Historical developments and current issues in fish nutrition

EAAP 2016

29th of August, Johan Schrama & Sachi Kaushik

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INRA
SCIENCE & IMPACT

Content presentation

- Historical development of aquaculture
- Trends in fish nutrition/fish feeds
- EU fish nutrition projects → ARRIANA
- Examples of issues in fish nutrition:
  - Mineral requirements ←→ fishmeal replacement
  - Minimizing waste production
  - Do fish drink? Chyme conditions and digestion
  - Enteritis in Salmonids and other fish

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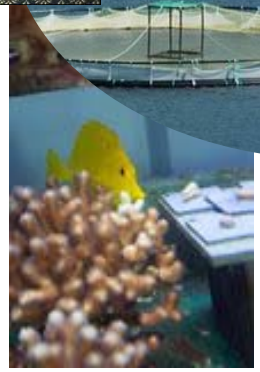
Historical development of aquaculture

Reasons to culture fish:

Reason

- Human food supply: aquaculture

- Ornamental fish



- Public aquaria & Zoos

Historical development of aquaculture

Why to eat fish:

- Source of nutrients: protein, fatty acids, vitamins, minerals

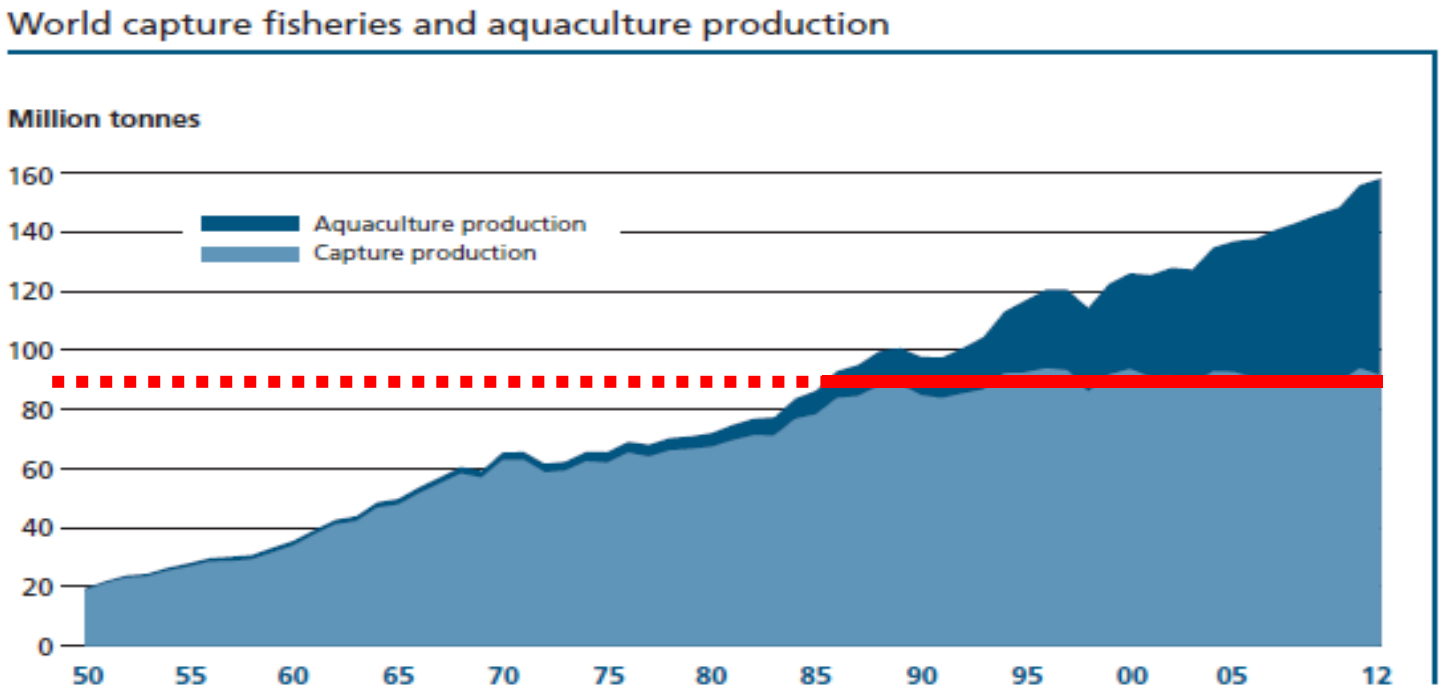
- Healthy → unsaturated fatty acids
  EPA, DHA & ARA (minimal in farm animals)

Nutritional intervention of farmed fish:

• Protein content & profile	No
• Fat level & fatty acid profile	Yes → Fishoil
• Mineral/trace elements/vitamins	+/-
• Contaminants (POPS, heavy metals)	Yes

Historical development of aquaculture

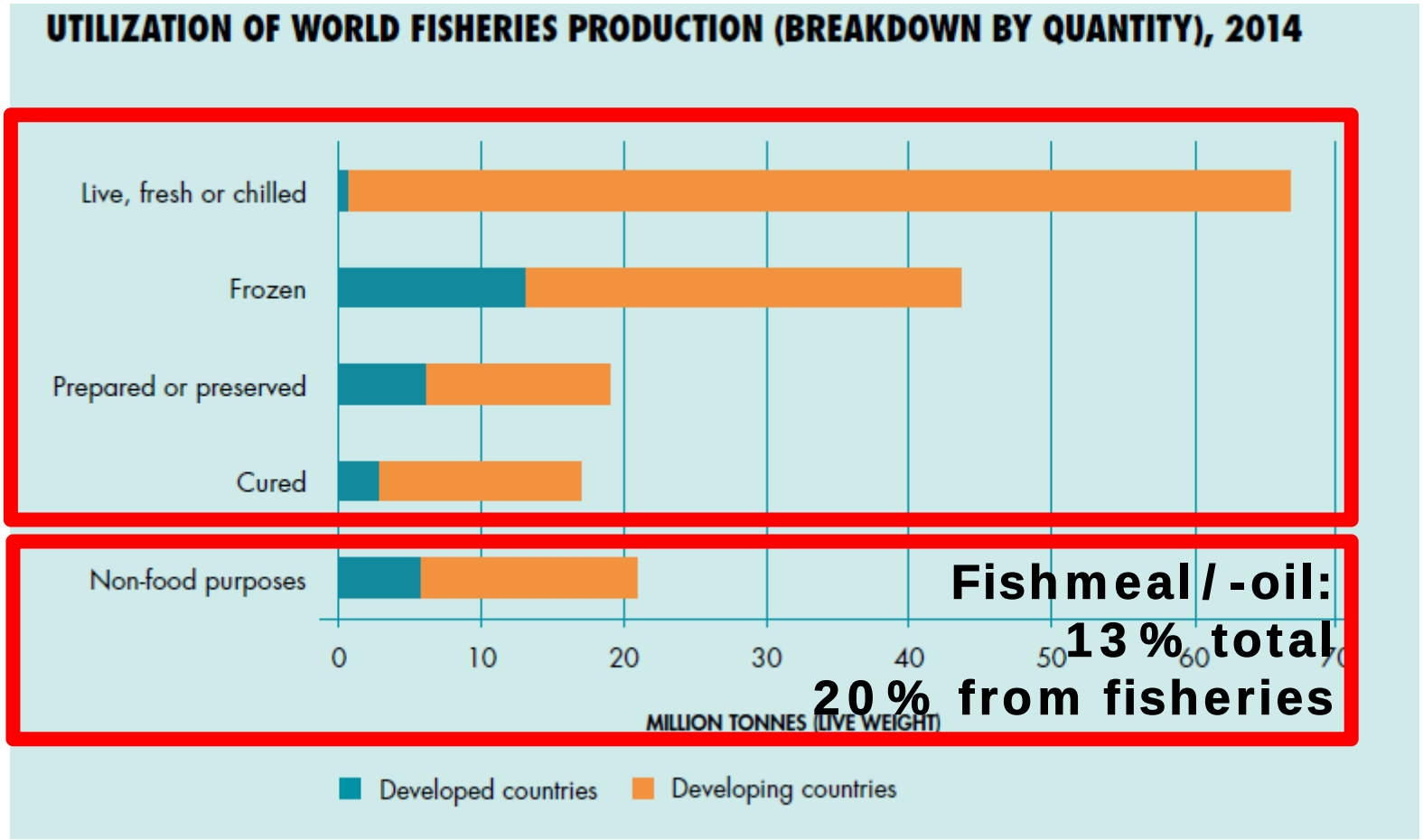
- Global fisheries and aquaculture production



Source: FAO, 2014. The State of World Fisheries and Aquaculture .

Historical development of aquaculture

- What is done with catch/cultured fish?



Source: FAO, 2016. The State of World Fisheries and Aquaculture .

