology and life cycle c) The pathogen's ability to survive on inanimate objects. Ans a,b,c Feedback: You should have selected a), b), and c) as all these factors determine the level of risk a pathogen presents.
2.4	Which components need to be cleansed following a disease outbreak on a RAS salmon farm? Select AS MANY as you believe to be correct. a) Water pipes b) Holding units c) Filters d) Sump Ans a,b,c,d Feedback: You should have selected a), b), c) and d) as all components need to be cleansed.
2.5	How does a defined boundary assist farm biosecurity? Select the CORRECT ANSWER from the options below. a) Unidirectional flow of staff b) Elimination of unauthorised entry c) Integrated disinfection points d) Staff designated to a specific work area e) Equipment dedicated to a specific work area Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.
2..6	What biosecurity policies typify the exclusion zone of a salmon farming facility. Select AS MANY as you believe to be correct. a) Unidirectional flow of staff b) Elimination of unauthorised entry c) Integrated disinfection points d) Staff designated to a specific work area

	e) Equipment dedicated to a specific work area Ans a,d,e Feedback: You should have selected a), d) and e) as the correct answer. Answers b) and c) are incorrect as they are policies that typically apply to other zones.
2.7	What are the disinfection points used for in a farm 'prevention zone'? Select AS MANY as you believe to be correct. a) Fish holding units b) Vehicles/trucks c) Salmon eggs d) Staff/visitors e) Machinery/equipment Ans b,d,e Feedback: You should have selected b), d) and e) as the correct answer. Answers a) and c) are incorrect as fish husbandry and hatchery routines address these important biosecurity requirements as opposed to level 2 disinfection.
2.8	Which of the following are typically under some form of directional movement control in a salmon farm facility exclusion zone. Select AS MANY as you believe to be correct. a) Staff b) Fish feed c) Live fish d) Fish mortalities e) Visitors Ans a,b,c,d,e Feedback: You should have selected all options a) – e) as they are all under some form of movement control.
2.9	Where is personal footwear normally permitted in a Salmon farm facility? Select AS MANY as you believe to be correct. a) Farm office b) Changing rooms c) Fish rearing areas d) Holding units Ans a,b Feedback: You should have selected a) and b) as the correct answer. Answer c) is incorrect as personal footwear is normally prohibited in all fish rearing areas.

2.10	What are the last two activities staff must conduct before entering their work area? Select the TWO you believe to be correct. a) Put on company boots b) Take a shower c) Sanitise hands d) Put on company PPE e) Disinfect boots Ans c,e Feedback: You should have selected c) and e) as the correct answer. Answers a), b) and d) are all incorrect as they are earlier activities when staff are getting ready for their work shift.
2.11	Place the following work preparation activities in the correct sequence from a biosecurity perspective. 1. Take shower 2. Put on personal clothing 3. Put on PPE 4. Put on work boots 5. Sanitise hands 6. Dip work boots in foot bath **Articulate creative** Create a drag and drop task
2.12	What should a hatchery technician have to wear when conducting fish husbandry tasks to comply with typical salmon farm biosecurity policies? Select AS MANY as you believe to be correct. a) Dedicated boots b) Coveralls c) Wet gear d) Apron e) Nitrile gloves Ans a,b Feedback: You should have selected a) and b) as the correct answer. Answers c), d) and e) are incorrect as these items are not required for fish husbandry in the hatchery.
2.13	What should a hatchery technician wear when conducting egg receipt tasks to comply with a typical salmon farm's biosecurity policies? Select AS MANY as you believe to be correct. a) Dedicated boots b) Coveralls

	c) Wet gear d) Apron e) Nitrile gloves Ans a,b,e Feedback: You should have selected a), b) and e) as the correct answer. Answer c) and d) is incorrect as these are not requirements when handling eggs in the hatchery.
2.14	What do grow out technician have to wear for routine fish handling operations to comply with a typical salmon farm's biosecurity policies? Select AS MANY as you believe to be correct. a) Dedicated boots b) Coveralls c) Wet gear d) Apron e) Nitrile gloves Ans a,b,c Feedback: You should have selected a), b) and c) as the correct answer. Answers d) and e) are incorrect as they are not required for fish handling operations during grow out.
2.15	What does a hatchery technician have to wear when working in the laboratory to comply with Pure Salmon biosecurity policies? Select AS MANY as you believe to be correct. a) Dedicated boots b) Coveralls c) Wet gear d) Apron e) Nitrile gloves Ans a,b,d Feedback: You should have selected a), b) and d) as the correct answer. Answers c) and e) are incorrect as they are not required for laboratory-based work.
2.16	When should salmon farming company vehicles be cleaned and disinfected? Select AS MANY as you believe to be correct. a) Routinely every 2 days b) Whenever soiled c) Routinely every month d) Routinely once a week Ans b,d

	Feedback: You should have selected b) and d) as the correct answer. Answers a) and d) are incorrect as the cleaning is either too frequent or two infrequent, respectively.
2.17	In which zone do vehicles not need to be disinfected? Select the CORRECT ANSWER from the options below. a) Boundary b) Prevention zone c) Exclusion zone Ans a Feedback: You should have selected a) as the correct answer as all other answers are incorrect.
2.18	Which vehicles need the authorisation of the facility manager to be allowed to enter the Prevention zone? Select AS MANY as you believe to be correct. a) Supply delivery vehicles b) Mortality extraction vehicles c) Staff vehicles Ans a,b,c Feedback: You should have selected a, b) and c) as the correct answer, as all these vehicles need authorisation.
2.19	What biosecurity measures should be applied when receiving fish feed deliveries? Select AS MANY as you believe to be correct. a) Floor loading area disinfected b) Feed pallet packaging disinfected c) Feed pellet packaging discarded d) Feed bags disinfected Ans a,c,d Feedback: You should have selected a), c) and d) as the correct answer. Answer b) is incorrect as the feed pallet packaging is not disinfected before it is discarded.
2.20	Typically, how often are Salmon farm laboratory work tops disinfected? Select the CORRECT ANSWER from the options below. a) Routinely twice daily b) Routinely daily

	c) Routinely once every 2 days d) Routinely once a week e) After every use Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.
2.21	Which surfaces in a RAS facility are cleaned with a pressure washer? Select AS MANY as you believe to be correct. a) Automatic feeders b) Floors c) Fish holding units d) Walls e) Filtration equipment Ans b,d Feedback: You should have selected b) and d) as the correct answer. Answers a), c) and e) are incorrect as a pressure washer would be an inappropriate method for cleaning these surfaces and could be damaging.
2.22	Which of the following surfaces are cleaned daily in a Pure Salmon RAS facility? Select AS MANY as you believe to be correct. a) Automatic feeders b) Floors c) Piping d) Walls e) Filtration equipment Ans a, c, e Feedback: You should have selected a), c) and e) as the correct answer. Answers b) and d) are incorrect as they are not cleaned as frequently.

Bank 3 Fish Disease diagnosis

3.1	What is the first informative stage of fish disease diagnosis? Select the CORRECT ANSWER from the options below. a) Gross pathology observation b) Fish behaviour observations c) Micro pathology observations d) External laboratory sample analysis	

	Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.	
3.2	What are the visible signs that a population of Atlantic salmon have a disease? Select AS MANY as you believe to be correct. a) Increased appetite b) Fish appear nervous c) Fish separate themselves of from the shoal d) External darkening of the skin e) Some fish swim near the surface Ans b,c,d,e Feedback: You should have selected b), c), d) and e) as the correct answer. Answers a) is incorrect as fish appetite reduces as opposed to increasing in response to disease infection.	
3.3	What is a gross pathological Atlantic salmon disease symptom? Select the CORRECT ANSWER from the options below. a) A symptom apparent from observing fish behaviour b) A symptom only visible when a fish is dissected c) A symptom only visible from microscopic examination d) A symptom visible with the naked eye Ans d Feedback: You should have selected d) as the correct answer as all other answers are incorrect.	
3.4	Why is gross pathology an unreliable way to confirm a specific disease in farmed Atlantic salmon? Select AS MANY as you believe to be correct. a) Most gross pathology symptoms are shared by many diseases b) Most gross pathology symptoms are not distinctive	

	c) Viewing gross pathology is impractical on a farm d) Confirmatory gross pathology symptoms are not always evident Ans a,b,d Feedback: You should have selected a), b) and d) Answer c) is incorrect as samples of salmon are captured for examination of any external symptoms/gross pathology.	
3.5	What is a microscopic pathological symptom? Select the CORRECT ANSWER from the options below. a) A symptom apparent from observing fish behaviour b) A symptom only visible when a fish is dissected c) A symptom only visible from microscopic examination d) A symptom visible with the naked eye Ans c Feedback: You should have selected c) as the correct answer as all other answers are incorrect.	
3.6	What procedures form a part of a typical disease sampling regime? Select AS MANY as you believe to be correct. a) Parasitology b) Length/weight sampling c) Virology d) Histology e) Bacteriology Ans a,c,d,e Feedback: You should have selected a), c), d) and e). Answer b) is incorrect as although length/weight sampling can inform Operational Welfare Indicators (OWIs) it is not part of disease sampling.	
3.7	What fish should a sample of Atlantic salmon intended for disease analysis include? Select AS MANY as you believe to be correct.	

	a) Moribund fish b) Fish that appear healthy c) Decomposing mortalities d) Recent mortalities Ans a,b,d Feedback: You should have selected a), b) and d). Answer c) is incorrect as decomposing mortalities are unsuitable for any form of disease analysis.	
3.8	When should bacterial samples be taken from a fish during disease sampling, if a bacterial infection is suspected? Select the CORRECT ANSWER from the options below. a) After the blood samples b) After the mucus scrapes c) At the same time as the histology samples d) Before all other samples are taken Ans d Feedback: You should have selected d) as the correct answer as all other answers are incorrect.	
3.9	Which parts of the Atlantic salmon's anatomy are bacterial samples be taken from? Select AS MANY as you believe to be correct. a) Digestive tract b) Head kidney c) Gill d) Spleen e) Liver Ans b,d Feedback: You should have selected b) and d) as the correct answer. Answers a), c) and e) are incorrect as they are not the sites for bacterial sampling.	
3.10	Which parts of the Atlantic salmon's anatomy are sampled to identify parasites? Select AS MANY as you believe to be correct.	

	a) Skin b) Kidney c) Gill d) Heart e) Liver Ans a,c Feedback: You should have selected a) and c) as the correct answer. Answers b), d) and e) are incorrect as they are not parasite sampling sites.	
3.11	Which parts of the Atlantic salmon's anatomy are excluded from routine histological samples? Select AS MANY as you believe to be correct. a) Fins b) Kidney c) Gill d) Heart e) Eye Ans a,e Feedback: You should have selected a) and e) as the correct answer. Answers b), c) and d) are incorrect as they are all included in routine histology samples.	
3.12	What observation would lead to the inclusion of fins and eyes in histology samples? Select the CORRECT ANSWER from the options below. a) Excess mucus b) Lesions c) Dark colouration d) Mechanical damage Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.	
3.13	Why is the accurate identification of the specific bacteria causing a bacterial disease important?	

	Select the CORRECT ANSWER from the options below. a) To be able to report it to national authorities b) To be able to record it in farm stock records c) To be able to prescribe the correct treatment Ans c Feedback: You should have selected c) as the correct answer as all other answers are incorrect.	

3.14	What is the next step if haemolytic or pigment producing bacteria colonise the initial agar culture plate? Select the CORRECT ANSWER from the options below. a) Send the plate to the external pathology laboratory b) Replate the culture using a sample taken from the colony c) Start the identification process by gram staining a sample of the colony d) Take another sample of bacteria from the kidney or spleen of another fish Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.	
3.15	Under what conditions can bacteria on the agar plates be cultured? Select AS MANY as you believe to be correct. a) Incubated in an incubator b) Incubated at room temperature (18C) c) Incubated at low temperatures (1- 4 C)	

	Ans a,b Feedback: You should have selected a) and b) as the correct answer. Answers c) is incorrect as the bacteria are not cultured at low temperatures.	
3.16	How is a sample of bacterial taken from the kidney or spleen of an Atlantic salmon for cultivation? Select the CORRECT ANSWER from the options below. a) On a mounted needle b) On a sterile loop c) Using a pipette d) Using a cotton swab Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.	
3.17	Which of these bacterial pathogens infecting Atlantic salmon test gram positive? Select the CORRECT ANSWER from the options below. a) Aeromonous salmonicida (Furunculosis) b) Vibrio salmonicida c) Bacterial Kidney disease (BKD) Ans c Feedback: You should have selected c) as the correct answer as all other answers are incorrect.	
3.18	What is the purpose of molecular PCR sampling? Select the CORRECT ANSWER from the options below. a) To narrow down the number of possible bacterial pathogens b) To confirm the specific bacterium and causative agent of disease c) To confirm whether the bacterium is gram positive or negative Ans b	

	Feedback: You should have selected b) as the correct answer as all other answers are incorrect.	
3.19	What size should the tissue sample be for molecular/PCR testing by the external pathology laboratory? Select the CORRECT ANSWER from the options below. a) 2 mm b) 5 mm c) 1 cm d) 2 cm Ans b Feedback: You should have selected b) as the correct answer as all other answers are incorrect.	
3.20	What size should the tissue sample be for histological analysis by the external pathology laboratory? Select the CORRECT ANSWER from the options below. a) 2 mm b) 5 mm c) 1 cm d) 2 cm Ans c Feedback: You should have selected c) as the correct answer as all other answers are incorrect.	
3.21	Where are mucus skin scrapes taken from for parasite identification? Select AS MANY as you believe to be correct. a) Skin above the lateral line b) Gill lamellae c) Skin to the rear of the vent d) Operculum (gill cover) e) Skin behind the pectoral fin Ans a,e Feedback: You should have selected a) and e) as the correct answer. Answers b), c) and d) are	

	incorrect as they are not recommended sampling sites for mucus skin scrapes.	
3.22	For what reasons are blood samples taken from farmed Atlantic salmon? Select AS MANY as you believe to be correct. a) To detect metabolic disturbances b) To detect pathogens c) Conduct red blood cell counts d) To monitor smoltification e) To detect pathogen antibodies Ans a,b,d, e Feedback: You should have selected a), b), d) and e) as the correct answer. Answer c) is incorrect as blood samples are not collected to conduct red blood cell counts.	
3.23	What are the key criteria for taking blood samples from farmed Atlantic salmon? Select AS MANY as you believe to be correct. a) The fish is humanely euthanized b) The blood sample volume (units) is no more than 3% of the body weight (units) c) The fish is anaesthetised d) The blood sample volume (units) is no more than 1% of the body weight (units) Ans c,d Feedback: You should have selected c) and d) as the correct answer. Answers a) and b) are not appropriate blood sampling criteria.	
3.24	From which blood vessel are blood samples collected? Select the CORRECT ANSWER from the options below. a) Dorsal aorta b) Renal artery c) Caudal vein d) Hepatic vein Ans c	

	Feedback: You should have selected c) as the correct answer as all other answers are incorrect.	

Unit Title:	**Fish health and welfare**
Guided Learning hours:	**60**
Unit level (EQF):	**4**

Tutor Support Pack Structure

This Tutor Support Pack is structured in the following way:

SECTION ONE

- List of Learning Outcomes (extracted from Unit Descriptor)

SECTION TWO

- Suggested Schedule for Delivery by Topic for each Learning Outcome with delivery suggestions.

SECTION THREE

Breakdown for each Learning Outcome

- Stated Learning Outcome
- Learning Content identifying what the student should be able to do at the end of the Outcome.
- Expansion of Learning Content
- Consolidation Activity to formatively assess Learning Outcome

SECTION FOUR

- Glossary

SECTION ONE

Unit Outcomes

1. Explain the management of viral and bacterial fish diseases with reference to their causes and symptoms.

2. Explain the management of parasitic and fungal fish diseases with reference to their causes and symptoms.

3. Describe the management of nutritional, environmental and genetic fish health problems with reference to their causes and symptoms.

4. Explain the legislative control of fish health management in the EU, with reference to relevant codes of practice and the implications to fish husbandry practices.

Overall Suggested Schedule for Unit

TOPIC	DELIVERY TYPE
LEARNING OUTCOME 1	
Outline the biology of viruses and bacteria, including their structure, life cycles and general pathology.	On-line learning episodes and/or lecture on the biology of common fish viruses and bacteria. Learner Activity: Investigation into a given specific viral disease to determine the symptoms and pathology.
Describe the pathology of specific viral and bacterial diseases most relevant to aquaculture sectors.	On-line learning episodes and/or lecture on the pathology of the most relevant viral and bacterial diseases Learner Activity: The development of a table / matrix to summarise the symptoms of the common viral and bacterial diseases.
Identify viral and bacterial infections from images, descriptions of the symptoms and pathology test reports, recording methodologies.	On-line learning episodes and/or lecture on the identification process and laboratory procedures for the identification of bacterial and viral diseases. Learner Activity: A practical activity removing tissue and organ samples.
Explain the methods used to prevent, treat or manage viral and bacterial diseases, including bio-security and hygiene procedures, husbandry and vaccination.	On-line learning episodes and/or lecture on the prevention of viral and bacterial diseases. Learner Activity: Investigation into disease treatment methods for viral and bacterial diseases.
CONSOLIDATION ACTIVITIES	The development of a web page: Common infectious fish diseases in North European salmonids. This could include their cause, prevention and cure.
LEARNING OUTCOME 2	

TOPIC	DELIVERY TYPE
Outline the biology of parasites and fungi, including the life cycles and symptoms for fish diseases most relevant to Salmonid aquaculture	On-line learning episodes and/or lecture on parasite biology for different life cycle stages. Learner Activity: The development of a collection of common Salmonid parasite lifecycle displays.
Describe the pathology of specific parasitic and fungal fish diseases most relevant to Salmonid aquaculture	On-line learning episodes and/or lecture on parasite and fungi pathology and their environmental requirements. Learner Activity: Investigation of the pathology of a common Salmonid fish parasite.
Identify parasitic and fungal fish diseases from images, descriptions of the symptoms and pathology test reports, recording methodologies.	Instruction in necroscopy procedures. Learner Activity: A laboratory practical making up slide preparations for examination.
Explain the techniques used to prevent, treat or manage parasitic and fungal diseases, including bio-security, hygiene, husbandry and therapeutics.	Instruction in disease treatment calculations and application methods for chemical bath treatments for parasites. Learner Activity: A practical exercise calculating holding unit volumes and dose rates and treating fish.
CONSOLIDATION ACTIVITIES	The development of a web page: Common infectious fungal and parasitic fish diseases in Northern Europe. This could include their cause, prevention, and treatment strategies.
LEARNING OUTCOME 3	
Describe significant environmental, nutritional and genetic fish health problems, with reference to the common causes.	On-line learning episodes and/or lecture on non-transmissible diseases. Learner Activity: Investigation into either: The tolerance limits of fish or nutritional deficiencies.
Describe the identification of significant environmental, nutritional and genetic health problems, with reference to their typical symptoms.	On-line learning episodes and/or lecture on the interaction between environmental conditions, fish nutrition and fish health. Learner Activity: The creation of a table that summarises the symptoms of nutritional deficiencies

TOPIC	DELIVERY TYPE
Outline the prevention and treatment of environmental, nutritional and genetic fish health problems.	A lecture on the prevention of environmental, genetic and nutritional diseases. Learner Activity: Learners note the feed storage conditions during their farm practical placements.
CONSOLIDATION ACTIVITIES	Learners could be given multiple choice test or quick quiz on the non infectious diseases. In addition 'fish health problem scenarios' could be given and solved based on visual or described symptoms.
LEARNING OUTCOME 4	
Explain the environmental and economic risks of infectious diseases spreading, with reference to movements of exotic species and diseases into new locations.	On-line learning episodes and/or lecture on the causes of disease transfer, the impact of pandemics, and biosecurity. Learner Activity: Learners could describe the bio security measures adopted on the farm they work on.
Outline the legislative and animal welfare issues arising from prevention and control of infectious and non infectious fish diseases.	On-line learning episodes and/or lecture on the animal welfare regulations impacting on the north Atlantic aquaculture sectors. Learner Activity: Learners note good practices and practices that could be improved during farm placement.
Outline the current legislation relevant to fish health management in the EU, including the jurisdiction of Government agencies and purpose of the legislation.	On-line learning episodes and/or lecture on the raft of legislation and regulations at European and national level. Learner Activity: The creation of a mind map to show the relationship between the main legislation.
Describe the codes of practice for fish stocking, fish transport, fish husbandry and humane slaughter with reference to their principles and purpose.	On-line learning episodes and/or lecture on the roles and responsibilities of different agencies with legislative responsibility. Learner Activity: An exploratory exercise to compare the Codes of Good Practice and Certification Schemes.
Outline the records kept for fish health management and compliance purposes	On-line learning episodes and/or lecture on farm-based record keeping systems - demonstrate computerised systems.

TOPIC	DELIVERY TYPE
within a fish farm or other fish holding facility.	Learner Activity: Recordkeeping exercise based on hypothetical or real data, providing learners the opportunity to practice record keeping of fish disease treatments.
CONSOLIDATION ACTIVITIES	Consolidation of the key learning point can be best achieved through the analyses of given farm scenarios, asking learners to criticise each from a recordkeeping and compliance perspective.

SECTION THREE

LEARNING OUCOME 1

Explain the management of viral and bacterial fish diseases with reference to their causes and symptoms

Learning Content

By the end of this Topic the Student should be able to:

- Outline the biology of viruses and bacteria, including their structure, life cycles and general pathology.
- Describe the pathology of specific viral and bacterial diseases most relevant to Salmonid aquaculture.
- Identify viral and bacterial infections from images, descriptions of the symptoms and pathology test reports, recording methodologies.
- Explain the methods used to prevent, treat or manage viral and bacterial diseases, including bio-security and hygiene procedures, husbandry and vaccination.

Learning Content Part 1: Outline the biology of viruses and bacteria, including their structure, lifecycles, and general pathology.

Unlike other microorganisms, viruses have no organelles for their own metabolism and depend entirely on the resources of the infected host for growth and reproduction, replicating the DNA of invaded cells.

Structurally, a virus is composed of a nucleic acid-based virion, the same chemical that makes up genes, encapsulated by a protein coat known as a capsid. To be successful viruses must complete a series of developmental stages. They must implant at a point of entry to the fish body and then reproduce in large numbers. The replicated virus must then spread to target organs (disease sites) via the lymphatic and circulatory system, using capillary transport to access organs, multiplying inside endothelial cells, moving through gaps or being carried on leukocytes. Finally the virus must spread to sites where distribution into the environment can occur in order to infect new hosts.

Conversely bacteria contain a well developed cell structure and can be spherical (coccus), rod like (bacillus), spirillum (spiral) or elongated (filamentous). Fish are susceptible to a wide variety of bacterial pathogens. Many of the bacteria able to cause disease in fish are saprophytic and only become pathogens when fish are physiologically unbalanced, nutritionally deficient or stressed as a result of poor water quality and/or over stocking, allowing opportunistic bacterial infections to proceed. Hence the emphasis placed on disease prevention rather than cure by the aquaculture industry.

Suggested activities

1. On-line learning episodes and/or lecture on the biology of common fish viruses and bacteria, including their structure, lifecycle, and general pathology.

2. A learner centred investigation into a given specific viral disease of a farmed fish to determine the symptoms and pathology. The outcome can be shared with the group to illustrate the common ground between the symptoms of different viral and bacterial diseases.

Royalty free images

- Insert images to illustrate the structure of virus and/or bacterium

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	The Merck Veterinary Manual	http://www.merckmanuals.com/vet/exotic_and_laboratory_animals/fish/viral_diseases_of_fish.html	A description of the fish viruses of concern in the USA. **Suitable for unguided learners**
2	MPDI – Overview of significant pathogens	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230840/	Comprehensive overview of many important viral diseases that impact on aquaculture. **Suitable for learners, but some tutor guidance may be needed**
3	Wikapedia – Bacterial cell structure	http://en.wikipedia.org/wiki/Bacterial_cell_structure	A well illustrated guide to the structure and biology of bacteria cells, (not specific to fish). **Suitable for learners, but some tutor guidance may be needed**
4.	Wikapedia – Bacterial cell structure	https://en.wikipedia.org/wiki/Introduction_to_viruses	A good guide to the structure and biology of viruses, (not specific to fish). **Suitable for learners, but some tutor guidance may be needed**

Learning Content Part 2: Describe the pathology of specific viral and bacterial diseases most relevant to salmonid aquaculture

In common with all other animal farming systems in which animals are raised in greater numbers than they would be found in nature, the farming of Atlantic salmon can potentially increase the risk of disease outbreaks due to the number of individual animals living near each other. It is essential that good husbandry and a pro-active approach to health management is adopted at each farm location to minimise and mitigate these risks.

Atlantic salmon can be affected by a range of viral and bacterial pathogens, the most important of which cause: Pancreas Disease (PD), Salmonid Rickettsial Septicaemia (SRS), Infectious Pancreatic Necrosis (IPN), Heart and Skeletal Muscle Inflammation (HSMI), Infectious Salmon Anaemia (ISA), and Gill Disease (GD). The effects of disease can have major economic impacts on the industry, for example the ISA outbreak in Chile.

The first line of defence in disease and pathogen management is effective biosecurity and health plans to minimise disease and its spread. Certification schemes require such plans, as do other initiatives, such as 'The Code of Good Practice for Scottish Finfish Aquaculture'.

When needed, there are a range of medicines and chemical treatments available to control Atlantic salmon disease and pathogens, including antibiotics. Antibiotics are used strictly as therapeutants by the industry; they are not used as growth promoters. Overuse of antibiotics in farming or for human medical treatment speeds up the development of antibiotic resistance, which is when bacteria change and become resistant to the antibiotics used to treat them. Generally, only limited amounts of antibiotics are used rearing Atlantic salmon due to the availability and efficacy of vaccines.

Suggested activities

1. A lecture on the pathology of the viral and bacterial diseases most relevant to Salmonid aquaculture

2. The development of a table / matrix to summarise the symptoms of the common viral and bacterial diseases of farmed salmonids.

Royalty free images

- Insert images of viruses and or bacteria responsible for relevant fish diseases above.

