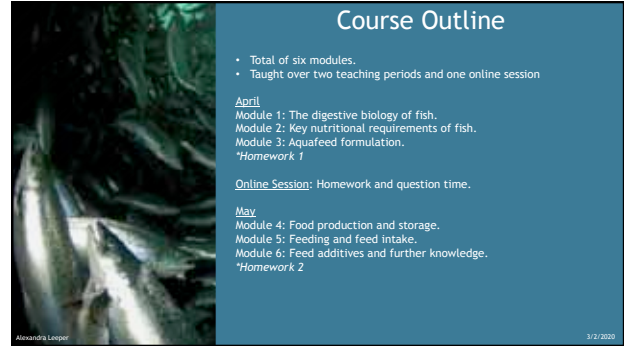


Feeding and Nutrition in Aquaculture (P1)

Course designed for industry education 2020

Alexandra Leeper
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Course Outline

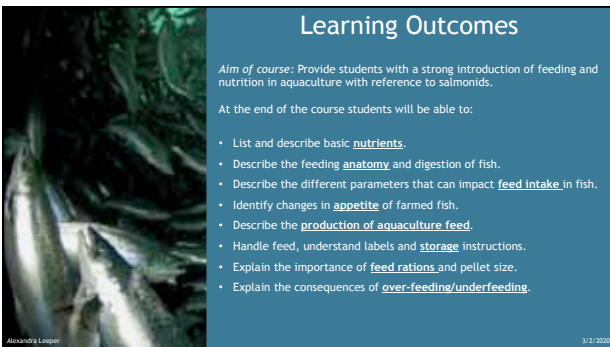
- Total of six modules.
- Taught over two teaching periods and one online session

April
 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.

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

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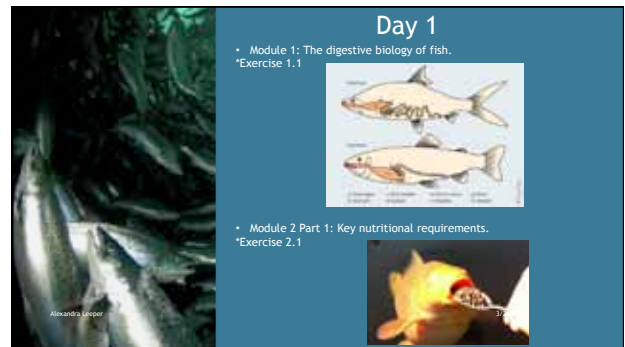
Learning Outcomes

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:

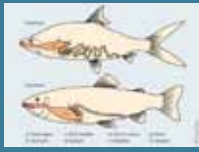
- List and describe basic nutrients.
- Describe the feeding anatomy and digestion of fish.
- Describe the different parameters that can impact feed intake in fish.
- Identify changes in appetite of farmed fish.
- Describe the production of aquaculture feed.
- Handle feed, understand labels and storage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

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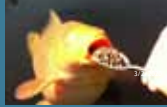


Day 1

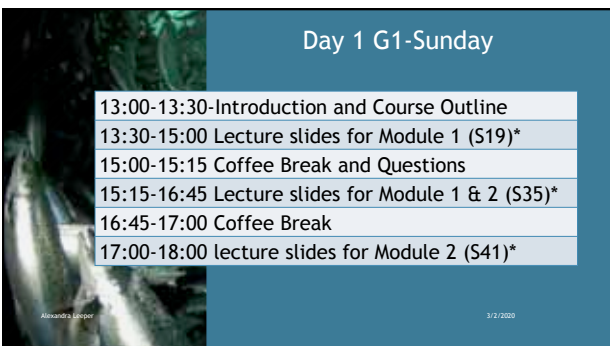
- Module 1: The digestive biology of fish.
*Exercise 1.1