Historical development of aquaculture

Fishmeal and fish oil production:

Raw materials:

• Whole fish from feed fishing fleets	17-18	Million tons
• Trimmings & rejects from food fish	5-6	Million tons
Total raw material	22-23	Million tons

Production of:

Fishmeal	5-6	Million tons
Fish oil	< 1	Million tons

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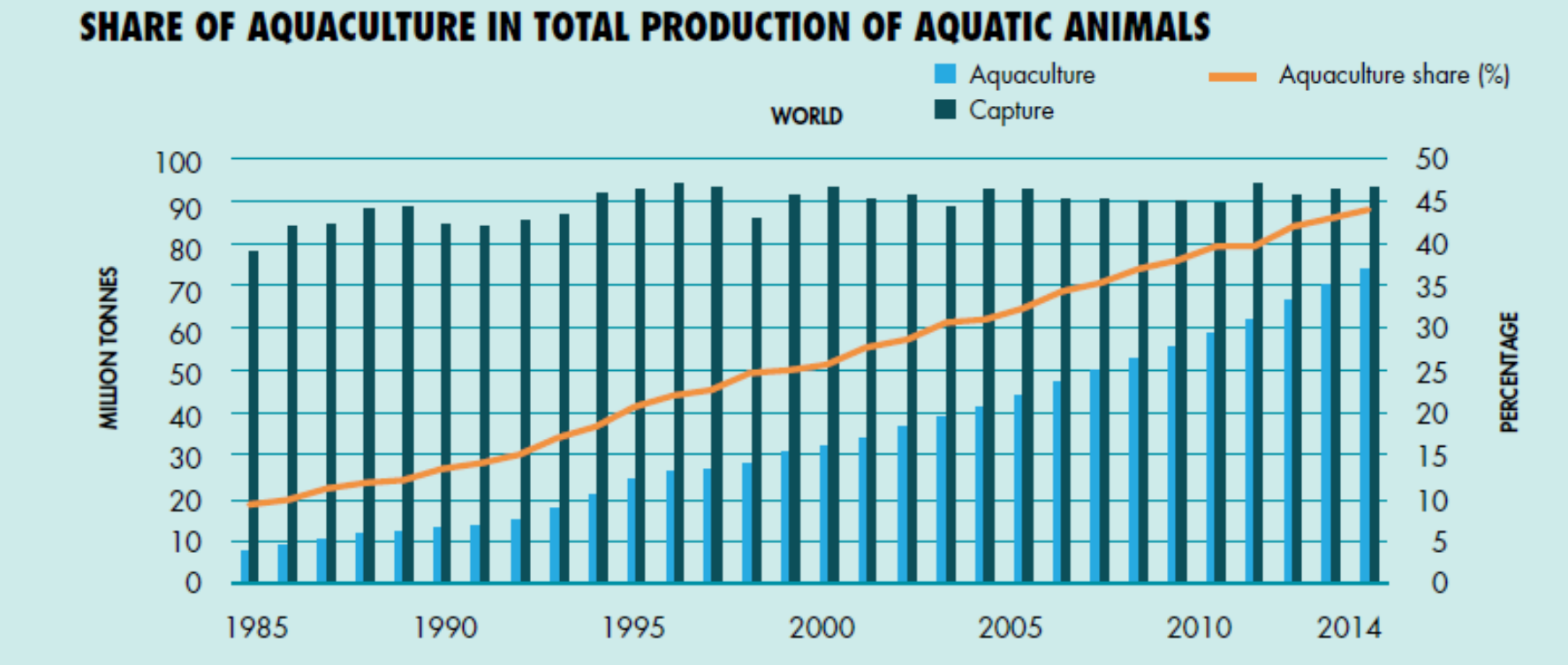
Historical development of aquaculture

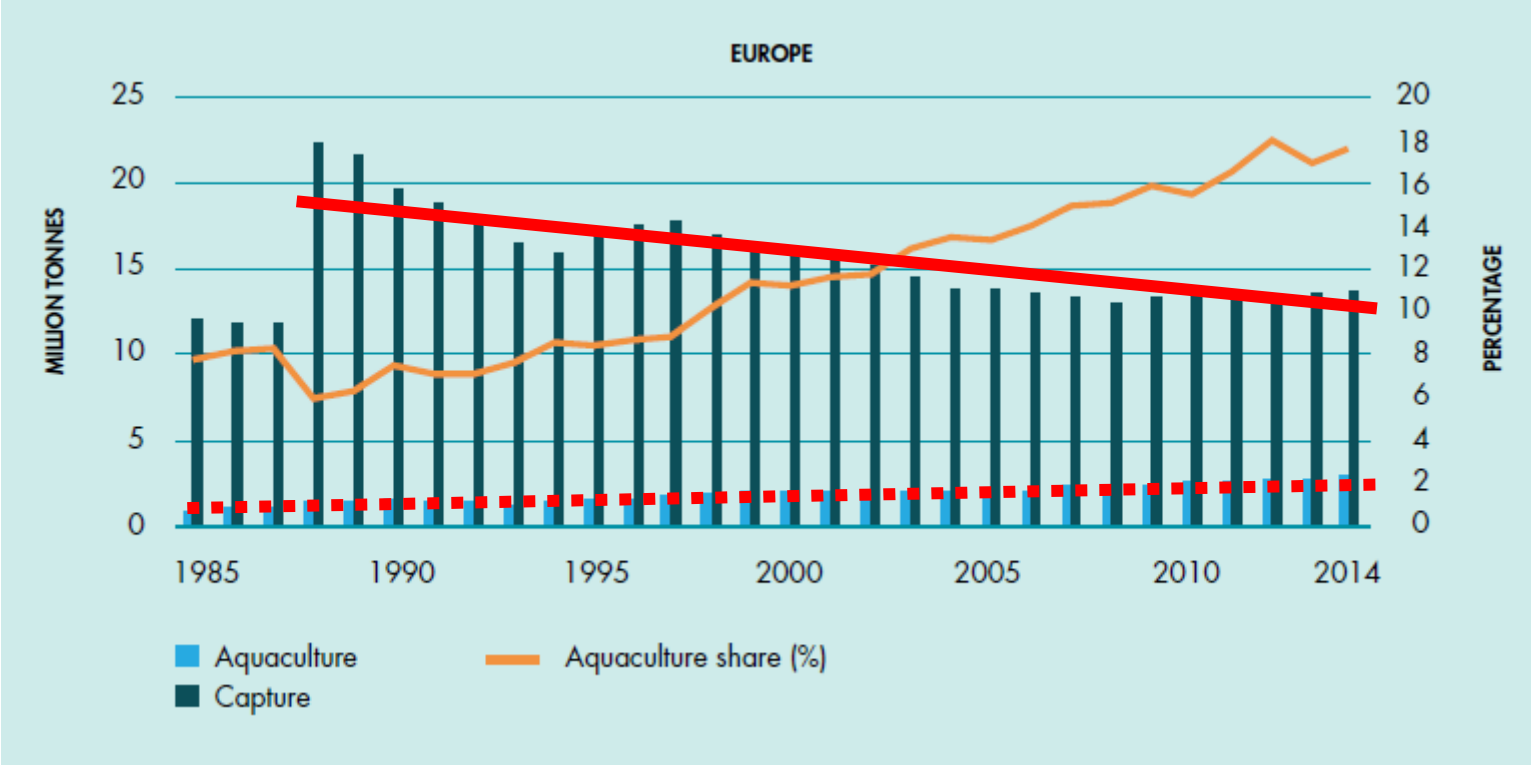
- Importance of aquaculture over the years. Globally.



Source: FAO, 2016. The State of World Fisheries and Aquaculture .

Historical development of aquaculture

- Importance of aquaculture in Europe ..



18% from aquaculture: growth small..

Source: FAO, 2016. The State of World Fisheries and Aquaculture .

Historical development of aquaculture

Diversity: aquaculture

Species

Intensity

Food web

Feed/food

High variability in aquaculture:

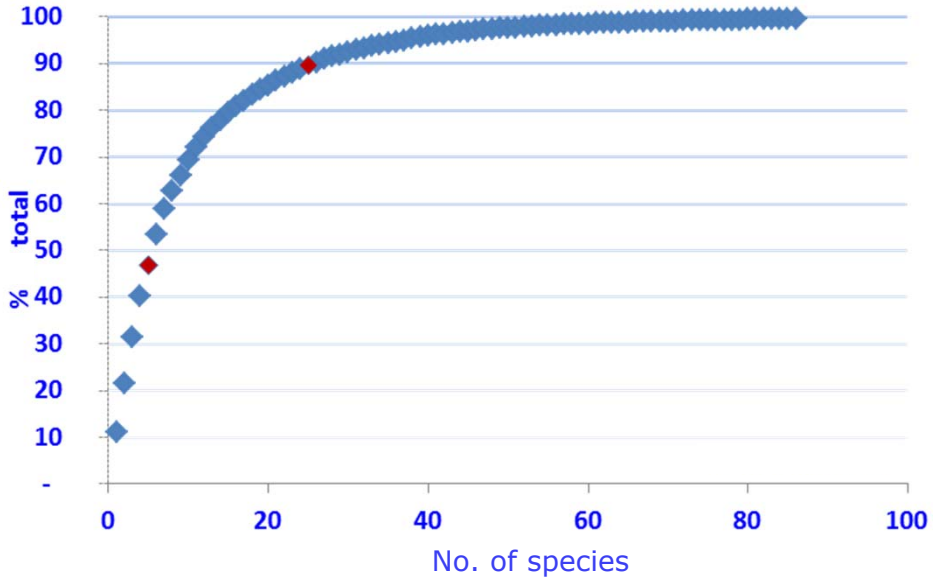
- **Species:**
  Molluscs ←→ crustacean ←→ fish
- **Type of systems:**
  Ponds ←→ raceways ←→ cages ←→ Indoor (RAS)
- **Type of feeds:**
  Food web ←→ formulated complete feed