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Infectious Salmon Anaemia (ISA)	Infectious Salmon Anaemia (ISA) - Diseases of wild and farmed Finfish - gov.scot (www.gov.scot)	Very accessible summary of Infectious Salmon Anaemia (ISA) **Suitable for unguided learners**
2	Infectious cardiomyopathy	https://www.gov.scot/publications/diseases-of-wild-and-farmed-finfish/pages/cardiomyopathy-syndrome/	Very accessible summary of Infectious cardiomyopathy syndrome **Suitable for unguided learners**
3	Bacterial Kidney Disease (BKD)	https://www.gov.scot/publications/diseases-of-wild-and-farmed-finfish/pages/bacterial-kidney-disease-bkd/	Very accessible summary of Bacterial Kidney Disease (BKD) **Suitable for unguided learners**
4	Amoebic gill disease	https://www.gov.scot/publications/diseases-of-wild-and-farmed-finfish/pages/amoebic-gill-disease-agd/	Very accessible summary of Amoebic gill disease **Suitable for unguided learners**
5	Enteric redmouth (ERM)	https://www.gov.scot/publications/diseases-of-wild-and-farmed-finfish/pages/enteric-redmouth-erm/	Very accessible summary of Enteric redmouth (ERM) **Suitable for unguided learners**
6	Infectious pancreatic necrosis (IPN)	https://www.gov.scot/publications/diseases-of-wild-and-farmed-finfish/pages/infectious-pancreatic-necrosis-ipn/	Very accessible summary of Infectious pancreatic necrosis (IPN) **Suitable for unguided learners**

Learning Content Part 3: Identify viral and bacterial infections from images, descriptions of the symptoms and pathology test reports.

Unlike many parasitic fish diseases the identification of viral and bacterial diseases cannot be completed on most fish farms without laboratory analysis by specialists. However, fish farmers are essential to information gathering leading up to a disease outbreaks, including; data on the environmental conditions, observations of fish behaviour and their external and internal appearance. They are also instrumental in gathering samples from dead and dying fish for analysis and the implementation of fish health management regimes.

The most important viral and bacterial diseases are invasive and attack a range of vulnerable disease sites. A sound knowledge of normal fish behaviour and external and internal appearance allows abnormalities to be more readily noticed on farm. The size, colour and texture of internal organs can be observed on dissecting recent mortalities. Common signs of bacterial and viral infection include; external and internal haemorrhaging, lesions and ulceration in the musculature, necrosis, enlarged organs, pale tubercles or furuncles and excess mucus deposits. Although the visible symptoms of specific diseases overlap considerably, observations of the disease sites can assist disease diagnosis. In the case of suspected bacterial diseases, a sample of the most infected tissues and organs is removed for laboratory analysis. Culturing on agar can be followed by gram staining and biochemical testing to identify the pathogen. Subsequent antimicrobial resistance testing will help the selection of the most effective chemical treatment.

As viruses are so small they are hard to detect and fish disease experts tend to first check for parasites, bacteria and fungi, to rule them out, before checking for viruses. Electron microscopy, or cell culture are the methods commonly used to identify a virus confirming the identification through serology, testing the blood for the presence of specific antibodies. Viruses are often species and tissue specific, making it difficult to isolate viral agents for some fish as they lack cell lines. Electron microscopy alone cannot be used to confirm a viral causative disease hence the need for confirmatory serology.

Suggested activities

1. A lecture on the identification process and laboratory procedures for the identification of bacterial and viral diseases.

2. A practical activity removing tissue and organ samples for the culture of a suspected bacterial pathogen. This could lead on to involvement of learners in the culturing, gram staining and testing the sensitivity of bacterial pathogens to chemical therapeutics, should the opportunity arise during the course.

Royalty free images

- Insert image of physical symptoms of viral/bacterial diseases

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Agar plating methodology	Aseptic Laboratory Techniques Plating Methods - Video (jove.com)	Comprehensive guidance including a video on agar plating techniques **Suitable for unguided learners**

2	Methods for the diagnosis of bacterial diseases	[Methods for the diagnosis of bacterial fish diseases | SpringerLink]()	Useful fish bacteriology overview **Suitable for learners in places, needs tutor support in others**
3	Fish health laboratory	[Fish Health Laboratory | PDF | Staining | Anatomy (scribd.com)]()	A sound overview of external and internal examination in the form of illustrated slides **Suitable for unguided learners**

Learning Content Part 4: Explain the methods used to prevent, treat or manage viral and bacterial diseases, including bio-security and hygiene procedures, husbandry and vaccination.

In principle, prevention is always better than cure. Globally there are many instances reported whereby the neglect of water quality, hygiene and basic husbandry have led to disease outbreaks which are then treated with chemotherapeutics. This can build pathogen resistance, allowing them to thrive further if the underlying causes of the disease outbreak remain unaddressed. The use of chemical disease treatments has dropped since the year 2,000. This is as a result of improved hatchery husbandry and management, biosecurity, the development of effective vaccines, improved feed formulations and the widespread use of immunostimulants.

Once a viral disease is in progress it cannot be altered through medication. Manipulation of water temperature and maintain a clean environment and good nutrition tend to be the best forms of defence to prevent secondary bacterial infections giving the immune system every opportunity to fight off the infection.

To improve general biosecurity, the planning of aquaculture facilities should consider potential disease interaction between wild and farmed stock to minimise the probability.

Suggested activities

1. A lecture on the prevention of viral and bacterial diseases through biosecurtiy, vaccination, fish husbandry and the management of the rearing environment.

2. A learner centred investigation into disease treatment methods for viral and bacterial diseases common to the North Atlantic region.

Royalty free images

- No images to recommend

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Salmon diseases, medicines and chemicals	https://www.seafish.org/responsible-sourcing/aquaculture-farming-seafood/species-farmed-in-aquaculture/aquaculture-profiles/atlantic-salmon/disease-medicines-and-chemicals/	A clear overview of the treatment options for salmonids **Suitable for unguided learners**
2	Bacterial vaccines for fish, and update on the situation world wide	http://europepmc.org/abstract/MED/15962470	1 page summary of an available paper. The full 19 page article can be acquired. Includes links to many research papers **Suitable for unguided learners**
3	Vaccines for fish in aquaculture	http://europepmc.org/article/MED/15757476	An overview and link to many free scientific papers **Suitable for learners, but some guidance may be needed**
5	The present and future of aquaculture vaccines against fish bacterial diseases.	http://om.ciheam.org/om/pdf/a86/00801069.pdf	Information dense main bacterial diseases and present and future treatments. (12 pages) **Suitable for tutors but wil need to be interpreted to learners in places**

Learning Outcome Consolidation

The development of a web page: Common infectious fish diseases in the North Atlantic region. This could include; their cause, prevention and cure. This could be informed by lectures, visits to fish farms and aquaculture research facilities, compiling and presenting summary information and illustrations. (Integrated with LO2)

LEARNING OUCOME 2

Explain the management of parasitic and fungal fish diseases with reference to their causes and symptoms.

Learning Content

By the end of this Topic the Student should be able to:

- Outline the biology of parasites and fungi, including the life cycles and symptoms for fish diseases most relevant to North Atlantic aquaculture.

- Describe the pathology of specific parasitic and fungal fish diseases most relevant to North Atlantic aquaculture.

- Identify parasitic and fungal fish diseases from images, descriptions of the symptoms and pathology test reports, recording methodologies.

- Explain the techniques used to prevent, treat or manage parasitic and fungal diseases, including bio-security, hygiene, husbandry and therapeutics.

Learning Content Part 1: Outline the biology of parasites and fungi, including the life cycles and symptoms of fish diseases most relevant to North Atlantic aquaculture.

Fish parasites come in many shapes sizes and from the relatively large, obvious and sometimes grotesque, down to the smallest protozoans, invisible to the naked eye, but none the less threatening to fish health. They can be placed in one of two categories, those that are found on the fish's skin or gills and those that are found in their internal organs. In all cases a parasite must complete its lifecycle in order to be successful, which is sometimes direct and at other times more complex and involving intermediary hosts. It has been found that parasites that have a free-swimming larval stage and direct life cycle tend to have a narrower range of host species than do parasites with indirect life cycles.

Fungi belong to a category of organisms called heterotrophs, which cannot manufacture their own nutrients from photosynthesis as plants do, and rely on living or dead matter for their growth and reproduction. In nature fungi are breaking down and recycling dead organic matter and are essential to healthy ecosystems, constantly. However, if fish are physically damaged, stressed and diseased or provided an inadequate diet, some species can be invasive. As well as attacking compromised fish and damaged exposed tissues, fish eggs can be smothered and killed during incubation.

Suggested activities

1. A lecture on parasite biology and the changing habitat requirements for different life cycle stages, illustrating their diversity and ingenuity.

2. The development of a collection of common North Atlantic region fish parasite lifecycle displays showing each stage with their environmental requirements. (This task could be shared between the group)

Royalty free images

- Insert image of fungi and relevant parasites

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Ichthyobodo infections of farmed and wild fish	http://www.uib.no/filearchive/phs-thesis-trond-einar-isaksen.pdf	A comprehensive pHD thesis on Ichthyobodo with high quality illustrations and considering the parasites impact across a wide geographic and species range. **Of interest to tutors but may need to be interpreted to learners in places**
2	Monogean parasites of fish	https://ueaeprints.uea.ac.uk/33182/1/Biologist_article.pdf	A comprehensive accessible and well illustrated overview of monogean fish parasites biology. **Suitable for unguided learners**

Learning Content Part 2: Describe the pathology of specific parasitic and fungal fish diseases most relevant to aquaculture in the North Atlantic region.

External parasites commonly found in farmed fish include small organisms, namely; the Monogeans, Trichodina, Cryptocaryon, Ichthoboda. The most common internal parasites are; Microsporidium, Myxidium, Ceratomyxa, Philasterides and Enteromyxum. The protozoans predominate and many infect the intestinal tract or urinary system. The lifecycles of parasites need to be fully unravelled and understood to devise and implement suitable health management regimes.

Fungi can spread through the release and distribution of resistant spores as well as the rapid growth of hyphae. The commonly pathogenic fungal fish diseases are; Saprolegniasis which appears as external ‘tufts’ growing on fish fins eyes gills and eggs, Branchiomycosis a specialist causing gill rot and Ichthyophonous which invades via canabalistic ingestion of infected fish and grows under the skin.

Suggested activities

1. A lecture on parasite and fungi pathology and their environmental requirements at different stages. (Integrate with Learning Content Part 1 – Activity 1)

2. Investigation of the pathology of a given common salmonid fish parasite. The outcome can be shared with peers. (Integrate with Learning Content Part 1 – Activity 2)

Royalty free images

- No Royalty free images

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Fish immune response to Myxazoan parasites	http://www.parasite-journal.org/articles/parasite/pdf/2008/03/parasite2008153p420.pdf	Scientific article on Fish immune response to Myxazoan parasites (Six pages) **Of interest to tutors but wil need to be interpreted to learners in places**
2	Parasites in cultures and feral fish	http://www.webpages.uidaho.edu/fish422and424/Fish%20Health%20424/424LabFiles/Lab%209%20Parasitology/Parasites%20Review.pdf	A summary description of the main categories of parasites affecting freshwater farmed fish (temperate). Lacks diagrams. **Suitable for unguided learners**
3	Sea lice infestations of farmed salmon	Sea lice infestations on farmed Atlantic salmon in Scotland and the use of ectoparasitic treatments - PubMed (nih.gov)	A comprehensive description of sea lice and the issues it causes in Scotland and elsewhere. **Suitable for unguided learners**

Learning Content Part 3: Identify parasitic and fungal fish diseases from images, descriptions of the symptoms and pathology test reports, recording methodologies.

Observations of the appearance and behavior of live fish can give an indication of invasion by external skin parasites that cause the fish to produce and shed excess mucus, visible as a grey sheen when viewing fish from above in clear water. Many external parasites can be identified on a fish farm by applying some basic necrsocopy. A macroscopic examination of fish eyes, opercula and gills, fins and the skin surface can reveal parasitic copepods, eye fluke and gill maggots.

Some skin parasites are visible to the naked eye, such as Ichtheopthyrius, which forms white cysts, whilst most are only identified by a microscopic examination of prepared samples. In addition, the general condition of the gills is indicative of whether or not it has been infected, and if they are ragged and pale, a microscopic examination of the gill lamellae could reveal microsporidean or myxazoan organisms.

To indentify microscopic parasites the ability to take and prepare skin mucus scrapes and gill lamellae squashes for viewing is all that is required, along with some basic microscopy skills. An initial internal examination may reveal general symptoms such as the buildup of internal fluids and hemorrhaging. Some large internal parasites if present are immediately visible, such as parasitic worms and their cycts. Others, such as the protozoans require microscopic examination of tissue samples from internal organs following slide sample preparations and are more difficult to identify.

Most fungi, such as Saprolegnia and Brachiomyces are made of filaments and as they grow into a cotton wool like mass are highly visible, however, the internal Ichthyophonous fungi is less obvious, and a rough texture felt under the skin is symptomatic.

Suggested activities

1. Instruction in necroscopy procedures and sample preparation for examining fish for external and internal parasites. The definitive identification features to look for should be emphasised.

2. A laboratory practical making up slide preparations of external skin mucus scrapes, gill lamellae squashes and samples of internal tissue for examination, leading to the identification of parasites. This can be assisted by given images.

Royalty free images

Basic microscopy equipment

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	The impact of sea lice on Scottish salmon farms	Impacts of lice from fish farms on wild Scottish sea trout and salmon: summary of science - gov.scot (www.gov.scot)	A description of the parasite and its distribution an dimpact **Suitable for unguided learners**
2	Diagram of Cryptocaryon irritans lifecycle	https://www.google.co.uk/search?q=Cryptocaryon+irritans+Amberjack&tbm=isch&tbo=u&source=univ&sa=X&ei=YB_UU_1HeWx0QWV44HYDg&ved=0CCsQsAQ&biw=1366&bih=643#facrc=_&img	Very good educational diagram.

		rc=vl_rBZ4DFG7eNM%253A%3BnbzkZV1kZ4tCNM%3Bhttp%253A%252F%252Faquarium-depot.com%252Fwp-content%252Fuploads%252F2012%252F04%252FMarine-ich.jpg%3Bhttp%253A%252F%252Faquarium-depot.com%252Fcryptocaryon-irritans-ich%252F%3B555%3B372	
3	Crustacean parasites	http://www.vims.edu/~jeff/biology/parasitic%20crustaceans.pdf	A detailed account of the biology of parasitic crustaceans with line drawings to assist identification. **Suitable for learners, but may need some tutor guidance**

Learning Content Part 4: Explain the techniques used to prevent, treat or manage parasitic and fungal diseases, including bio-security, hygiene, husbandry and therapeutics.

All of the principles of maintaining a high quality aquatic environment and good husbandry standards as a means of disease prevention apply to parasites as much as they do to any other pathogen. For external parasites, a bath or 'flush' treatment, immersing fish in the appropriate concentration of approved chemical, such as formalin, for the recommended duration is the common method of treatment. Care must be taken to ensure that the treatment is well mixed and that there are no 'hot spots' in the holding unit. The process is generally easier and can be more precisely controlled when treating stocks held in land based holding units as opposed to cages.

Suggested activities

1. Instruction in disease treatment calculations and application methods for chemical bath treatments for parasites.

2. A practical exercise on farm calculating holding unit volumes and dose rates and treating fish for external parasites. This can be mocked up in the event there being no infested fish to treat.

Royalty free images

- None to recomend

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	FAO – Fish disease prevention and treatment	ftp://ftp.fao.org/fi/cdrom/fao_training/FAO_Training/General/x6709e/x6709e15.htm	A wide range of information on freshwater parasites and their treatment, with equipment advice. **Suitable for unguided learners**
2	Merck Veterinary manual	Viral Diseases in Aquaculture - Exotic and Laboratory Animals - MSD Veterinary Manual (msdvetmanual.com)	Comprehensive information on parasitic disease of ornamental fish and their treatment. **Suitable for unguided learners**
3	Use of formalin to control fish parasites	http://edis.ifas.ufl.edu/pdffiles/vm/vm06100.pdf	The use of formalin in different fish holding situations is described procedurally and from a human and fish safety perspective. **Suitable for unguided learners**

Learning Outcome Consolidation

The development of a web page: Common infectious fungal and parasitic fish diseases in the North Atlantic region. This could include; their cause, prevention and cure. This could be informed by lectures, visits to fish farms and aquaculture research facilities, compiling and presenting summary information and illustrations. (Integrated with LO1)

LEARNING OUCOME 3

Describe the management of nutritional, environmental and genetic fish health problems with reference to their causes and symptoms.

Learning Content

By the end of this Topic the Student should be able to:

- Describe significant environmental, nutritional and genetic fish health problems, with reference to the common causes.
- Describe the identification of significant environmental, nutritional and genetic health problems, with reference to their typical symptoms.
- Outline the prevention and treatment of environmental, nutritional and genetic fish health problems.

Learning Content Part 1: Describe significant environmental, nutritional and genetic fish health problems, with reference to the common causes.

As well as the wide range of diseases caused by infectious pathogens, there are non transmittable diseases with environmental, nutritional and genetic origins that can arise on fish farms, and in wild stocks in some cases. Gas bubble disease caused by supersaturated ground water leading to nitrogen, release into the fish blood stream is a well known environmental disease, as is acidiosis, caused by a sudden lowering of the pH. There are also many water quality parameters which need to be within the tolerance limits of the fish in order to avoid stress, and toxic substances entering waterways could compromise the fish immune system, making it more vulnerable to infectious diseases.

Some nutrients are known as key nutrients, including essential fatty acids (EFAs) and essential amino acids (EAAs), vitamins and minerals. When absent in the diet or undersupplied, nutritional deficiency diseases can result. If an impoverished diet continues the fish will lose condition, compromising their immune system and exposing them to pathogens.

Genetic diseases can take on a variety of expression, including skeletal curvature and misshapen morphology. Such conditions occurring in the marine fish larvae of hatcheries resulting from defective embryonic development and often attributed to inbreeding can also be seen in wild larvae. It has been shown that sudden changes in water temperature at critical stages of development can be the cause.

Suggested activities

1. A lecture on non transmissible environmental, nutritional and genetic diseases.

2. A learner centred investigation into either:

a) The tolerance limits of fish which when exceeded can lead to environmental diseases.
b) The symptoms of nutritional deficiencies (EAAs, EFAs and vitamins)

The learners work can be followed by an information exchange seminar

Royalty free images

- Insert images of deformed fish as a result of genetic disease

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Environmental diseases in fishes and their management	http://agropedia.iitk.ac.in/content/environmental-diseases-fishes-and-their-management	A brief description of Acidosis and gas bubble disease. **Suitable for unguided learners**
2	Genetics and environmentally induced abnormalities	http://books.google.co.uk/books?id=Rbn2fCSOlSsC&pg=PA201&lpg=PA201&dq=genetic+diseases+of+fish&source=bl&ots=qP_cFWuajX&sig=-KQJzrDf7gFhgDlCTlYTjxJxnvE&hl=en&sa=X&ei=Ud43VLPWAcjtavnggYAO&ved=0CDkQ6AEwADgU#v=onepage&q=genetic%20diseases%20of%20fish&f=false	Chapter 9 of an on line book – Principal diseases of marine fish and shellfish. **Suitable for unguided learners**
3	Nutritional fish pathology	http://www.fao.org/docrep/003/T0700E/T0700E00.HTM	Comprehensive details on al fish nutritional deficiency problems that can arise. **Suitable for learners, but may need some tutor guidance**

Learning Content Part 2: Describe the identification of significant environmental, nutritional and genetic health problems, with reference to their symptoms.

The establishment of a water quality monitoring regime, testing and recording of the key water parameters in the supply, the holding units and farm outlet should provide all of the data needed to identify environmental conditions compromising fish health. Over time, data collection will enable seasonal trends in water quality to be anticipated and production plans can be implemented to reduce the risk.

Identifying nutritional deficiencies can be challenging as some have very general and widely shared symptoms. One of the commonest is a noticeable reduction in growth rate which has a multitude of potential causes. Research has shown that a lack of omega 3 and 6 essential fatty acids can lead to growth reduction and a deterioration of feed utilisation efficiency, as well as deterioration in cardiovascular function and the immune response. Similarly, a deficiency in Folic Acid, one of the ‘B’ vitamins integral to metabolic pathways leads to poor as the general symptom. This is an example of two very different nutrients exhibiting similar general symptoms.

Conversely, there are other vitamin deficiencies with more specific symptoms making diagnosis easier. Vitamin C (Ascorbic Acid) for example cannot be synthesised by the fish and must be provided in the diet. Poor feed storage can lead to rapid break down and loss, resulting in ‘broken back syndrome’. The use of a stabilised form of vitamin C and adequate feed storage in a cool dry environment is the solution. There are a wide range of more specific symptoms associated with deficiencies in many of the ‘B’ vitamins, other than Folic Acid, such as, ‘clubbed gill’, a loss of equilibrium, hyper-pigmentation and clouding of the eyes, spasms and convulsions. In addition vitamin E deficiency has been related to muscular deformity.

The physical deformity associated with many genetic diseases is usually noticeable at an early stage within the hatchery cycle. However, poor water quality as opposed to genetics can often be the real underlying cause, and hatchery mangers need to remain alert to this possibility. (See Unit: The Farming of Sea bream, Sea bass and Meagre)

Suggested activities

1. A lecture on the interaction between environmental conditions, fish nutrition and fish health

2. The creation of a table that summarises the symptoms of nutritional deficiencies for reference purposes and as a revision aid

Royalty free images

- No images to recommend

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance

1	The Merck Veterinary Manual	Nutritional Diseases of Fish - Exotic and Laboratory Animals - MSD Veterinary Manual (msdvetmanual.com)	A basic overview of nutritional diseases focussing on Vitamin deficiencies. **Suitable for unguided learners**
2	Nutrition and health of fish.	http://www.uanl.mx/utilerias/nutricion_acuicola/V/archivos/lall.pdf	A comprehensive overview of nutritional health problems in fish. **Useful resource for tutors, but needs interpretation to learners.**

Learning Content Part 3: Outline the prevention and treatment of environmental, nutritional and genetic fish health problems.

When the supply of essential nutrients or the conditions of the environment are suboptimal, this can compromise the fish immune system allowing pathogens to invade. It is often the secondary diseases that are diagnosed, leaving the inadequate diet and/or environmental conditions that weakened the fish initially to continue as a 'dripping tap'. When the symptoms are general, such as a reduction in growth rate, identification can be problematic. There is a strong case for prescribing prevention over cure, ensuring that fish receive the essential nutrients they need and are held in optimal environmental conditions at all times. This is easier to say than do in developing countries lacking the scientific support and a well established fish feed manufacturers. Diets are often homemade and nutritional deficiencies commonplace. When acceptable limits are constantly compromised, the chemical treatment of secondary diseases builds pathogen immunity, creating a downward spiral that can be difficult to break unless the real underlying causes are identified and rectified.

Regarding health problems with an environmental cause, the preventive measures are threefold:

- Farm site selection to ensure the water supply is adequate in quantity and quality to meet the requirements of the fish species to be farmed.
- The management fish stocks and the rearing environment to ensure that waste substances produced by fish metabolism are cleansed from the system.
- If necessary, water treatment technology to ensure that the water supply to the fish holding units is maintained within the fish tolerance limits at all times.

Nutritional diseases are prevented by ensuring that the nutritional requirements of the farmed fish are known and diets are formulated to provide available essential nutrients within properly balanced diets that are attractive to the fish. The proper storage of fish feed within cool, dry conditions, feed rotation to ensure older feed is used first, and the disposal of wet or contaminated food are important basic disciplines to establish.

Hatcheries avoid genetic diseases by the periodic introduction of new genetic stock to broaden the gene pool to avoid inbreeding and a loss of hybrid vigour. An impoverished gene pool is more susceptible to genetic deficiency and disease.

Suggested activities

1. A lecture the prevention of environmental, genetic and nutritional diseases, integrated to Activity 1 in Learning Content Part 2 above.

2. Learners can be encouraged to note the feed storage conditions during their farm practical placements to see if they meet the above requirements.

Royalty free images

- Insert images of feed storage

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	FAO Fish feed storage and transportation	http://www.fao.org/docrep/x5744e/x5744e0j.htm	A very wide overview of fish feed storage and transportation practices globally. **Suitable for unguided learners**

Learning Outcome Consolidation

Learners could be given multiple choice test or quick quiz on the non infectious diseases.

In addition 'fish health problem scenarios' could be given and solved based on visual or described symptoms. The scenarios would be devised so as a range of potential causes including non infectious and infectious disease have to be considered. They then have to decide what questions to ask the farm, what they would need to investigate to narrow down an on farm diagnosis, and at what point they call in the fish pathologist.

LEARNING OUCOME 4

Explain the legislative control of fish health management in the EU, with reference to relevant codes of practice and the implications to fish husbandry practices

Learning Content

By the end of this Topic the Student should be able to:

- Explain the environmental and economic risks of infectious diseases spreading, with reference to movements of exotic species and diseases into new locations.

- Outline the legislative and animal welfare issues arising from prevention and control of infectious and non infectious fish diseases.

- Outline the current legislation relevant to fish health management in the EU, including the jurisdiction of Government agencies and purpose of the legislation.

- Describe the codes of practice for fish stocking, fish transport, fish husbandry and humane slaughter with reference to their principles and purpose.

- Outline the records kept for fish health management and compliance purposes within a fish farm or other fish holding facility.

Learning Content Part 1: Explain the environmental and economic risks of infectious diseases spreading, with reference to movements of exotic species and diseases into new locations.

Alongside the optimisation of environmental conditions and the adoption of fish welfare orientated husbandry practices to minimise stress, biosecurity sits at the core of most fish health management policies. The introduction of pathogens that are not endemic is a particularly high risk, as the immunity of potential hosts can be low, and pandemics become more likely. The near extinction of the European freshwater crayfish *(Austropotamobius pallipes)* native to Britain as a result of the introduction of the larger and more aggressive exotic American Signal crayfish illustrates this point The 'Signals' carry a fungal disease to which it is immune, but to which the native species is very susceptible. Waterways previously holding good stocks of native crayfish, have been depleted, and are now infested with the American imposter, leaving many concerned about the long term environmental impact.