- Module 2 Part 1: Key nutritional requirements.
*Exercise 2.1



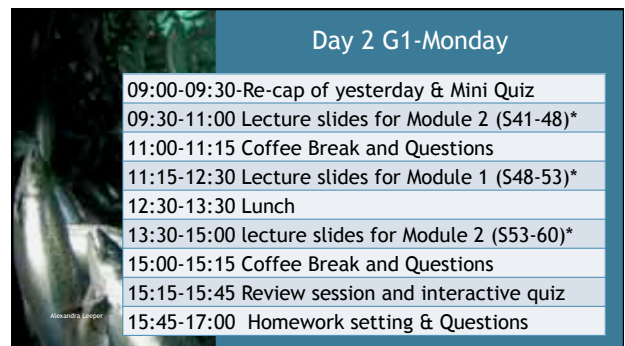
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Day 1 G1-Sunday

13:00-13:30-Introduction and Course Outline
13:30-15:00 Lecture slides for Module 1 (S19)*
15:00-15:15 Coffee Break and Questions
15:15-16:45 Lecture slides for Module 1 & 2 (S35)*
16:45-17:00 Coffee Break
17:00-18:00 lecture slides for Module 2 (S41)*

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Day 2 G1-Monday

09:00-09:30-Re-cap of yesterday & Mini Quiz
09:30-11:00 Lecture slides for Module 2 (S41-48)*
11:00-11:15 Coffee Break and Questions
11:15-12:30 Lecture slides for Module 1 (S48-53)*
12:30-13:30 Lunch
13:30-15:00 lecture slides for Module 2 (S53-60)*
15:00-15:15 Coffee Break and Questions
15:15-15:45 Review session and interactive quiz
15:45-17:00 Homework setting & Questions

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Day 1 G2-Tuesday

09:00-09:30-Introduction and Course Outline
09:30-11:00 Lecture slides for Module 1 (S19)*
11:00-11:15 Coffee Break and Questions
11:15-12:30 Lecture slides for Module 1 (S24)*
12:30-13:30 Lunch
13:30-15:00 lecture slides for Module 2 (S35)
15:00-15:15 Coffee Break and Questions
15:15-15:45 Review session and interactive quiz
15:45-17:00 Lecture slides for Module 2 (S41)*

Day 2 G2-Wednesday

09:00-09:30-Re-cap of yesterday & Mini Quiz
09:30-11:00 Lecture slides for Module 2 (S41-48)*
11:00-11:15 Coffee Break and Questions
11:15-12:30 Lecture slides for Module 1 (S48-53)*
12:30-13:30 Lunch
13:30-15:00 lecture slides for Module 2 (S53-60)*
15:00-15:15 Coffee Break and Questions
15:15-15:45 Review session and interactive quiz
15:45-17:00 Homework setting & Questions

Digestive biology

Digestion = The process by which food is broken down into simple chemical compounds that can be absorbed and used as nutrients or eliminated by the body.

Mono-gastric = having a stomach with only a single compartment.

Ruminant= four stomachs and eat plant matter with the help of enzymes.

The diagrams show the digestive tracts of a fish, a bird, and a cow. The fish has a simple stomach. The bird has a crop and a gizzard. The cow is a ruminant with four distinct stomach compartments: rumen, reticulum, omasum, and abomasum.

Digestive biology

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This slide is identical to the previous one but includes red circles around the stomachs of the fish, bird, and cow to emphasize the differences in their digestive anatomy.

Digestive biology

- Even within the fish kingdom there is a huge difference in digestive biology.
- Factors affecting digestive biology:
 - Feeding strategy
 - Nutritional content
 - Size & structure of feed
 - How easy the food is to digest
 - Environmental factors

The diagram illustrates three feeding strategies: Surface-feeding (planktonic organisms), Midwater-feeding (zooplankton), and Bottom-feeding (detritus). A photograph of a fish is shown at the bottom left.