Historical development of aquaculture

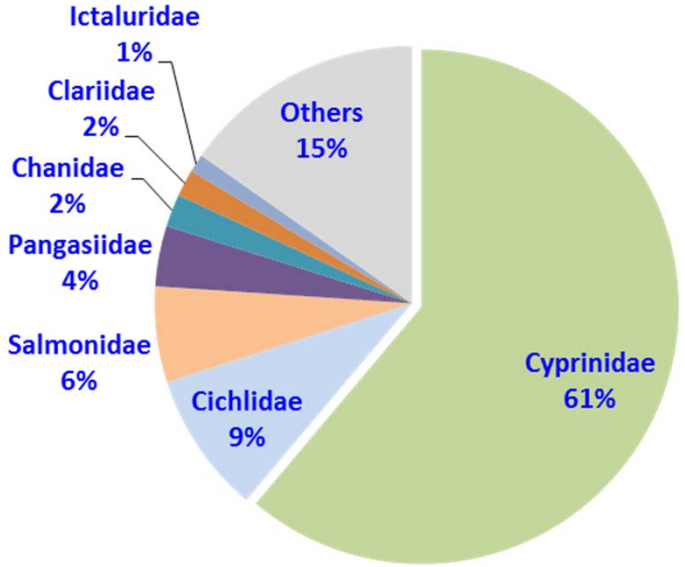
Diversity: aquaculture

Historical development of aquaculture

What do we rear ? Diversity of species



- **Cyprinids > 60 % of volume**
- **Majority of fish from low trophic levels**



> 300 species reported under aquaculture
< 5 species represent 50 % of volume produced
< 25 species represent 90 % of volume produced

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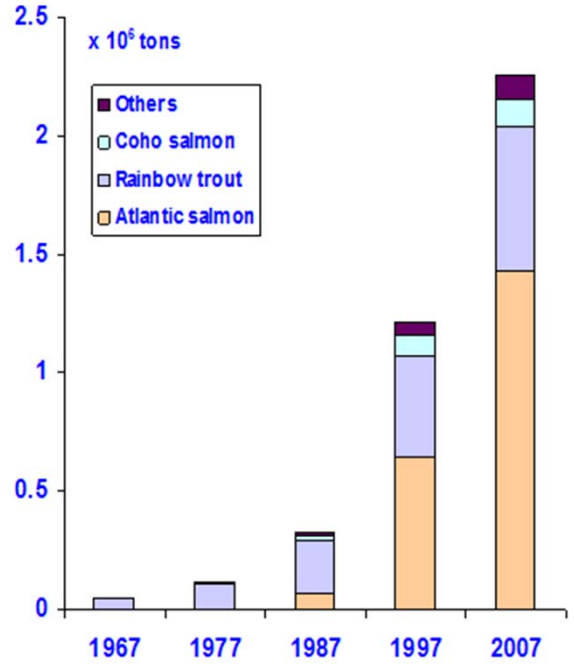
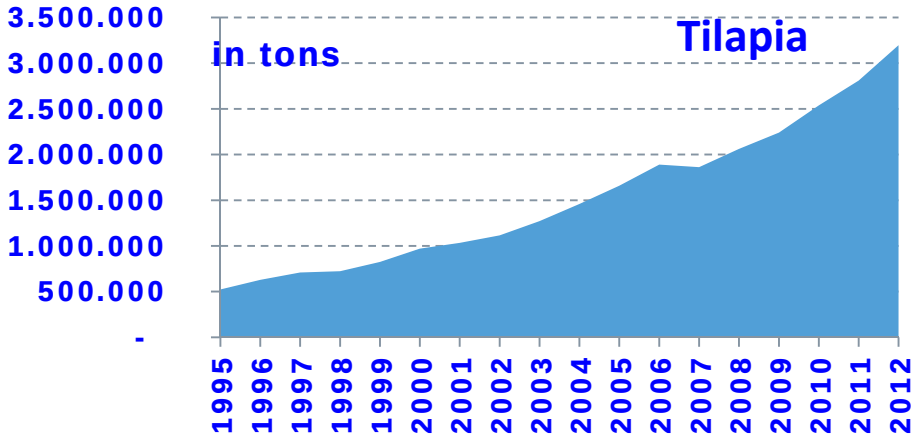
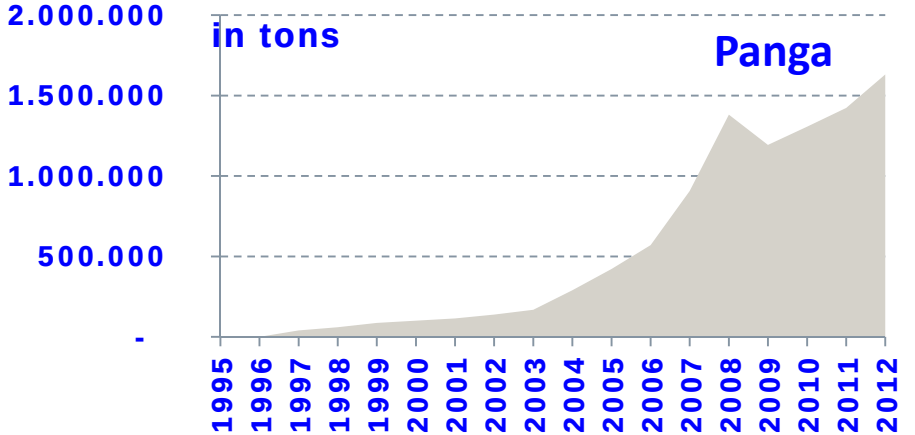
Historical development of aquaculture

European aquaculture dominated by 5 species of finfish
(Atlantic salmon, rainbow trout, Seabream, European seabass, Carps)



New comers : Asia





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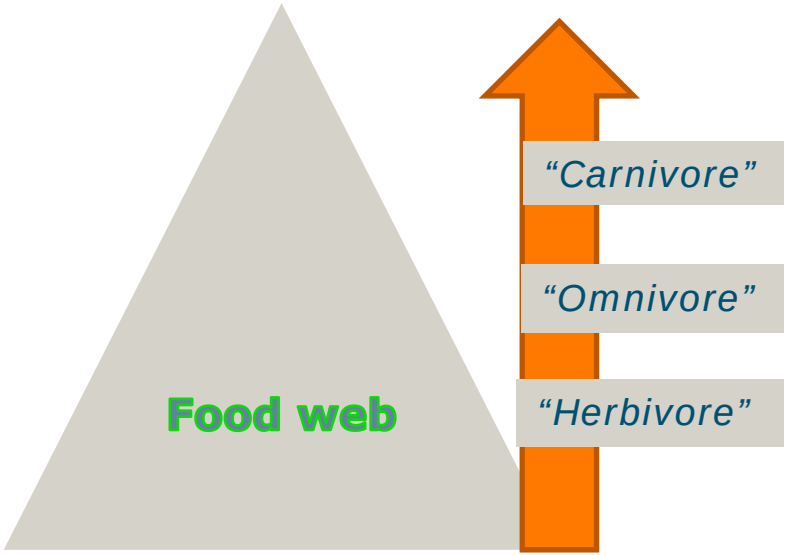
Historical development of aquaculture

Diversity: Feeding ecology



Fish species	Trophic level
Salmon	4.4
Yellowtail kingfish	4.1
Sea bass	3.8
Cod	3.7
Pangasius	3.1
Grass carp	2.0
Nile tilapia	2.0

http://fishbase.org/

Generally energy flow in food web:

- Only 10% of the energy is transferred to the next trophic level

(Pauly &Christensen, 2005)