This is one example among many of the risks that unrestricted and unregulated movements of fish and other aquatic organisms can pose, transferring previously unknown disease agents between stocks and in some cases, jumping entire continents. Another is the fear that an unknown species of the parasite Gyrodactylus could get introduced by anglers returning from fishing Norwegian rivers that have been devastated by the parasite. The destruction of the premier salmon fisheries in Scotland would be massive blow to the rural economy, and therefore all Scottish river boards have been promoting greater biosecuriy awareness amongst their anglers. In response, the Fisheries Authorities have devised tight regulations to govern and control all fish movements. In addition, most European fish farms operate stringent biosecurity measures to minimise the risk of new pathogens entering and threatening farm stocks, or leaving the farm and infecting fish elsewhere.

Suggested activities

1. A lecture on the causes of disease transfer, the environmental impact of pandemics, and the biosecurity measures being adopted salmonid farms.

2. Learners could describe the bio security measures adopted on the farm they work on for their work experience in their farm diary.

Royalty free images

- No images to suggest other than bio security in action, or images of species threatened as a result of the introduction of exotic species

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Introduction to biosecurity in aquaculture	An Introduction to Fish Farm Biosecurity | The Fish Site	An accessible introduction to fish farming biosecurity measures and considerations. **Suitable for unguided learners**
2	Biosecurity site checklist	Biosecurity in Aquaculture, Part 1: An Overview | The Fish Site	An overview of biosecurity in aquaculture **Suitable for unguided learners**
3	Scottish salmon biosecurity plan	Scottish salmon: World leading health, hygiene and biosecurity standards | Salmon Scotland	Overview of biosecurity policies for the Scottish salmon industry **Suitable for unguided learners**

Learning Content Part 2: Outline the legislative and animal welfare issues arising from prevention and control of infectious and non infectious fish diseases.

Today, society and the European regulatory bodies treat the welfare of fish held in captivity as seriously as they treat the welfare of any other animal. The European Food Safety Authority (EFSA) points out;..... "*the intensification of fish farming has inevitably resulted in the emergence of disease problems, in particular of diseases of infectious origin, although over recent years a number of issues relating to health and disease have been successfully addressed through better husbandry and the introduction of vaccines*". The EFSA concludes that disease in farmed fish is "*generally an indicator of an underlying husbandry or environmental deficiency*". A scientist supporting the ESFA position writes that under farming conditions, ... "*fish may reach the outer limit of their physiological margin due to maximal exploitation and stress, making them susceptible to a wide range of diseases threatening ethical and welfare standards*". A Norwegian scientist contributing to the debate writes,.... "*there is a legitimate public concern that fish are kept at too high densities in intensive aquaculture*". Similarly, a UK researcher stresses, ..."*stocking density is a pivotal factor affecting fish welfare in the aquaculture industry, especially where high densities in confined environments are aimed at high productivity*".

It is irrefutable that stress reduces the ability of a fish to fight disease and that keeping large numbers of fish under conditions of high stock density facilitates the transmission of infectious diseases. In the United Kingdom the 'producer organisations' for trout and salmon farming have developed Codes of Good Practice for their members, keeping them abreast of European requirements. Most of the Scottish salmon farming sector has already achieved Freedom Foods Status, and as a result stocking densities in the rearing cages have been significantly reduced, to the benefit of fish welfare. This trend is likely to continue and spread to other fish producing countries, driven by a growing market demand globally for fish produced under certificated high welfare conditions.

Suggested activities

1. A lecture on the animal welfare regulations impacting on the aquaculture sector.

2. Learners could be asked to remain observant during their periods on farm practical, noting good practices and practices that could be improved from a fish welfare perspective. This could inform a discussion and debate on the fish welfare standards within the salmon farming sector

Royalty free images

- Insert images

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	The welfare of farmed fish	https://www.ciwf.org.uk/media/3818654/farmed-fish-briefing.pdf	A passionate compassion in world farming briefing for higher standards of welfare to reduce the suffering of fish as a result of intensive farming and disease, with reference to European regulations. **Suitable for unguided learners**
2	The UK Farm Animal Welfare Committee	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319323/Opinion_on_the_welfare_of_farmed_fish.pdf	A comprehensive account of the UK governments opinion on the UK industry response to fish welfare requirements **Suitable for unguided learners but may benefit from tutor navigation as it is a large document.**

3	The UK RSPCA view of fish welfare issues	http://www.rspca.org.uk/adviceandwelfare/farm/fish/keyissues	A brief summary of the RSPCA view of Fish welfare. **Suitable for unguided learners**

Learning Content Part 3: Outline the current legislation relevant to fish health management in the EU, including the jurisdiction of Government agencies and the purpose of the legislation.

Members of the European Union have to comply with the legislation developed in Brussels by the European parliament and reflect it in their own statutes. This effectively leaves each member state responsible for the development of their own legislation to comply with European requirements. Arguably, the legislation gives most attention to the control of fish movements, and understandably so, considering the potential impact that the transfer of pathogens via their aquatic hosts into aquatic environments where they were previously absent, can have.

Suggested activities

1. A lecture on the raft of legislation and regulations at European and national level, highlighting their main provisions and differentiating legislation from Codes of Good Practice.

2. The creation of a mind map to show the relationship between the main legislation impinging on aquaculture activities in Europe, clearly indicating the relationships and hierarchy.

Royalty free images

- No images to recommend.

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Fish welfare	Fish welfare | EFSA (europa.eu)	Provides an overview of European legislation being used to promote high standards of fish welfare in aquaculture **Suitable for unguided learners**

Learning Content Part 4: Describe the codes of practice for fish stocking, transport, husbandry and humane slaughter with reference to their principles and purpose.

At the highest levels of governance, the Marine Programme of the International Union for Conservation of Nature (IUCN) promotes best practice in the aquaculture sector. In 2005 IUCN and the Federation of European Aquaculture Producers (FEAP) signed a cooperative agreement in support of sustainable aquaculture development.

Within this overarching guideline, the representatives of each aquaculture sector are responsible for the development and promotion 'Codes of Good Practice' with their members, in order to 'level up' the standards of husbandry to meet European legislative requirements for animal welfare. Linked to this, the development and implementation of Certification Schemes is also encouraged to promote consumer confidence in the products as a result of the close 'tie up' to the improved production practices valued and insisted on by many consumers.

Suggested activities

1. A lecture on the roles and responsibilities of different agencies with legislative responsibility influencing the governance of the aquaculture sector. (Integrated with Activity 1, Learning Content Part 3)

2. An exploratory exercise to compare the Codes of Good Practice and Certification Schemes that have been developed by different European aquaculture sectors, to determine the similarities and differences.

Royalty free images

- No images to recommend

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	Responsible Practice and Certification	http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCEQFjAA&url=http%3A%2F%2Fwww.eatip.eu%2FDocdownload.asp%3FID%3D8CEC8968D80D050097&ei=LrlwVOmpLojfPa-	A comprehensive guideline on the requirements underpinning the development of Codes of Good Practice and Certification schemes designed to give the European consumer confidence. **Suitable for unguided learners**

		pgbgL&usg=AFQjCNElmyg5lYyeY4FAKT0ob_MaCNxATA	

Learning Content Part 5: Outline the records kept for fish health management and compliance purposes within a fish farm or other fish holding facility.

A productive and efficient fish farm business supplying table fish to wholesale markets dominated by the supermarkets cannot be run without a comprehensive and effective record keeping system in place. This will provide the 'traceability' required for quality assurance purposes and in order to remain legally compliant.

This will include records of:

- Fish stocks for each holding unit and fish movements within the farm.
- Incoming and outgoing stock, including eggs, gametes and juvenile stock.
- Fish disease treatments including the chemical used treatment method and dose rate.
- Hazardous substances stored on site.
- Harvest and sales records
- Environmental monitoring incoming water supply and effluent, and the water quality within holding units.

Computerisation has greatly assisted the development of sophisticated stock record keeping systems that provide the farm manager total control of the population number, biomass and size of fish held in each holding unit. This allows feeding regimes to be planned and rations calculated according to water temperature and fish biomass. Many Certification Schemes require the demonstration of full stock control and evidence that stock densities are kept within reasonable limits from a fish welfare perspective.

Arguably, in terms of legislative compliance, the records of fish movements, including ova and gamete, on and off site, and fish disease treatments are the most important and can be subject to inspection. In addition, to satisfy the demands of today's fish consumer, it should be possible to trace back the entire history of the fish from ova to plate from the records kept on a farm.

Suggested activities

1. A lecture on farm based record keeping systems and a demonstration of a computerised system used by commercial farms.

2. Recordkeeping exercise based on hypothetical or real data, providing learners the opportunity to practice record keeping of fish disease treatments.

Royalty free images

- No images to suggest

Hypertext links to additional resources:

No	Title	Hypertext link	Guidance
1	UK Government record keeping.	https://www.gov.uk/fish-shellfish-or-crustacean-farm-authorisation#records-you-must-keep	A brief summary of the records required when setting up a shellfish farm. **Suitable for unguided learners**
2	Scottish government inspection system.	http://www.scotland.gov.uk/topics/marine/fish-shellfish/fhi	Information on the Inspectorate system applied to the Scottish Aquaculture sector. **Suitable for unguided learners**
3	The importance of an aquatic animal health plan	http://www.ncaquaculture.org/documents/RosemaryImportanceofanAquaticAnimalHealthPlan.pdf	Slides to illustrate the importance of record information as the platform for reliable biosecurity. **Suitable for unguided learners**

Learning Outcome Consolidation

Consolidation of the key learning point can be best achieved through the analyses of given farm husbandry scenarios, asking learners to criticise each from a recordkeeping and compliance perspective.

SECTION FOUR

Glossary

Term	Meaning
Organelles	A number of organized or specialized structures within a living cell.
Virion	The infective form of a virus outside a host cell, with a core of RNA and a capsid.
Endothelial	The thin layer of cells that lines the interior surface of blood vessels and lymphatic vessels. It forms an interface between circulating blood or lymph in the lumen and the rest of the vessel wall.
Leukocytes	A white (blood) cell - a colourless cell which circulates in the blood and body fluids and is involved in counteracting foreign substances and disease.
Encephalopathy	A disease in which brain function is affected by some agent or condition (such as viral infection or blood toxins).
Retinopathy	Disease of the retina which results in impairment or loss of vision.
Protozoans	A single-celled microscopic animal belonging to a group of phyla of the kingdom *Protista*, exemplified by amoeba, flagellate, ciliate, or sporozoan.

Unit Title:	Salmon nutrition and feeds
Guided Learning hours:	**60**

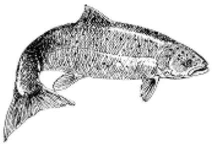
Unit level (EQF): 5

Introduction

The learning resources in this guide have been designed to support 'short episodes' of focussed learning' on a specific topic within Salmon nutrition and feeds following the Recognition of Prior Learning (RPL) using the multiple-choice question sets. Each episode has a title and number that relates it to a specific multiple-choice question or questions within the subject area.

The resources cover fish Salmon nutrition and feeds, including considerations of sustainable feeds. The aim is to provide prospective unit managers with enough information, insight and understanding of Salmon nutrition and feeds so as they can make netter informed decision regarding feed selection and feeding.

SNF 1 Salmon nutrition and feeds



Macro and micro-nutrients

The wild salmon is a carnivorous fish with a protein rich diet during its freshwater and marine growth phases. However, a wide range of nutrients are required in order to sustain the health of farmed salmon and to optimise their growth, and scientists have identified which nutrients are needed and in what quantities, allowing feed manufacturers to formulate well balanced diets.

Atlantic salmon feeding

What does a manufactured diet provide the salmon?

A salmons diet provides nutrients for body maintenance and repair, growth and a source of metabolic energy.

Different nutrient groups are required by the salmon in different quantitiies and the precise requirement and balance between them changes as the fish grows. Some are essential nutrients which must be provided in the diet to sustain fish health and normal growth and can not be substituted.

Those nutrients required in relatively large amounts are called 'macro-nutrients' and those required in small quantities 'micro-nutrients'.

Table

Category	
Macro nutrients	
Essential micro-nutrients	
Metabolisable Energy	
Pigment	

Articulate creative

Design first page to include all of the introductory text, the image above, the text on essential nutrients and three **overarching terms**

The text for all 3 macro and micro nutrients is then called up by clicking the category.

A selection of the text from fats and proteins referring to energy is called up when clicking **energy in the diet**

Why are some nutrients essential?

Essential nutrients are those required for the normal growth, health and well-being of the fish, and include;

- nutrients that the fish is unable to synthesise from other dietary nutrients

OR

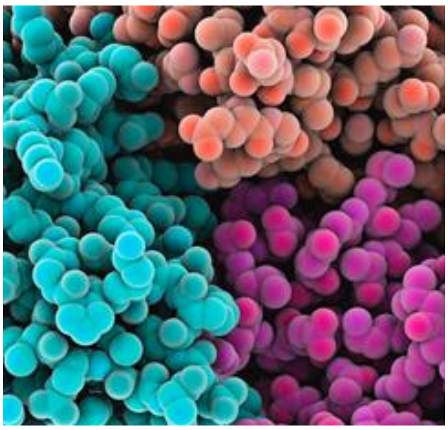
- nutrients that can be synthesised by the fish but not in sufficient quantity to avoid nutritional defficiency problems.

Proteins and fats contain some components that are essential and others that are non-essential, whereas vitamins and minerals are all essential nutrients.

Proteins

Proteins are involved in a multitude of functions, and vary in structure and shape at the molecular level and are composed of 20 amino acids, often called 'the building blocks of protein'.

Protein molecule



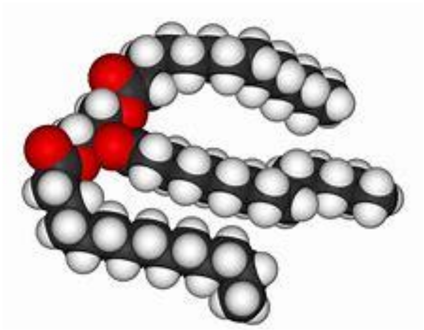
Some amino acids can be synthesised from others supplied in the diet. Those which cannot be synthesised are 'Essential Amino Acids' (EAA) of which there are ten. They must be supplied in the diet in sufficient quantity to maintain fish health and prevent nutritional deficiencies.

Proteins can be catabolised as an energy source, but this causes pollution from metabolic wastes and is uneconomic as a source of energy.

Fats

Chemically, fats are formed from glycerol and three fatty acids.

Fat molecule



Many animals, including fish, have a limited ability to convert short chain fats into longer chain fats, some of which are essential to cell membrane formation and are therefore Essential Fatty Acids (EFAs). Fats in the fom of oils abstracted from marine fish are an irreplaceable source of EFAs.

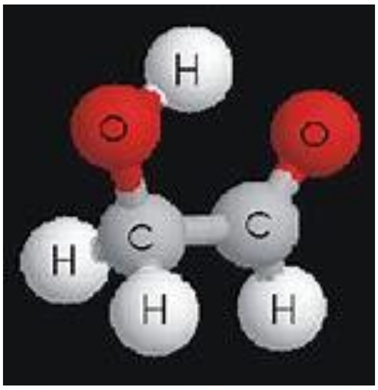
By adding sufficient fat to provide all of the salmon's metabolic energy requirement, 'protein catabolism' is discouraged and proteins are 'spared for growth'

Carbohydrates

Formed from carbon, oxygen and hydrogen and available as simple sugars (monosacharides) or more complex molecules (poly sacharides). Provide a vital role in binding and stabilising feed pellets.

Unsurprisingly, as the salmon is carnivorous, carbohydrates are non essential nutrients that can provide a very limited source of energy in salmon diets as they are not easily digested.

Carbohydrate molecule



Micro nutrients in the diet are required in low to very low levels, but some are essential to ensuring fish health and well-being**.**

Vitamins

The eleven water soluble and four fat soluble vitamins are organic chemicals essential for animal health and well-being.

Most of the water soluble vitamins tend to have specific metabolic functions whilst the fat soluble have a diverse range of direct functions

Minerals

Inorganic chemicals that are essential nutrients with each having a specific role.

Relevance to salmon husbandry:

Salmon must be fed a palatable, well-balanced diet that contains sufficient essential nutrients and energy to maximise their growth potential.

Understanding fish nutrition helps the salmon farmer to select a suitable pelleted diet for each stage of the production cycle.

Minerals are divided into macro-minerals, required in larger quantities but supplemnted by gill uptake, and micro minerals, sometimes called trace elelments, which are required in smallest quantities.

Pigments

The flesh of Atlantic salmon is normally coloured some shade of pink, red or orange due to carotenoids (astaxanthin and canthaxanthin). The most commonly used pigment astaxanthin can be provided from natural sources, but is normally synthesised.

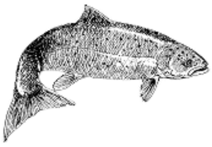
Although non-essential, pigments do have useful physiological functions as antioxidants protecting fats and as a precursor to Vitamin A.

Key points:

- Salmon diets contain macro nutrients (required in large amounts) and micro-nutrients (required in small quantities).
- Proteins, fats, and carbohydrates are the three macro-nutrients in salmon diets.
- Essential nutrients must be provided in the diet in the correct amount for healthy growth
- Vitamins and minerals (micronutrients), EAAs and EFAs are all essential nutrients in salmon diets.
- All three macro nutrients can provide energy, but fat, in the form of fish oil, is the primary energy source in salmon diets.
- Carotenoids are micro-nutrients added to salmon diets to pigment flesh and are non-essential nutrients.

Pigmented salmon flesh

SNF 2 Salmon nutrition and feeds



Proteins

Protein consumption by animal and humans is associated with muscle growth and development, and whilst this is an essential function, proteins in the diet have multiple and diverse roles.

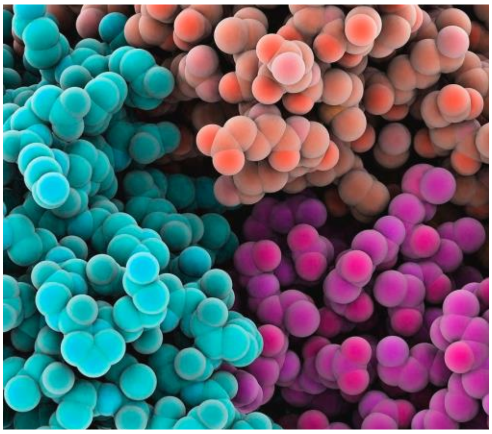
What are proteins made of and what do they look like?

Protein molecules are composed of 20 amino acids, often referred to as the 'building blocks of protein. They are large complex molecules with a primary, secondary, tertiary, and quaternary structure.

At the primary level, proteins are polymers, more specifically polypeptides. They are formed from sequences of amino acids, with each having undergone a condensation reaction, losing a water molecule to form a peptide bond. A chain under 30 amino acids is often referred to as a peptide, rather than a protein.

To be able to perform their biological function, proteins fold into one or more specific spatial conformations as exemplified by the well-known alpha helix. This is driven by non-covalent interactions such as hydrogen bonding (responsible for secondary structures), and ionic interactions, Van der Waals forces, and hydrophobic packing which are instrumental in forming tertiary and quaternary structures.

Protein molecule



Articulate creative: Insert a suitable stylised diagram of a protein molecule to illustrate components and structure. Use image from web as a guide

Some amino acids can be synthesised from others supplied in the diet.

The ten essential amino acids (EAA), arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine, cannot be synthesized by fish, and therefore must be provided in the diet.

The EAAs must be supplied in the diet in the required quantity to ensure the fish can grow normally, unlimited by any sub-optimal EAAs and remain healthy.

What do proteins do?

Virtually all cellular functions require proteins as they are important to many, metabolic and endocrine functions and provide structural components, including:

- Contractile protein for muscle development which includes the essential amino acids (EAAs) needed for healthy growth
- Enzymes as catalysts for biological processes such as digestion
- Hormones such as insulin which controls blood sugar levels

- Structural protein such as collagen found in tendons and ligaments
- Antibodies central to the immune system
- Carriers of molecules between cells such as haemoglobin transporting oxygen in red blood cells

How much protein do salmon need in their diet?

The amount of protein in fish feed varies according to the dietary requirement of each fish species and the protein requirements of carnivores, omnivores and herbivores differ, with carnivores needing relatively high levels of dietary protein. In addition, the protein requirement varies according to fish size and age, peaking for young fish but decreasing as they grow.

Where does the protein in salmon diets come from?

Capelin

There are many protein sources used in farmed salmon diets, selected according to:

- Their digestibility,
- the profile and bioavailability of Essential Amino Acids (EAAs),
- the avoidance of 'anti-nutritional' factors, and
- their availability and cost.

Fish meal provides the main protein source in salmonid diets and has been of central importance since the introduction of dry pelleted salmon feeds.

As it closely matches the salmon's natural diet It has several advantages:

- Very digestible,
- Contains all ten Essential Amino Acids (EAAs), and
- No "anti- nutritional" factors.

As aquaculture uses over 80% of the fish meal (and oil) produced globally, some observers argue that feeding fishmeal-based diets to carnivorous fish is inefficient and unsustainable. Consequently, the substitution of fish meal with alternative proteins, has been a growing trend. Vegetable proteins are often utilised within salmonid feeds to address sustainability concerns, whilst helping to reduce feed costs.

Can fish meal be substituted by alternative more sustainable protein sources?

Without the inclusion of some fish meal, salmon feed formulations cannot be 'optimised', to ensure a well-balanced and digestible diet with a 'complete' EAA profile (all ten EAAs available in the quantity required). Fish meal is an essential provider of Lysine, methionine and arginine (also known as threonine). These are most limiting amino acids when fishmeal levels are reduced, and plant protein increased.

Fish meals (and oils) can be produced using fish and fish products from a variety of sources, including pelagic fish not in demand for human consumption, discards, and waste from the fish processing industry. However, the bulk of global production comes from Southern Hemisphere industrial marine fish species, largely due to concerns about toxin residues in the northern hemisphere fish stocks.

Capelin

Is the exploitation of industrial fish species by aquaculture well regulated?

The aquaculture industry is discouraged from using fishmeal or fish oils made from fish on the World Conservation Union's (IUCN) list of endangered species. In Norway for example, about 90% of the wild fish used in fishmeal and fish oil comes from regulated fisheries.

The most suitable species are herring, blue whiting, capelin, sprat, and anchovy and the stocks can fluctuate for many reasons, including the size of the international fishing fleet's catch. Their exploitation is regulated to keep within the sustainable yield, and for some species, direct human consumption takes priority. Herring, for example, is only utilised when the catch exceeds consumer demand, processing the surplus into fish meal.

To ensure that the wild fish come from regulated fisheries, fish feed companies monitor their suppliers through traceability systems and audits.

How is fish meal produced?

The fish are cooked, dried, and then milled to produce a brown floury material. It can take a lot of fish to produce fish meal with approximately 12 Kg of whole wild fish providing approximately 2.5 Kg of fish meal and 1 Kg of fish oil.

There are different quality grades of fish meals.

LT meal

The protein in lower quality meals can be denatured (damaged) by excess heat during the drying process.

Low Temperature (LT) meals are produced from chilled raw fish and subjected to low drying temperatures to avoid damaging the proteins. This is a longer process, making them more expensive.

Salmon hatchery feeds incorporate LT meals which have the highest digestibility and bioavailability of EAAs to maximise initial growth.

What are the alternatives to fish meal as a protein source?

Blood meal

Alternative protein sources have always been included in salmonid feeds. Blood meal, a widely available by-product of the meat processing industry has contributed to salmonid diets as an alternative source of relatively high-quality protein. However, it does not have a 'complete' EAA profile and its use has steadily been decreasing over time for a variety of reasons.

There are several vegetable protein sources in common use, including soya, maize, and rape-seed meal. Some have 'anti-nutritional factors' to be aware of, such as the trypsin inhibitor in soya meal and are processed further to make them suitable.

...the science says:

Amino acid nutrition of salmonids: Dietary requirements and bioavailability.

SUMMARY: The amino acid (AA) requirements of salmonid fishes and the shortcomings of methods used to estimate AA requirement are briefly reviewed.

https://pdfs.semanticscholar.org/e195/e4aa5f7945fde76ade36364d4bbdff4dea2e.pdf

Soldier fly larvae meal

- Proximate digestibility coefficients for Atlantic salmon fed black soldier fly larvae meal (BSFM) were determined.
- Atlantic salmon fed diets containing up 200 g kg−1 BSFM grew similarly to fish fed the control.
- BSFM at up to 200 g kg−1 inclusion in Atlantic salmon diets shows promise.
- The authors recommend testing higher protein diets containing BSFM levels above 200 g kg−1.

https://www.sciencedirect.com/science/article/abs/pii/S0044848619324330

Maize -Vegetable protein

However, fish meal supplementation remains essential to achieving the correct EAA profile for a healthy, nutritionally balanced diet.

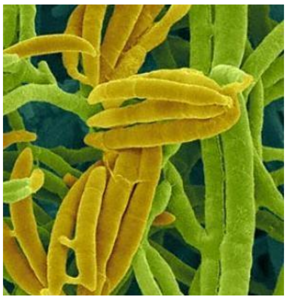
Are plant proteins the only viable alternative source?

Research into alternative protein sources is ongoing and some novel sources may be commercialised in the future. Soldier fly larvae shows early promise as a fish meal substitute with a suitable EAA profile. However, the viability of scaling up production as a major protein source is unproven at this stage.

Bacterial single cell protein has been a successful fish meal substitute in some trials.

Soldier fly larvae

Single cell protein



Some research indicates that fish meal could be reduced to as little as 5% of the diet potentially, without affecting growth so long as there was a minimum of 5% fish oil, and animal by-products did not exceed 26% of the diet. However, it is inadvisable to reduce the fish meal content of diets designed for the hatchery phase. Other work ongoing suggests that the complete replacement of fish meal and oil is possible.

Relevance to salmon husbandry

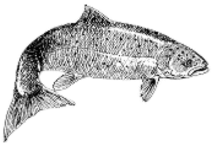
The cost of salmon diets can be reduced by reducing the quantity of fish meal and replacing it with alternative and more sustainable vegetable proteins. This also makes them more sustainable.

However, when comparing low and high-cost feeds, the food conversion ratio as well as feed costs must be considered to determine the cost of each tonne of fish production.

Hatchery feeds should always include the highest quality LT meal to maximise growth rate during the first few weeks and months.

Key points

- Proteins are composed of 20 amino acids, 10 of which are essential nutrients (EAAs).
- Fish meal is an essential source of protein within salmon diets to ensure all 10 EAAS are provided.
- Alternative proteins can be added to salmon diets to reduce the level of fish meal
- Diets containing the highest quality low temperature (LT) fish meal should be used in hatchery feeds.
- Suitable vegetable protein sources include soya, maize and rape seed meal.
- Novel protein sources under development include soldier fly larvae and single cell protein.