Digestive biology

- Even within the fish kingdom there is a huge difference in digestive biology.
- Factors affecting digestive biology:
 - Feeding strategy
 - Nutritional content
 - Size & structure of feed
 - How easy the food is to digest
 - Environmental factors

The graph plots 'Nutritional Demands' on the y-axis against 'Omnivores' and 'Carnivores' on the x-axis. A yellow arrow points from the origin towards the carnivore end, indicating that nutritional demands increase. A text box notes: 'Regardless of nutritional quality, fish have high protein and lipid demands.'

Digestive biology

- These systems look different but have all the same function which is digestion but are designed for different environments, diets and nutritional needs.

B) is the digestive tract of a Rainbow Trout

- Rainbow trout is a salmonid

All from different types of fish

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Digestive biology: Salmonids

Reminder: What is a salmonid?

Key parts of the digestive biology we will explore

- Esophagus
- Stomach
- Gall bladder
- Spleen
- Pyloric caeca
- Intestine (mid and hind)
- Anus

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Digestive biology: Salmonids

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Digestive biology: Mouth and Esophagus

Function: The mouth acts as an opening for food and the esophagus facilitates food passing from the mouth to the stomach by muscle movement.

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Digestive biology: Stomach

Function: Mechanical digestion of food from mixing and churning action of stomach muscles, breaking the food down into more manageable particle sizes. Chemical digestion by enzymes called pepsins and breakdown by acidity.

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Digestive biology: Pyloric caeca

Digestive fluids: Bile, Pancreatic juices and mucus all reach the partially digested food here and help to break all the different components down to smaller and smaller sizes.

Function: Location where the bulk of the chemical digestion is taking place (especially for fat and carbohydrates but also further breakdown of proteins and small peptides). Absorption of nutrients from digested food also starts here.

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Digestive biology: Pancreas, Liver, Gall Bladder

Pancreas found inside the pyloric caeca

Gall bladder

Liver

Function: Production or transport of important fluids to the pyloric caeca and mid-intestine that aid facilitate chemical digestion.

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Digestive biology: mid-intestine

Inside the gut

In the blood stream.

Diffusion

and nutrient absorption through the intestinal wall.

Intestinal diameter

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Hind-intestine

Microbiome IN NUMBERS

100 Trillion

95%

150:1

>10,000

90%

5:1

2.5

Function: Final stage of digestible material

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Transit of food: Summary

Carotid

- How long does this take in an adult Atlantic Salmon?
- What factors effect transit time through the digestive tract?

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Development of Digestive Tract

- As salmonids go from egg to post-smolt-adult

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Module 1: Exercise 1.1

This exercise will be to label key parts of a fish digestive tract diagram and a small multiple-choice quiz using an online application.

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Day 1 part 2 & Day 2

- Module 2 Part 2: Key nutritional requirements. *Exercise 2.2
- Module 3: Aquafeed Formulation. *Exercise 3.1




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Module 2 Key nutritional Requirements




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We are what we eat.....and so are fish

Just like us, fish need certain dietary requirements in order to be healthy and ultimately tasty for the consumer.

Proteins



Fats



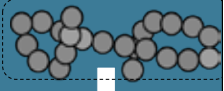
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Proteins

Key Functions



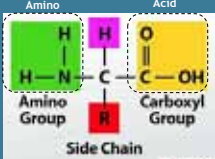
- Enzymes e.g. help in the break down of food
- Muscle Building
- Hormones e.g. insulin for blood sugar control
- Immune System e.g. Antibodies that fight disease
- Structure e.g. Collagen found in ligaments/tendons

Providing the body with amino acids



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Proteins

Different Amino Acids

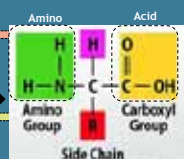
Amino Group: $\text{H}-\text{N}-\text{H}$