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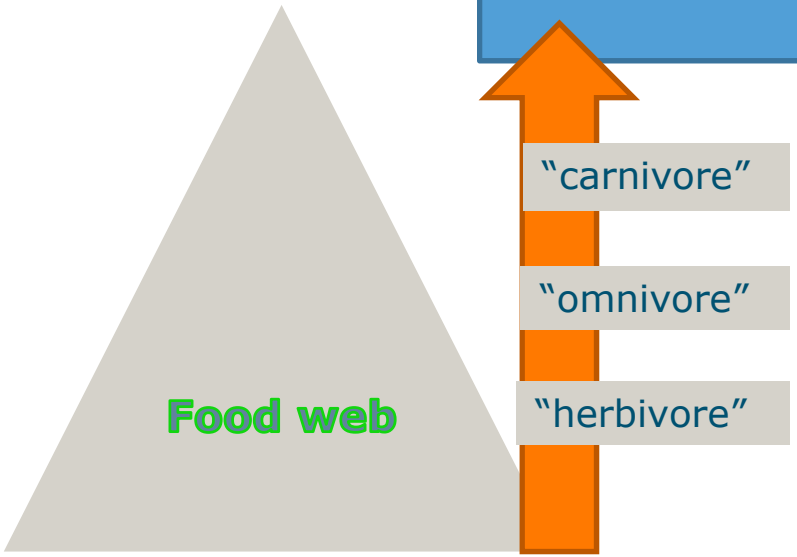
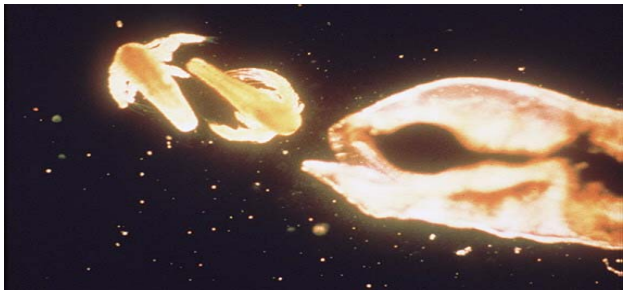
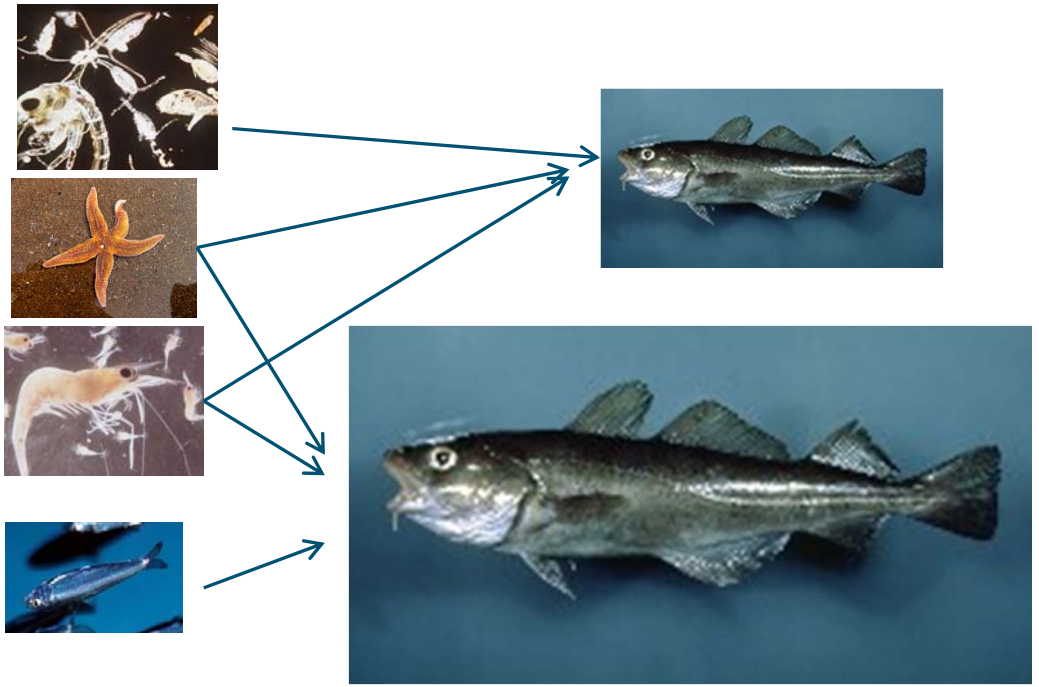
Historical development of aquaculture

Diversity: Feeding ecology within species



Trophic level of fish:
→ life stage dependent.
→ mouth size.
→ energy budgets (effort)





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Historical development of aquaculture

Summarizing:

- Aquaculture strong growth globally, but local differences.
- Large diversity in fish species cultured..
- Large variety in culture conditions...
  From open to more closed/controlled conditions
- Young sector → highly innovative

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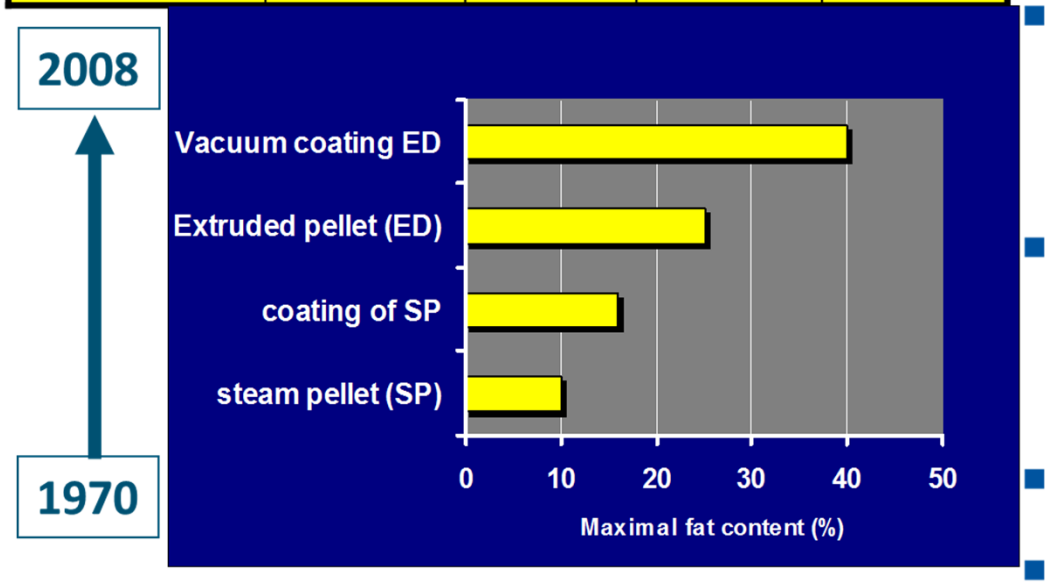
Trends in fish nutrition/fish feeds

Animal species	Crude prot.	Fat	Ash	Carb.
Fish	30-48	7-40	7-12	7-35
Pigs	14-20	4-6	5-8	54-65
Poultry	15-24	6-11	10-12	41-57

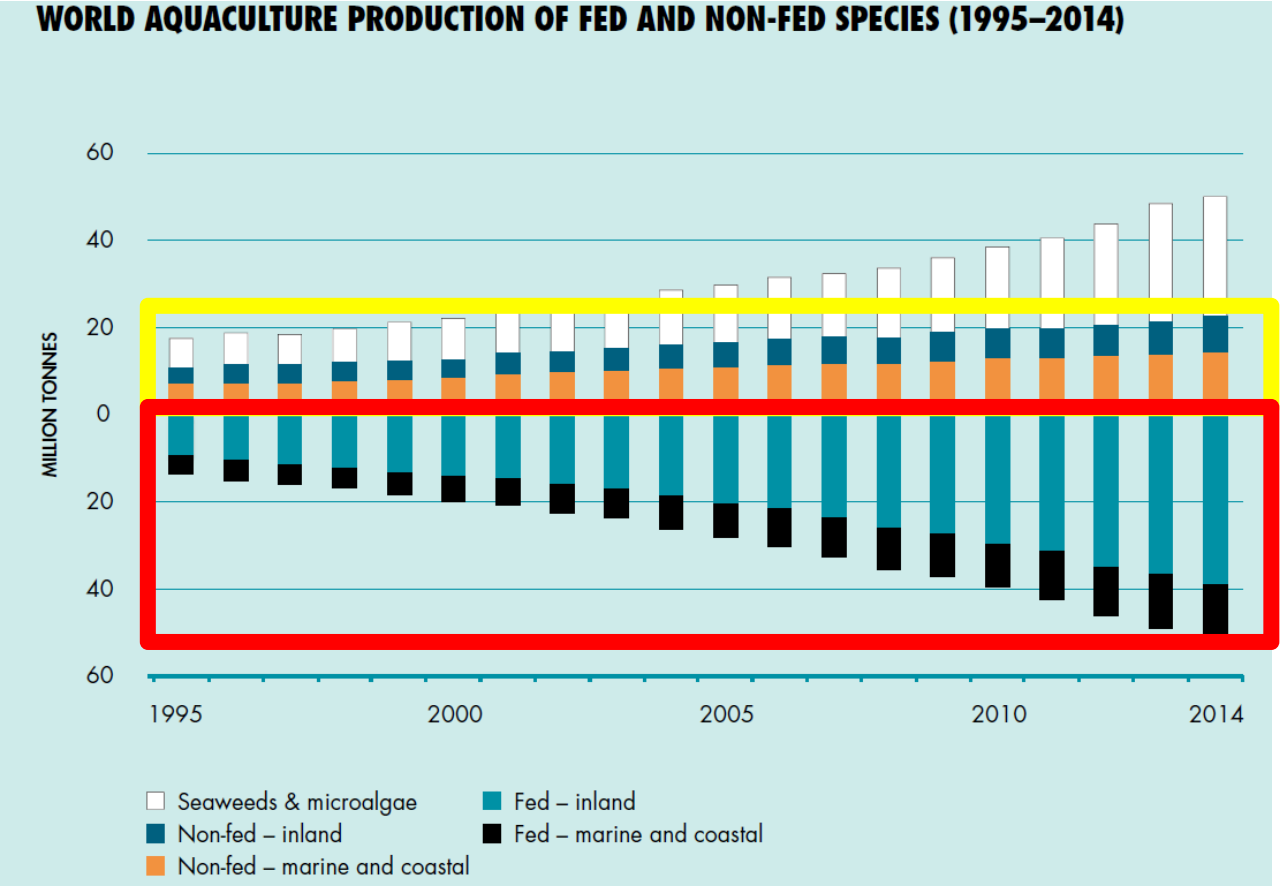


Fish feed pellets:

- Nutrient content:
  - High protein
  - High fat
  - Low carbohydrate
- Ingredients:
  - Fish meal
  - Fish oil
- Mostly extrudates:
  - Pellet quality
  - Nutrient availability
- Waste production (water quality)
- Filet quality (EFA content)

Trends in fish nutrition/fish feeds

- Growth aquaculture sector → mainly in fed species



Source: FAO, 2016. The State of World Fisheries and Aquaculture .