Fats

Fats provide energy during exertion and an energy store for mobilising during periods of inadequate food intake. The migration by salmon in their return upstream to spawn can take many weeks and stored fat deposits 'fuel' metabolic processes during this strenuous journey.

Salmon can metabolise fat (oils) very effectively but have little ability to metabolise carbohydrate. Consequently, supplying energy is the primary role of fats in salmon diets, ensuring that dietary proteins are not catabolised and are used for growth, which is also known as 'protein sparing'.

What are fats made of and what do they look like?

Many of us are familiar with the two basic types of fat in our own diets, saturated and unsaturated fats, as they can influence our health. We are advised that 'unsaturated fats' are generally good for us whereas 'saturated fats' have been linked to high cholesterol and heart disease. But what do these terms signify and why is one good and the other seemingly bad?

Fats are a subgroup of lipids, also known as triglycerides, meaning their molecules are formed from one molecule of glycerol and three fatty acids. Different fatty acids can be differentiated based their chemical structure. The length of the carbon chain and the number and relative position of double bonds between carbon atoms, varies from no double bonds to multiple double bonds.

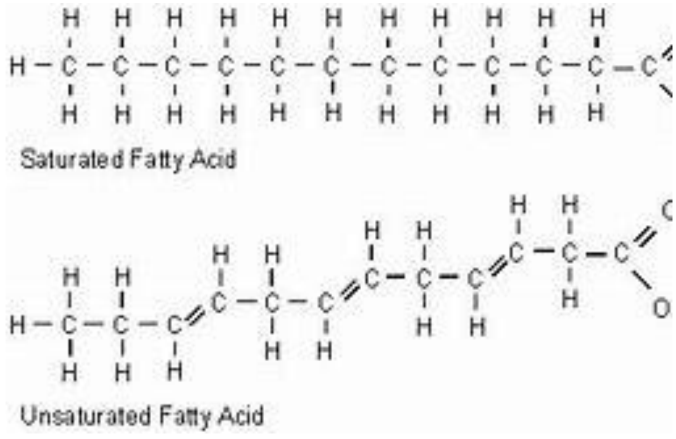
Saturated animal fat and polyunsaturated fish oil

Saturated fats contain no double bonds between carbon atoms: Generally animal fats which are solid at room temperature or colder, such as butter, cream, and cheese.

Monounsaturated fats contain one double bond between the carbon atoms: Found in plants which are liquid at room temperature and semi solid when cold in a fridge, such as olive oil, avocado and sesame oil.

Polyunsaturated contain more *than one double bond between carbon atoms*: Found in fish, marine animals, some plants, and seeds and are liquid at room and lower temperatures, such as cod-liver oil and the oil extract from walnuts and sunflower seeds.

Fatty acids are found as a straight chain or with branch chain components. Many of the fats (oils) in fish contain numerous unsaturated double bonds in the fatty acid structures and are described chemically by their 'omega' (w) number. This identifies the position of the first double bond counting from the methyl end of the molecule. For example, Linolenic acid (often referred to as omega 3 fatty acid) is written as 18:3w 3. The first number identifies the number of carbons; the second number, the number of double bonds; and the last number, the position of the double bonds.

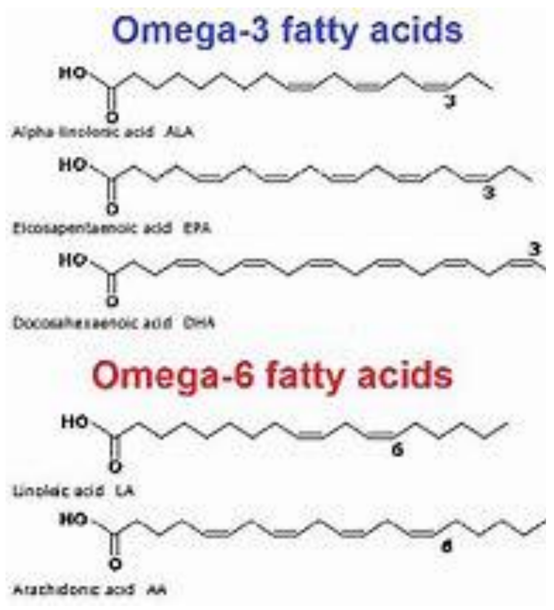


Saturated and unsaturated fat

Although counter intuitive, the double bonds in unsaturated fatty acids are easier for enzymes to act on and break down, making them more digestible.

Polyunsaturated fats are the most digestible of all and are known to have great benefits. Salmon and other sea food are an excellent source of polyunsaturated fats and therefore an extremely healthy and nutritious source of human food.

Articulate creative: Insert a suitable stylised diagram of a fat molecule to illustrate components and structure. Use image from web as a guide.



Omega 3 and 6 EFAs

What do fats do?

Fats and oils have multiple functions and are important molecules in all cells.

- Dietary energy – fats are very easily digested and have the highest energy/weight of all food sources.
- Structural – essential layers which make up the cell membranes of living cells.
- Communication - fats are important precursors of hormones such as testosterone and prostaglandins (a group of lipids made at sites of tissue damage or infection that are involved in dealing with injury and illness)

- Storage function - fats can be stored as energy reserves and are most noticeable as a white residue between the muscle blocks. Fat can also be stored in the liver and surround the intestine and stomach.

Are fats essential nutrients?

Image - fat between muscle

Some fatty acids are essential nutrients in the salmon's diet.

- Omega 3 fatty acids: commonly found in fish and other seafood and are important EFAs in animals. There are the two main types of omega-3 fatty acids: Long-chain omega-3 fatty acids are EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid).

- Omega 6 fatty acids: found in seeds and nuts and linoleic acid is the most common and can be converted into longer omega-6 fats such as arachidonic acid (ARA)

Research with land-dwelling animals has shown that the omega-6 series of fatty acids are the "essential fatty acids", while the omega-3 series are 'non-essential' or only have a partial sparing action on EFA-deficiency.

However, Salmonids, including the Atlantic salmon, have an essential requirement for Linoleic acid (omega-3), which is present in relatively large concentrations in fish oil whereas vegetable oils provide omega- 6 fatty acids.

Alternative dietary fats for salmon- vegetable oil

Source of fats and EFAs in the diet

Fish feed manufacturers have relied heavily in the past on using fish oils only in fish feed diets because they contain all the EFAs required. However, this is expensive, and suitable vegetable oils have been added to fish feed diets recently to provide the fish's energy needs, reducing the amount of fish oil added to provide EFAs.

As feed production methods have improved, higher levels of vegetable oils (up to 70%) have been added to diets. The upper limit will vary according to the fish species, the aquatic environment in which they are grown, and their ability to convert EFAs.

This is illustrated by the below table:

Fish	**EFAs converted**	**EFA requirement in diet**
Warm water	Omega 6 to Omega 3	Increased Omega 6
Marine	Little ability to convert Omega 3 to Omega 6	Mainly Omega 3
Salmonids	Limited ability to convert Omega 3 to Omega 6	Mixture of Omega 3 and Omega 6

The greater degree of unsaturation of fatty acids due to high levels of 20:5w 3 and 22:6w 3 fatty acids seen in fish oils allows cell membranes to be flexible at lower temperatures. The w 3 structure allows a greater degree of unsaturation than the w 6 or w 9. This theory is consistent with the fact that cold water fish have a greater nutritional requirement for w 3 fatty acids, while the EFA requirement of some warm water fish can be satisfied by a mixture of w 6 plus w 3.

How much fat (oil) do salmon need in their diet?

Grow out diets for carnivorous fish such as salmonids can contain relatively high levels of oil (30-35%) as their ability to utilise carbohydrates is limited and oil is their major energy source.

The oil levels of salmon grow out diets has been increased latterly, to ensure the fish do not utilise dietary protein as an energy source which is more expensive and can increase ammonia production, a metabolic waste from protein digestion.

Where does the fat in salmon diets come from?

The fat (oil) incorporated within salmon diets comes from two main sources, marine fish, or vegetable oils. Fish oil is abstracted from fish used to produce fish meal as part of the same process. From one kilogram of industrial fish, approximately 80 grams of fish oil can be produced.

There are two main reasons to reduce the % of fish oil used in salmon diets.

- Some marine fish species from the northern hemisphere may contain contaminants.
- Fish oils are a finite resource and expensive.

Vegetable oils can displace some of the fish oils, however, their inclusion reduces the level of Omega 3 fatty acids in the diet.

Which vegetable oils can be used?

Despite the large growth in the aquaculture industry over the last 30 years, no more wild fish are used in the feed today than was the case in the past as feed companies have been replacing some of the marine ingredients with plant ingredients. The amount of fish oil (and fishmeal) can be reduced without compromising fish health and welfare or product quality.

Vegetable oils and fish oils have a different fatty acid composition and previously, fish oils rich in EPA and DHA were the sole source of fat. Both vegetable oils and fish oils contain a mixture of saturated, monounsaturated, and polyunsaturated fatty acids and composition profiles vary when comparing vegetable oils to fish oils, different vegetable oils, and fish oils from different fish species. Some vegetable oils, such as linseed, are high in polyunsaturated omega-3 fatty acid 18:3n-3 (LNA/ALA) but lack positive biological effects of the marine omega-3 fatty acids EPA and DHA.

For marine fish species including Atlantic salmon the marine omega-3 fatty acids EPA and DHA in their diet are ‘essential nutrients’. Whilst salmon can convert LNA/ALA into EPA and DHA to some extent, they must be provided some of the marine fatty acids to achieve optimal growth and health. To ensure that the fatty acid profile reflects fish oil-based feed, a mixture of linseed oil, rape seed oil and palm oil can be used (instead of a single vegetable oil). This results in good fatty acid digestibility and more effective storage of the marine omega-3 fatty acids by the salmon.

In addition, the salmon receives high levels of preferred fatty acids for its metabolism, and high levels of the omega-3 fatty acid LNA/ALA which can be converted to marine omega-3 fatty acids (EPA and DHA), to a limited extent.

If fish meal is used as a source of protein, it is possible for all the fish oil to be replaced by a mixture of vegetable oils. The salmon's EPA and DHA requirement is covered by the small proportion of fat found in the fish meal.

Salmon which have consumed fish oil based feed in the period immediately preceding harvesting (when the salmon's weight is doubled) manage to increase the EPA and DHA muscle content, but not up to the level of those salmon whose feed included fish oil throughout.

Does the replacement of fish oil by vegetable oil affect the tase of the salmon?

The taste of salmon is known to vary, depending on the composition of the salmon feed. However, 'sensory analysis studies' show that fillets from salmon fed a mixture of vegetable oils have a similar taste and aroma as fillets from salmon fed fish oils, but with a less characteristic marine taste and aroma. Salmon fed vegetable oil-based feed, and which are given fish oil for 4-5 months prior to harvesting taste the same as salmon which have always been fed fish oil-based feed.

Key points

- Fats are the main energy source for salmon as they are a carnivore and cannot easily digest carbohydrates
- Fat molecules are made up of glycerol attached to three fatty acids, some of which are 'essential nutrients (EFAs).
- Fats are needed for immediate energy use, energy storage, cell membrane construction and a minor role in the endocrine system
- The Omega 3 fatty acids are essential nutrients and must be provided in the diet.
- Most of fish oil in the diet can be replaced by vegetable oil, but this can have a noticeable effect on salmon flavour

...the science says:

Research showed that increasing levels of dietary n-3 fatty acids up to 1% gave faster growth rates in salmon fry, and fish fed the mixture of 20:5 n-3 and 22:6 n-3 seemed to grow faster than fish fed only 18:3 n-3. No significant effect on growth rate was seen when the dietary level of 18:2 n-6 was increased. Dietary inclusions of n-3 fatty acids reduced the mortality of salmon, while dietary 18:2 n-6 had no such beneficial effects.

See full account at: https://onlinelibrary.wiley.com/doi/abs/10.1046/j.1365-2095.2000.00137.x

New fish oil replacement

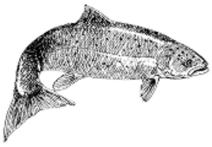
Apparent digestibility of proximate nutrients, energy and fatty acids in nutritionally balanced diets with partial or complete replacement of dietary fish oil with microbial oil from a novel Schizochytrium sp. (T18) by juvenile Atlantic salmon (Salmo salar L.)

Canadian research has concluded:

- Novel Schizochytrium strain T18 oil contains >40% DHA.
- First evaluation of Schizochytrium strain T18 oil for salmonid aquafeeds.
- Complete 100% fish oil replacement with no negative effects on dietary ADCs.
- Dose-response increase in ADC of SFAs with Schizochytrium T18 oil inclusion.
- Significant increase in ADC of DHA with Schizochytrium T18 oil inclusion

https://www.sciencedirect.com/science/article/abs/pii/S0044848619333769

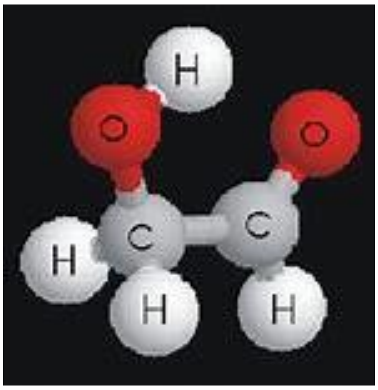
SNF 4 Salmon nutrition and feeds



Carbohydrates

Carbohydrates (also known as saccharides) are a most important biomolecule. They are responsible for various roles in all living things, most notably in controlling the energy in cells as well as providing structural integrity (within plant cells). Carbohydrates of various size (carbon chain length) and complexity (one to several units bonded together) are synthesized by plants (photosynthesis). Cellulose and other fibrous carbohydrates are found in the structural components of plants and are indigestible to monogastric animals, including fish. Consequently, the amount of crude fibre in fish feeds is usually kept under 7 percent of the diet to limit the amount of undigested material entering the culture system.

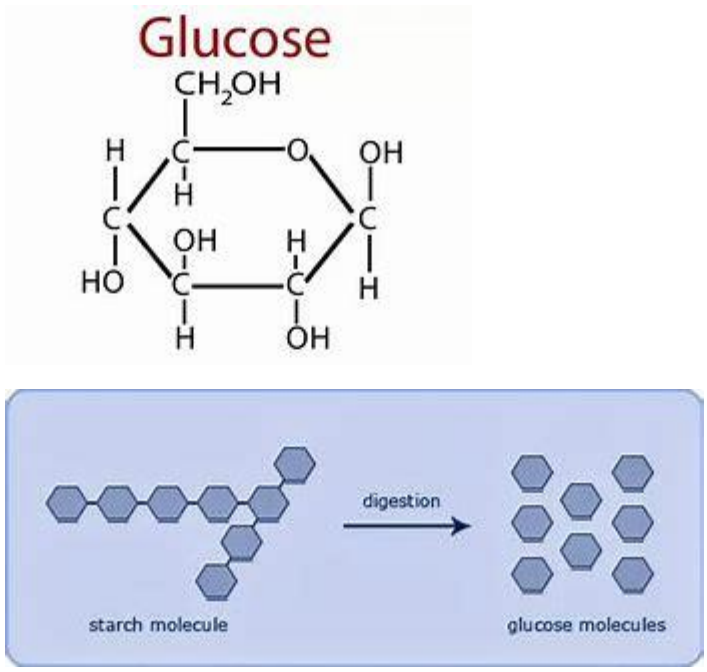
Carbohydrate molecule



The energy contained in simple sugars is readily available on consumption.

As they are broken down by digestive enzymes, the more complex carbohydrates release their energy slowly, providing an important energy source for herbivorous and omnivorous animals that is widely available and inexpensive.

Carbohydrates are an excellent source of energy and carbon for many species of farmed fish. However, the Atlantic salmon has undergone evolutionarily adaptation of its physiology and metabolism to suit a natural diet that contains extremely limited or no nutritive carbohydrates.



Glucose and complex carbohydrate (starch)

Consequently, they are not able to efficiently regulate their intestinal glucose uptake following a carbohydrate rich meal, resulting in a prolonged high level of glucose in the blood (hyper-glycaemia), sometimes referred to by scientists as ‘glucose intolerance’.

What are carbohydrates made of and what do they look like?

Most of us are familiar with the every-day food items, such as sugar, bread, potatoes, rice, and pasta that provide us our carbohydrates.

Chemically, carbohydrates are a diverse group of biomolecules consisting of carbon (C), hydrogen (H) and oxygen (O) atoms, usually with a hydrogen–oxygen atom ratio of 2:1 (as in water). Their empirical formula Cm (H2O) n (where m may be different from n)

Among the different forms of carbohydrates that are abundant in plant sources, only starch and sugars have nutritive value in fish nutrition. Soluble carbohydrates such as starch are primary energy reserves found in seeds, tubers, and other plant structures. Animal tissues such as liver and muscle contain small concentrations of soluble carbohydrate in the form of glycogen, which resembles starch structurally.

What do carbohydrates do?

Carbohydrates provide a source of energy which is significant for omnivorous and herbivorous fish species but limited for carnivorous species such as the Atlantic salmon. However, the details of the carbohydrate digestive process in fish is not generally well understood. (See **the science says**).

Energy from carbohydrate can be stored, deposited in the form of glycogen in tissues such as liver and muscle, where it is readily available. Some dietary carbohydrate is converted to lipid and deposited in the body for energy.

The role of different carbohydrates (saccharides)

Carbohydrate	**Common name examples**	**Use or function**
Monosaccharide	Glucose	The simplest form of sugar and the most basic units of carbohydrates. They are usually colourless, water-soluble, and crystalline solids. Some monosaccharides have a sweet taste and can provide energy to living cells.

Disaccharide	Sucrose, lactose, and maltose	Sugars formed when two monosaccharides are joined by glycosidic linkage. Like monosaccharides, disaccharides are soluble in water and are used by plants to transport sugars.
Oligosaccharide	Glycans	A saccharide polymer containing a small number of monosaccharides with many functions including cell recognition and cell binding. Commonly attached to glycolipids and located in cell membranes with an important function in immune response.
Polysaccharide	Glycogen and Starch (cellulose)	Long chain carbohydrates composed of monosaccharide units bound together by glycosidic linkages. This carbohydrate can react with water (hydrolysis) using amylase enzymes at catalyst, which produces constituent sugars (monosaccharides, or oligosaccharides). Glycogen is commonly stored in animals as an energy source and starch is stored in plants for structural use. Structural non-starch polysaccharides (fibre) has no nutritional value.

How much carbohydrate should there be in a salmon diet?

Atlantic salmon have no essential requirement for dietary carbohydrates nutritionally. Although carbohydrates are the cheapest source of energy in fish diets, with a unit cost 3-5 times less than proteins and fats, unfortunately, carnivorous fish more readily convert proteins and fats into glucose at the cellular level.

At high levels the digestibility of lipids in the salmon’s diet is affected and more particulate matter is excreted to the environment due to undigested carbohydrates.

But, despite their poor ability to regulate blood glucose when the carbohydrate load is excessive, salmon do have sufficient carbohydrases within their digestive system to utilise limited quantities of complex carbohydrates.

Relevance to salmon husbandry

- Carbohydrate is essential to the production of extruded feed pellets which are more stable and leach less nutrients into the water.

- Optimal inclusion of dietary carbohydrates is known to increase protein and lipid retention thereby reducing nitrogen discharge in farm effluents.

- Providing a well-balanced diet in the form of a stable pellet helps to minimise the waste loadings on filters, which is particularly important to RAS.

Key points

- Carbohydrates are non- essential nutrients but can provide salmon some of their energy requirement.
- Salmon lack carbohydrate digestive enzymes and have limited ability to regulate their blood glucose.
- Starch is the most common source of digestible carbohydrate used in salmon diets.
- Carbohydrate has an essential role in binding extruded pellets to improve their water stability
- Carbohydrate is cooked when extruded pellets are made, which improves its digestibility.
- Excess carbohydrates in the diet (>25%) can lead to water pollution due to solid waste excretion.

The maximum recommended levels of dietary carbohydrate inclusion fall within 15-25 percent for salmonids and other carnivorous marine fish, whilst it can go up to 50 percent for herbivorous and omnivorous species like carp, tilapia and catfish. These species have superior amylase activity, intestinal glucose uptake capacity and can control their blood sugar.

Are carbohydrates necessary in salmon diets if they are 'non-essential' nutrients?

Although salmon are not efficient convertors of carbohydrates, there is still an essential requirement for them to be added to commercially produced pelleted salmon feeds.

Their inclusion as an ingredient helps to ensure pellet quality during the feed production process of cooking extrusion, including,

- binding and stability,
- starch digestibility, and
- buoyancy.

In addition, on farm feed wastage through pellet fragmentation and nutrient leaching are both reduced.

Therefore, as extruded feeds have become an essential part of many 'grow out' feeding regimes, it can be concluded that carbohydrate is vital to modern pelleted fish feed manufacture.

Can carbohydrate utilisation by salmonids be improved?

There is nothing fish farmers can do to improve carbohydrate utilisation, but the scientists are working on this challenge. Increased carbohydrates in salmonid diets would improve the economic viability and sustainability of the industry, by taking pressure of finite marine resources (fish meal and oil).

Some promising strategies are being investigated to overcome the carbohydrate utilisation challenge in farmed carnivorous fishes. By applying the concept of nutritional programming metabolic pathways or functions may be 'tailored'. This is based on a hypothesis that high carbohydrate stimulus exerted at critical developmental stages in early life may imprint an adaptive ability to cope with high carbohydrate diets in later life. This strategy has been found to improve starch digestibility in rainbow trout.

Based on observed genetic variability and **phenotypic plasticity** in glucose tolerance and metabolism in carnivorous fishes, it appears that specific **genotypes** that can adapt better to carbohydrate rich diets could be selectively bred. Selection for the ability to adapt to a totally plant based diet has proven to be successful in rainbow trout.

In addition, transgenic salmon with implanted growth hormone genes have an enhanced ability to metabolise carbohydrates, well above the inclusion level considered acceptable when farming their non-transgenic counterparts.

...the science says:

Carbohydrate utilisation by fish is not well understood: Although numerous investigations on the digestion of starch and other carbohydrates by fish have been published, the existing information is highly fragmentary.

See: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2095.2004.00327.x

Optimal carbohydrate inclusion rates for Atlantic salmon: The results of Atlantic salmon feed trials showed that feeding a diet containing 22% lipid with no starch or a starch inclusion higher than 22% exerts negative effects on growth and feed utilisation. A starch inclusion above 9% resulted in decreased starch digestibility, while protein digestibility was not influenced by the dietary starch content. Undigested starch is suggested to affect lipid digestibility in the same manner as dietary fibre. The reduced digestibility of high levels of dietary starch led to an increased loss of particulate matter to the environment. Considering feed utilization and environmental aspects, the experiment suggests that a diet containing approximately 9% starch is optimal

https://www.researchgate.net/publication/227968622_Carbohydrate_nutrition_in_Atlantic_salmon_Salmo_salar_L_Growth_and_feed_utilization#:~:text=Salmonids%20have%20lesser%20bacterial%20diversity%20than%20herbivorous%20fish%3B,al.%202002%3BKrogdahl%20et%20al.%202004%29%20and%20bacterial%20enzymes.

Carbohydrates in fish nutrition:

- In euryhaline fishes like rainbow trout and salmon, changes in salinity was found to interact with the regulation of glucose metabolism. Starch digestibility was lower in seawater than in freshwater, both possibly related to the osmoregulatory adaptation of the fish.

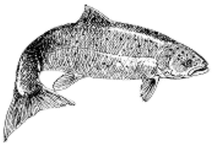
- Other environmental variables such as photoperiod also influence glucose tolerance and possibly carbohydrate utilisation in fish. For example, Atlantic salmon reared under continuous light showed higher glucose regulation capacity than those fish exposed to simulated winter photoperiod.

- Studies have shown that the utilisation of carbohydrate energy depends on the macronutrient composition of the diet. High level of dietary lipids was found to reduce starch digestibility.

- The availability of whole genome sequence can further facilitate the recognition of relevant quantitative trait loci. However, the feasibility and efficacy of non-destructive selection criterions is yet to be explored. Other critical aspects that can improve carbohydrate use is finding a fine balance between dietary macronutrients in evolving feed compositions and acquiring a symbiotic gut microbiome that can functionally contribute to carbohydrate digestion and metabolism

See: https://www.researchgate.net/publication/301636071_Carbohydrates_in_fish_nutrition

SNF 5 Salmon nutrition and feeds



Vitamins

Vitamins are organic compounds required in relatively small concentrations to support specific structural or metabolic functions and are essential for health and well-being in all animals. They are required in trace amounts in commercial fish feed diets to ensure the diet is well balanced and to avoid any defficiency that could develop in to a nutritional disease.

How are the vitamins categorised?

Vitamins can be are divided into two groups based on solubility.

Fat-soluble vitamins: are metabolised and deposited in association with body lipids. This enables fish to go for long periods without these vitamins in the diet before they show any signs of deficiency. They are; vitamin A (retinol), vitamin D (cholecalciferol), vitamin E (alpha-tocopherol) and vitamin K. Generally, fat-soluble vitamins function as an integral part of cell membranes; in addition, some of them may have hormone-like functions.

Water soluble vitamins: are required more regularly as they are not retained in the way that the fat soluble are. There are 11 water soluble vitamins including ascorbic acid (vitamin C), biotin, choline, folic acid, inositol, niacin, pantothenic acid, pyridoxine, riboflavin, thiamin and vitamin B12.

The requirements of water-soluble vitamins are lower than values recommended from late 20th century research. The values were determined by maximum liver storage or certain enzyme activity data and these are often higher than values based on weight gain and the absence of deficiency.

Relevance to salmon husbandry:

- Vitamins can degrade if they get wet or are kept for too long in storage. Therefore, a well maintained, cool, dark, dry and vermin free feed store is needed to ensure food is not damaged or degraded after delivery before use.

- A feed stock control system will assume the food is used while fresh and not trapped in the back of the store by later arriving deliveries of fresh feed.

Water soluble vitamins can not be stored in appreciable amounts in the body, so deficient diets become apparent within weeks in young, rapidly growing fish. Most are components of coenzymes with specific metabolic functions.

Detailed information about the functions of vitamins and the amounts needed by fish have been established for many cultured species. It is important to note that vitamins degrade over time if not stored correctly, which can lead to defficiency and nutritional disease.

