Feeding and Nutrition in Aquaculture (P2)

Course designed for industry education 2020

Alexandra Leeper
alexandral@matis.is

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Learning Outcomes

Aim of course: Provide students with a strong introduction of feeding and nutrition in aquaculture with reference to salmonids.

At the end of the course students will be able to:

- List and describe basic **nutrients**.
- Describe the feeding **anatomy** and digestion of fish.
- Describe the different parameters that can impact **feed intake** in fish.
- Identify changes in **appetite** of farmed fish.
- Describe the **production of aquaculture feed**.
- Handle feed, understand labels and **storage** instructions.
- Explain the importance of **feed rations** and pellet size.
- Explain the consequences of **over-feeding/underfeeding**.

Course Outline

- Total of six modules.
- Taught over two teaching periods and one online session

May
Module 1: The digestive biology of fish.
Module 2: Key nutritional requirements of fish.
Module 3: Aquafeed formulation.
**Homework 1*

Online Session: Homework and question time.

August
Module 4: Food production and storage.
Module 5: Feeding and feed intake.
Module 6: Feed additives and further knowledge.
**Homework 2*

Day 1

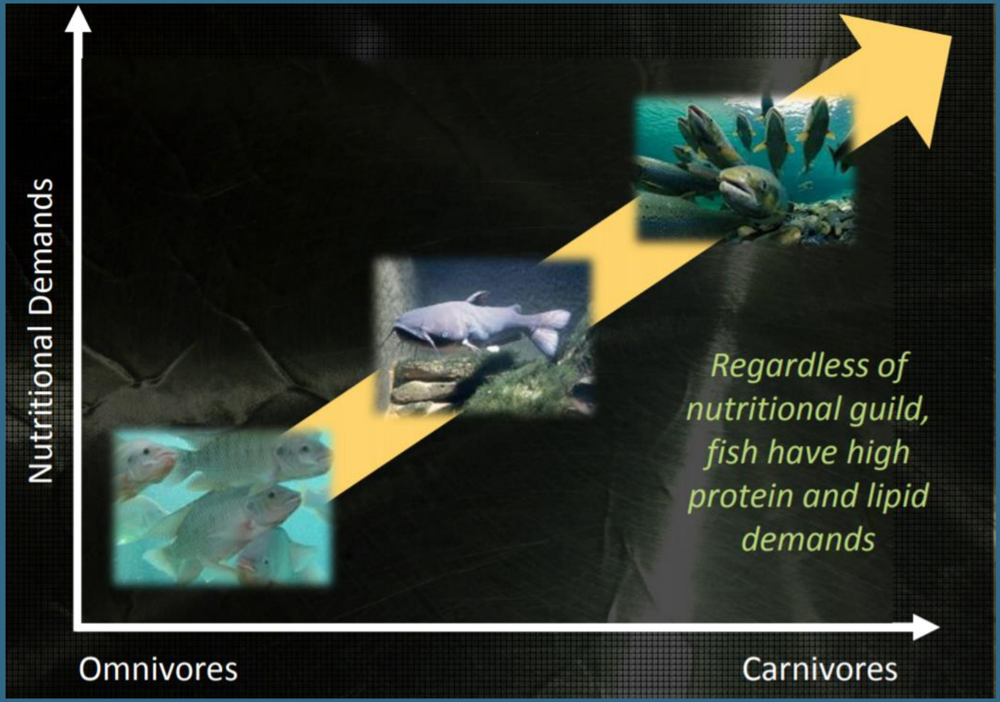
- Module 4: Food production and storage.

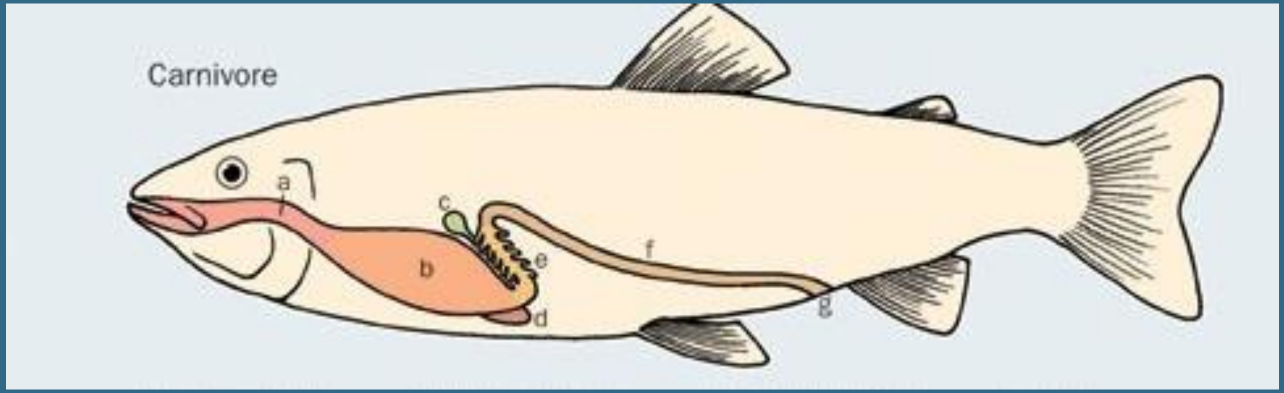
*Exercise 4.1

- Module 5 Part 1: Feeding and feed intake.

*Exercise 5.1

Re-cap summary slide





Lipids(Fats & Oils)

Energy storage

Dietary Energy

Insulation

Structural
e.g. in cell membranes

Hormone
They are the building blocks

Module 4 Food production and storage

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Why do we feed fish?

Energy

- To metabolize and access nutrients in food
- To grow and develop
- For reproduction
- For immune system support
- To promote characteristics desirable to the consumer

Not all forms of fish farming involve proving feed to fish

Different feed types

No Feeding

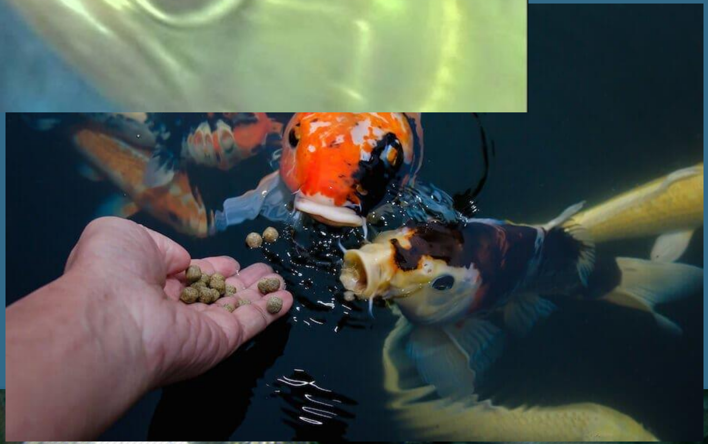
Live Feeding

Flake Feeding

Different feed types

Pellet Feeding

Floating Pellets

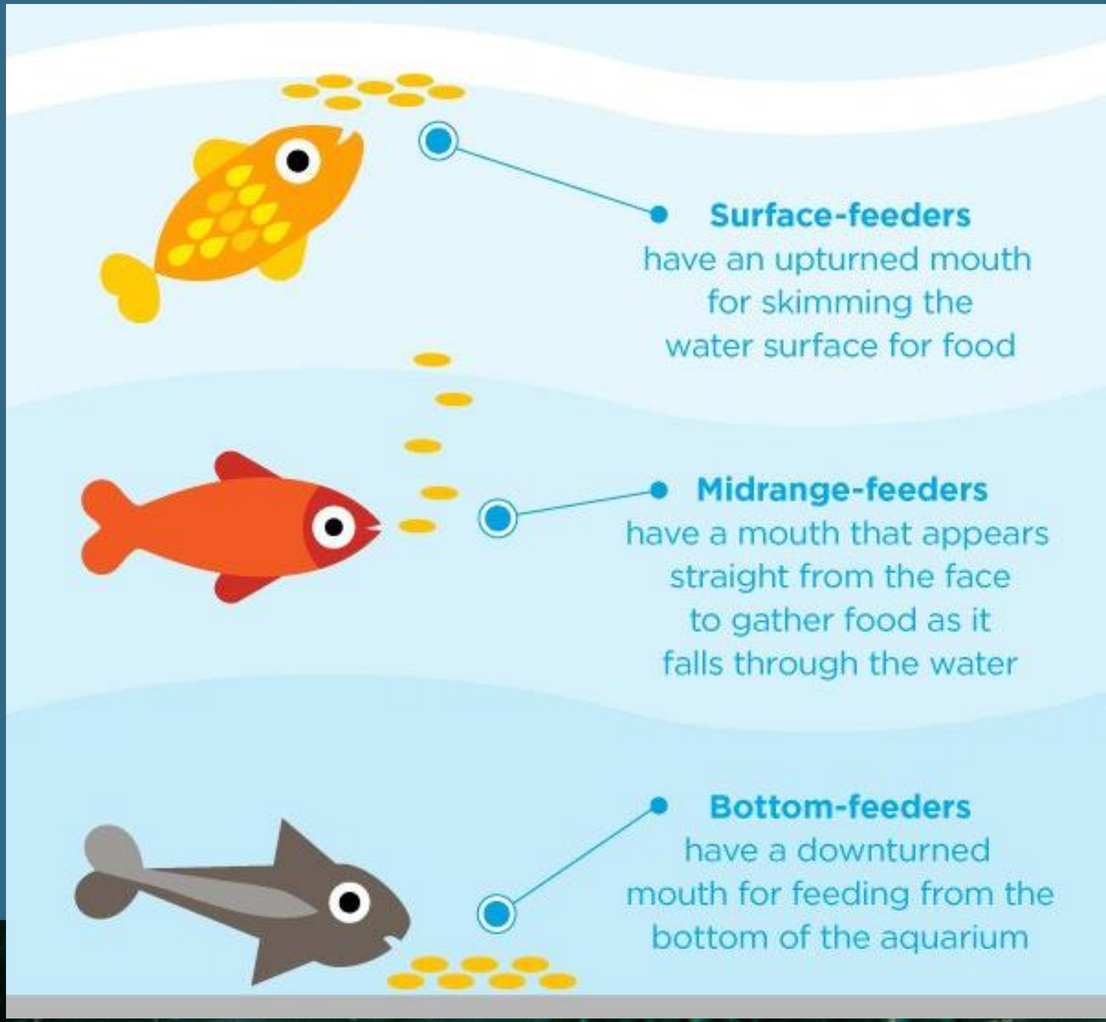


Sinking Pellets

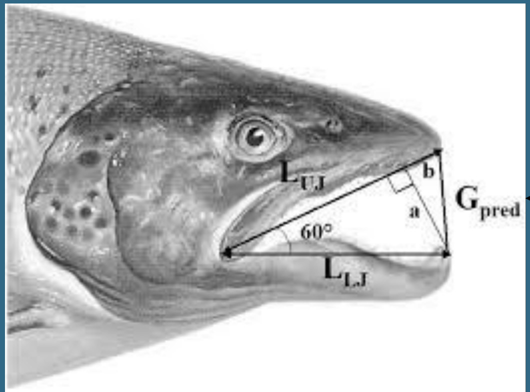
Selecting feeding types

Many considerations for what feeding methods and feed types are needed:

- Where the fish feeds in the water column
- Species
- Life stages
- Characteristics of the feed used
- Environmental Conditions
- Husbandry practices
- Ingredient types
- Equipment used to deliver the food
- Manpower
- Cost
- Size of farm

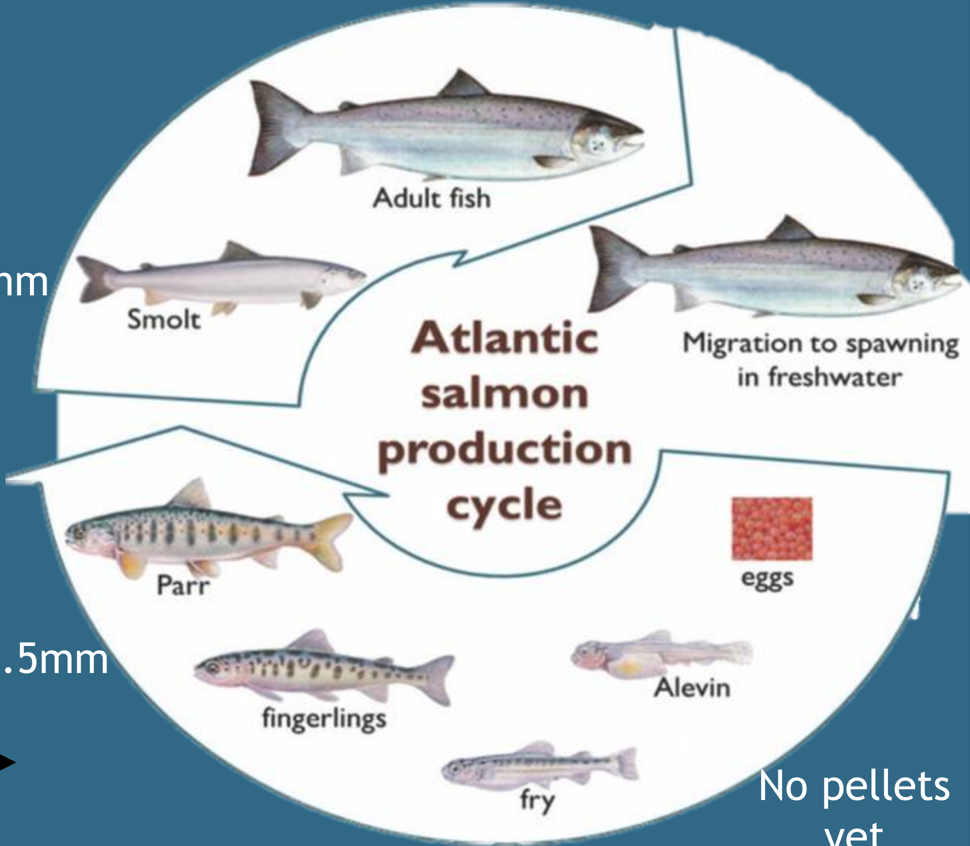


Atlantic Salmon feed size



Pellet seize for Atlantic salmon is based on **mouth gap**

2.0-4.5mm



The ideal pellet size will be 20-50% of the **mouth gape**

1.0-1.5mm

Mouth gape increases as the fish grows

No pellets yet

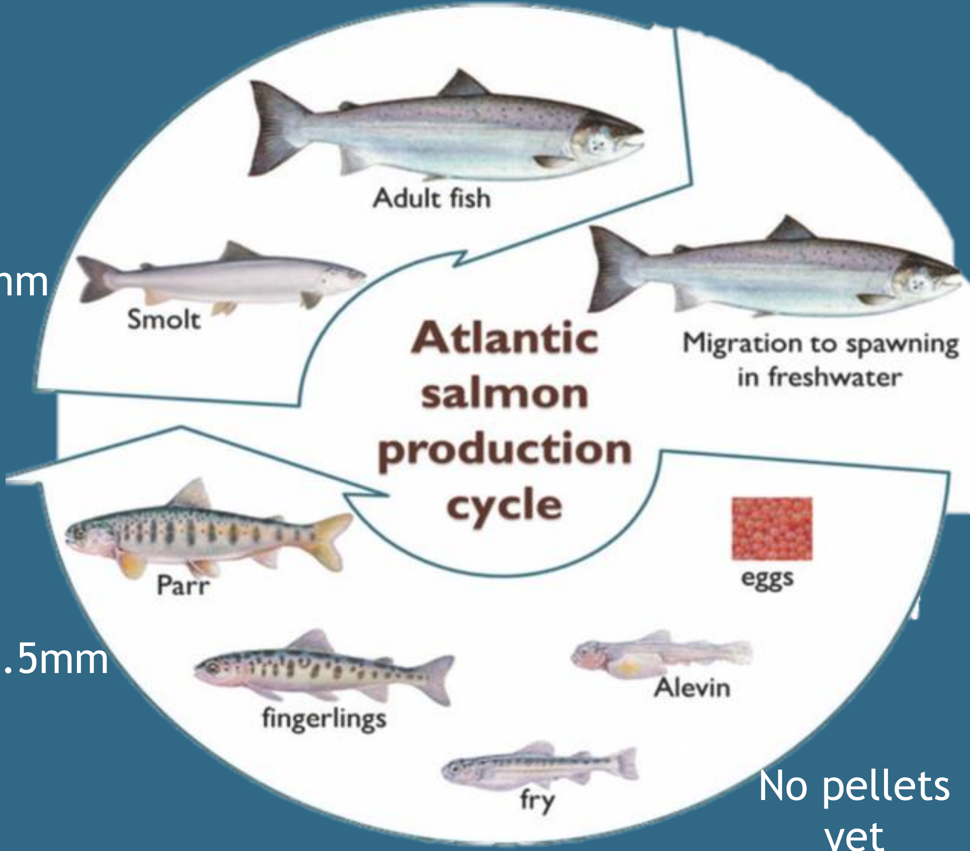
Start feed 0.05-1.0mm

Atlantic Salmon feed size

What if the feed is:

Too small	Too big
Will use more energy to get enough feed	Trouble eating the pellet
Will need to feed more	Take in and spit out
Reduced growth or higher cost	Risk of choking
Won´t harm the fish	Reduced growth
	Will not be able to access feed

2.0-4.5mm



1.0-1.5mm

No pellets yet

Start feed 0.05-1.0mm

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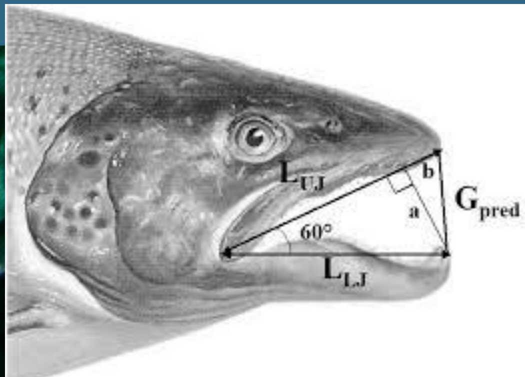


Production of Salmon feed pellets

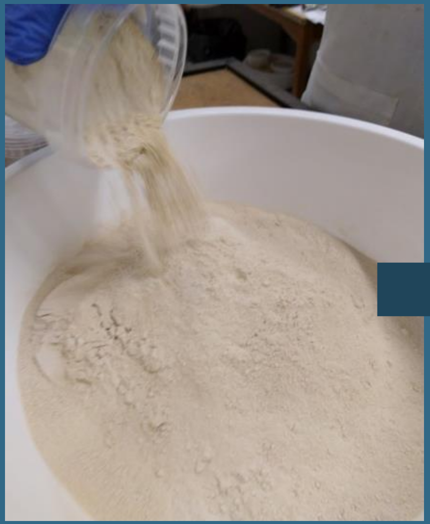
Feed production has changed a lot over time and varies dependent on situation.

Atlantic Salmon in commercial farms are now exclusively fed on **extruded pellets**, often with **lipid coating** & sometimes with medical treatments added to the coating.

In research and on smaller farms feed is still often made using **cold pelletisation**.

Feed cold pelletisation

Step 1

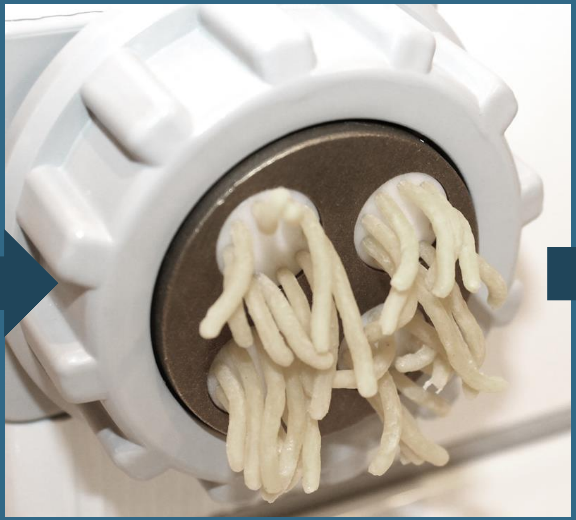


Mixing of dry ingredients

Step 2

Mixing in fish oil and water & any other wet ingredients

Step 3



Mix pushed through a diplate of the diameter wanted.