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Trends in fish nutrition/fish feeds

- Total feed used in aquaculture.

Summary totals for fed species and aquafeed production (thousand tonnes)

Year	Total fed aquaculture production	Total feeds used
1995	4 028	7 612
2000	7 684	14 150
2005	13 048	22 585
2007	16 126	26 950
2008	17 476	29 194
2010	21 201	35 371
2015	32 315	51 002
2020	46 917	70 969

20 % inclusion level ingredient

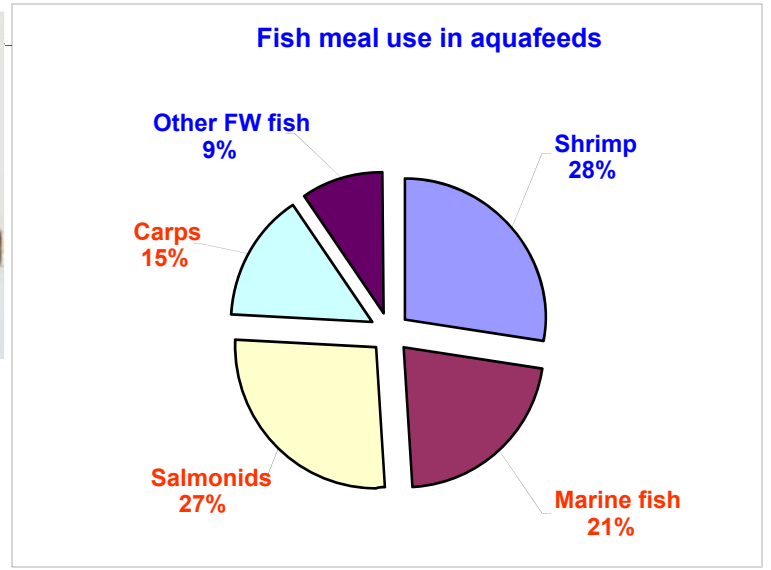
7 million tonnes

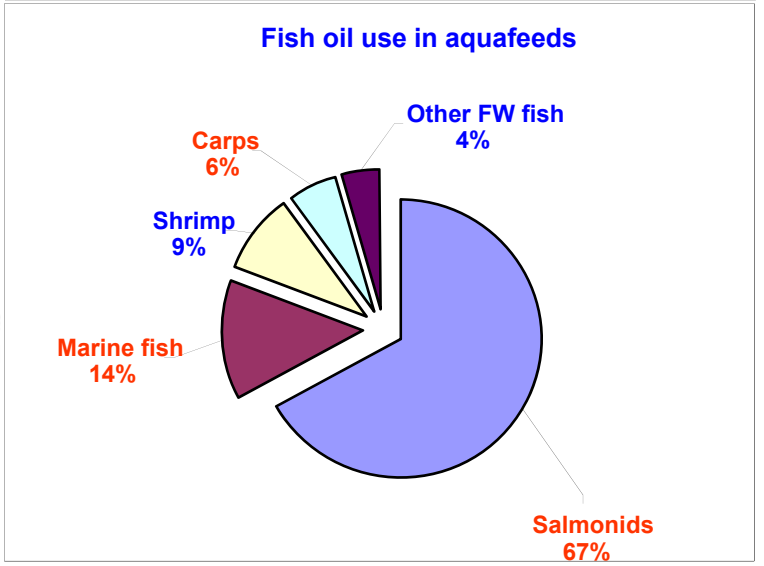
14 million tonnes

Source: FAO, 2011. Demand and supply of feed ingredients for farmed fish and crustaceans.

Trends in fish nutrition/fish feeds

Salmonids, marine fish and cyprinids consume over 60% of FM and over 80% of FO used for aquaculture





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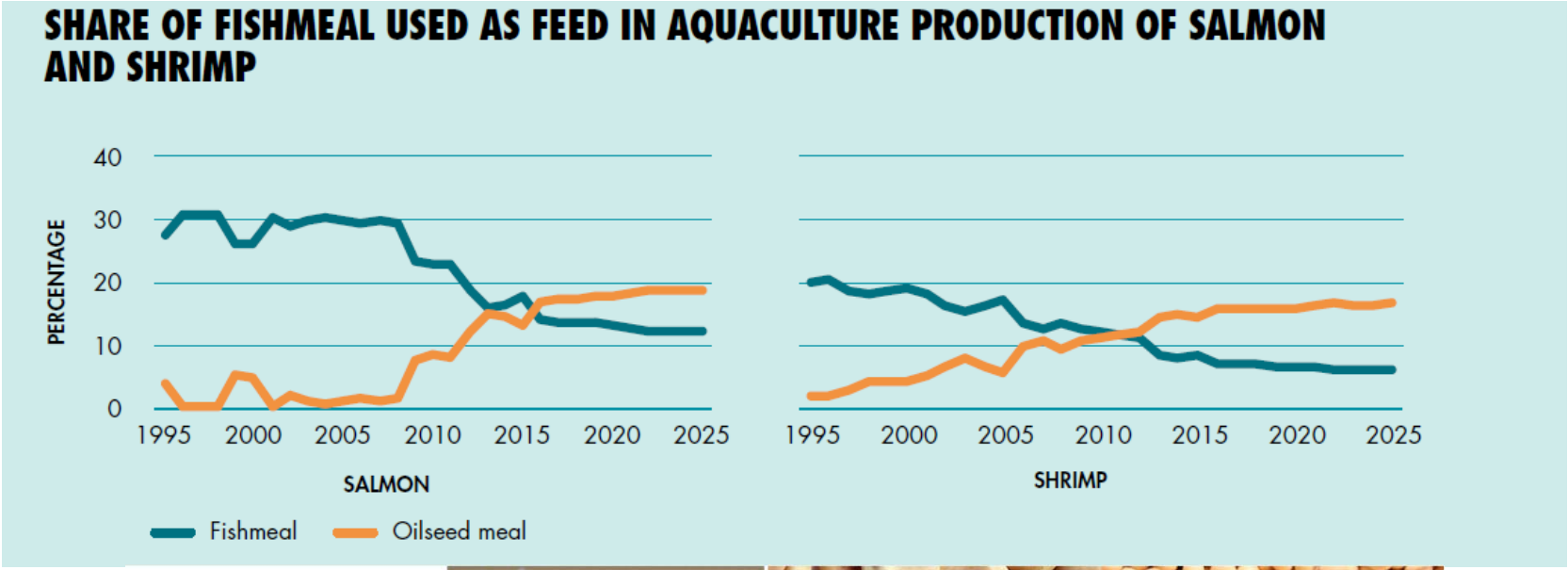
Trends in fish nutrition/fish feeds

- Aqua-feeds → less Fishmeal/-oil used



Source: FAO, 2016. The State of World Fisheries and Aquaculture .

Trends in fish nutrition/fish feeds

Summarizing:

- Historically with intensification fish species → concentrated diets, increasing fat content
- Growing sector → more aqua feed needed
  Doubling 2010 → 2020
- Composition → limited amount of FM & FO
  Alternative ingredients

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EU fish nutrition projects → ARRIANA

EU projects (FP5&FP6) last 15 years, fishmeal (FM) and oil (FO):

- **PEPPA** → FM replacement by plant protein sources (trout, gilthead seabream)
- **RAFOA** → FO replacement by veg oils (salmon, trout, European seabass)
- **Gutintegrity** → effects of dietary factors on gut (salmonids)

  => **FORM** for collective dissemination to stakeholders

- **Aquamax**, FP6 integrated project, combined replacement of FM & FO (salmon, trout, seabream, carps)
- **ARRAINA,** FP7 → FO & FM devoid diets: full life cycle, nutrient requirements .... (salmon, trout, seabream, European seabass, carps)