The stability of vitamins during feed manufacture and storage has been improved over the years through the use of protective coatings and/or chemical modifications. This is exemplified by the development of various stabilised forms of the very labile ascorbic acid (Vitamin C).

Therefore, vitamin deficiencies are rarely observed in commercial salmon production

Never the less, all feed must therefore be stored appropriately and used within the 'use by' date to ensure fish receive the appropriate quality and quantity of vitamins.

Key points

- Vitamins can be fat soluble, which are retained or water soluble, which need to be regularly consumed.
- Most water-soluble vitamins act as coenzymes within specific metabolic functions.
- Fat soluble vitamins are an integral component of cell membranes
- Vitamins can degrade if fish feed is not stored properly and used when fresh
- Vitamin C is the most unstable vitamin in the diet and an indicator of the quality of manufacture and storage processes.

Vitamin and E and A are key factors in maintaining fish in top breeding condition. Vitamin K is critical for proper blood clotting.

Anytime a fish is under stress the need for Vitamin A is increased, which can make the difference between falling prey to disease and remaining healthy.

What are vitamins needed for?

Vitamins and some of their major functions as established in Fish.

Fat-soluble vitamins	Function
vitamin A, retinol	epithelial tissue maintenance, vision
vitamin D, cholecalciferol	bone calcification, parathyroid hormone
vitamin E, tocopherol	biological antioxidant
vitamin K	blood clotting
Water-soluble vitamins	
thiamin, B_1	carbohydrate metabolism
riboflavin, B_2	hydrogen transfer
pyridoxine, B_6	protein metabolism
pantothenic acid	lipid & carbohydrate metabolism
niacin	hydrogen transfer
biotin	carboxylation & decarboxylation
choline	lipotrophic factor, component of cell membranes
folic acid	single-carbon metabolism
cyanocobalamin, B_{12}	red blood cell formation
ascorbic acid, vitamin C	blood clotting, collagen synthesis
inositol	component of cell membranes

From the Fish Site

Qualitative and quantitative requirement values of most fat-soluble (A, D, E and K) and water-soluble (thiamin, riboflavin, niacin, pyridoxine, pantothenic acid, biotin, folic acid, vitamin B12 and vitamin C) vitamins established for rainbow trout and chinook salmon have been used for the feed formulation of Atlantic salmon with some exceptions.

There is evidence of improvement on health immune function and disease resistance in salmon with higher supplementation of vitamin C and other vitamins; however, the response under farming conditions is not always consistent with laboratory findings.

What is the Atalantic salmons vitamin requirement?

Ascorbic acid (Vitamin C) is the most unstable vitamin required in fish diets. Therefore, the extent of destruction of ascorbic acid in a feed gives some indication of manufacturing methods and storage conditions.

..the science says...

Plant based salmon feeds could be lacking in essential vitamins

Salmon feed formulations have changed dramatically the last 10–15 years – previously they were composed of fishmeal and fish oil, but most commercial salmon feeds now contain more than 70% plant ingredients, according to NIFES data.

Plants contain anti-nutrients that can cause the fish to absorb less of the nutrients in the feed; salmon fed plant based diets, therefore, need different quantities of vitamins and minerals.'

By Jane Byrne

11-Oct-2017 - Last updated on 12-Oct-2017 at 13:55 GMT

https://www.feednavigator.com/Article/2017/10/11/Plant-based-salmon-feeds-could-be-lacking-in-nutrients

In addition to losses associated with manufacturing and storage, there can be some loss of vitamins due to leaching during the feeding process.

However, at least for salmonids, the leaching of vitamins from properly manufactured dry pellets and granules is not a major problem.

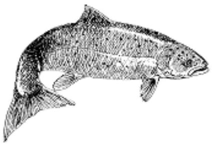
For juvenile salmon, the minimum requirement of vitamin E has been estimated as 60 mg/kg dry feed a value higher than that for other salmonids. A dietary supplement of 500 mg/kg has been recommended as a measure to prevent oxidative damage of salmon fillet during storage, as well as to maintain optimum flesh pigmentation.

What happens if vitamins are not available in the right quantities?

Water-soluble vitamins act as coenzymes accelerating enzymatic reactions and often serve as carriers for specific chemical groupings. Diseases due to vitamin deficiencies are a gradual process.

When the deficiency persists, the level in cells falls and the metabolic processes involving a specific vitamin are impaired. However, the changes do not occur at a uniform rate throughout all tissues of the body because some retain specific vitamins more readily, while other tissues are sensitive to changes in vitamin availability.

Therefore, generally, vitamin supplementation of feeds should consider fish genetic strains, physiological status, growth, and stress.



Minerals

Minerals are inorganic elements the body requires for various purposes. Atlantic salmon require the same minerals as terrestrial animals for tissue formation, osmoregulation and other metabolic functions. However, dissolved minerals in the water may satisfy some of the metabolic requirements of fish. Requirements have been reported for phosphorus, magnesium, iron, copper, manganese, zinc, selenium and iodine. The exchange of ions from the surrounding water complicates the measurement of mineral requirements, and uptakes of water-borne minerals were not always taken into account in requirement studies.

How are the minerals in salmon diets categorised?

Minerals are classified as either macro- or microminerals, based on the quantities required in the diet and stored in the body.

The macrominerals are calcium, phosphorus, magnesium, chloride, sodium, potassium and sulfur. Dietary deficiencies of most macrominerals are uncommon in fish because of the uptake of ions from the aquatic environment by the gills.

What is the most critical macro mineral in the diet?

Phosphorus is a major constituent of hard tissues such as bone and scales and is also present in various biochemicals. Impaired growth and feed efficiency, as well as reduced tissue mineralization and impaired skeletal formation in juvenile fish, are common symptoms when fish have phosphorus deficient diets, so it must be well provided in the feed.

However, phosphorus is an important macromineral for another reason. The digestibility of phosphorous in fishmeals ranges between 40 and 60 percent which means a high proportion is excreted. It is a scarce nutrient in many aquatic ecosystems limiting plant growth. Therefore, excreted phosphorus can upset the natural balance and lead to the eutrophication of water bodies and algal blooms.

Consequently, phosphorus nutrition has been extensively researched, with the aim of minimising phosphorus excretion and environmental impact of aquaculture.

Relevance to salmon husbandry

Minerals are rarely a problem in manufactured pelleted feeds as the requirements are added to the feed ingredients as a premix.

The ‘overprovision’ of phosphorus in the diet leading excretion of the excess and eutrophication of waters receiving effluent is a potential to conventional aquaculture due to eutrophication effects.

As RAS does not discharge effluent, and excess phosphorous increases the nutritional value of the RAS filtrate which can be productively recycled for crop production.

Is nutrient recycling the plan? Does the RAS reality have any real effect on diet formulation regarding minerals?

What are the other mineral requirements?

Chloride, sodium and potassium are important electrolytes involved in osmoregulation and the acid–base balance in the body and are usually abundant in water and feedstuffs and therefore rarely a problem.

Magnesium is involved in intra- and extracellular homeostasis and in cellular respiration and is also is abundant in most feedstuffs.

Which minerals are required in the lowest concentrations?

The microminerals (also known as trace minerals) include cobalt, chromium, copper, iodine, iron, manganese, selenium and zinc. Impaired growth and poor feed efficiency due to micromineral deficiencies are uncommon, but may occur after an extended period of feeding deficient diets. The quantitative dietary requirements for some fish species have been established. The metabolic functions of trace minerals are shown below.

Trace Minerals and some of their Prominent Functions.

Trace mineral	Function
Copper	metalloenzymes
Cobalt	vitamin B_{12}
Chromium	carbohydrate metabolism
Iodine	thyroid hormones
Iron	hemoglobin
Manganese	organic matrix of bone
Molybdenum	xanthine oxidase
Selenium	glutathione peroxidase
Zinc	metalloenzymes

From the Fish site

Copper, iron, manganese, selenium and zinc are the most important to supplement in diets because practical feedstuffs contain low levels of these microminerals and because interactions with other dietary components may reduce their bioavailability.

Although it is not usually necessary to supplement practical diets with other microminerals, an inexpensive trace mineral premix can be added to nutritionally complete diets to ensure an adequate trace mineral content.

How are minerals provided in the diet?

Atlantic salmon feeds may contain a high proportion of fishmeal and marine by-products supplemented with trace elements at a higher concentration than required due to limited information on their requirements and bioavailability from feed ingredients.

Key points

- Minerals are classified as either 'macro', needed in large quantities, or 'micro' only needed in trace amounts.
- Phosphorous is a macro mineral that is important to bone growth, but also responsible for eutrophication as it is oversupplied and excreted.
-

Feeds are often supplemented with zinc, iron, copper, manganese, selenium, iodine and phosphorus; however, they may also contain other trace elements supplied from common feed ingredients.

Elevated levels of zinc, copper, cadmium and manganese have been found in sediments under sea cages and in solid wastes generated by fish farms that affect the ecology of benthic organisms.

What happens to the salmon if the mineral levels provided are too low?

If mineral levels supplied in the diet fall below the salmon's requirement, defficiencies can arise.

Mineral deficiency signs in salmon and other fish include reduced bone mineralization, anorexia (potassium), lens cataracts (zinc), skeletal deformities (phosphorus, magnesium, zinc), fin erosion (copper, zinc), nephrocalcinosis (magnesium, selenium toxicity), tetany (potassium), thyroid hyperplasia (iodine), muscular dystrophy (selenium) and hypochromic microcytic anemia (iron).

... **the science says**

- Bioavailability of dietary phosphorus is influenced by several factors, including chemical form, digestibility of diet, particle size and interaction with other nutrients, feed processing and water chemistry. High concentrations of some minerals can create a mineral imbalance in the diet and cause a pollution problem in effluent waters.

- Plant proteins contain phytates (inositol hexaphosphoric acid), which are unavailable to salmonids. Supplementation of microbial phytase has been effective in improving phosphorous bioavailability of plant feed ingredients provided the activity of this enzyme is maintained and the water temperature is optimum for feed utilisation.

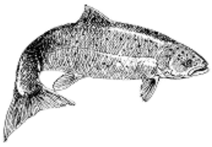
- Zinc bioavailability is reduced by plant phytates and higher concentrations of calcium phosphate supplied by bones in fishmeal.

See the Fish site

- **https://thefishsite.com/articles/principles-of-fish-nutrition**

Vitamins and minerals (FAO)

- http://www.fao.org/fishery/affris/species-profiles/atlantic-salmon/nutritional-requirements/en/#:~:text=The%20following%20two%20types%20of%20carbohydrate%20are%20derived,to%20improve%20the%20stability%20of%20extruded%20feed%20pellets.



Pigments

Although there are some examples of white-fleshed wild Atlantic salmon, typically, their flesh is orange to red, as a result of the carotenoids (largely astaxanthin and canthaxanthin) within the crustacea consumed during their marine feeding phase. These organic pigments found throughout the natural world are produced by a range of plants and algae, as well as several bacteria and fungi. They can be yellow, orange, or red, giving carrots, corn, tomatoes, pumpkins, canaries, flamingos, and daffodils their characteristic colour.

More than 95% of the carotenoids found in wild salmon flesh is in the form of astaxanthin.

What sources of pigment are used in farmed salmon feeds?

Castaxanthin has been used as a pigment additive in salmonid feeds in the past but was banned from use in fish feeds for a period of time due to unfounded human health scares.

Astaxanthin is added to farmed salmon feed formulations to produce this rich orange appearance.

Consequently, the only pigment used in salmonid feeds that provides the flesh its ‘trademark’ pink to orange colour is the carotenoid astaxanthin.

In what form are pigments added to salmon feeds?

Anthaxanthin is the carotenoid normally added to salmon feeds. It can be obtained from natural sources; green algae (Haematococcus pluvialis), the red yeast, (Phaffia rhodozyma), as well as crustacean by products.

Key points on pigments

- Used to pigment salmon flesh to a level that is acceptable to consumers
- Have an important health role in immune system and a precursor to vitamin A.
- Act as Antioxidants that protects fats and developing salmonid eggs
- Available as a 'nature identical' chemical synthetic or from natural sources.
- Can be included in diets during the freshwater and marine phase.
- Pigment deposition is influenced by stress, vegetable ingredients in the diet, sexual maturation, and fish genetics.

Shrimp meal is available from the shrimp processing industry which provides a natural form of pigmentation.

The company Roche dominate the pigment market. The astaxanthin most used is a 'nature-identical' chemical synthetic derived from petroleum sources. This has caused controversy at times.

New naturally derived astaxanthin products are being developed, including a recent source created from a strain of the leaf symbiotic (Methylobacterium extorquens). This breakthrough provides the aquaculture industry 'biologically produced' astaxanthin on a commercial scale that is competitively priced and shows great promise.

During which stages of the salmon's production cycle are pigments added?

Pigment is added to the diet of growout stocks destined for harvest, more to satisfy consumer requirements than as a nutrient essential to fish health.

In addition, in order to achieve satisfactory pigmentation of salmon with a shortened marine growing phase, pre-smolts are also being provided anthaxanthin during the hatchery freshwater phase.

Relevance to salmon husbandry

An important goal for salmon producers is to safely produce good, even pigmentation of their fish at the lowest possible cost.

Early sexual maturation can be a problem within salmon production, and this can disrupt pigment uptake.

Crowding and stress and can lead to pigmentation problems.

Feeding pigments during the freshwater phase is now legal and commonplace. It can improve pigmentation and is also more cost effective.

However, astaxanthin has some important biolochemical functions:

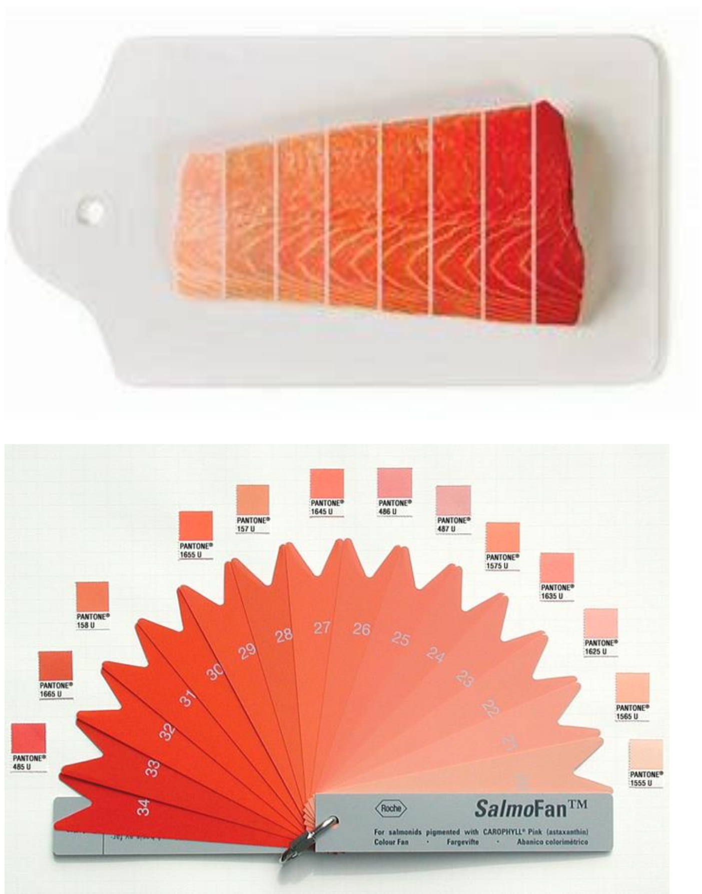
- Powerful antioxidant with a positive effect on the immune system
- Protects fats from oxidisation

The pigment is added to salmon broodstock diets as an essential nutrient for healthy ova development, as salmon eggs are rich in Essential Fatty Acids (EFAs) and benefit from protection.

In the past, EU regulations prevented salmonids being given synthetic astaxanthin in the first six months of their life. This ban has been lifted by the 'Panel on Additives and Products or Substances used in Animal Feed' (FEEDAP), with a concentration of 100mg/kg now deemed safe within both the freshwater and marine phase.

What is an aceptable level of pigmentation in farmed Atlantic salmon?

After freshness, a sufficient pigmentation is regarded as the most important quality criteria for farmed Atlantic salmon. An astaxanthin level in the range of 1.5-3 mg/kg was acceptable during the 1970’s, but the required level has steadily increased, and today an astaxanthin level above 8 mg/kg is necessary to achieve market acceptance which represents level 16 on the ‘Roche Colour Card Score’.



Roche salmon colour chart

What pigmentation feeding regimes can be deployed by salmon farmers?

The desire for a level of pigmentation similar to the Atlantic salmon’s cousins in the genus ‘Oncorhynchus’, has been driving farmers to feed astaxanthin fortified diets during the whole production cycle to achieve the highest possible carotenoid deposition in Atlantic salmon muscle.

Typically, pigments were added to commercial feeds in relatively small quantities of 20 gm/tonne (ppm) of feed, latterly. However, despite these low inclusion rates, they have been the most expensive dietry component, accounting for 10-20% of total feed costs.

In addition, not all of the pigment added is absorbed by the fish. A growing inefficiency of pigment deposition has led to increased inclusion rates and earlier feeding of pigment, which has been increasing salmon production costs. Manufacturers have added excess pigment in an attempt to satisfy the consumers requirement for stronger flesh pigmentation.

How effective are pigmentation regimes?

Pale and/or uneven red colour in salmon muscle is increasingly reported as a quality problem for Norwegian farmed salmon. The pigment level has been steadily declining in recent years, and in 2020, farmers will report the lowest ever pigment levels measured in Norwegian farmed salmon.

The previous response of increasing pigment levels in the feeds to resolve this problem has not been successful and more research has now been commissioned in Norway.

The effectiveness of pigmentaton regimes can be incluenced by a range of factors.

Factor	Elaboration
Stress	Particularly when caused by crowding, but sometimes as a result of disease treatments such hydrogen peroxide bath for delousing, stress is a major contributor to the break down of astaxanthin to idoxanthin in salmon. In trials, simulations that haven't included bathing but have lowered the water levels have also triggered the breakdown of astaxanthin to idoxanthin The mechanisms controlling the degrading of pigmentation in larger fish in seawater systems will be subject to further research. (See **the science says**)
Dietry composition	Salmon diets have changed, increasing the proportion of ingredients of a vegetable origin during the period that pigmentation issues have been growing and may be a contributory cause of poor pigmentation.
Fish genetics	Some fish in a population will break down some of their astaxantin into idoxanthin (a metabolite of astaxanthin) when faced with a stressful event. Some individual fish are affected to a much larger degree than others, which explains the variation seen in the pigmentation response between individual fish. Research is underway to determine which genes are instrumental in pigment deposition
Sexual maturation	The early maturation (grilsing) of fish stocks can disrupt pigment deposition in the flesh as the caretenoids are diverted to protect the developing ova.

Alternative pigmentation regimes showing how much astaxanthin is in the feed at each stage of production.

SALMON FARMER	FW	100	200	500	1000	2000	3000	PPM
Salar	NO	80	80	80	60	40	40	50
Salar	NO	40	40	40	60	50	50	50
Salar	NO	70	70	70	70	60	50	55
Salar	SI	70	70	70	70	70	70	70
Salar	SI	70	70	70	70	70	70	70
Salar	SI	70	70	70	70	70	70	70
Salar	SI	80	80	80	80	80	80	80
Salar	NO	60	60	60	60	60	60	60
Salar	NO	60	60	60	60	60	60	60
INVERMAR	SI	60	60	60	60	60	60	60
Salar	NO	70	70	70	70	60	60	61
Salar	NO	60	60	60	60	60	60	60
Salar	NO	80	80	80	50	50	50	55
Salar	NO	70	70	70	70	70	70	70
Salar	SI	70	70	70	70	60	60	61
Salar	NO	60	60	60	60	40	40	45
Salar	SI	75	75	75	75	60	60	65
PPM IN DIET		**70**	**70**	**70**	**65**	**60**	**60**	**65**

... **the science says**

Freshwater phase pigmentation regimes

Conventionally, salmon smolts have been grown to 40 grammes before transfer to the sea cages. More recently, fish are kept in freshwater for longer, up to 100 grammes plus, to help shorten the marine phase and reduce sea-lice exposure.

The reduced time that salmon now spend growing at sea has compromised the pigmentation process in most salmon producing regions.

To overcome this pigmentation challenge, and following extensive trials with astaxanthin, nutritionists working for a global leader in aquaculture feeds, has formulated freshwater-specific feeds containing astaxanthin, enabling pigmentation to begin prior to transfer.

Their findings established that diet formulations containing 70ppm pigment for use during the freshwater phase aligned most effectively with the conventional seawater pigmentation regimes that followed.

https://www.skretting.com/en/media/news/a-head-start-for-salmon-smolt-pigmentation/977424

Pigmentation and stress

While the use of astaxanthin in salmon feed has increased, the amounts that remain in the muscles of Norwegian farmed salmon are relatively low. Scientists at Nofima have carried out experiments that have shown that the level of omega-3 in the feed contributes to determining the quality of the colour uptake. They have also discovered that stress may play a confounding role in the interaction between colour and diet.

One of the breakdown products from astaxanthin is idoxanthin. The scientists have found that the level of idoxanthin increases when that of astaxanthin falls if the level of marine omega-3 in the feed is at the same time low. They have also shown that there is a relationship between the genes involved in the metabolism of astaxanthin and the level of marine omega-3 in the feed.

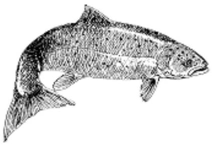
https://nofima.no/en/nyhet/2016/02/whats-causing-paler-salmon-fillets/

Factors affecting the utilisation of carotenoids in salmonid fishes

The results explain the reduced flesh pigmentation that has been reported after periods with rapid growth. It is also shown that the timing of seawater transfer can influence flesh pigmentation and other quality traits in Atlantic salmon. Finally, it is shown that neither the plasma transport capacity nor the muscle binding capacity seems to be limiting factors for flesh pigmentation of Atlantic salmon. Future work should focus on identifying the uptake mechanisms in muscle and other organs involved in carotenoid utilisation

https://thefishsite.com/articles/factors-affecting-utilisation-of-carotenoids-in-salmonid-fishes

SNF 8 Salmon nutrition and feeds



Energy

All living organisms, plants, and animals require energy to sustain life. Plants fix sunlight energy through 'photosynthesis' whereas animals satisfy their energy needs from the food they consume. Some of this energy is retained within the newly formed muscle and tissue, whilst a portion of it is released through cellular respiration, to supply daily metabolic needs.

What are the potential sources of energy in fish diets?

The three main energy sources in a fish diet can be ranked in order of the most expensive to least expensive:

- **Protein**

The most expensive form of energy in manufactured fish feeds and source of Essential Amino Acids (EAAs).

Key points

- The nutritional composition and digestibility of potential feed ingredients inform feed formulation.
- Proteins are the most expensive source of energy and should 'spared' for growth.
- Fats in the diet provide the most suitable energy source in salmonid feeds.
- Metabolisable energy is available for maintenance or growth and is determined by the gross energy and digestibility of feed ingredients.

Due to the expense of high-quality proteins, it is more cost effective if all the protein supplied in a diet is used for growth and tissue repair to maximise growth rates. If fish utilise protein as an energy source this will increase nitrogenous wastes from protein catabolism, increasing waste discharge and pollution. To prevent protein being used for energy, manufactured diets include alternative energy sources (fats and carbohydrates) to ensure protein is used for growth. Feed formulators refer to this as 'protein sparing'.

- **Fats**

The second most expensive form of energy in manufactured fish feeds and source of Essential Fatty Acids (EFAs).

Fats contain more energy per unit weight than any other macro-nutrient. Marine fish oils are the main source of fats but as they are expensive, they are partially displaced as an energy source by feed formulations by less expensive vegetable oils. The quantity of oils added to a diet will depend on a range of factors including fish species and age and 'protein sparing'.

Any surplus fats that are not metabolised can be stored as an energy reserve in the muscle, liver and as fat deposits surrounding the intestine and stomach.

- **Carbohydrates**

The least expensive source of energy in manufactured fish feeds.

Not all fish can efficiently utilise carbohydrates compared to other macro-nutrients. Carnivorous species more readily utilise proteins and fats as an energy source. Herbivorous and omnivorous fish can cope with higher levels of carbohydrates and use them as their primary source of energy. The carbohydrate most used in commercial diets is starch sourced from wheat. Its main function in salmonid diets is to act as a binding agent for other components to stabilise the feed pellet.

How do we measure the energy in feeds?

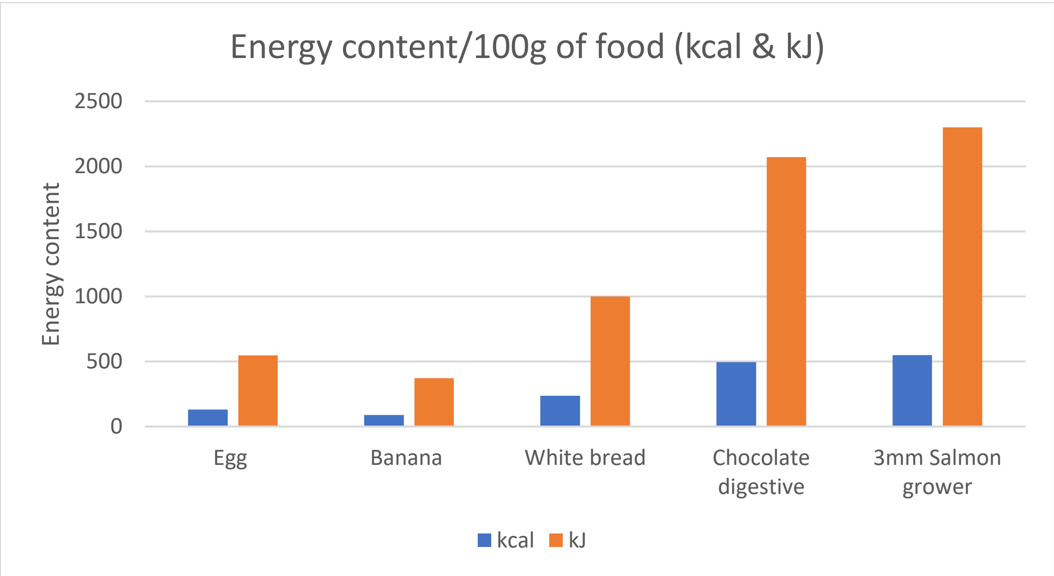
The amount of energy available in fish food can measured in joules (usually kilojoules = kJ) or calories (usually Kilocalories = Kcal or Cal); whereby 1 (kcal) is equal to 4.18 kJ.