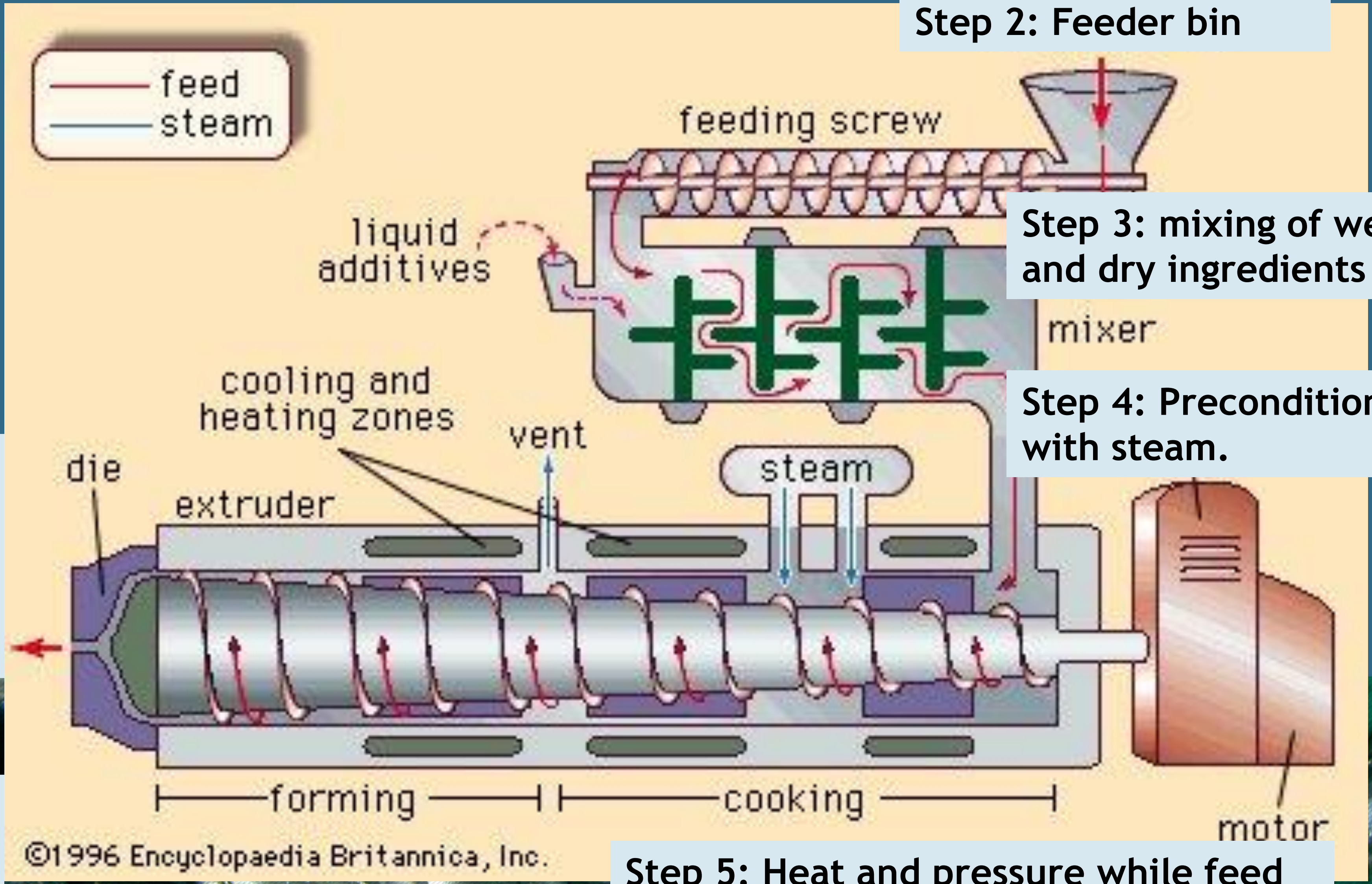
Step 4

Baking in drying oven temp dependent on content.

Feed extrusion (and expansion)

- The same process is used for cat and dog food as well as commercial fish feed.

Step 1: raw material homogenisation.



Step 2: Feeder bin

Step 3: mixing of wet and dry ingredients

Step 4: Preconditioning with steam.

Step 5: Heat and pressure while feed moved around twin/single screw

Step 6: mixture is pushed out the die plate at the desired size, mechanically cut and cooled

Step 7: lipid coating for fish feeds in vacuum drum.

Feed extrusion (and expansion) benefits

- Allows for much greater lipid levels and so energy into the fish feeds = less feed needed.
- Much longer lasting feeds.
- Can control how sinkable the feed pellets are.
- Improves the digestibility of the ingredients.
- Can allow more cereals in feed (e.g. wheat).
- High heat kills most bacteria.
- Feeds much more stable in water.

Pellet physical and mechanical properties

- **Density:** dense enough for slow sinking feed
- **Hardness:** hard enough to be water stable
- **Moisture Content:** dry enough to be stored
- **Pellet size**: Depend on species and life stage (changed by die plate).
- **Feed dust:** needs to be reduced

Feed Mixture	A1	
Feed Processing Technology	Pelleted	Extruded
Mass/Volume (g/L)	612	580
Durability (Mechanical, Pfost) (%)	87	100
Durability (Pneumatic, Holmen) (%)	25	97
Floatability (% residues at 30 seconds)	0	0
Sinking rate (cm/second)	8	6.2
Water stability (% residues at 10 minutes & 1 hour)	30 / 89	0 / 4
Slope of particle breakdown (10–60 minutes)	0.0114	0.0097
Oil absorbing capacity (%)	16	18

Extrusion and novel ingredients

Fish Oil

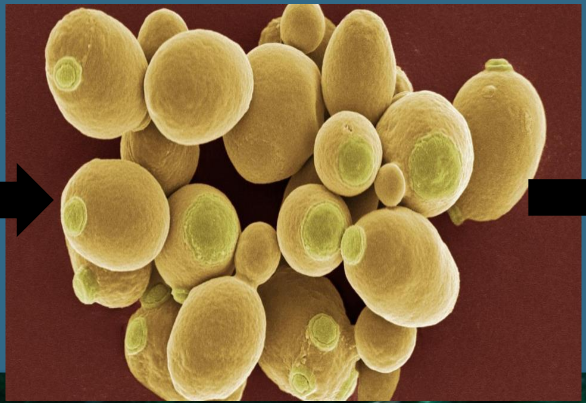
Rapeseed Oil

Canola Oil

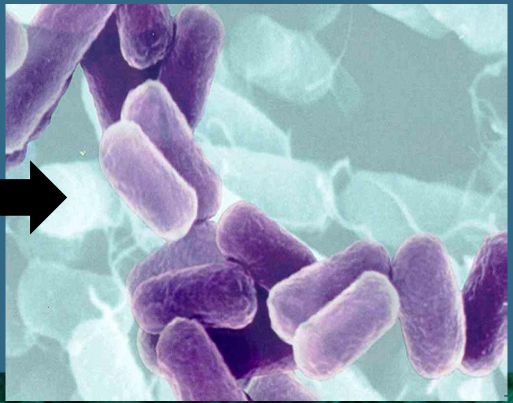
Microalgae Oil

Soy Protein

Insect Proteins



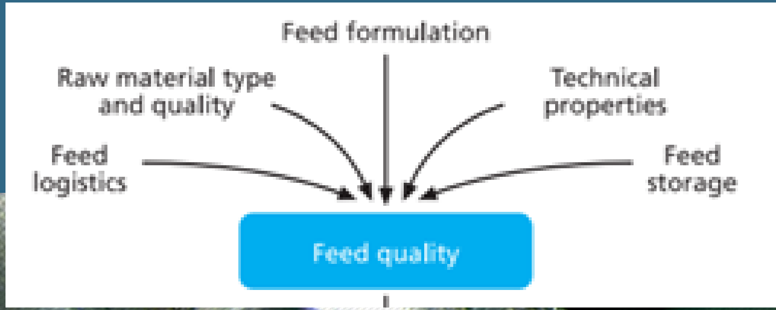
Fungal Proteins



Bacterial Proteins

Storing and preserving feed

- Really important to keep feed away from high temperatures-oil breaks down.
- Consider the logistics (is feed transported in bulk and stored or regularly transported).
- Fluctuations in temperature during transport and storage.
- Feeds should always be kept dry.
- Storage time ideally should be minimised.
- Trade-off for remote locations

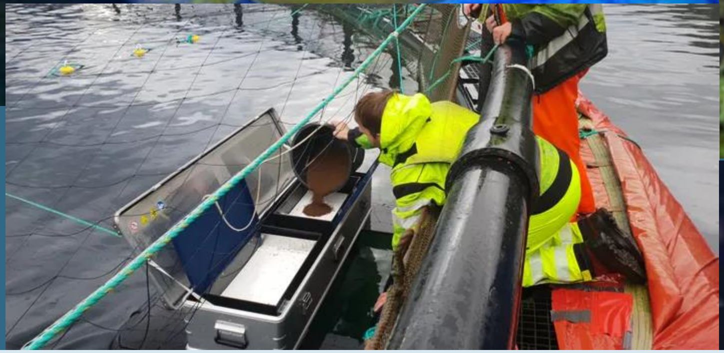


Lump fish feed type

Juvenile Lumpfish

-Live feeds: help train lumpfish to feed on lice.
-Some pelleted feeds with krill and very high quality and expensive.
- Feed blocks introduced as a method to provide extra nutrition.

Adult Lumpfish



-Specific located pelleted feeds
-Feed blocks to provide extra nutrition.
-Lice on fish and lice larvae in the water column.
-they will also feed on plankton and zooplankton in the water column.

Not all lumpfish are created equal

Key points from Module 4

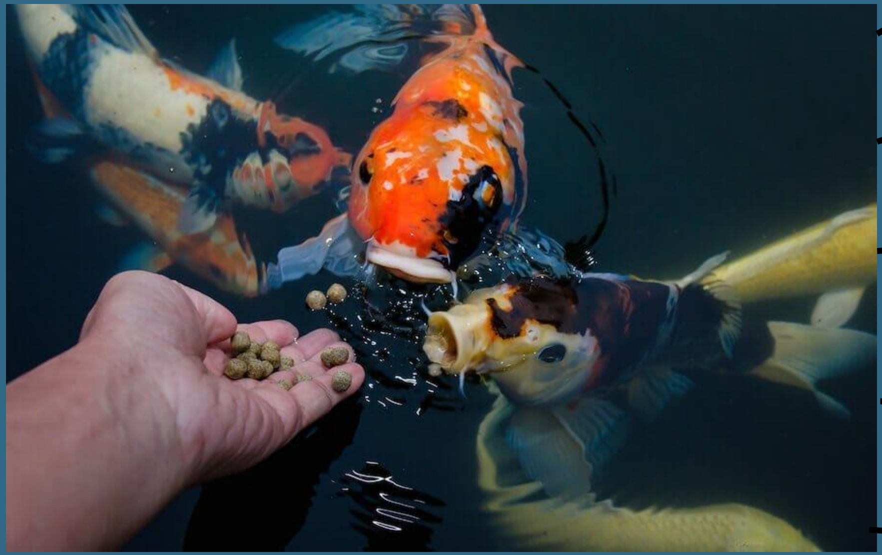
- Atlantic Salmon are mid and upper water column feeders.
- They feed on slow sinking extruded pellets.
- Most commercial feed in Europe is now extruded: high heat and pressure and lipid coating.
- Extrusion is great but complicated
- Storing feeds in cool dry places and considering demand and supply is key.
- Feeding lumpfish is increasingly important

Module 4: Exercise 4.1

multiple-choice quiz.

Module 5 Feeding and feed intake

Why do we need to control how much we feed farmed salmon and when?



- To avoid waste and environmental pollution
- To feed enough to optimise growth
- To manage feed that needs to be purchased and stored (minimise costs)
- To match the fish best activity time
- To optimise the amount fish eat

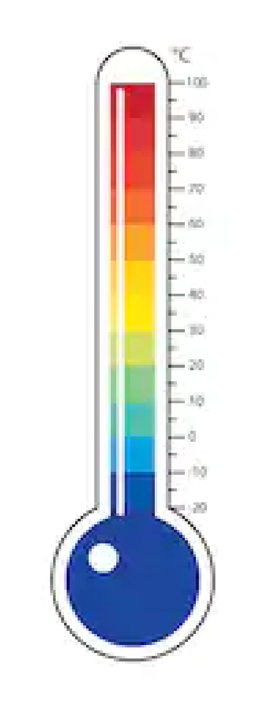
How much do we need to feed Atlantic salmon?