Acid: $\text{H}-\text{C}-\text{C}(=\text{O})-\text{OH}$

Side Chain: R

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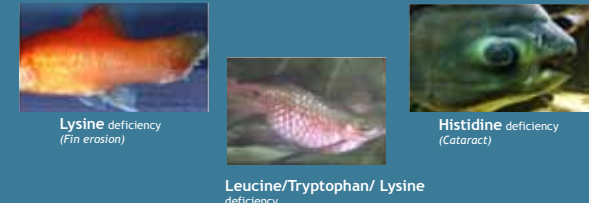
Essential Amino Acids



Different Amino Acids	Function
Arginine	
Histidine	Prevents cataracts
Isoleucine	
Lysine	
Methionine	Increases cell survival
Phenylalanine	
Threonine	
Tryptophan	Reduces aggressive behaviour
Valine	

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Examples of AA deficiencies



Lysine deficiency
(Fin erosion)

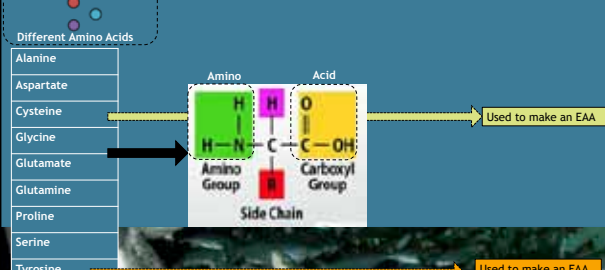
Leucine/Tryptophan/ Lysine deficiency
(Spinal deformities)

Histidine deficiency
(Cataract)

Different Amino Acids

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Non-Essential Amino Acids



Different Amino Acids


- Alanine
- Aspartate
- Cysteine
- Glycine
- Glutamate
- Glutamine
- Proline
- Serine
- Tyrosine

Used to make an EAA

Used to make an EAA

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Protein Sources in Fish Feed



Fish meal


Rapeseed meal

Soybean meal

WHAT IS FISH MEAL?

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Protein Sources in Fish Feed



Rapeseed meal

Soybean meal

Fishmeal

Soybean meal

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Novel Protein Sources in Fish Feed



Insect Proteins

Fungal Proteins

Bacterial Proteins

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We are what we eat.....and so are fish

Just like us, fish need certain dietary requirements in order to be healthy and ultimately tasty for the consumer.

Fats & Oils = Lipids



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Lipids (Fats & Oils)

Key Functions

- Dietary Energy
- Insulation
- Structural e.g. in cell membranes
- Hormone: They are the building blocks
- Communication
- Energy storage

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Lipids (Fats & Oils)

Fatty Acid

Saturated Fat
In animal fats

$$H-C-C-C-C-H$$

Unsaturated Fat
In plant fats

$$H-C=C-C-C-C-H$$

Polysaturated Fat
In fish/plants/seed fats

$$H-C=C-C=C-C-C-H$$

Glycerol

Fatty Acid

Fatty Acid

Fatty Acid

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Lipids Essential Fatty Acids

Fatty Acid

Polysaturated Fat
In fish/plants/seed fats

Omega-3

EPA
Eicosapentenoic acid

DHA
Docosahexaenoic acid

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Sources Essential Fatty Acids

Rapeseed Oil

Fish Oil

Canola Oil

Microalgae Oil

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Carbohydrates

Role: Energy source & binding agent

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Minerals, Vitamins & Pigments

Ca
Calcium
40.078

Role: bone formation

Vitamin C

Role: Skeletal growth

Fe
Iron
55.847

Role: Hemoglobin (O2 transport)

Vitamin K

Role: Blood clotting

Role: Health, Vit A (precursor), anti-oxidant

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Minerals, Vitamins & Pigments

Vitamin C

Source: Vitamin and mineral premix

Vitamin K

Source: natural prey (wild) from krill or red microalgae.