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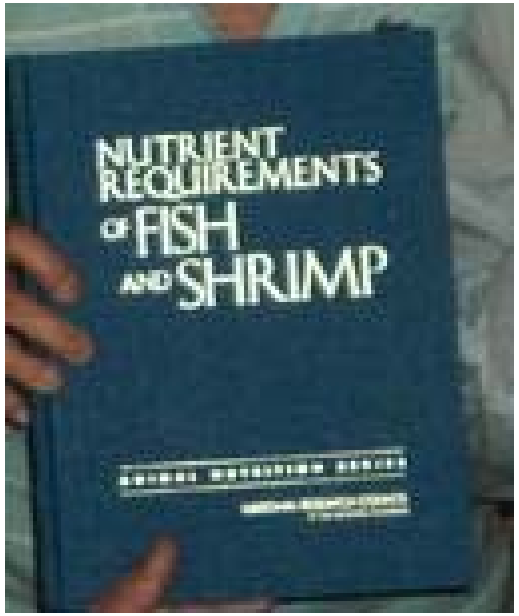
EU fish nutrition projects → ARRIANA

Background

ARRAINA
Advanced Research Initiatives for Nutrition & Aquaculture



More than 300 species are farmed around the world

But, quantitative data on the needs for all essential nutrients are available only for a few species

Not accounting for life stage





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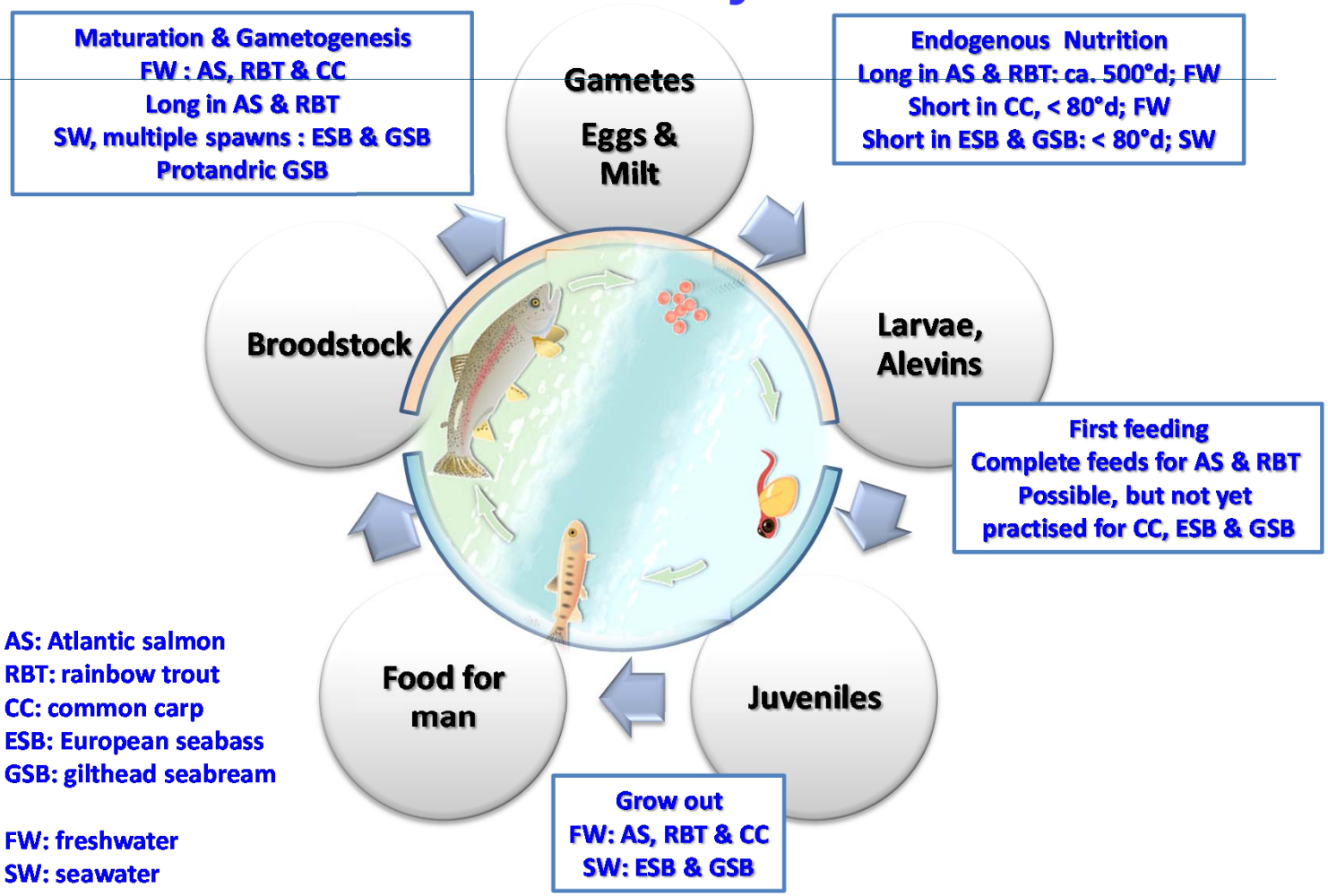
EU fish nutrition projects → ARRIANA

Species with different life cycles



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Mineral req. ←→ fishmeal replacement

Background

- Fishmeal → source of minerals
- Replacement plant ingredient: different amounts & forms (e.g. phytate)
- Within ARRAINA assessment of:
    - Variability between fish species
    - Within species (life cycle)
    - Dietary factors
    - Culture conditions

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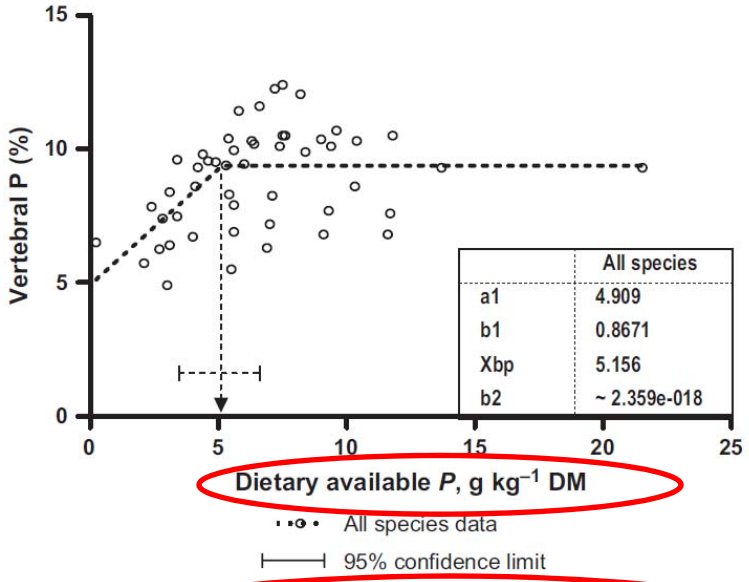
Mineral req. ←→ fishmeal replacement

Factors affecting requirements:
Meta analysis



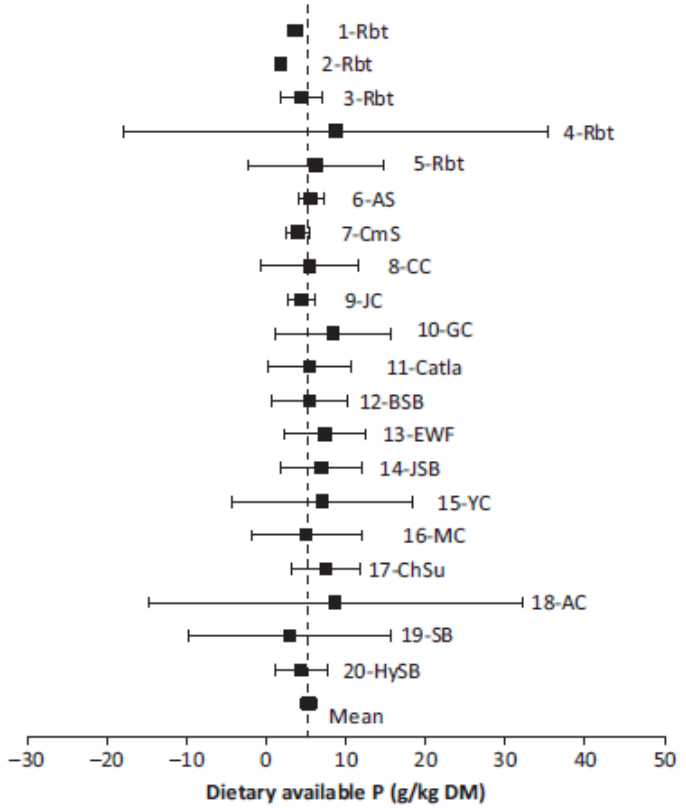


Figure A1 Forest plot presentation of the meta-analytic estimates on the minimal dietary inclusion levels of available P, data presented in Table A1 of appendix.