- Feed tables from feed producers
- Apparent and visual satiation
- Lots of factors effect feed intake and appetite
- Biotic and abiotic factors are important to consider

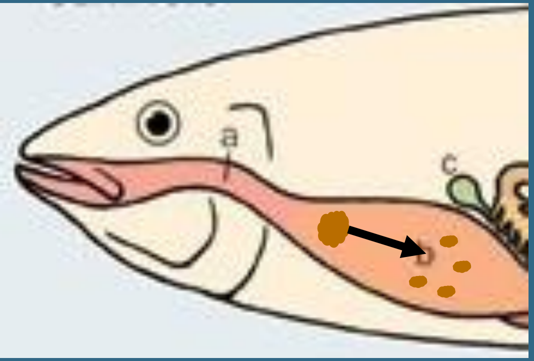
What time of the year do you feed your sea cage salmon the most…..and why?

Temperature, metabolism and feed

- Fish are ectotherms & poikilotherms
- The warmer it is, the more we need to feed



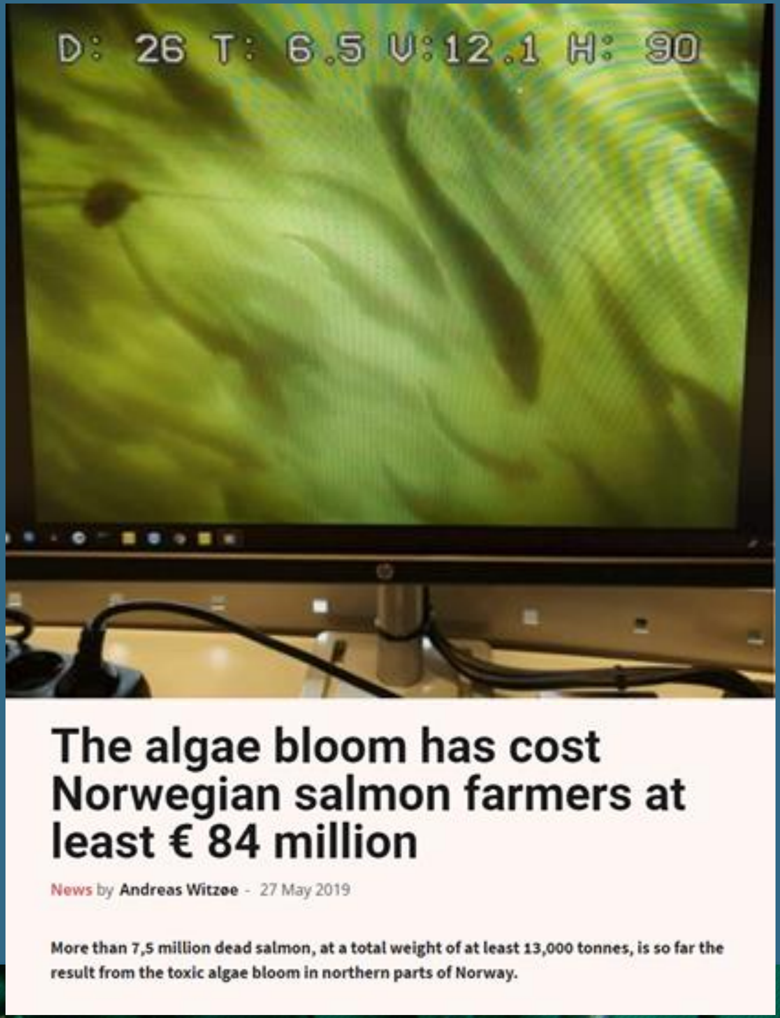
Increased water temperature means feed transits through the gut more quickly



Other factors effecting appetite

Environmental: Dissolved Oxygen, Light (photoperiod), time of day, handling.

Biological Factors: Competition and aggressive behaviour, Periods of starvation, any medical treatments applied, Pellet size, energy content of the feed, algal blooms.

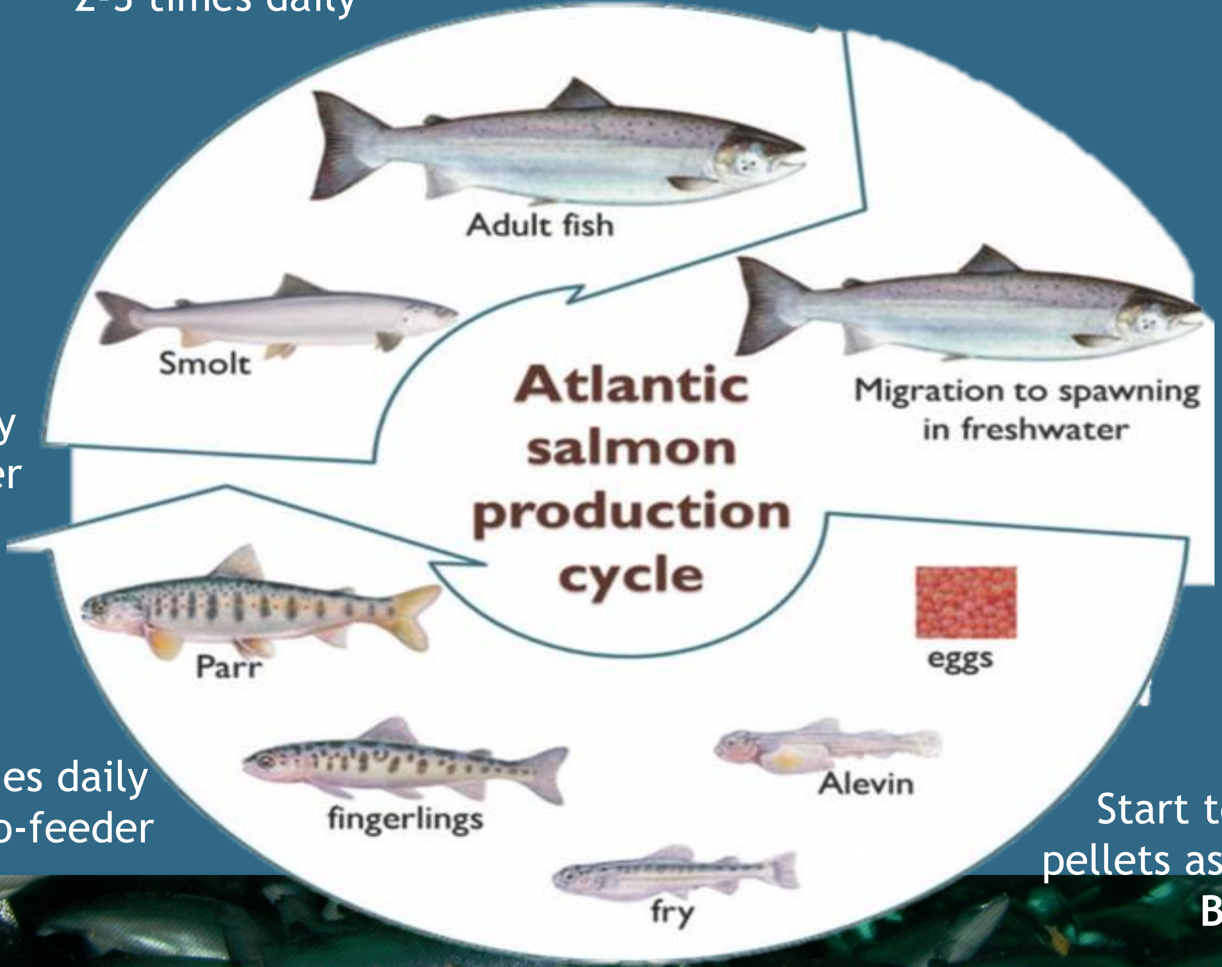


The algae bloom has cost Norwegian salmon farmers at least € 84 million

News by Andreas Witzøe - 27 May 2019

More than 7,5 million dead salmon, at a total weight of at least 13,000 tonnes, is so far the result from the toxic algae bloom in northern parts of Norway.

Frequency of feeding



Adjusting for daily and feed time variation in appetite

2-3 times daily

2-3 times daily
via auto-feeder

4-5 times daily
via auto-feeder

Start to offer some pellets as swim-up starts
By hand

Continuous,
small amounts

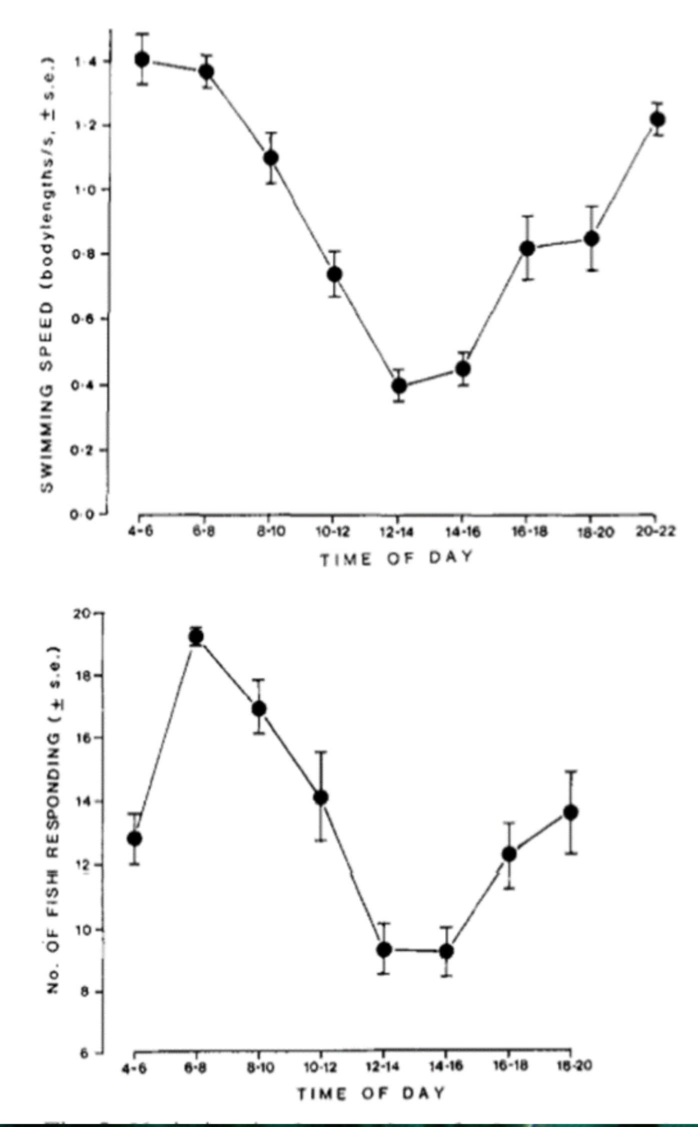
Timing of feeding

For bigger fish : best to match feeding times with natural rhythms of activity.

More swimming activity and fish response in the early morning and evening.

Fish response is generally lowest in the afternoon.