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Probiotics and Prebiotics

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

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

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Non-nutritional Ingredients

Immunostimulants

- B glucans
- Peptidoglycans
- Lipopolysaccharides

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Nutritional Requirement Varies

Different species

Different developmental period

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Nutrition Summary

Macro Nutrient	Key Roles
Protein	Enzymes, muscle building, hormones, structural proteins (collagen), immune support (anti-bodies), amino acid source.
Lipids	Dietary energy, insulation, cell membrane structure, hormone structure, energy storage, immune support.
Carbohydrates*	Energy Sources (herbivores/omnivores), binding agent (carnivores)

Micro-Nutrient	Key Roles
Minerals	e.g. bone formation and hemoglobin
Vitamins	e.g. skeletal growth and blood clotting
Pigments	Vitamin A production & Antioxidants, protecting fatty acids in eggs.

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Source Summary

Macro Nutrient	Traditional Sources	Emerging sources
Protein	Fish meal, Soybean Meal, (some other plant meals)	Bacterial meals, fungal meals, insect meals.
Lipids	Fish oil, rapeseed oil, canola oil*	Microalgae oils
Carbohydrates	Wheat	

Micro-Nutrient	Sources
Minerals	Mineral premix
Vitamins	Vitamin premix
Pigments	Crustacean material and red-microalgae

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Module 2: Exercise 2.1 & Exercise 2.2

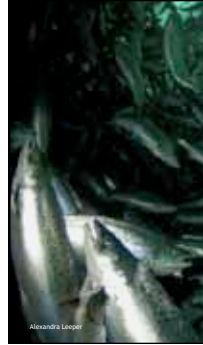
Fill in a blank table about the sources and roles of nutrients and a small multiple-choice quiz using an online application.



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Module 3 Aquafeed Formulation

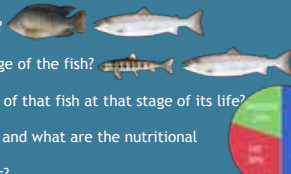


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Feed formulation

- What is the species of interest?
- What is the developmental stage of the fish?
- What are the nutritional needs of that fish at that stage of its life?
- What ingredients are available and what are the nutritional compositions of those ingredients?
- Cost (?)



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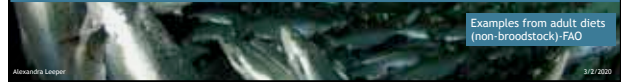
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Formulation for different species



Macro-nutrient	Common Carp	Nile Tilapia	Atlantic Salmon
Protein %	28	26	34
Lipid	5-15(omega3 & 6)	10-15(omega-6)	24 (Omega-3)
Carbohydrate	38.5	40	Not required for nutrition*

Examples from adult diets (non-broodstock) FAO



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Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34



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Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34

Ingredient	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34
Lipid	5-15(omega3 & 6)	10-15(omega-6)	24 (Omega-3)	Not required for nutrition*		
Carbohydrate	38.5	40				



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Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
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Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34

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Additional Feed formulation considerations

- Digestibility & biological availability of feed ingredients
- Palatability & attractability of feed ingredients
- Compatibility with the pellet production process
- Anti-nutritional Factors & Toxins

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Digestibility & availability

Anti-nutritional factors

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Palatability & Attractability

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Module 3: Exercise 3.1

Match the formulation with the species and the developmental stage and justify answer. Explore the feed ingredients and info from diets fed on farms. Small question and answer session to review any material from the first three modules.