On available P basis variability < then on total P basis

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Reviews in Aquaculture (2014) 6, 1–48

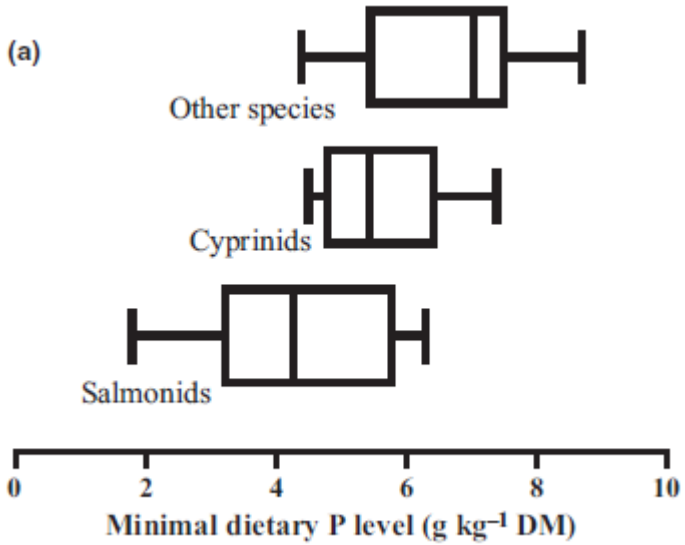
Mineral requirements of fish: a systematic review

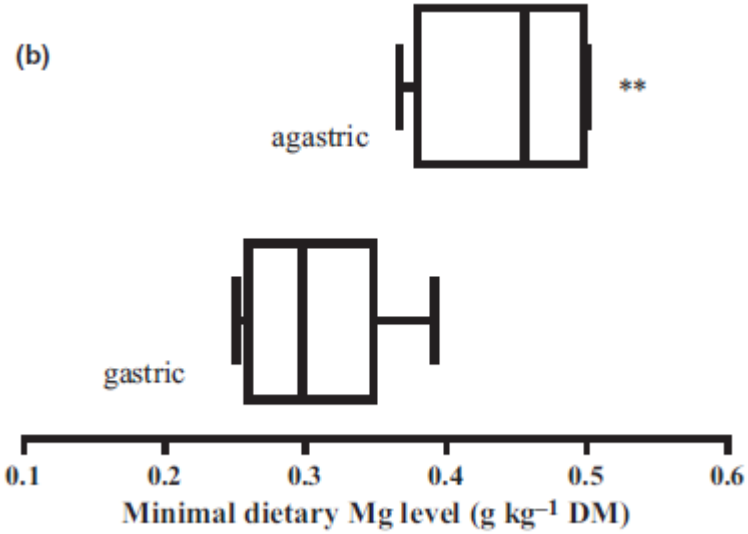
P. Antony Jesu Prabhu[1,2,3], Johan W. Schrama[2] and Sadasivam J. Kaushik[1]

1 INRA, UR 1067, NuMeA, Aquapôle, Saint-Pée-sur-Nivelle, France
2 AFI, WIAS, Wageningen University, AH Wageningen, The Netherlands
3 AgroParisTech, Paris, Cedex 5, France

Mineral req. ←→ fishmeal replacement

Factors affecting requirements:
Species differences





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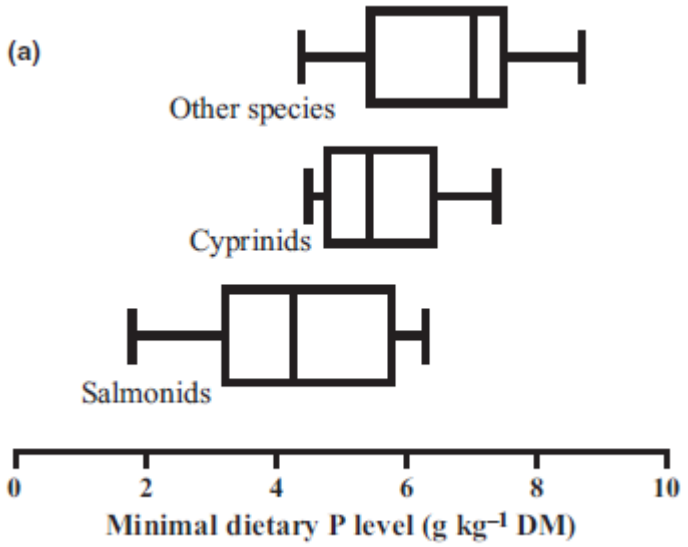

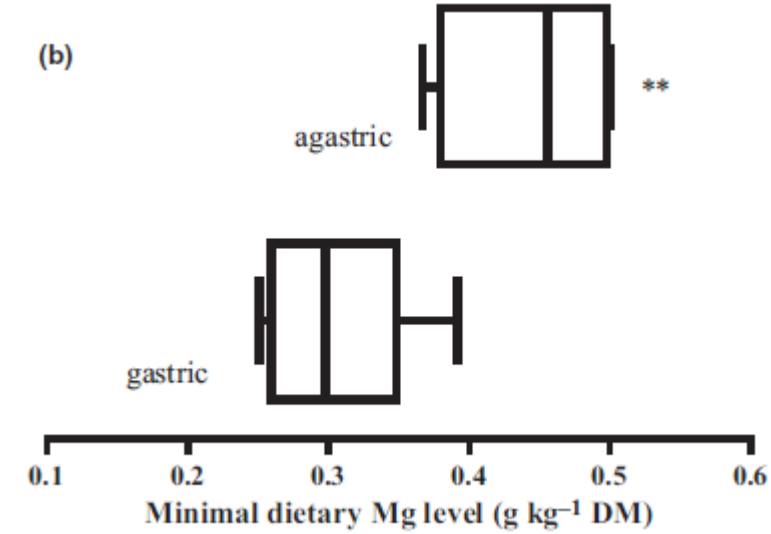

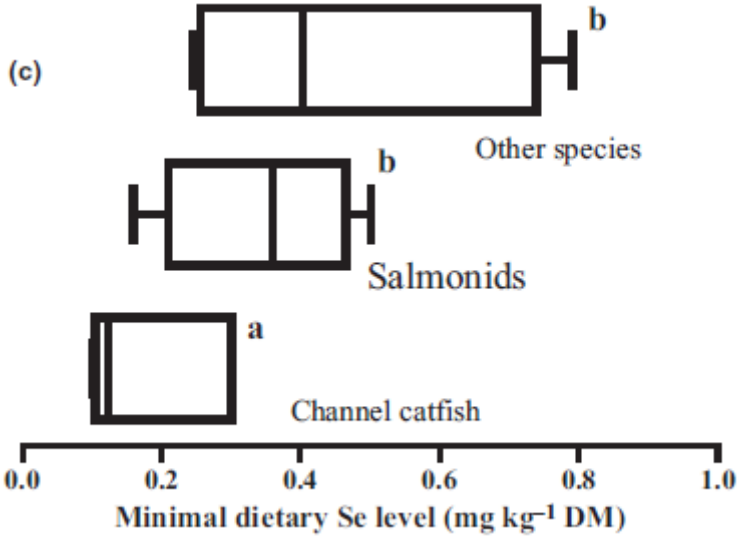

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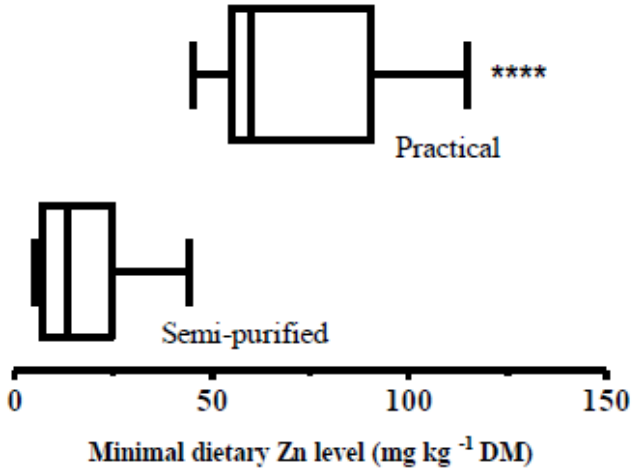
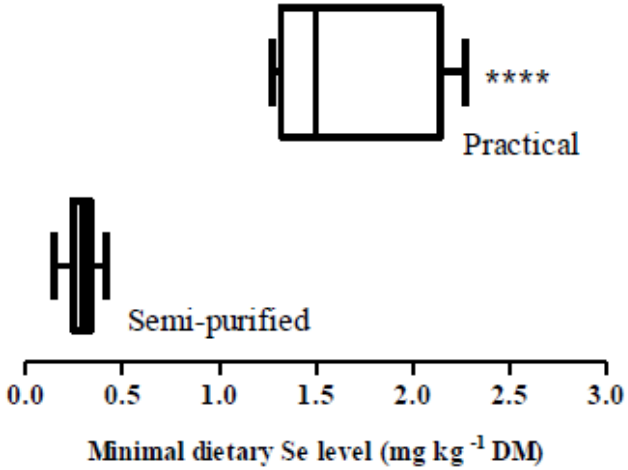
Mineral req. ←→ fishmeal replacement

Factors affecting requirements:
Dietary factors





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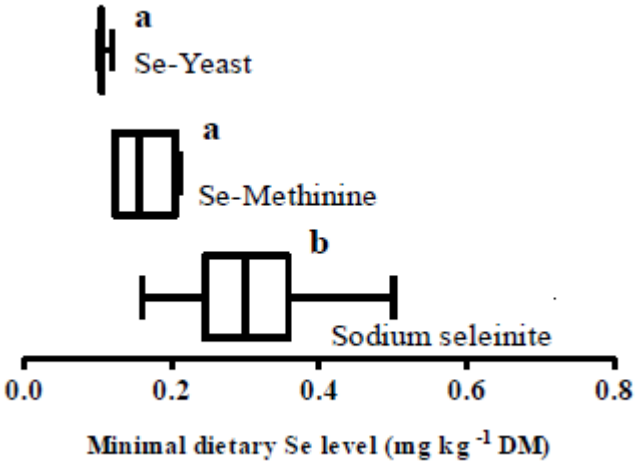