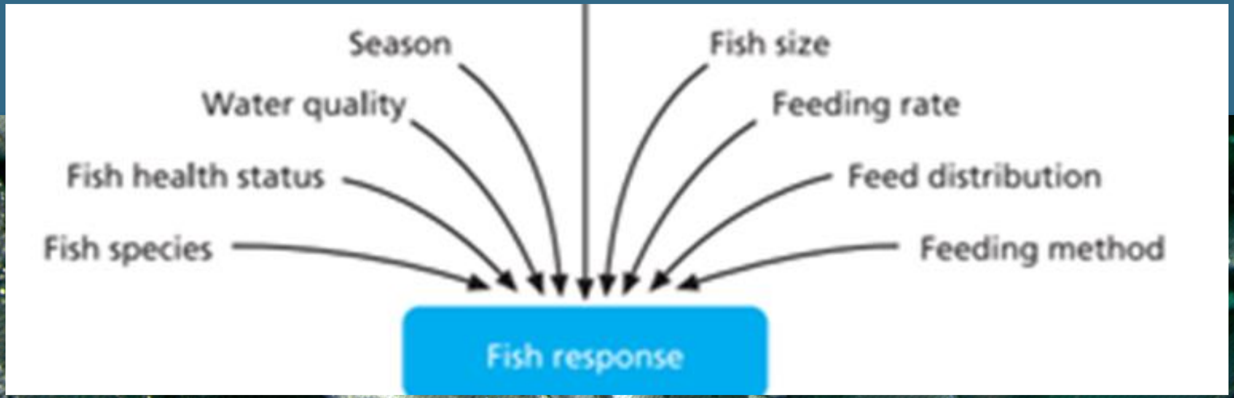
Polar and sub-polar locations have such variable day length which may change these timings seasonally



How much to feed

As well as factors effecting appetite we also consider:

- Stocking density
- Weather
- Water quality
- Pellet size
- Any logistics (e.g medical treatments or transports)



Monitoring feed intake

Adjusting for daily and feed time variation in appetite

Why do we monitor every feeding in salmon cages?

- To monitor feed intake and appetite variability.
- To see how long each feeding session should work….what cues (?)
- To observe the environmental conditions during feeding
- To record feeding behaviour to note anything unusual.
- During testing: do fish like the feed?

What else do you record or look for?

How do we monitor every feeding in salmon cages?

- In water and above water cameras at variable depth
- Scuba divers
- Remote sensing & pit tag monitors.
- Surface observation

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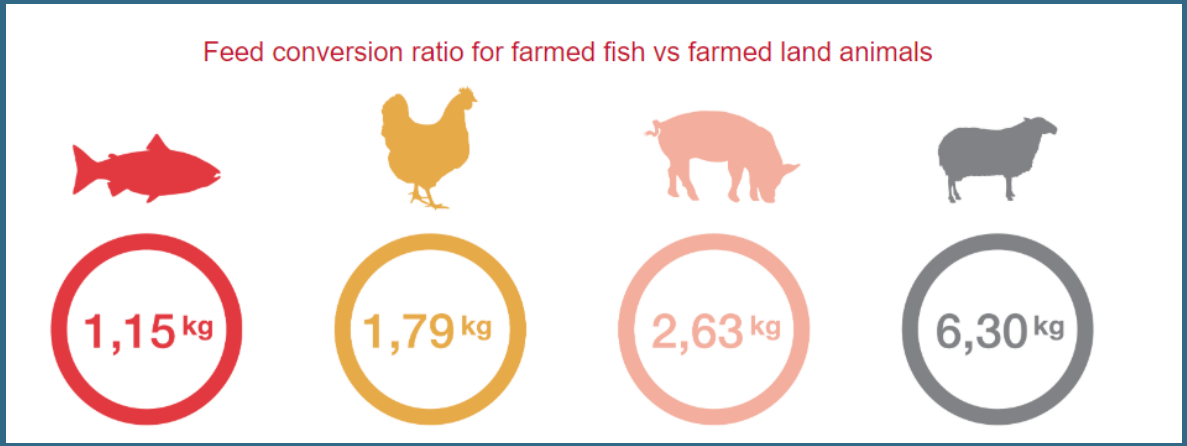
Feed Conversion Ratio

$$FCR = \frac{Feed\ given * time}{Fish\ weight\ gain}$$ = The amount of feed needed to produce 1kg of animal



Fish have a much lower Feed Conversion Ratio than other farmed animals, making them more efficient.
= Less feed for more product

Why are fish more efficient?

Feed Conversion Ratio Group Question

$$FCR = \frac{Feed\ given * time}{Fish\ weight\ gain}$$

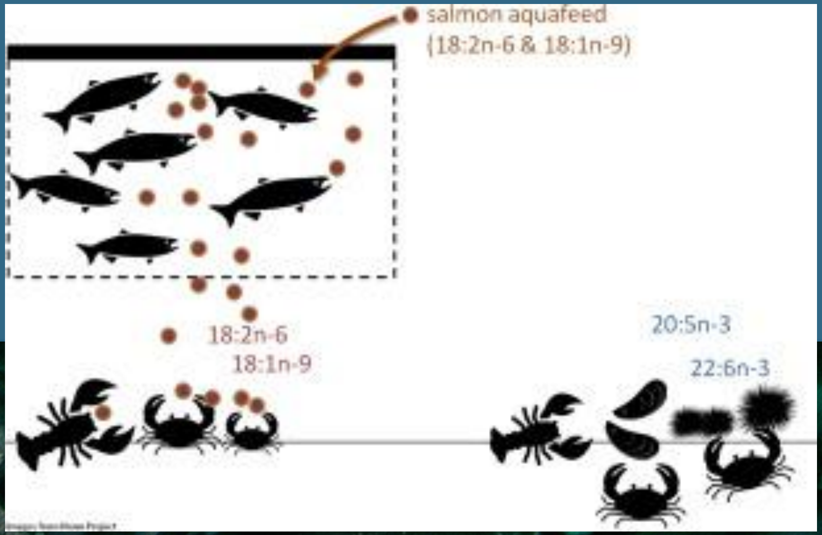
If you have a starting biomass of **3000g** and after 14 days you have a biomass of **7000g**, and you have given **430g** of feed to the fish, what is the *Feed Conversion Ratio?*

Module 5: Exercise 5.1

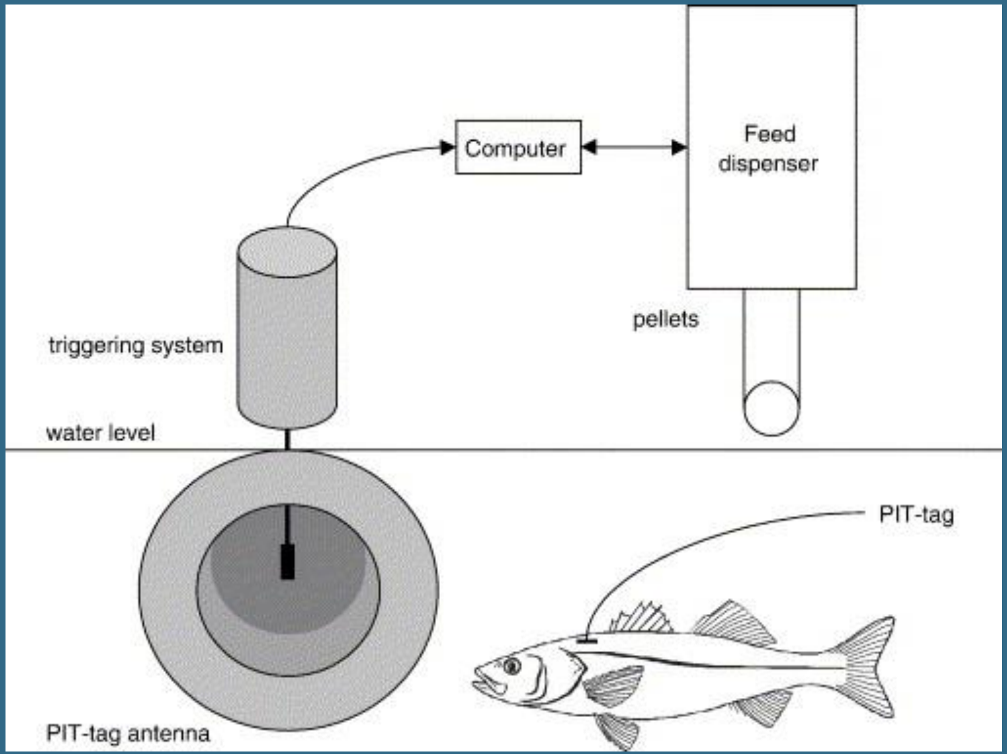
multiple-choice quiz & and FCR question.

Consequences of over and under feeding

Underfeeding	Overfeeding
Economic losses	Economic losses
Less growth	Food wastage
Possible mortality	Environmental pollution
More time in sea cages to reach harvest size.	Reduced water quality
	Reduced oxygen
	Change in local biology



Self feeding and training

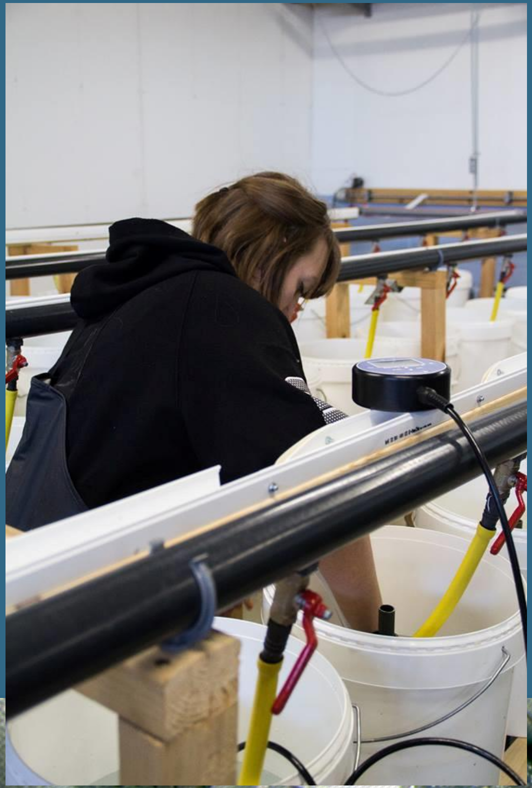


Self feeding of sea bass on farms

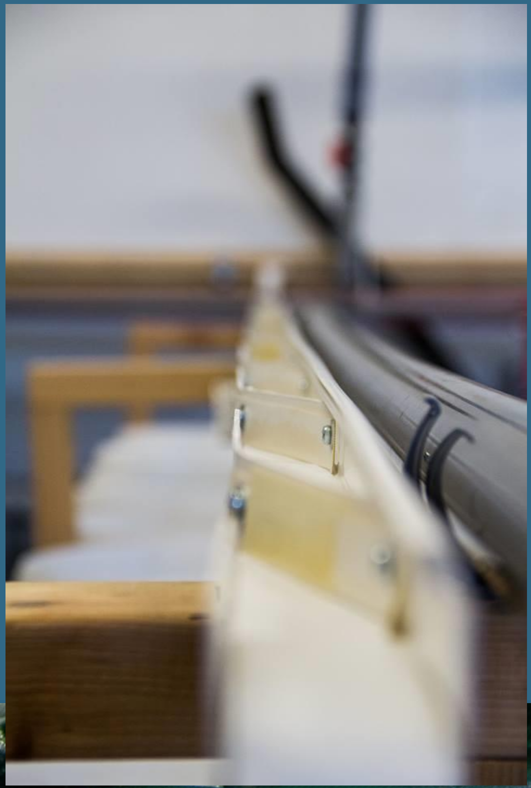
Target training in aquaria

Feed delivery methods & tools (juveniles and pre-smolt)