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	100 ¹	50 ²	25 ³	10 ⁴		100 000	50 000	25 000	10 000
Wheat	750	375	187.5	75	Wheat	750	375	187.5	75
Fish protein	250	125	62.5	25	Fish oil	250	125	62.5	25
Plant protein	15	7.5	3.75	1.5	Plant protein mix	15	7.5	3.75	1.5
Fish oil	100	50	25	10	Plant protein concentrate	15	7.5	3.75	1.5
Wheat	750	375	187.5	75	Wheat gluten meal	15	7.5	3.75	1.5
Fish	250	125	62.5	25	Soy protein concentrate	15	7.5	3.75	1.5
Plant	15	7.5	3.75	1.5	Wheat gluten meal	15	7.5	3.75	1.5
Oil	100	50	25	10	Soy protein concentrate	15	7.5	3.75	1.5
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Plant	15	7.5	3.75	1.5	Wheat gluten meal	15	7.5	3.75	1.5
Oil	100	50	25	10	Soy protein concentrate	15	7.5	3.75	1.5

Digestion	Diet B1	Diet B2	Diet B3	Diet B4
Fishmeal	30	30	30	30
Soybean protein concentrate	6	6	6	6
Truncated Animal Protein	12	12	12	12
Fish Oil	10	10	10	10
Plant Oil	6	6	6	6
Mineral supplements	0.2	0.2	0.2	0.2
Proximate analysis				
Digestible protein	36	36	36	36
Digestive energy	30	30	30	30

Ingredients:	Unit	FM 0	Ingredients:	Unit	FM 0
Fish meal	g/kg	676.8	Fish meal	g/kg	401.8
Fish oil	g/kg	103.5	Fish oil	g/kg	38.3
Wheat	g/kg	209.7	Wheat	g/kg	549.9
Plant protein mix	g/kg	0.0	Plant protein mix	g/kg	0.0
Corn gluten meal	g/kg	0.0	Corn gluten meal	g/kg	0.0
Soy protein concentrate	g/kg	0.0	Soy protein concentrate	g/kg	0.0
Wheat gluten meal	g/kg	0.0	Wheat gluten meal	g/kg	0.0
SYLPRO ®	g/kg	0.0	SYLPRO ®	g/kg	0.0
Lysine	g/kg	0.0	Lysine	g/kg	0.0
Methionine	g/kg	10.0	Methionine	g/kg	0.0
Premix	g/kg	1000.0	Premix	g/kg	10.0
Nutrient composition, calculated as is:			Nutrient composition, calculated as is:		
Dry matter	g/kg	923.3	Dry matter	g/kg	895.3
Crude protein	g/kg	500.0	Crude protein	g/kg	350.0
Crude lipid	g/kg	160.0	Crude lipid	g/kg	80.0
Crude fiber	g/kg	4.6	Crude fiber	g/kg	12.1
Crude ash	g/kg	100.0	Crude ash	g/kg	69.9
NFE	g/kg	144.5	NFE	g/kg	398.9
Starch	g/kg	124.6	Starch	g/kg	326.6
Phosphor	g/kg	14.6	Phosphor	g/kg	10.1
Lysine	g/kg	35.1	Lysine	g/kg	22.3
Cystine	g/kg	4.7	Cystine	g/kg	4.0
Methionine	g/kg	13.1	Methionine	g/kg	3.5
Methionine + Cystine	g/kg	17.9	Methionine + Cystine	g/kg	12.6
Histidin	g/kg	11.1	Histidin	g/kg	7.8
GE (Calculated)	MJ/kg	20.7	GE (Calculated)	MJ/kg	18.3

Table 1
Dietary formulation and proximate composition of the diets

Foed formula	%	Proximate composition	%
Fish meal *	36.0	Crude protein (N x 6.25)	39.8
Fish oil *	12.5	Lipid	14.4
Extruded wheat	28.0	Nitrogen free extract	16.9
Wheat (Tylose)	2.0	Moisture	8.3
Nitrogen perox *	1.0	Ash	10.3
Mineral perox *	0.5		
Carapax Fish (2% water)	0.0 (14 g kg ⁻¹)		

* Nore LT, Norvoldal, Bergen, Norway.
* Refined marine oil (scum oil) and cod liver oil (Medicine oil 11:1), M. Marasa s.s., Bergen, Norway.
* Standard proprietary product (Ewos Aqua, Sweden).

Homework module 1-3

To be set