1 kcal is the energy required to raise the temperature of 1 Kg of water by 1^{0}C.

The energy used by fish is more difficult to establish. It is also dependent on a range of factors e.g. maximum growth is influenced by water temperature, size/age of fish, diet composition and nutrient availability.

What is the typical energy value of commercial fish feed?

The energy content of fish feed is normally shown on the feed bag label as MJ/Kg of pellets. The diet used in the following examples is a salmon grower 3mm pellet with an approximate 23 MJ/kg. This is 23000 kJ per kg of fish feed.



The 3mm salmon grower diet is the most 'energy dense' with over four times the calories than 100g of eggs!

It is important to notice the high protein content of the 3mm salmon grower diet. This is required in a healthy balanced diet for Atlantic salmon because they are carnivores. However, not all the protein supplied will be sourced from animal protein and some will come from plant proteins.

How do the fish use the energy supplied in a diet?

Not all the energy supplied can be utilised for growth because some is lost to other essential functions.

The table below shows where energy losses occur.

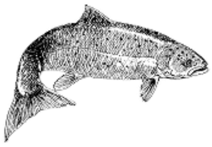
Energy used	**Essential function**	**Approx % lost**
Digestion	Breaking down food molecules	5-10
Heat production	Oxidising food molecules	10-20
Faeces	Waste and undigested food	20-30

The remaining energy can be utilised for body maintenance and then growth in that order of priority.

Each of the steps described is usually displayed on the feed labels of the bags the fish feed is supplied in. They are broken down and shown as abbreviations, as tabulated below:

Abbreviation	**Name**	**Description**
GE	Gross Energy	The total potential energy available
DE	Digestible Energy	The total potential energy the fish can digest
ME	Metabolisable Energy	The potential energy available after digestion and losses from heat
M	Maintenance	The energy required for all basic functions
RE	Retained Energy	The energy remaining that can be utilised for growth

SNF 9 Salmon nutrition and feeds



Salmon feed sustainability

A wide range of ingredients are sourced and assessed by fish feed manufacturers for use in salmon feed formulations. Consequently, salmon producers are dependent on their feed company when striving to improve their sustainability.

Fish meal remains an important ingredient within salmon feeds, but inclusion rates are reducing as other ingredients play an increasingly important role. Today, feed companies must ensure any new ingredient is sustainable as well as nutritionally suitable and economic.

The feed companies source ingredients from all over the world as most ingredients are commodities being traded within a large and at times volatile global market. Their selection of ingredients is influenced by

- availability and price,
- nutritional profile, digestibility, and bio availability, and
- their carbon footprint and sustainability.

How do feed companies make sure the ingredients they use are sustainable?

There is an elaborate process that must be completed before a company can contract a new supplier of an ingredient, whether it is in common use or novel.

A Life cycle analysis (LCA) is conducted to determine an ingredients carbon footprint throughout its production cycle. This includes all stages of extraction and processing, wherever they are conducted. An examination of practices in several different countries that are part of the ingredients supply chain may be necessary.

The process is formalised by risk assessing suppliers and subjecting them to sustainability audits that include environmental, social, and legal aspects.

There is an increasing emphasis on developing novel raw materials that do not compete with the human food chain. Marine ingredients can still be sourced, but within a highly regulated environment to ensure finite marine resources are not put at risk.

Herring trawler

Can fish meal still be used in feeds that claim to be 'sustainable'?

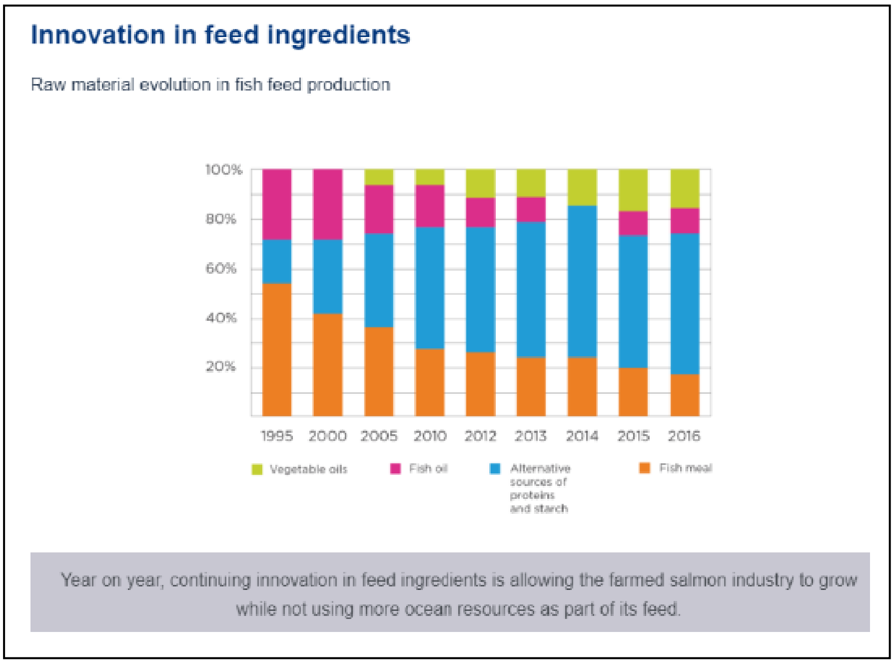
The aquaculture industry cannot use fishmeal or fish oils made from fish on the World Conservation Union's (IUCN) list of endangered species. Species exploitation is regulated to keep within sustainable yields, and for some species, direct human consumption takes priority. For example, North Sea herring is only utilised as a fish feed ingredient when the catch exceeds consumer demand, and the annual surplus is processed into fish meal.

The use of captured fish as a source of meal is increasingly controversial. Some researchers have claimed that 90% of the fish used for fish meal globally are suitable for direct human consumption. The feeding of fish meal-based diets to carnivorous farmed fish, although economic, is not a sensible use of finite global resource, in the context of rising human food security issues, they argue.

This means that Fish feed companies must audit suppliers to ensure that the wild fish come from regulated fisheries.

Is the dependency on fish meal by salmon feed manufacturers increasing or decreasing?

Feed manufacturers are genuinely trying to improve the ‘forage fish dependency ratio’ (FFDR) with significant success. This is the quantity of wild fish needed to produce 1 Kg of farmed salmon. The lower the FFDR the lower the inclusion rate of wild fish.



The percentage inclusion of fish meal in diets reduced from over 50% in 1995 to less than 20% by 2016.

Today, the use of alternative protein and oil sources, including novel ingredients, has grown in the drive for improved sustainability.

Research indicates that fish meal could be reduced to as little as 5% of the diet, without affecting growth. This is provided animal by-products do not exceed 26% and fish oils do not fall below 5%.

However, hatchery diets are more dependent on fish meal than grower diets, currently. Appetite and growth rates cannot be compromised during the early stage of the production cycle.

Can marine ingredients ever be completely replaced in salmon feeds?

Some feed companies are aiming to eliminate fish meal and oil dependence entirely in the long term and are testing and developing ‘novel’ ingredients.

Other feed companies have already developed salmon diets containing no fish meal for post smolt to 4.5 Kg. An overall FCR of 1.18 has been achieved in feed trials and the fish were in good health with low mortality.

There are a range of alternative ingredients regularly used already and others showing promise in the drive for lower FFDRs.

Which alternative proteins are most often included in salmon feeds?

Poultry meal

Alternative animal proteins have always been included in salmonid feeds to some degree. Some are a good source of EAAs despite lacking one or more EAAs compared to fish meal.

- **Animal by-products**

The following animal by-products are commonly used by major feed manufacturers including Skretting:

- Animal by-product (Poultry meal)
- Crustacean meal (Krill, shrimp, crab)

Poultry meal is a widely available by-product of the meat processing industry. It is a palatable and high-quality feed ingredient containing EAAs, fatty acids, vitamins, and minerals.

However, the EAA profile is lysine deficient, and it cannot completely replace fish meal.

How useful are vegetable proteins for replacing some of the fish meal?

There are several sources of vegetable protein commonly used, including soya, maize, and rape-seed meal.

Maize

Some have ‘anti-nutritional factors’ to be aware of, such as the trypsin inhibitor in soya meal and need to be further processed before inclusion.

The EAA profile of plant protein sources compared to fish meal would be undersupplied, depending on the plant protein source.

The complete displacement of fish meal by any plant protein source would lead to severely impaired growth and a nutritional deficiency disease.

Feed additives are used to counter the deterioration in the salmon’s gut microflora community that occurs when vegetable protein inclusion rates are increased.

- **Insect larvae**

Some insect larvae have a similar EAA profile to fish meal and could be a total replacement. The soldier fly shows most potential and can consume a variety of organic food wastes and plants.

Soldier fly larvae

Scientists have shown that soldier fly larvae can also be fed on fish farm sludge. Fed this way, larvae become rich in the marine fatty acids EPA and DHA, as well as minerals such as iron, zinc and selenium. A wider range of wastes are expected to become available as larvae feed following recent changes to legislation prohibiting their inclusion.

Consumer taste tests panels were unable to tell those fish reared on soldier ply larvae-based feed from fishmeal-based diets.

Pilot scale soldier fly larvae

Industrial scale larvae production is already under development and a test factory targeting the production of 50, 000 Tonnes/Annum by 2025 is being set up in Norway.

Single cell protein

The term single cell protein (SCP) refers to dead, dry cells of micro-organisms such as yeast, bacteria, fungi and algae which grow on different carbon sources. Bacterial SCP has a more rapid growth rate than yeast and fungi.

How is SCP produced?

A pure culture of specified microorganisms is grown on suitable raw materials by fermentation and then separated by screening. Phototrophic bacteria are most recommended for production. Bacterial SCP strains produce high crude protein content (>80 %) and EAA values, along with vitamins, phospholipids, and other functional compounds.

Feed trial testing SCP

In trials, salmon fed a diet containing SCP achieved encouraging growth performance comparable to salmon on a conventional diet.

Do salmon fed SCP based diets remain healthy?

Gut health is well supported, and antibiotic use reduced during throughout the production cycle. SCP could be a realistic total replacement for fish meal without any detrimental fish health impact.

What progress has been made with the replacement of fish oils in salmon feeds?

Alternatives to fish oil that provide the right EFA profile to support healthy growth and do not taint the salmon flesh are being sourced and some novel replacements being developed. There has been a lot of progress made with fish oil replacement.

- **Poultry oil**

Poultry oil is obtained from the tissue of poultry in the commercial process of rendering or extracting and has several attributes as a feed ingredient.

Poultry industry

It is the most unsaturated terrestrial animal fat with a lower carbon footprint than vegetable oils. It offers a low-cost energy source that can form part of the fat component of salmon feeds. Its calorific value is high energy, and it contains the EFA Linoleic acid.
Mixed with omega 3 oils, it can replace 60-70% of fish oil.

- **Vegetable oils**

Some vegetable oils, such as sunflower, have a different fatty acid composition to marine fish oils. They are deficient in the ‘essential nutrients’, omega-3 fatty acids (EPA and DHA). However, many do contain omega-3 fatty acid (LNA/ALA), some of which salmon can convert into EPA and DHA, to gain their positive biological effects.

Vegetable oil

As salmon feed production methods have improved, up to 70% of dietary fat is now provided by vegetable oil in some salmon feeds.

When using vegetable oils, it is possible for some of the salmon’s essential EPA and DHA requirement to be provided by the residual oil retained in fish meal.

Do salmon fed a vegetable oil-based diet taste the same as those consuming fish oil?

The taste of farmed salmon is dependent on salmon feed composition.

Sensory analysis studies show that the fillets from salmon fed a mixture of vegetable oils have a similar taste as fillets from salmon fed fish oils. However, they have a less characteristic marine taste and aroma.

Taste testing panel

Tasting tests have demonstrated that the taste of salmon fed vegetable oil, followed by fish oil for 4-5 months prior to harvest, is indistinguishable from salmon constantly fed on fish oil-based diets.

- **Canola oil**

Canola is a high-grade rapeseed oil with a superior EFA profile than other vegetable oils. It is a rich source of DHA and contains no more than 2% erucic acid.

Farmed salmon feed trials have demonstrated several benefits to canola oil as a feed ingredient. The fillet colour is improved because of the impact on muscle structure or composition. The prevalence and severity of dark melanin spots in salmon fillets is reduced. Nutritionally, the DHA is increased content and the omega 6: omega 3 ratios in salmon tissues reduced.

Rape seed

Feed trials compared the performance of salmon fed two diets, one containing canola oil the other fish oil. There were no significant differences in overall fish growth, weight at harvest, and feed conversion ratio.

There is no need to feed salmon on fish oil-based diets for 4-5 months pre-harvest.

- **Camelina oil**

The quantity and ratios of omega 3: omega 6 fatty acids make camelina an excellent fish feed ingredient. Being high in omega-3 (35%) and omega-6 (25%) with a ratio >1, it is nutritionally superior to alternatives including canola.

Camelina

Camelina oil enhances the salmon's ability to synthesise healthful long-chain omega-3 fatty acids needed for optimal growth.

- **Algal oil**

The company Veramaris have certified sustainable algal oil which it launched in 2018. This product is rich in EPA and DHA omega-3 fatty acids.

This fish oil substitute is produced by a fermentation process requiring just algae and sugar. During fermentation, the algae cells multiply and convert dextrose into omega-3 fatty acids to form an oil concentrate which is removed for fish feeds.

The solid fraction is used as a protein source in cattle feed or converted into biogas energy.

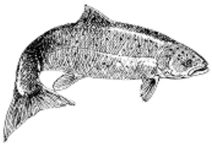
Some feed companies are already incorporated algal oils in feeds used during the grow out phase. Sixty tonnes of fish would be required to produce the nutrition contained in one tonne of Veramaris algal oil.

Algal oils can have a big role to play within fish oil replacement tin the future.

Key points

- Fish are captured from well-regulated fisheries for meal production. The inclusion rate has dropped from >50% in 1995, to <20% in 2016.
- The use of alternative animal and vegetable proteins is increasing, but many alternatives lack one or more EAAs.
- Soldier fly larvae have a similar EAA profile to fish meal and do not taint the salmon flesh.
- Bacterial single cell protein has a high protein content (>80%) and grows rapidly in commercial fermenters.
- Poultry oil is the most unsaturated animal fat and can replace 60-70% of the fish oil in the diet.
- Vegetable oils are a source of omega 3 fatty acids, some of which can be converted into essential eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).
- Canola and camelina oils have superior EFA profiles and are a rich source of DHA.
- Algal oil is rich in EPA and DHA and is a viable replacement for all dietary fish oil.
- Feed additives are used to counter the deterioration in the salmon's gut microflora community due to vegetable proteins.

SNF 10 Salmon nutrition and feeds



Feed formulation

Salmon farmers need to be confident that their fish receive sufficient energy for daily maintenance and growth from well-designed diets that can provide the nutrients essential to keeping their fish stocks healthy.

There are many potential ingredients available to feed manufacturers that have been chemically analysed. As well as a full knowledge of each ingredients nutrient profile, including the essential nutrients, feed manufacturers must know the digestibility of their feed ingredients for the farmed species targeted.

However, feed formulation remains an art, with a degree of judgement involved and strongly influenced by economics and world markets.

Can absolute recommendations be made regarding feed raw materials and nutrient inclusion rates?

It can be difficult at times to make precise recommendations regarding feed ingredients (raw materials) and nutrient inclusion rates in fish feeds for many reasons.

Results of nutrition trials are always conditional on the specific circumstances of the trial and depend on many factors. This is due to the interactions between the many ingredients and specific nutrients in any test diet. A low fish meal diet might give good results if some other ingredient supplies a specific amino acid, while another trial using the same fish meal level might report a very poor result because the other ingredients used were different, or the same ingredients were used but had different quality, such as unknown degree of heat-damaged proteins.

Key points

- Gaps remain in the scientific knowledge of fish nutrition for some fish developmental stages.
- The availability and cost of feed ingredients influences feed formulations.
- If an essential nutrient is provided at a sub optimal level, fish compensate by consuming more.
- Feed formulators tend to 'over supply' essential nutrients to compensate for any damage and variability in raw materials.
- Consumer perceptions and preferences can influence diet formulation (as exemplified by pigmentation)

There are thousands of published scientific papers related to fish nutrition, but the science remains imperfect. For some farmed fish there are gaps in the knowledge base regarding interactions between the changing nutritional requirements of each developmental stage, available feed ingredients and the aquatic environment. Much of the research demonstrates conflicting results, allowing a 'preferred' view to be supported, or the views of others contradicted, on a selective basis. This is something salmon farmers should be aware of when discussing feed formulations with the manufacturers.

How do diet formulation vagaries impact on salmon production?

Fish nutritionists must establish nutrient intake from potential ingredients to determine their suitability and inclusion level. Fish, like all animals, can sense their metabolic wellbeing resulting from a given diet. They adjust their feed intake to mitigate any imbalance in the diet.

For example, if fed to satiation, feed intake will increase to compensate for a limiting nutrient, and the excess intake of other nutrients will be stored as body fat or excreted.

Therefore, an imbalanced diet composition can lead to increased

- food intake,
- Biological Food Conversion Ratio (bFCR),
- stores of body fat, and/or,
- discharges to the environment.

Such imbalances are minor in modern salmon diets and uncommon. Typically, when salmon do increase their feed intake to compensate for a sub optimal diet, the impact on growth and the biological FCR (bFCR) is undetectable and 'guised' by other factors, such as husbandry. Feeding regimes can be particularly influential, along with fish genetics, environmental factors, and grading regimes.

What influence does the relative cost of different sources of nutrients have on feed formulation?

Economics, raw material availability and costs, and the practicalities of feed manufacture can lead to formulations that are not optimised nutritionally. For the farmer, if a diet is 20% cheaper than a 'higher quality diet' but the bFCR increases by only 10%, then the cheaper diet may give the most economic result.

... the science says

The INRA-CIRAD-AFZ feed tables provide a library of information on the nutrient profile of a wide range of feed ingredients and their digestibility by a range of farmed livestock including fish

The data base is in the public domain and the breakdown and digestibility of most common ingredients and some novel can be accessed

https://www.feedtables.com/content/table-feed-profile

Many trials report in vitro measurements (e.g. some metabolic parameter measured in a test tube) or results from short-term, controlled trials in a laboratory. Whether these results can be extrapolated to give meaningful differences in commercial fish production is often speculative.

The drive for increased sustainability is having an ongoing impact on the sourcing of ingredients and is also incentivising the development of novel ingredients.

Can the consumer influence fish feed formulations?

Without doubt the consumer can be very influential. If they believe that aquaculture's use of fish feeds high in fish meal and oils is unsustainable, then the industry will take remedial action.

If concerns are raised regarding toxin levels in fish meals derived from northern hemisphere fish stocks, then this will stimulate a move towards exploiting southern hemisphere stocks with much lower residues, whether the health concerns of consumers are fully proven or not.

Consumer perceptions regarding the colour of salmon flesh has driven the industry to increase anthaxanthin inclusion rates to 'intensify' pigmentation.

The consumer demands can influence feed formulations as well as other aspects of salmon farming.

How are diets formulated to ensure salmon receive the correct nutrition?

The nutritional requirements of salmonids' have been well known for twenty years. But for many farmed fish species, the precise nutrient requirements have not been established, particularly for essential amino acids and vitamins. In practice, feeds for relatively new carnivorous species are often formulated to meet the requirements of salmon or trout. This assumes that all carnivorous species with a similar ecology and natural diet will have similar nutritional requirements.

In practice when formulating feeds, a margin of safety is commonly applied, whereby nutrient levels are increased to compensate for processing and storage losses, variation in composition and the bioavailability of nutrients in feed ingredients, possible interactive effects, and any variation in requirements caused by environmental effects.

Providing the correct energy contribution from each of the macro-nutrients in the diet for protein sparing and growth is essential to cost effective salmon grow-out feeding regimes.

Relevance to salmon husbandry

Commercial diets tend to evolve through incremental 'baby-steps'.

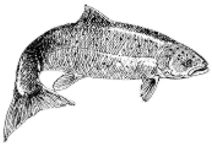
As the effect of small changes in feed formulations on fish growth, bFCR, and body composition are not usually detectable, diet formulation by feed manufacturers can "creep" in a direction determined by market forces and consumer demands.

The raw material availability and prices, feed price, and feed marketing policies and the feed company's own profit targets, can influence formulation more than strict nutritional principals. However, fish feed production is an extremely competitive business and farming companies have a lot of influence.

Therefore, salmon farmers should understand the purpose of each feed ingredient and factors that influence the quality, cost and performance of fish feeds and the impact on fish health and the economic viability of production.

Modern salmon feeds are well formulated, and husbandry factors determine salmon farming success more often than the selection of alternative feed formulations. It is up to the Feed companies to design feeds and provide their customers trustworthy guidance.

SNF 10 Salmon nutrition and feeds



Feed manufacture and selection

When selecting feeds the salmon farmer should not leave themselves at the mercy of the feed companies marketing and sales machine. It is important to be able to look behind the shop window and ask the right questions. The prices of feed raw materials and of farmed salmon fluctuates, which, alongside the specific challenges of the farm operation, can influence feed selection.

As both feed input costs and harvest values can be volatile, the farmer must remain vigilant and choose feeds designed to meet the farm circumstances, whilst satisfying the consumer and providing the best financial return to the business.

Extruded feeds dominate the market.

The farmers choice of feed should be influenced by the constituent raw materials included in the feed formulation and the physical characteristics of the feed particle.

A knowledge and understanding of the role, nutritional profile and digestibility of each ingredient is particularly useful. This enables salmon farmers to engage in discussions with their feed supplier regarding feed selection and value for money, based on a common understanding of salmon nutrition and feeding.

There are several major feed manufacturers dominating the global market to select from, each offering a wide product range. The customisation of feeds to suit a particular farm is increasingly common, necessitating farm feed trials to compare the costs and benefits of different feed formulations. Trials must be well designed and accurately conducted so as the data gathered is reliable and results meaningful.

Salmon feed manufacturing process

The process for manufacturing dry pelleted feeds has changed considerably since salmonid diets were first produced. The original dry feed pellets were made feed manufacturing plants that compressed the mix of selected ingredients through a pellet die head to form and angular, and relatively dense pellet.

This produced a pellet with several disadvantages compared to modern extruded feeds:

Original pelleted feeds (not extruded)

- Fast sinking and therefore not always available for long enough in the water column to be captured and ingested.

- Not always stable, and readily fragmenting at the edges, leading to higher dust levels and waste.

- A physically dense structure limiting fish oil uptake and retention, the primary source of energy, leading to more dietary protein being catabolised.

Today, the 'extruded fish feeds' that are within widespread use at all stages of production are made using a feed extrusion technology. Initially, initially, extruded feeds were only available in larger pellet sizes for the grow out stage. But today, all the main manufacturers also use extrusion technology to produce hatchery feeds in the smaller pellet sizes, down to 0.5 mm for first feeders of 0.18 grammes.

The table below describes the 10-step process for producing a modern extruded feed.

Process	**Sequence**
Ingredients are sourced from suppliers	1
The ingredients are milled to a homogenous fine particle size	2
A mash is made of raw ingredients by adding water	3
The mash is heated	4
The heated mash is forced through the extruder and pressurised	5
As the pressure drops rapidly steam is produced which cooks the carbohydrate and expands.	6
Pellets are produced by a rotating blade cutting the extruded	7
Oil is added at the level required according to the feed specification	8
The pellets are quality assured by checking their resistance to pressure, nutritional composition and sink rate	9
The feed is bagged up and delivered to the farm	10

The extruders use superheated steam to process and cook the raw ingredients preventing pathogen transfer. On cooking, the complex carbohydrates in the mix change their structure, expanding during

Pellet ring die head

the extrusion process to create a matrix that binds the ingredients within a low-density pellet, with micro air spaces throughout.

Extruded pellets offer several advantages:

- The micro air spaces in the pellet structure can absorb oil without destabilising and causing it to break up. The feed manufacturers can add high levels of oil to the feed (up to 35%) to create high energy feeds.

- The pellet is less dense and sinks more slowly making it more available to fish in the water column (In the case of some specialist trout feeds, it can even be made to float.)
- As the mash is superheated, long chain proteins and carbohydrates break down into smaller chains, which makes them easier to digest.

- Feed pellets are a more rounded shape, uniform in size, and do not readily break up to create dust, leading to waste feed.

Insert video on Extruded pellet manufacture

url: https://www.youtube.com/watch?v=dAJnkkgGnT4

A 1minute quick glimpse!

- The FCR (Food Conversion Ratio) can be extremely low.

The disadvantages of the extrusion process are:

- Because the mash is superheated, vitamins and some nutrients are degraded.

- This means additional vitamins and nutrients may need to be added to supplement the diet and ensure a nutritional balance.