Hand-feeding

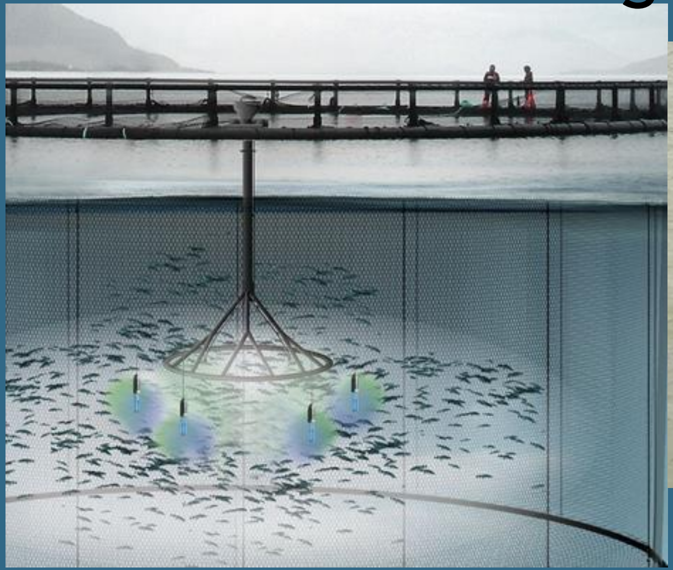


Auto-feeding



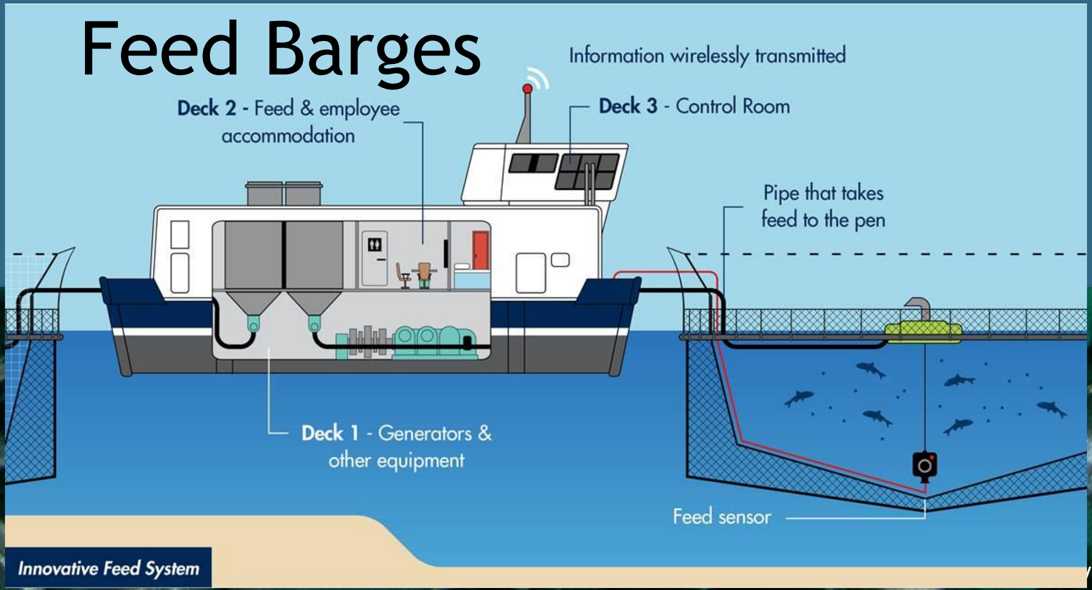
Feed delivery methods & tools (post smolts sea cages)

Sub-surface feeding



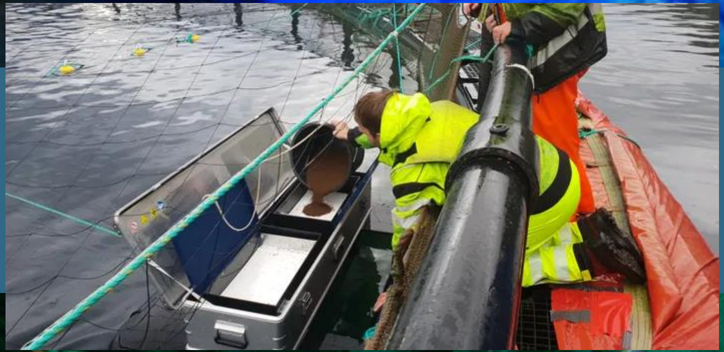
Automatic feeding

Feed Barges



How much to feed lumpfish

- Very different feeding habitats to salmon.
- Opportunists, and foraging.
- They are more suited to grazing strategies.
- Feed blocks allow constant feeding throughout the day (demand feeding).
- Still a lot to learn with lumpfish feeding and welfare.



Module 5 summary points

- How much fish want to eat, and how much we feed them depends on a lot of factors e.g temperature.
- How often we feed fish changes throughout their life.
- It is best to match feeding with natural activity rhythms.
- Montoring and measuring feeding and growth is key.
- There are many feed delivery methods.
- Don´t forget about the lumpfish!

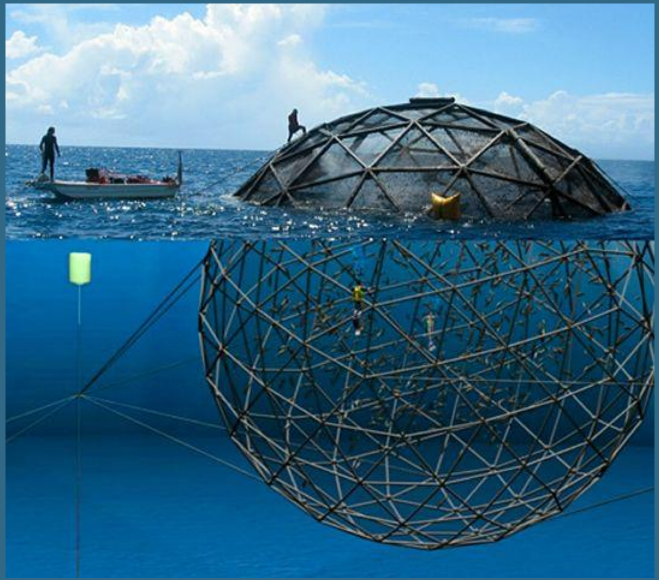
Module 5: Exercise 5.2

multiple-choice quiz.

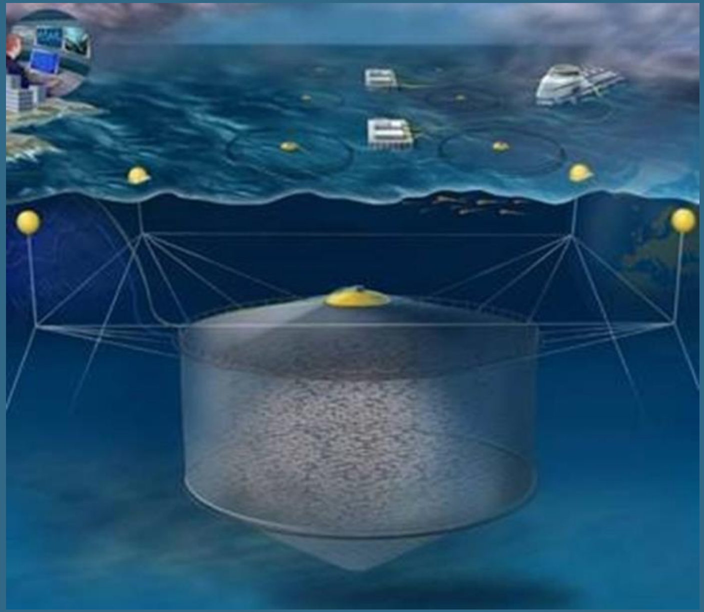
Module 6 The future of aquaculture And feeding farmed fish

New technologies for farming fish at sea

The egg: self contained units



Semi-floating cages not fixed.



Submerged sea cages.

All of these technologies are trying to solve specific problems in modern salmon aquaculture: waste output, lice & escapes and combating high wave energy offshore but they are still under development and have some of their own issues too.

The rise of land based farming

Taking the whole life-cycle on land (e.g. RAS)

Aquaponics

- Both of these technologies already exist but present unique challenges.
- The set up costs for both are high

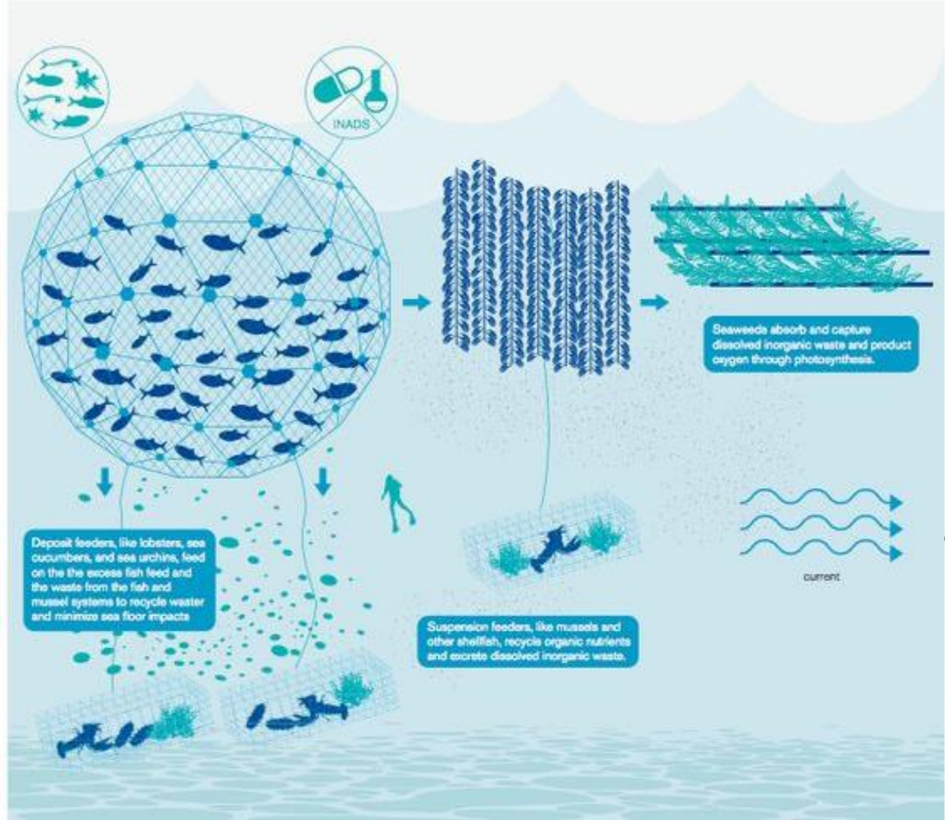
Atlantic sapphire and the challenge of RAS

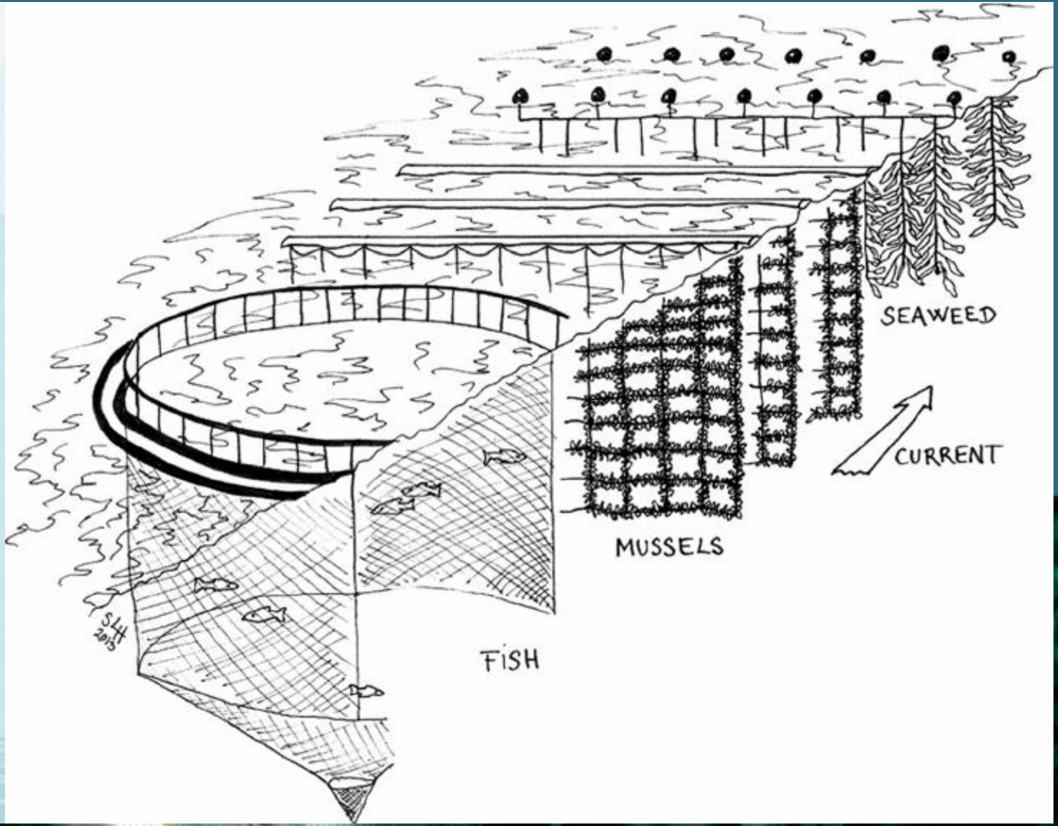
- Both of these technologies already exist but present unique challenges.
- The set up costs for both are high

Land-based in Iceland

Integrated Multitrophic Aquaculture

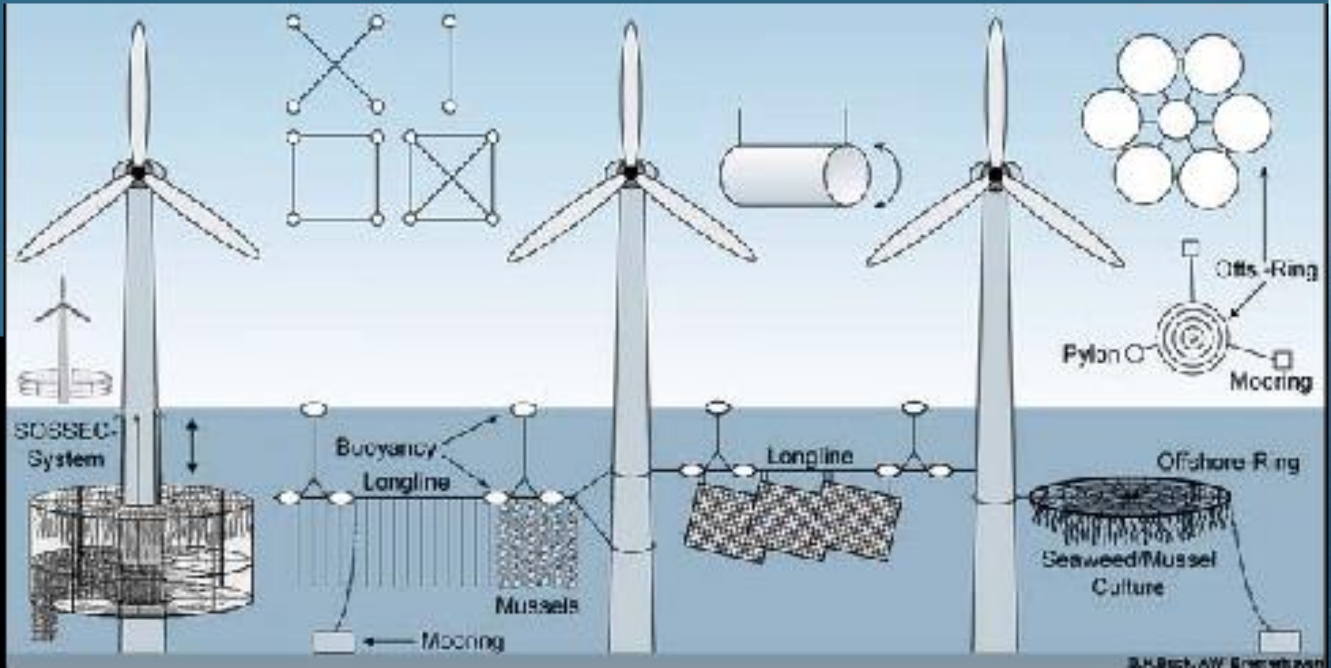
- Combining complimentary farmed species
- Multiple income streams
- Waste from fish farms captured and useable.
- Scalability and practicality challenges still.





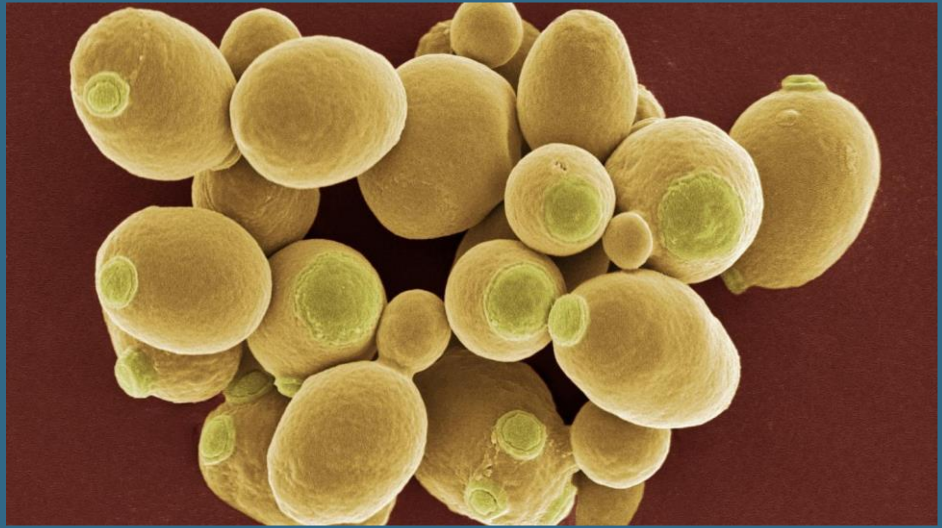
Integrated Multitrophic Aquaculture

- Still in the research stages but multiple purpose platforms are being tested experimentally in the North sea.
- These zones are no fishing zones.
- Wave power and durability of equipment still a challenge.
- Power transfer and personnel transport challenge