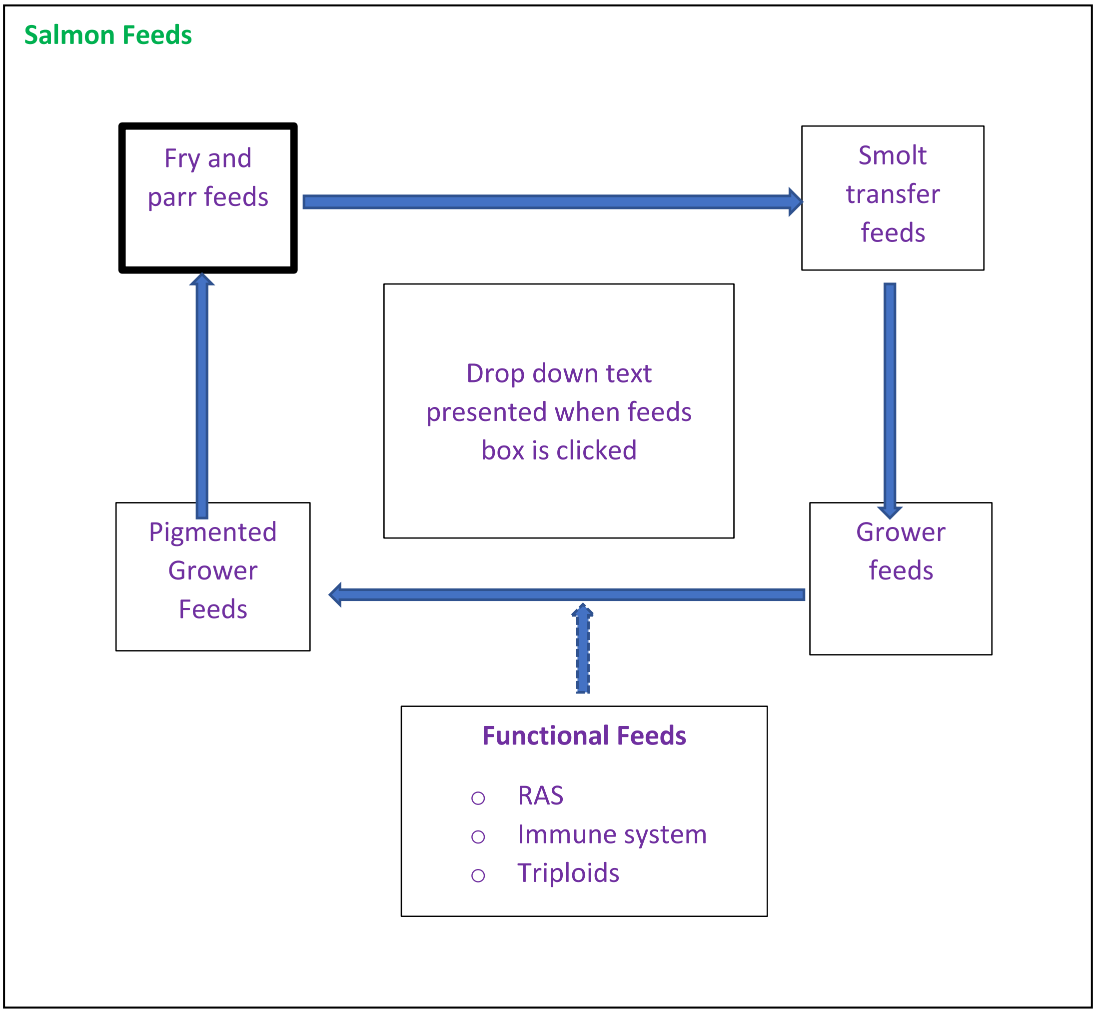
What range of salmon feeds are available from feed manufacturers?

Providing optimal nutrition according to the stage of the salmon's lifecycle is the underlying objective of all salmon feeds at every stage, hatchery and grow out, and ingredients are sourced and tested on this basis. However, some feeds are designed to include additional features.

Those diets that are sold as 'functional feeds', designed to include an additional feature or features, to achieve specific farming objectives that go beyond optimising salmon nutrition.

In addition to the standard range of feeds shown, there are organic feeds certified used by specialist producers for the niche organic salmon market. There are strict standards to comply with, including the use of permitted fish meal sources only.

Articulate creative: Develop a graphic that is composed of images to represent each of the following diets, and/or production stages, with a central drop-down text (See below) on clicking.



- **Fry feeds**

The digestive system of fry at first feeding is rudimentary, not very well developed, and the number of pyloric caeca increases with fish size. The fish are metabolically active causing a mismatch between the growth potential of the fish and the capacity of its digestive system to support that growth.

Well-designed fry feeds provide ‘bioavailable’ essential nutrients for cellular growth including the highest quality Low Temperature (LT) fish meals as the sole source of protein to help the fish develop anatomically and metabolically.

The diets are provided in the form of ‘micro extruded pellets’ to encourage feeding behaviour and appetite, as the low-density slow sinking feed particles remain visible in the water column for longer and are easy to see and ingest with minimal waste.

Typically, fry feeds are available in several pellet sizes: 0.5 mm for first feeders (0.18 grams), 0.7 mm for growing fry and 1.0 mm for more advanced fry (3.5 grams)

- **Smolt feeds**

Feed manufacturers produce seawater transfer feeds for salmon going through parr-smolt transformation. In addition to the full complement of macro and micro-nutrients, these diets contain salt, betaine, amino acids, nucleotides, and other supplements to improve the osmotic adaptation of smolts to seawater leading to improved survival. Smolts are then fed marine grower feeds after the seawater acclimation is complete.

Some manufacturers produce functional feeds specifically for RAS smolt production that are functionally enhanced. They are formulated to ensure the faeces are well bound and sink, aiding their removal and taking load off the biofilters and components to strengthen the immune system during the transfer period are added. These diets are often fed for up to 6 weeks post seawater transfer.

- **Grower diets**

  Most grower feeds are high energy diets with high levels of oil (20-35%) to maximise biomass production and shorten the production cycle. They are extruded pellets based on highly digestible raw materials that provide high quality proteins and fats, resulting in fast growth and reduced emissions to the aquatic environment or RAS filtration system.

  Protein can be provided by fish meal and alternative protein sources, mainly of vegetable origin, in various proportions, which can influence the price and performance of the feed.

  Some oil is provided as fish oil, but the majority can be provided as vegetable oil, switching to fish oil dominated diets before harvest to optimise the sensory qualities (taste) of the salmon for the consumer. Whether this is necessary depends on the type of vegetable oils used.

- **Pigmented feeds**

  Astaxanthin is the carotenoid added to salmon feeds to pigment the flesh during the final period of grow out. Pigment inclusion rates have grown to satisfy consumer demand for a more intensely pigmented salmon flesh.

  Pigmentation regimes have also evolved and where the marine grow out phase has been shortened due to the production of larger smolts, pigmented diets are sometimes being fed to pre-smolts, as well as fish post marine transfer.

  Typical pigmentation rates within the salmon farming industry range between 45-70 ppm of astaxanthin, per Kg of fish feed, within a variety of regimes.

- **Functional feeds**

  One of more functional ingredients are included for a range of specific farming benefits:

  - To manage the faeces quality and indirectly water quality, by reducing the load on the RAS filtration system,
  - To support the fish's immune system by increasing the level of antioxidants and other additives to help to maintain the skin, intestine, and gills, and
  - to support the normal development of skeletal and bone structures within fast growing triploid salmon.

Farm based feed trials

A new salmon feeds can be purchased, based entirely on the manufacturer's advice, if trusted, and used across the entire farm. Usually, they are tested on a smaller scale through farm-based feed trials, before full adoption, which is more advisable.

Image of fish sampling

As RAS based salmon production is relatively new, the design of functional feeds to suit RAS and the management of RAS feed programmes is still evolving. This makes farm-based feed trials more important, conducted in close cooperation with the feed supplier.

What determines the reliability of on farm feed trials?

The reliability of any farm feed trial data depends on the execution of the trial and will be determined by;

- The accuracy of the fish stock records at the start of the trial.
- The accuracy of feed input records.
- The fish sampling regime (fish sample sizes and sample capture methods).

If feed trials are comparative, whereby the performance of one feed is being compared to another, it is essential to eliminate other potential variables that could influence the result.

These include:

- The fish population (genetics, size range, stock density and health status).
- The aquatic environment (water quality and flow rates).
- The feeding strategy (feeding to satiation or rationing).
- The feeding method (automatic feeders, meal sizes).

How do feed trials within RAS production differ?

The monitoring of water quality impacts, Dissolved Oxygen, Total Ammoniacal Nitrogen (TAN) and pH, will be particularly important when comparing the benefits of alternative RAS functional feeds. Reducing the filtration load and maintaining high water quality, whilst maintaining efficient fish production, is the objective of a RAS functional feed.

How can on farm feed trial accuracy be ensured?

Depending on the duration of the feed trial and stage of the production cycle, it is helpful to be able to end the trial period with a fully accurate fish stock assessment, either by harvesting to establish the actual biomass and average weight, or by bulk weighing the entire stock (and sampling with larger sample sizes) prior to relocating for the next phase of the production cycle, such as when smolts move to grow-out.

The biggest danger with a feed trial is that the inaccuracies are greater than the real impact of the different feed. As inaccuracies can move in either direction, positive or negative, this may produce a false benefit for one feed over another, or completely guise real benefits. The salmon feed market is competitive and therefore any ‘real’ performance improvements are marginal and require accurate trails to detect them.

Multiple choice question banks- Salmon nutrition and feeds

Blue Mentor Guidance: Multiple Choice

This series of multiple-choice questions have been designed so as there is only one possible correct and complete response. This allows prior knowledge to be established through pre-testing.

These questions have been devised for use within a learning management system (LMS) with feedback to learners provided.

Taxonomy: Bank number, Subject, Question title

Bank 1 Role of nutrients

1.1	Where in the natural world are carotenoid pigments found? Select AS MANY as you believe to be correct. a) Carrots b) Cabbages c) Tomatoes d) Atlantic salmon e) Flamingos Ans a,c,d,e Feedback: You should have selected a), c), d) and e). Answer b) is incorrect as the green colour of cabbages is due to chlorophyl as opposed to carotenoids.
1.2	What form of carotenoid makes up 95% of the pigment in wild Atlantic salmon flesh? Select the CORRECT ANSWER from the options below. a) Astaxanthin b) Anthaxanthin c) Castaxanthin d) Canthaxanthin Ans a Feedback: You should have selected a) as the correct answer. All the other statements are incorrect.
1.3	What are the biochemical benefits of astaxanthin?

	Select AS MANY as you believe to be correct. a) Promotes bone development b) Positive effect on immune system c) Boost metabolism and growth d) Antioxidant protecting fats Ans b,d Feedback: You should have selected b) and d). Answers a) and c) are incorrect as astaxanthin does not promote these biochemical benefits.
1.4	What human health issue did canthaxanthin cause, leading to its removal in the 1980s? Select the CORRECT ANSWER from the options below. a) It was found to be toxic b) It turned skin orange c) It caused nervous system disorders d) It crystalised in human eye tissue Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
1.5	What is the earliest stage that astaxanthin can **first** be added to salmon feeds? Select the CORRECT ANSWER from the options below. a) Immediately post smolt transfer b) Pre-smoltification c) During smoltification d) Six weeks pre-harvest Ans b Feedback: You should have selected b) as the correct answer. All the other statements are incorrect.
1.6	What are the potential sources of astaxanthin? Select AS MANY as you believe to be correct. a) Green algae b) Red yeast

	c) Crustacean by-products d) Leaf bacteria e) Petroleum Ans a,b,c,d,e Feedback: You should have selected all these options as sources of astaxanthin.
1.7	What advantage do natural sources of astaxanthin have over synthetic astaxanthin? Select the CORRECT ANSWER from the options below. a) Higher concentrations of astaxanthin b) More pronounced immune system boost c) Higher pigment retention d) Greater antioxidant capacity Ans b Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
1.8	What changes to their environment cause the green algae (Haematococcus pluvialis) to encyst and release astaxanthin? Select AS MANY as you believe to be correct. a) Nutrient deprivation b) Temperature increase c) Salinity increase d) Strong light Ans a,d Feedback: You should have selected a) and d). Answers b) and c) are incorrect as they are not the environmental triggers leading to astaxanthin release.
1.9	What source of astaxanthin is most used in salmon feeds? Select the CORRECT ANSWER from the options below. a) Green algae b) Red yeast c) Crustacean by-products d) Leaf bacteria

	e) Petroleum Ans e Feedback: You should have selected e) as the correct answer. All the other statements are incorrect.
1.10	Which crustacean meals are available to fish feed manufacturers as a source of pigments? Select AS MANY as you believe to be correct. a) Crab b) Shrimp c) Lobster d) Krill Ans b,d Feedback: You should have selected b) and d). Answer a) is incorrect as crab meal is not used in fish feeds and answer c) is incorrect as lobster meal is not commercially available.
1.11	What level of astaxanthin is required in salmon flesh to satisfy consumers? Select the CORRECT ANSWER from the options below. a) 2 Mg/Kg b) 4 Mg/Kg c) 8 Mg/Kg d) 16 Mg/Kg Ans c Feedback: You should have selected c) as the correct answer. All the other statements are incorrect.

Bank 2 Macro nutrients

2.1	What is included in the chemical composition of carbohydrates. Select AS MANY as you believe to be correct. a) Carbon b) Hydrogen c) Nitrogen

	d) Oxygen Ans a,b and d Feedback: You should have selected a), b) and d) as the correct answer, Answer c) was incorrect as carbohydrates don't contain nitrogen.
2.2	Which of the following categories of fish can digest and break down starch, to release glucose? Select AS MANY as you believe to be correct. a) Herbivorous fish species b) Omnivorous fish species c) Salmonids Ans a,b,c Feedback: You should have selected a), b) and c) as they can all digest starch to varying degrees, but in small quantities only for the Atlantic salmon.
2.3	What is the upper limit of carbohydrate inclusion for the Atlantic salmon, Select the CORRECT ANSWER from the options below. a) 35-50% b) 25-35% c) 15-25% d) 5-15% Ans c Feedback: You should have selected c) as the correct percentage inclusion rate. All the other definitions are incomplete or incorrect.
2.4	What is the upper limit for the percentage of fibre in RAS feeds? Select the CORRECT ANSWER from the options below. a) 2% b) 5% c) 10% d) 15% Ans c

	Feedback: You should have selected a) as the correct upper limit for fibre inclusion in salmon fry feeds.
2.5	In what chemical form is most of the unutilised energy from carbohydrate stored in the salmon? Select the CORRECT ANSWER from the options below. a) Lipid b) Amino acids c) Fatty acids d) Glycogen Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
2.6	What is the impact on feed quality of cooking carbohydrates during pellet extrusion. Select AS MANY as you believe to be correct. a) Improved starch digestibility b) Improved pellet binding and stability c) Increased oil absorption capacity d) Improved protein digestibility e) Slower pellet sink rate Ans a,b,c,e Feedback: You should have selected a), b), c) and e) as the correct answer. Answer d) is incorrect as cooking the carbohydrates does not change the digestibility of proteins.

Bank 3 Micronutrients

3.1	Where in the natural world are carotenoid pigments found? Select AS MANY as you believe to be correct. a) Carrots b) Cabbages

	c) Tomatoes d) Atlantic salmon e) Flamingos Ans a,c,d,e Feedback: You should have selected a), c), d) and e). Answer b) is incorrect as the green colour of cabbages is due to chlorophyl as opposed to carotenoids.
3.2	What form of carotenoid makes up 95% of the pigment in wild Atlantic salmon flesh? Select the CORRECT ANSWER from the options below. a) Astaxanthin b) Anthaxanthin c) Castaxanthin d) Canthaxanthin Ans a Feedback: You should have selected a) as the correct answer. All the other statements are incorrect.
3.3	What are the biochemical benefits of astaxanthin? Select AS MANY as you believe to be correct. a) Promotes bone development b) Positive effect on immune system c) Boost metabolism and growth d) Antioxidant protecting fats Ans b,d Feedback: You should have selected b) and d). Answers a) and c) are incorrect as astaxanthin does not promote these biochemical benefits.
3.4	What human health issue did canthaxanthin cause, leading to its removal in the 1980s? Select the CORRECT ANSWER from the options below. a) It was found to be toxic b) It turned skin orange c) It caused nervous system disorders d) It crystalised in human eye tissue

	Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
3.5	What is the earliest stage that astaxanthin can **first** be added to salmon feeds? Select the CORRECT ANSWER from the options below. a) Immediately post smolt transfer b) Pre-smoltification c) During smoltification d) Six weeks pre-harvest Ans b Feedback: You should have selected b) as the correct answer. All the other statements are incorrect.
3.6	What are the potential sources of astaxanthin? Select AS MANY as you believe to be correct. a) Green algae b) Red yeast c) Crustacean by-products d) Leaf bacteria e) Petroleum Ans a,b,c,d,e Feedback: You should have selected all these options as sources of astaxanthin.
3.7	What advantage do natural sources of astaxanthin have over synthetic astaxanthin? Select the CORRECT ANSWER from the options below. a) Higher concentrations of astaxanthin b) More pronounced immune system boost c) Higher pigment retention d) Greater antioxidant capacity Ans b Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.

3.8	What changes to their environment cause the green algae (Haematococcus pluvialis) to encyst and release astaxanthin? Select AS MANY as you believe to be correct. a) Nutrient deprivation b) Temperature increase c) Salinity increase d) Strong light Ans a,d Feedback: You should have selected a) and d). Answers b) and c) are incorrect as they are not the environmental triggers leading to astaxanthin release.
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3.11	What level of astaxanthin is required in salmon flesh to satisfy consumers?

	Select the CORRECT ANSWER from the options below. a) 2 Mg/Kg b) 4 Mg/Kg c) 8 Mg/Kg d) 16 Mg/Kg Ans c Feedback: You should have selected c) as the correct answer. All the other statements are incorrect.

Bank 4 Sustainable feed ingredients

4.1	Which of the following feed ingredients are being partially replaced with more sustainable ingredients? Select AS MANY as you believe to be correct. a) Poultry oil b) Vegetable proteins c) Fish meal d) Vegetable oils e) Fish oil Ans c, e Feedback: You should have selected c and e. Answers a, b and d are incorrect, as these ingredients are becoming more important as substitutes for fish meal and oil.
4.2	How do salmon feed manufacturers ensure that their feeds more sustainable? Select AS MANY as you believe to be correct. a) By subjecting their ingredients suppliers to sustainability audits b) By never buying fish meal or oil c) By determining each ingredients carbon footprint d) By developing novel raw materials that do not compete with the human food chain

	e) By selective sourcing of marine ingredients Ans a,c,d e Feedback: You should have selected a,c,d and e. Answers b is incorrect, as feed manufacturers still buy marine ingredients selectively.
4.3	Which essential amino acid (EAA) is poultry meal deficient in? Select the CORRECT ANSWER from the options below a) Lysine b) Methionine c) Tryptophan d) Threonine Ans a Feedback: You should have selected a) as the correct answer. All the other statements are incorrect.
4.4	Which of the following protein sources could totally replace fishmeal without damaging fish health? Select AS MANY as you believe to be correct. a) Soya meal b) Rapeseed meal c) Soldier fly larvae d) Maize meal e) Single cell protein Ans a,c,e Feedback: You should have selected c) and e). Answers a), b) and d) are incorrect, as none of them have a complete EAA profile.
4.5	Which is the most productive (fastest growing) source of single cell protein (SCP)? Select the CORRECT ANSWER from the options below

	a) Yeast b) Algae c) Fungi d) Bacteria Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
4.6	What category of nutrients does poultry oil have in greater abundance than the fat from any other terrestrial farmed animal? Select the CORRECT ANSWER from the options below a) Vitamins b) Minerals c) Essential Amino Acids d) Unsaturated fats Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
4.7	What is the maximum percentage of fish oil in a salmon grower diet can be replaced by poultry oil, without any detrimental impact on fish health? Select the CORRECT ANSWER from the options below a) 80-90% b) 60-70% c) 40-50% d) 20-30% Ans b Feedback: You should have selected b) as the correct answer. All the other statements are incorrect.

4.8	Which source of vegetable oils has the best omega 3:6 ratio? Select the CORRECT ANSWER from the options below a) Sunflower b) Canola c) Camelina d) Rapeseed Ans c Feedback: You should have selected c) as the correct answer. All the other statements are incorrect.
4.9	For how long should salmon fed on a vegetable oil-based feed be fed a fish oil-based feed to impart the marine taste? Select the CORRECT ANSWER from the options below: a) 2 weeks b) 1-2 months c) 4-5 months d) > 6 months Ans c Feedback: You should have selected c) as the correct answer. All the other statements are incorrect.
4.10	What aspect of the digestive system is affected by the replacement of fish meal with vegetable proteins in salmon feeds? Select the CORRECT ANSWER from the options below: a) Production of bile b) Production of stomach proteases c) Production of pancreatic enzymes d) Gut microflora community

	Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.

Bank 5 Feed design and selection

5.1	During which stages of production is astaxanthin pigment added to salmon feed formulations? Select AS MANY as you believe to be correct. a) First feeding b) Fry to parr c) Smolt d) Post smolt grow out Ans b,c,d Feedback: You should have selected b), c) and d) as the correct answer. Answer a) is incorrect as astaxanthin is not added to first feed formulations.
5.2	Which of the following are included in RAS salmon smolt transfer feed formulations? Select AS MANY as you believe to be correct. a) Additives to improve faecal binding b) Additives to enhance health c) Additives to support smoltification d) Astaxanthin for pigmentation Ans a,b,c,d Feedback: All these additives are included in RAS smolt transfer feeds.
5.3	Which salmon age group has the highest protein inclusion rate in its feed formulations? Select the CORRECT ANSWER from the options below: a) Fry to parr

	b) Smolt transfer c) Post smolt to grow-out d) All the same Ans a Feedback: You should have selected a) as the correct answer. All the other statements are incorrect.
5.4	Which salmon age group has the highest oil inclusion rate in its feed formulations? Select the CORRECT ANSWER from the options below: a) Fry to parr b) Smolt transfer c) Post smolt to grow out d) All the same Ans c Feedback: You should have selected c) as the correct answer. All the other statements are incorrect.
5.5	Why is high digestibility a more important criteria for salmon production in RAS than 'through flow' systems? Select AS MANY as you believe to be correct. a) To accelerate growth b) To avoid overloading the filters c) To improve pigment retention d) To maintain water quality Ans b,d Feedback: You should have selected b) and d) as the correct answer. Answer a) is incorrect as accelerated growth is no more important to RAS than it is to through flow systems. Answer c) is incorrect as digestibility does not affect pigment retention.
5.6	Which RAS feed design criteria help to maintain high water quality? Select AS MANY as you believe to be correct.

	a) Stable extruded pellets b) Faecal binding additive c) Health additive d) Slow sink rate e) High digestibility Ans a,b,d,e Feedback: You should have selected a), b), d) and e) as the correct answer. Answer c) is incorrect as health additives have no impact on water quality.
5.7	How is the density and sink rate of extruded pellets controlled? a) By reducing the amount or fish meal in the formulation b) By varying the amount of oil added to the extruded pellet c) By manipulating the temperature during extrusion d) By varying the amount of carbohydrate in the formulation Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
5.8	Which component of RAS technology does Pure Salmon rely on for the removal of leached oil? a) Drum filters b) Protein skimmers c) Biofilters d) Oxygen diffusers Ans b Feedback: You should have selected b) as the correct answer. All the other statements are incorrect.
5.9	What are feed manufacturers compensating for when applying a safety margin during salmon feed formulation? Select AS MANY as you believe to be correct. a) Nutrient losses to due to processing b) Variations in nutrient bioavailability

	c) Variations between individual salmon nutrient requirements d) Possible effects of nutrient interactions e) Nutrient losses due to storage Ans a,b,d,e Feedback: You should have selected a), b), d) and e) as the correct answer. Answer c) is incorrect as the salmon's nutrient requirements do not vary between individual fish in a population.
5.10	When salmon are being fed to satiation (appetite), what would be the effect of an unbalanced feed formulation with an under supplied essential nutrient? Select AS MANY as you believe to be correct. a) Increased food intake b) Higher food conversion ratio c) Increased body fat d) Nutritional deficiency disease e) Increased waste discharge Ans a,b,c,e Feedback: You should have selected a), b), c) and e) as the correct answer. Answer d) is incorrect as the salmon would increase its feed intake to compensate and increase the intake of the essential nutrient to the level required.
5.11	What criteria does the feed have to satisfy for farmed salmon to qualify for organic status? Select AS MANY as you believe to be correct. a) Must not include fish meal and oils b) Include fish meal and oil from MSC certified fisheries only c) Include vegetable protein sources only d) Include natural forms of pigment only Ans b,d Feedback: You should have selected b) and d) as the correct answer. Answer a) is incorrect as fish oils from MSC certified fisheries can be included. Answer c) is incorrect as the protein does not have to be 100% of vegetable origin for organic status.
5.12	How does the manufacture of extruded feeds differ to manufacture of pelleted feeds? Select AS MANY as you believe to be correct.

	a) Higher moisture in the feed mix b) Feed mix is subjected to a higher temperature c) Higher quantities of oil in the feed mix d) Higher pressure during the pelleting process Ans a,b,d Feedback: You should have selected a), b) and d) as the correct answer. Answer c) is incorrect as oils are added to the pellet by vacuum coating the pellet after extrusion
5.13	For which age classes of farmed salmon have feed manufacturers produced extruded feeds? Select AS MANY as you believe to be correct. a) First feeders b) Fry to par c) Smolt d) Post smolt to grow out Ans a,b,c,d Feedback: There are extruded feeds for all age classes of farmed salmon
5.14	What ingredient provides all the protein in salmon first feed diets? Select the CORRECT ANSWER from the options below: a) Soya meal b) Standard fish meal c) Soldier fly larvae meal d) Low temperature fish meal Ans d Feedback: You should have selected d) as the correct answer. All the other statements are incorrect.
5.15	Why is the concentration of Vitamin C lower in first feeds than fry to parr and smolt feeds? Select the CORRECT ANSWER from the options below: a) Because Low Temperature fish meal in the feed provides additional Vitamin C b) Because the packaging of fry feeds is completely sealed to protect all nutrients

	c) Because first feeding fry have a lower Vitamin C requirement than the later stages d) Because yolk sac remnants provide first feeders an early Vitamin C boost Ans b Feedback: You should have selected b) as the correct answer. All the other statements are incorrect.
5.16	What are the key characteristics of micro extruded fry feeds? Select AS MANY as you believe to be correct. a) Palatable to encourage first feeding behaviour. b) Uniform sized feed particle. c) Low-density slow sinking particles d) Wide range of particle sizes e) Dust free to safeguard gill health. Ans a,b,c,e Feedback: You should have selected a), b), c) and e) as the correct answer. Answer d) is incorrect as fry have a precise feed particle size requirement that changes as they grow.
5.17	What are the key characteristics of grower feeds for the grow out phase once the fish have reached 1,500 g? Select AS MANY as you believe to be correct. a) Pellet stability b) Faecal binding c) High oil (31%) d) 70 ppm astaxanthin e) 30 ppm astaxanthin Ans a,b,c,e Feedback: You should have selected a), b), c) and e) as the correct answer. Answer d) is incorrect as astaxanthin is reduced from 70 ppm to 30 ppm before the fish reach 1,500 g.

Multiple choice question banks- Salmon hatchery operations

Blue Mentor Guidance: Multiple Choice

This series of multiple-choice questions have been designed so as there is only one possible correct and complete response. This allows prior knowledge to be established through pre-testing.

These questions have been devised for use within a learning management system (LMS) with feedback to learners provided.

Taxonomy: Bank number, Subject, Question title

Bank 1 Hatchery operations overview

1.1 Which of the following environmental parameters **can** be controlled in a Recirculation Aquaculture System (RAS) salmon hatchery

Select AS MANY as you believe to be correct.