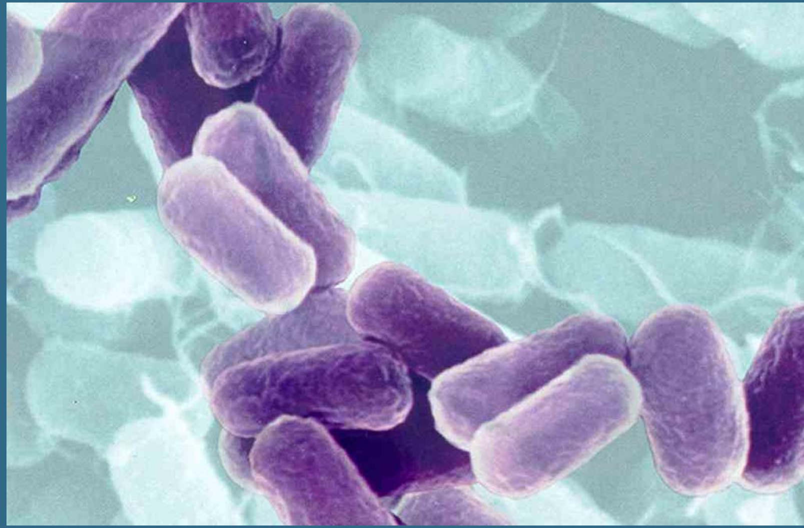


New raw ingredients and sources of ingredients

Insect Proteins



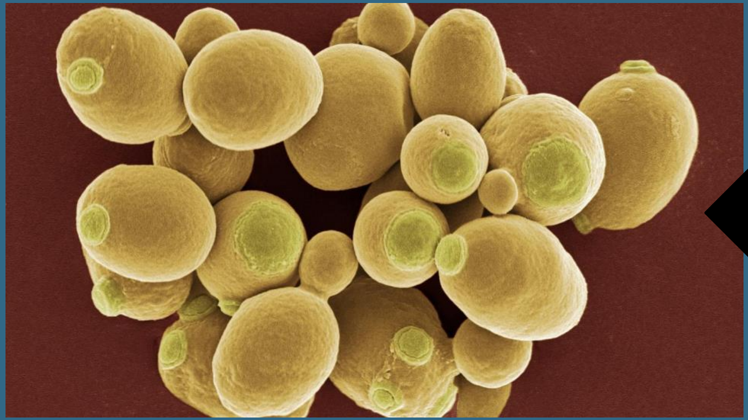
Fungal Proteins



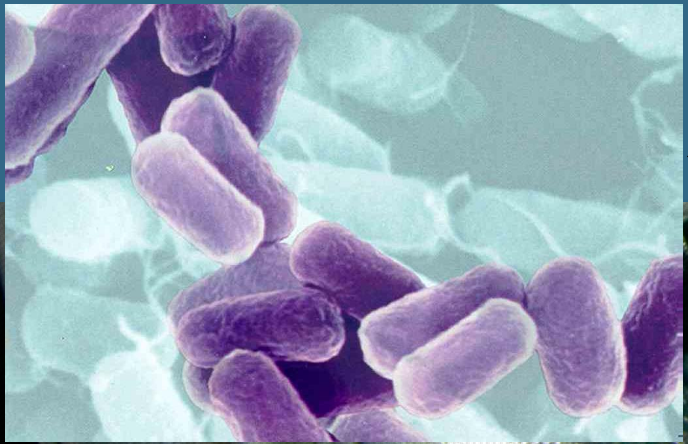
Bacterial Proteins

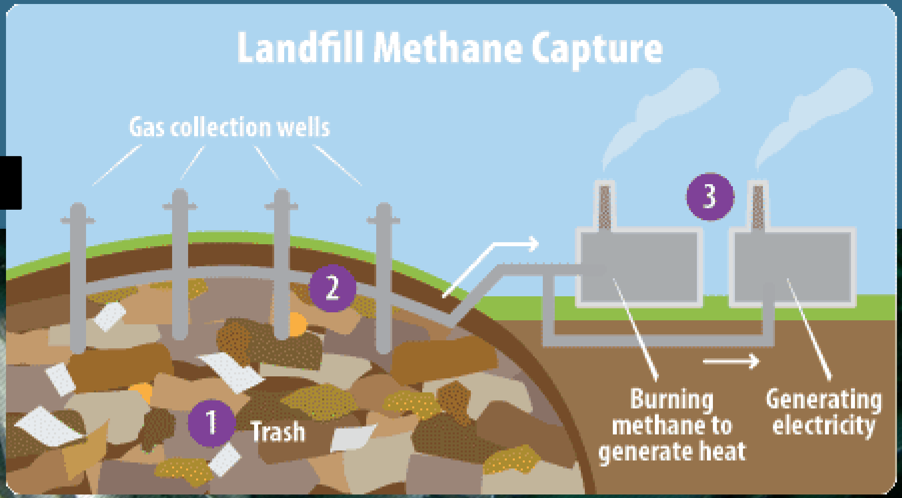
New raw ingredients and sources of ingredients

Fungal Proteins



Bacterial Proteins

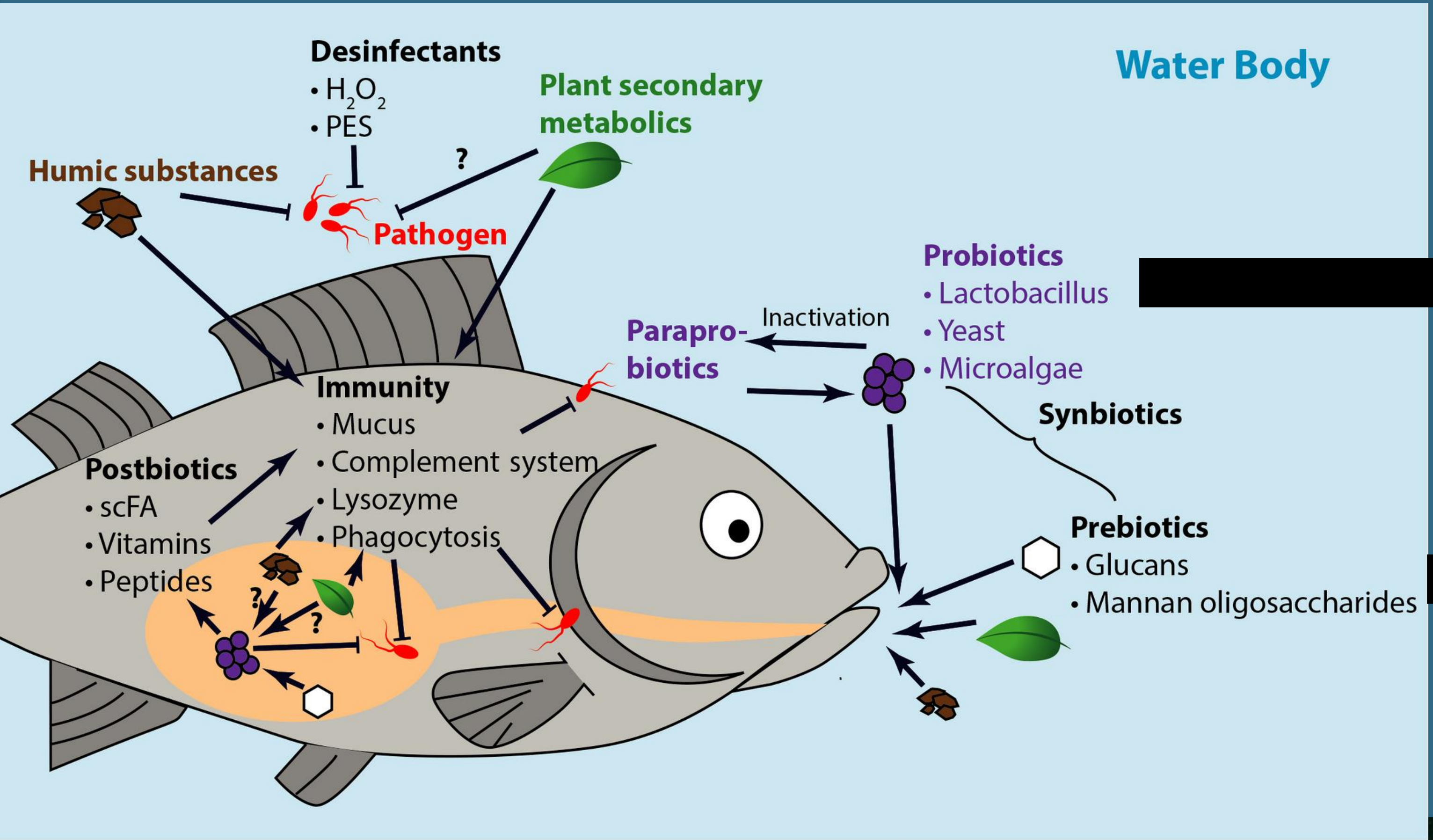




New raw ingredients and sources of ingredients

Insect Proteins

Probiotics and prebioitcs



Live organisms that directly alter the gut microbiome that play a role in digestion and immuno-support.

Non-digestible and benefit the fish by supporting beneficial bacteria in the gut and support of growth and metabolism.

Genetics and selection: Salmon

Selective breeding: choosing the individuals for broodstock with the best traits…. both visually and genetically

Desirable traits for future salmon:
- Lice resistance
- Disease resistance
- High growth rates
- Sterile salmon

What else would be beneficial?

JURASSIC PARK

CRISPR and the future

Genetics and selection: lumpfish

Selective breeding: **choosing the individuals for broodstock with the best traits…. both visually and genetically**

Desirable traits for future lumpfish:

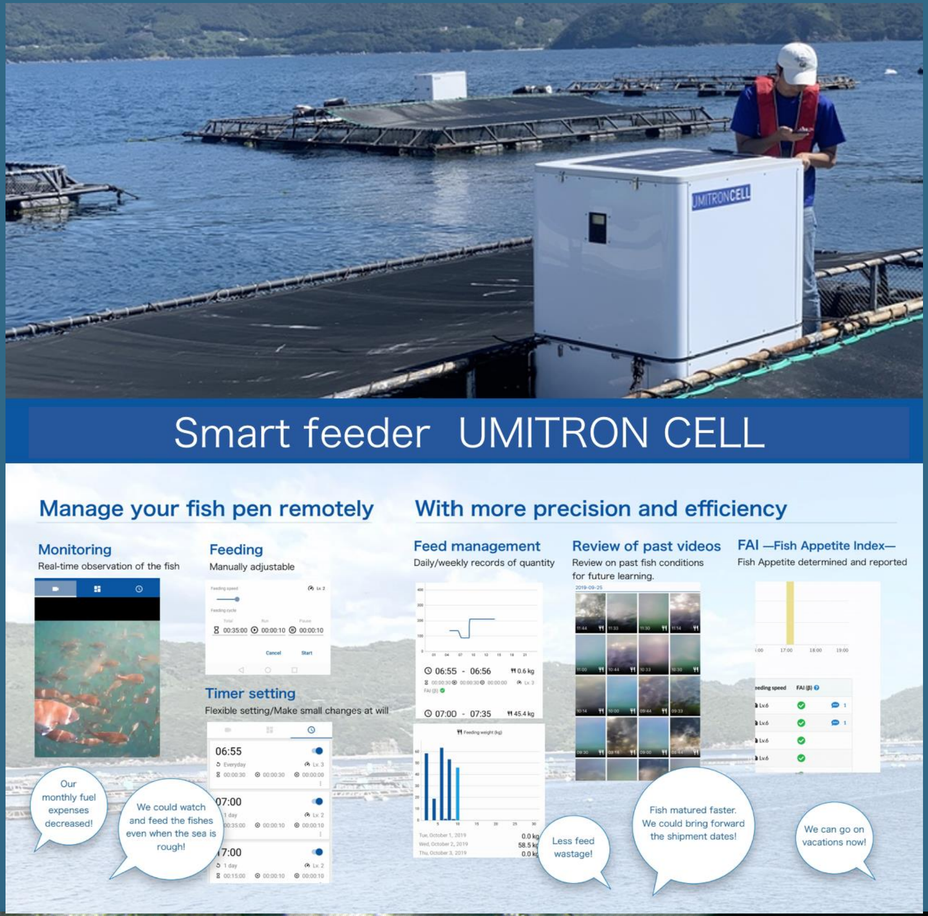
- **Better eaters of lice**
- **Disease resistance**

What else would be beneficial?

Other future solutions for lice management

- Contain sea cages or move them completely on land.
- Try to breed salmon that are lice resistant or super lumpfish lice eaters *.
- Targeted lice killers (chemicals and lasers).
- Feeds like Slice only more effective.
- Holding longer on land before sea cage transfer
- Feeds with natural ingredients that make the salmon skin hard to attach to or taste bad for lice

The future is now: AI, robots, machine learning



- Self-propelled, self-moving fish cages
- Underwater cleaning robots-net cleaning.
- Technologies that constantly learn from the fish to predict how much food is needed and how much waste will be produced:

Climate change and aquaculture

- Rising water temperatures
- Ocean acidification
- More dramatic weather events
- More Harmful algal blooms/lice
- More pandemics

Not a doomsday slide!!! But it is important to consider the challenges faced and changes that will have to be made to protect the future of aquaculture and make it more sustainable.

Module 6 summary points

- Lots of cool emerging and future idea technology.
- Many challenges to face.
- Climate change will change the industry.
- Like all industries, to survive aquaculture will have to evolve.

Module 6: Exercise 6.1

Discussion of challenges observed in aquaculture.

Final summary quiz

Questions from all modules.

Homework to be set

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