*a) Water temperature

*b) Water flow rates

*c) Water quality

d) Feed quality

*e) Biosecurity

*f) Light levels

1.2 The eggs purchased by Pure Salmon for incubation in their hatcheries are of an unknown genetic origin

True or **False**

1.3 To calculate the number of days it will take a specific batch of salmon eggs to hatch requires a knowledge of:

Select AS MANY of the following as you believe to be essential to this assessment

*a) the eggs stage of development in Degree-days

b) the dissolved oxygen concentration in the incubation trays

*c) the hatchery incubators temperature regime in Degrees centigrade

d) the hatchery light regime

1.4 The temperature of the water in a RAS hatchery cannot possibly vary, as it is under constant control.

True or **false?**

1.5 The velocity (speed) of water movement can vary in different locations in hatchery fish holding units.

True or false**?**

1.6 Water flow rates in the hatchery fish holding Units should be set so as they are sufficient to remove metabolic wastes

True or false**?**

1.7 The Dissolved oxygen saturation levels in hatchery fish holding units should be maintained at:

Select the CORRECT ANSWER from the options below

*a) >100%

b) >90%

c) > 80%

d) > 70%

d) > 60%

1.8 The release of carbon dioxide from fish respiration in the hatchery fish holding units will cause the water PH to:

Select the CORRECT ANSWER from the options below

a) stay the same

b) increase

b) initially decrease then increase

*c) decrease

1.9 Which gas most commonly causes 'supersaturation' problems in a RAS hatchery that can threaten the health of the fish stocks?

Select the CORRECT ANSWER from the options below

a) Carbon dioxide

b) Oxygen

*c) Nitrogen

d) Ammonia

Bank 2 Egg procurement

2.1 What 'desired traits' are in general demand from salmon farmers and guide the selection of brood stock by egg suppliers?

Select AS MANY as you believe to be correct

*a) growth rate

*b) disease resistance

c) skin colouration

*d) flesh quality

2.2 Individual fish within family groups of broodfish (40-50 individuals) established by egg suppliers show the selected desired traits to precisely the same degree.

True or **false**?

2.3 The 'marker assisted selection technology' allows superior individual fish to be identified from family groups.

True or false?

2.4 The genomic selection process is primarily used to establish superior family groups of broodfish

True or **false**?

2.5 The genomic selection process allows superior individual brood fish in family groups to be identified

True or false?

2.6 The genomic selection process allows several different traits to be selected for at the same time.

True or false?

2.7 Atlantic salmon strains are being developed to help to optimise salmon production within RAS

True or false?

2.8 Genomic selection is superior because:

Select AS MANY as you believe to be correct

*a) the Atlantic salmon SNP chip allows up to 930,000 genetic markers to be analysed

b) it is focussed on the family level as opposed to individual level of selection

*c) it is focussed on the individual level as opposed to family level of selection

d) it can analyse the DNA of developing eggs to identify superior individuals

2.9 The problems caused by early sexual maturation when producing salmon within RAS can be countered by:

Select AS MANY as you believe to be correct

*a) stocking an all-female population

b) growing fish on a restricted feed ration

c) increasing ‘grow out’ holding-unit flow rates

*d) stocking a triploid population

e) delaying smoltification during the hatchery phase

2.10 Atlantic salmon normally have 2 sets of chromosomes at the cellular level.

True or false?

2.11 Triploid Atlantic salmon with 3 sets of chromosomes at the cellular level and can still reproduce normally

True or **false**?

2.12 Commercial salmon egg suppliers can produce all-female Atlantic salmon eggs by:

Select the CORRECT ANSWER from the options below

a) feeding female hormones to salmon fry to make males genetically female, despite being physically male, which on maturing produce milt to fertilise eggs and produce all-female offspring

*b) feeding male hormone to a mixed sex stock of juvenile salmon, to masculinise the females, which on maturing, produce milt to fertilise eggs and produce all-female offspring

c) pressure shocking mixed sex salmon eggs after fertilisation to change the genetic makeup of the eggs destined to become male, so as they become female

d) feeding female hormones to the male brood fish for 3 months before spawning, so as their milt becomes genetically female and fertilises eggs to produce all-female offspring

2.13 Commercial salmon egg suppliers can produce sexually sterile triploid eggs by:

Select the CORRECT ANSWER from the options below

a) feeding female hormones during the first 3 months in the hatchery so as when the male salmon mature, their milt can be used to produce triploid (sexually sterile) fertilised eggs.

b) feeding male hormones to a mixed sex stock of juvenile salmon, to masculinise the females which on maturing produce milt that can be used to produce triploid fertilised eggs

c) pressure shocking mixed sex salmon eggs after fertilisation to change the genetic makeup of the eggs by adding an additional set of chromosomes to transform diploid into triploid eggs

d) feeding female hormones to male brood fish for 3 months before spawning, transforming their milt from diploid to triploid for fertilising salmon eggs to produce 100% triploid stock

*e) Pressure shocking fertilised diploid all female eggs at the appropriate stage of development to produce triploid eggs

2.14 At the cellular level the male has:

Select the CORRECT ANSWER from the options below

a) two sets of X chromosomes

*b) an X and Y chromosome

c) two sets of Y chromosomes

2.15 At the cellular level the female has:

Select the CORRECT ANSWER from the options below

*a) two sets of X chromosomes

b) an X and Y chromosome

c) two sets of Y chromosomes

2.16 When sexually mature, masculinised females can be selected for milt extraction to produce all female eggs by:

Select the CORRECT ANSWER from the options below

a) selecting fish that look female as they lack of a kype (distended lower jaw) but have darker than normal external colouration and a ‘flattened body shape’ (no swollen belly)

*b) killing and dissecting the sexually mature male brood stock to identify those with no sperm duct between the testes and vent and removing their testes

c) by selecting and stripping all males to collect viable milt from masculinised females with milt from normal males, will has been inactivated by the previous hormone treatment.

2.17 Why can triploid fish stocks perform better on the farm than normal diploid stocks?

Select the CORRECT ANSWER from the options below

a) Because the triploidisation process interacts with genes inhibiting fish growth, allowing higher growth rates to be reached.

b) Because triploid fish are far hardier that normal salmon and less affected by water quality variations and stress

c) Because triploid fish respond better to 24-hour light regimes, leading to an increased daily feed intake and greater overall growth

*d) Because triploids are sexually sterile and resources cannot be diverted into the production of sexual products (eggs and milt), allowing all of their nutrition to be used for growth

2.18 To calculate the number of eggs needed to produce a given output of fry for transfer to the nursery, the technician needs to know:

Select AS MANY as you believe to be correct

a) the survival rate during incubation up to hatch

b) the water temperature

*c) survival rate from egg receipt to nursery transfer

d) the holding capacity of the incubators

*e) The target number of fry for nursery transfer

2.19 If the survival rate is 80% from egg receipt to nursery transfer how many eggs does the hatchery need to produce an output of 100,000 fry

Select the CORRECT ANSWER from the options below

a) 120,000

b) 180,000

*c) 125,000

2.20 To calculate the egg holding capacity of the hatchery incubation system the technician needs to know:

Select AS MANY as you believe to be correct

*a) the egg stock density limit per egg tray

b) the survival rate during incubation up to hatch

*c) the number of egg trays in the incubation facility

d) The target number of fry for nursery transfer

2.21 To calculate how many batches of eggs the hatchery can incubate annually; the manager needs to know:

Select AS MANY as you believe to be correct

*a) the water temperature regime

b) survival rate from egg receipt to nursery transfer

c) the egg holding capacity of the egg trays

*d) the Degree days exposure the eggs have had on receipt

*e) The Degree days required from fertilisation to first feeding

Bank 3 Egg transit and receipt

3.1 The eggs purchased by pure salmon are transported at the eyed stage, because:

Select AS MANY of the following as you believe to be correct

a) eyed eggs do not need oxygen

b) they are close to hatching

*c) they are physically robust

e) they have just been fertilised

3.2 Different batches of eggs from different brood stock are always identical in size.

True or **false**?

3.3 The supplier measures the eggs into the egg trays for transport by:

Select AS MANY of the following as you believe to be correct

a) counting by eye

b) machine counting

*c) volumetric measurement

e) their weight

3.4 In transit the polystyrene egg boxes have two trays of ice above the egg trays which:

Select AS MANY of the following as you believe to be correct

a) keeps eggs just above freezing (0.5-1 oC) and stop their metabolism

b) keeps the egg box internal temperature within 8 -12 oC

*c) helps to keep the eggs moist with any ice melt

*e) keeps the internal egg box temperature within 4-6 oC

3.5 On arrival at the hatchery staff collecting the egg boxes from the airport should:

Select AS MANY of the following as you believe to be correct

*a) check the egg box packaging for signs of damage

b) immediately arrange the return of all damaged egg boxes

*c) photograph any signs of damage to any egg box and record

*d) check the eggs for signs of physical damage and record

e) discard all eggs from any boxes that are damaged or contain damaged eggs

*f) set up hatchery monitoring of all eggs from any damaged boxes

3.6 To avoid thermal shock on arrival the temperature of the eggs in the egg boxes should not differ to the incubation system by more than:

Select the CORRECT ANSWER from the options below

a) 4 oC

b) 3 oC

c) 2 oC

*d) 1 oC

e) O.5 oC

3.7 To acclimatise the eggs the process should include:

Select AS MANY of the following as you believe to be a part of the egg acclimatisation process

*a) trickling incubator water over the eggs at intervals (< 5 minutes) from a low height (<15")

b) gradually warming the eggs in a thermostatically controlled bath (if cooler than the incubator water)

c) checking and recording the temperature of the eggs at 15-minute intervals

*d) checking and recording the temperature of the eggs at 5-minute intervals

3.8 What are the acclimatised salmon eggs ae disinfected with?

Select AS MANY of the following as you believe to be correct.

a) Bleach

b) Dilute Hydrochloric acid

*c) Buffodine

d) Alcohol

3.9 Why is sodium carbonate added during egg disinfection?

Select AS MANY of the following as you believe to be correct.

a) To increase the potency of the disinfectant and help kill pathogens

b) To dampen the exothermic reaction and moderate the temperature

c) To soften the eggshells carbonates to assist the hatching process *d) To maintain the pH of the solution within safe limits (pH 6-8) during disinfection

Bank 4 Egg incubation

4.1 How can the rate of salmon egg development in a hatchery be manipulated?

Select AS MANY of the following as you believe to be correct

a) By controlling water flow rate

b) By controlling dissolved oxygen

*c) By controlling water temperature

d) By controlling light regime

4.2 Why are eggs are sometimes sampled on receipt to assess the number of eggs per litre?

Select AS MANY of the following as you believe to be correct.

*a) To check the egg suppliers egg count is accurate

b) To check that the eggs have not shrunk during transport due to dehydration

*c) To calculate the volume of eggs to lay out in the incubators to achieve the correct stock density

d) To check whether the eggs have swollen during transport due to water absorption

4.3 What are the potential disadvantage(s) of horizontal incubators compared with vertical incubators?

Select AS MANY of the following as you believe to be correct.

a) They need less hatchery floor space

b) They offer water flow control in each individual hatchery tray

c) They are designed to offer a more comfortable working position

*d) They are dual purpose as fry can be first fed in them

4.4 What are the advantage(s) of vertical over horizontal incubators?

Select AS MANY of the following as you believe to be correct.

*a) They offer water flow control in each individual egg tray

*b) They are more compact and require less hatchery floor space

*c) They are designed to offer a more comfortable working position

d) They are dual purpose as fry can be first fed in them

4.5 Why must staff ensure there is no air entrapment within the incoming water flow when setting up the incubator egg trays?

Select AS MANY of the following as you believe to be correct.

*a) Because the water flow through incubation tray screens can be blocked, reducing Dissolved Oxygen

b) Because metabolic wastes will collect in the incubation trays due to the disrupted flows

c) Because the water level in the incubation trays will drop

*d) Because the eggs can be unnecessarily agitated when the entrapped air is released

4.7 How can the Degree days' exposure of a batch of developing eggs 'be calculated?

Select the CORRECT ANSWER from the options below.

a) By multiplying the number of days by the water temperature in degrees Fahrenheit

b) By dividing the number of days by the water temperature in Degrees Centigrade

c) By dividing the water temperature in Degrees Centigrade by the number of days

*d) By multiplying the number of days by the water temperature in Degrees Centigrade

4.8 The biological development of Atlantic salmon eggs at temperatures lower than 5°C is:

Select the CORRECT ANSWER from the options below

a) slower than the Degree days calculation would suggest

b) the same as the Degree days calculation would suggest

*c) quicker than the Degree days calculation would suggest

4.9 The thermal regime in salmon hatcheries aims to provide a stable water temperature of:

Select the CORRECT ANSWER from the options below

a) 6 oC

*b) 8 oC

c) 10 oC

d) 12 oC

4.10 The hatchery target temperature is changed following an unexpected deviation to keep to the planned hatch date.

True or false?

4.11 The staff must notify the hatchery manager when the egg incubation temperature deviates from the target temperature by:

Select the CORRECT ANSWER from the options below

a) +/- 2.0 °C

b) +/- 1.5 °C

c) +/- 1.0 °C

*d) +/- 0.5 °C

4.12 The target flow rate during incubation is:

Select the CORRECT ANSWER from the options below

a) 5 Litres/Minute

*b) 7 Litres/Minute

c) 9 Litres/Minute

d) 12 Litres/Minute

4.13 If flow rates in the incubators vary by +/- 0.5 L/min from the technician should immediately:

Select the CORRECT ANSWER from the options below

a) Inform the hatchery manager so as they can remediate

*b) Increase or decrease the flow to meet the target flow rate

c) Record the flow rate deviation in the Hatchery Records

4.14 If the water level of the trays is beneath the standpipe level, this indicates that:

Select the CORRECT ANSWER from the options below

a) the water inflow rate has reduced below the optimum

b) the standpipes have been dislodged or tampered with

*c) the incubation tray's water inlet screen has been blocked and needs to be cleaned

d) the incubation tray has been removed and not returned to its correct position

4.15 The eggs should always be kept in the dark during incubation

True or false?

4.16 When working on the eggs the technicians must:

Select AS MANY of the following as you believe to be correct

a) only put the main hatchery lights on for 10 minutes at a time

*b) never put the main hatchery lights on

c) only put the main hatchery lights on for 30 minutes at a time

*d) only ever use red light to allow them to see what they are doing

e) only ever use Ultraviolet light to allow them to see what they are doing

Bank 5 Egg husbandry

5.1 How often is water quality routinely monitored by the hatchery technicians during egg incubation?

Select the CORRECT ANSWER from the options below

a) twice daily

*b) daily

c) once every two days

d) one a week

5.2 Which of the following parameters are routinely monitored by the hatchery technicians?

Select AS MANY of the following as you believe to be correct

*a) Dissolved oxygen

*b) Water temperature

c) Heavy metals

*d) pH

*e) Conductivity

5.3 How are dead and moribund (almost dead) eggs identified by the hatchery technicians?

Select AS MANY of the following as you believe to be correct

a) They float to the water surface

*b) They are completely white

c) They break up into fragments

*d) They have white patches

*e) They are pale or discoloured

f) They are orange in colour

5.4 How are dead and moribund (almost dead) eggs removed by hatchery technicians?

Select AS MANY of the following as you believe to be correct

a) With their fingers

*b) With forceps

c) With a teaspoon

*d) With a pipette

f) By lancing them with a mounted needle

5.5 The number of dead eggs removed from the incubator trays should be low, because:

Select AS MANY of the following as you believe to be correct

a) Dead eggs completely dissolve within 12 hours

*b) Most of the unviable eggs are removed by the supplier

c) No more than 1 in a 100,000 salmon eggs will ever die

d) All egg mortalities occur before the eyed stage

5.6 How is the egg hatching process initiated?

Select AS MANY of the following as you believe to be correct

a) The eggs absorb water which eventually splits the eggshell

b) The alevins chew through eggshell to break free

c) The eggshell naturally disintegrates after 420-430 Degree days

*d) Enzymes are released by the embryo that soften the eggshell

5.7 What happens to the eggshell after the alevin has broken free?

Select AS MANY of the following as you believe to be correct

*a) It starts to break down which releases ammonia

b) It sinks to the bottom of the incubator tray

*c) It floats to the surface and blocks the incubator tray screens

d) It is consumed by the alevin

Bank 6 Alevin husbandry

6.1 How long does it take alevins held at 8 oC to drop through the hatching grid on the base of the incubator tray?

Select the CORRECT ANSWER from the options below

*a) 2- 4 hours

b) 12- 24 hours

c) 2 days

d) 4 days

6.2 What benefit(s) does the alevin substrate placed in the bottom of the holding units provide?

Select AS MANY of the following as you believe to be correct

a) It is safe physical habitat within which the alevins can move more freely

*b) Physical contact which pacifies the alevins, helping to conserve their energy

c) It acts as a biofiltration medium, helping to remove metabolic wastes

*d) Physical support, keeping alevins upright, helping to conserve their energy

6.3 What is the daily light regime for alevins during their incubation?

Select the CORRECT ANSWER from the options below

a) Light for 24 hours a day

b) Light for 12 hours a day

c) Light for 12 hours a day increasing to 16 hours a day

*d) Complete darkness

6.4 What happens if the alevins become too active?

Select AS MANY of the following as you believe to be correct

a) They will need more dissolved oxygen than is available at the low flow rates

*b) They will burn up energy and waste their yolk sac reserves

* c) They will risk damage to the yolk sack through pinching off an entrained oil globule

*d) They will become a smaller first feeder, reducing their survival chances

6.5 Hatchery hygiene routines are vitally important, and the alevins yolk sac development should be checked:

Select AS MANY of the following as you believe to be correct

a) under white light to ensure full visibility

*b) under red light and without white light

*c) once a day

d) Twice a day

d) Three times a week

6.6 How are dead and moribund (almost dead) alevins removed by hatchery technicians?

Select AS MANY of the following as you believe to be correct

a) With their fingers

*b) With forceps

c) With a teaspoon

*d) With a pipette

f) Lancing with a mounted needle

6.7 In what way(s) are the moribund (almost dead) alevins treated differently by hatchery technicians, compared to dead alevins?

Select AS MANY of the following as you believe to be true

a) They are counted and recorded

*b) They are euthanised with an overdose of MS222 before recording and disposal

c) They are classified using the PS Mortality Classification system

d) They are subjected to a full post-mortem

6.8 Which of the following statements are true?

Select AS MANY of the following as you believe to be true

*a) Before disposal, all mortalities should be classified by ‘suspected cause’ using the company classification system

b) Any dead or moribund fish found to have signs of a pathological infection (bacteria, fungi, virus, or parasite), are disposed of in a different container to separate them from any other mortalities

c) Any infection should be reported to the unit Manager and disclosed to the facility veterinarian.

*d) Any infection other than fungal (Saprolegnia) should be reported to the unit Manager and disclosed to the facility veterinarian.

* e) A full Post-Mortem will normally follow the reporting of any secondary infection

6.9 Yolk sac elongation, contraction and posterior displacement of the lipid drop can be indicative of:

Select AS MANY of the following as you believe to be correct

*a) high fish activity due to high water flow or stress

b) excessive gas pressure

c) genetic problems

d) nutritional problems

e) water quality problems

f) low hardness (<50mg/L CaCO3)

6.10 The presence fluid between the yolk sac and yolk sac membrane (yolk sac adema) can be indicative of:

Select AS MANY of the following as you believe to be correct

a) high fish activity due to high water flow or stress

*b) excessive gas pressure

c) genetic problems

d) nutritional problems

e) water quality problems

f) low hardness (<50mg/L CaCO3)

6.11 Spinal deformities (kyphosis) can be indicative of:

Select AS MANY of the following as you believe to be correct

a) high fish activity due to high water flow or stress

b) excessive gas pressure

*c) genetic problems

*d) nutritional problems

e) water quality problems

f) low hardness (<50mg/L CaCO3)

6.12 White spots on the yolk area (coagulation of the yolk sac) can be indicative of:

Select AS MANY of the following as you believe to be correct

a) high fish activity due to high water flow or stress

*b) excessive gas pressure

c) genetic problems

d) nutritional problems

*e) water quality problems

*f) low hardness (<50mg/L CaCO3)

6.13 A week prior to when the alevins are predicted to have absorbed their yolk sac (800 Degree days from fertilisation) the alevins are sampled, and their yolk sacs checked for full absorption:

Select the CORRECT ANSWER from the options below

a) once every 2 days

b) once a day

*c) twice a day

d) four times a day

6.14 As a direct visual guide, the alevins are ready for first feeding once:

Select the CORRECT ANSWER from the options below

a) all the sample has consumed all their yolk sac

b) all the sample has consumed 90% of their yolk sac

*c) 90% of the sample has consumed 90% of their yolk sac Once a day

d) 70% of the sample has consumed all their yolk sac

e) 70% of the sample has consumed 70% of their yolk sac

6.15 If first feeding (and transfer) must be delayed for any reason the water temperatures should be:

Select the CORRECT ANSWER from the options below

a) increased by 1.0 oC

b) increased by 0.5 oC

c) reduced by 0.5 oC

d) remain unchanged

e) reduced by 1 oC

Bank 7 First feeding

7.1 A minority of the alevins will not have fully absorbed their yolk sac when the majority are ready for transfer to the first feeding unit, equivalent to:

Select the CORRECT ANSWER from the options below

a) 1- 2%

b) 1-5 %

*c) 5- 10%

d) 10-20%

7.2 The alevins that have not fully absorbed their yolk sac when the majority are ready for transfer to the first feeding unit are dealt with by:

Select the CORRECT ANSWER from the options below

a) reducing the flow rate to conserve their energy whilst they complete yolk sac absorption

b) stocking them in a screened off an area of the tank, undisturbed by the first feeding fry

c) euthanasia with an MS222 overdose and disposal, to avoid them dying in the tank

*d) installing five or six small areas of alevin substrate away from the central screen.

7.3 When first feeding fry are evenly distributed within the first feeding units the maximum stocking density should not be exceeded, which is:

Select the CORRECT ANSWER from the options below

*a) 9,000/M2

b) 15,000/M2

c) 25,000/M2

d) 40,000/M2

7.4 As an approximate guide, the first feeding holding unit should be set up to run at a flow rate equivalent to:

Select the CORRECT ANSWER from the options below

a) 10.0 body length/sec

b) 3.0 body length/sec

*c) 0.3 body length/sec

d) 0.1 body length/sec

7.5 To avoid temperature shocking the fish any temperature difference between the hatchery incubation facility and the nursery unit must not exceed:

Select the CORRECT ANSWER from the options below

a) 0.5 Degrees Celsius

b) 1 Degrees Celsius

*c) 2 Degrees Celsius

d) 3 Degrees Celsius

7.6 The dissolved oxygen level of the first feeding unit must be maintained at:

Select the CORRECT ANSWER from the options below

a) no less than 80% saturation and 5 mg/L.

b) no less than 90% saturation and 6 mg/L.

*c) no less than 100% saturation and 7 mg/L.

7.7 To stock the alevins in the first feeding units they are:

Select the CORRECT ANSWER from the options below

a) syphoned into a bucket for transport to the fry holding unit

*b) moved in their incubation trays, designed to be removed and transported on a trolley

c) captured in a fine mesh hand net, placed in a bucket for transport to the fry holding unit

d) moved automatically by a fish pump with no handling involved and minimal stress

7.8 First feeding fry can actively swim to capture food particles

True or **false**?

7.9 The feed particles fed to first feeding fry should be designed to:

Select AS MANY of the following as you believe to be correct

a) sink quickly to where the fish can effortlessly ingest them from the tank base

*b) float before gently sinking to stimulate the young salmon’s natural feeding response.

c) float continuously, so as weaker first feeders can easily capture them from the surface film

*d) be presented in low water flow rates to make them more readily available

e) be presented in moderate flow rates to stimulate the fish’s appetite

7.10 The feed is presented to first feeders:

Select the CORRECT ANSWER from the options below

a) by automatic feeders from the outset

*b) by hand only for two days to establish appetite, before introducing automatic feeders

c) by hand only for the first two weeks before introducing automatic feeders

d) by hand only until the fry reach a 2 gramme average weight

7.11 High standards of hygiene in the holding units must be maintained during the first week of feeding fry, by:

Select AS MANY of the following as you believe to be correct

a) daily removal of waste feed accumulating on the tank base with a syphon

*b) gently lifting and replacing the substrate twice a day to allow any accumulated waste feed to be removed.

*c) gently brushing waste towards the centre screen at the same time as the tank is flushed

d) increasing the flow rate for 20 minutes twice a day to flush away waste feed.

Bank 8 Feeding growing fry

8.1 After the first feeding fry have been feeding for a week:

Select AS MANY of the following as you believe to be correct

*a) water flow adjustments should be made to ensure feed particles continually pass the fish

b) feed rates should be adjusted every 3 days, following sample weighing to determine the fish average weight and biomass

*c) Feed rates should be adjusted daily, to ensure constant feed availability to the rapidly growing fish.

d) The water temperature should be increased by 2 oC to increase fish metabolism and food intake

*e) The position of the automatic feeders should be optimised by adjusting the ‘drop height’ and angle of delivery when the pellet meets the water

*f) Lighting should be provided constantly to ensure 24 hrs a day feeding to maximise feed intake and growth.

8.1 Flow rates should be adjusted and can be guided by fish distribution from the water inlet to a position two thirds around the tank perimeter, so as:

Select the CORRECT ANSWER from the options below

a) The weakest fish is 5 centimetres from the side of the tank

*b) The strongest fish is 5 centimetres from the side of the tank

c) The strongest fish is 15 centimetres from the side of the tank

d) The weakest fish is 15 centimetres from the side of the tank

8.3 As the fish grow during the second and third week of feeding, it is important to:

Select AS MANY of the following as you believe to be correct

*a) brush the base of the tank two or three times a day to remove any waste feed

b) never exceed the feed manufacturer’s recommended daily feed rate to avoid waste feed

*c) never underfeed as this can lead to territorial behaviour and aggression, resulting in damaged eyes, operculum shortening and/or fin damage

d) sample weigh the fish every 2 days to monitor growth, stock biomass and densities and determine feed pellet size changes

*e) sample weigh the fish every week to monitor growth, stock biomass and densities and determine feed pellet size changes

*f) mix feed pellets for 3 days to allow for a smooth transition when increasing the particle size

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