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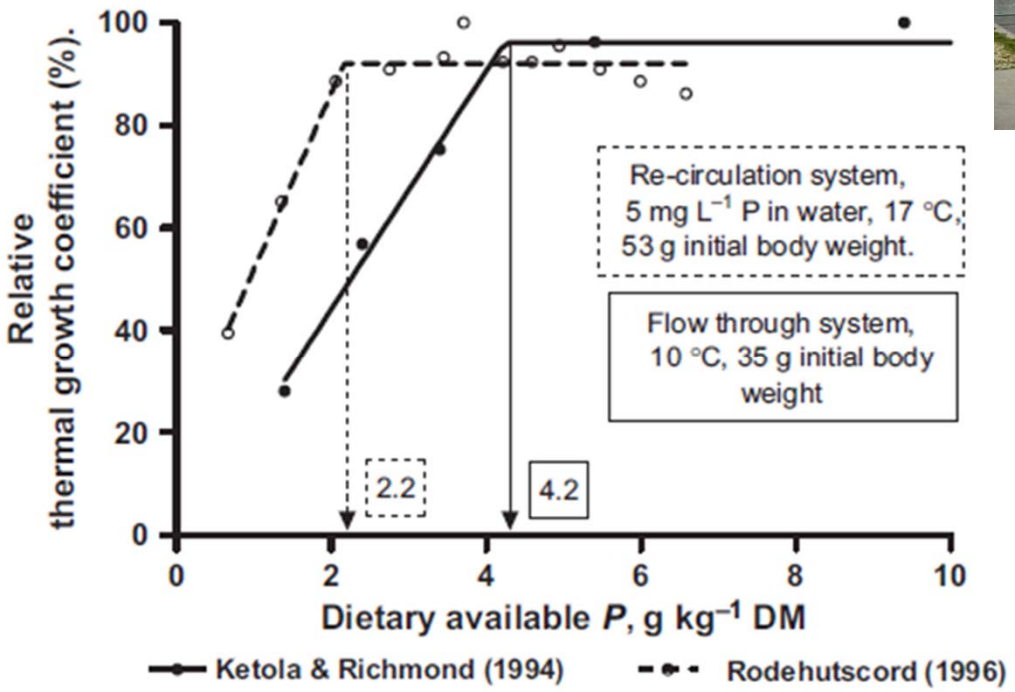
Mineral req. ←→ fishmeal replacement

Factors affecting requirements:
Culture conditions



Aquaculture Nutrition 2013 doi: 10.1111/anu.12042

Quantifying dietary phosphorus requirement of fish – a meta-analytic approach

P. ANTONY JESU PRABHU[1,2], J.W. SCHRAMA[2] & S.J. KAUSHIK[1]

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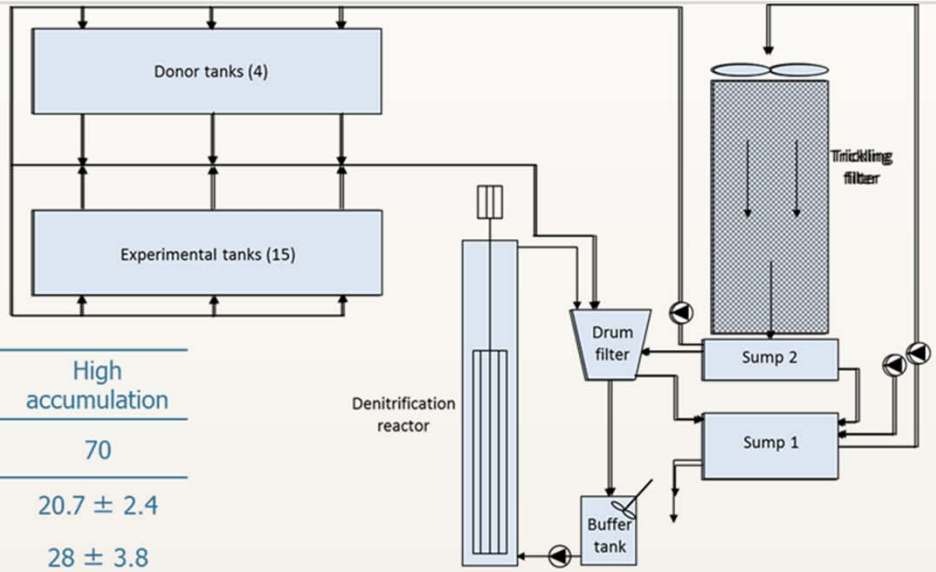
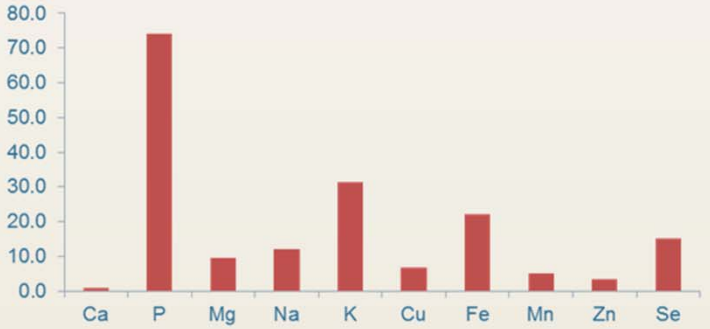
Mineral req. ←→ fishmeal replacement

System Design and realized contrast in water mineral content



	Low Accumulation	High accumulation
Water refreshment rate (L/kg feed)	1700	70
Calcium	26.5 ± 0.3	20.7 ± 2.4
Phosphorus	0.4 ± 0.1	28 ± 3.8
Magnesium	2.5 ± 0.1	23.8 ± 3.1
Sodium	6.8 ± 0.4	81.6 ± 10.3
Potassium	4.4 ± 0.6	137.7 ± 20.2
Copper	2.3 ± 0	15.7 ± 0
Iron	3.3 ± 0	73.3 ± 0
Manganese	0.3 ± 0	1.7 ± 0
Zinc	10.3 ± 0	36.3 ± 0
Selenium	0.1 ± 0	1.1 ± 0.2

Mineral concentration of high accumulation system as a relative proportion to low accumulation system



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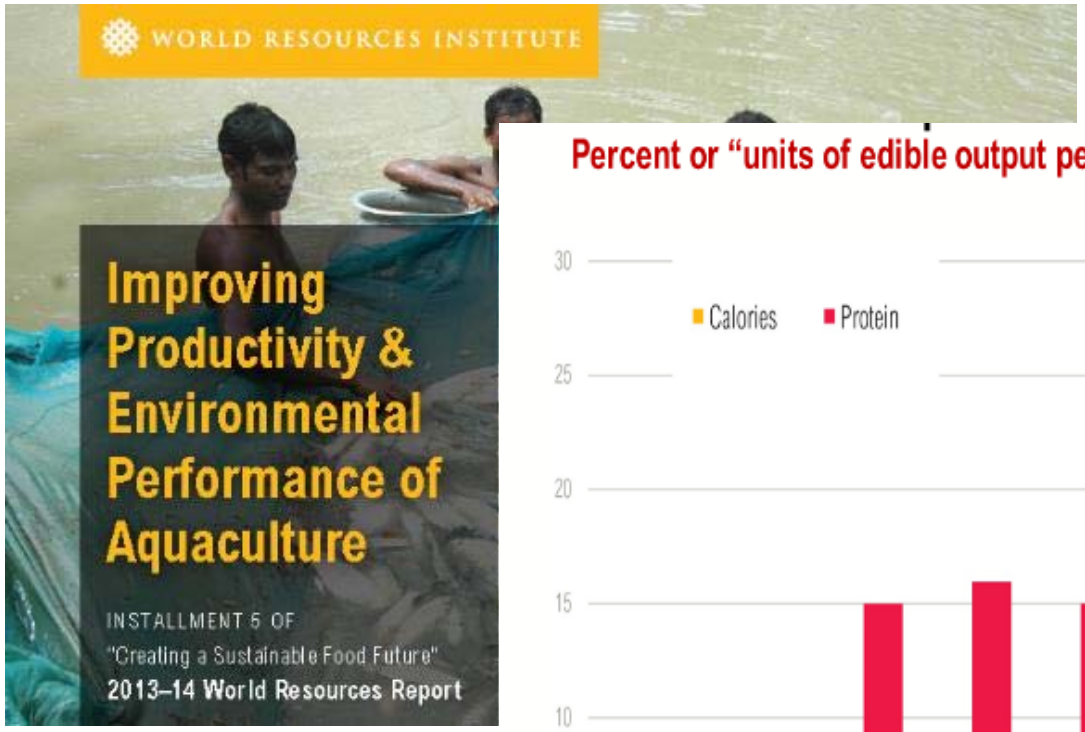
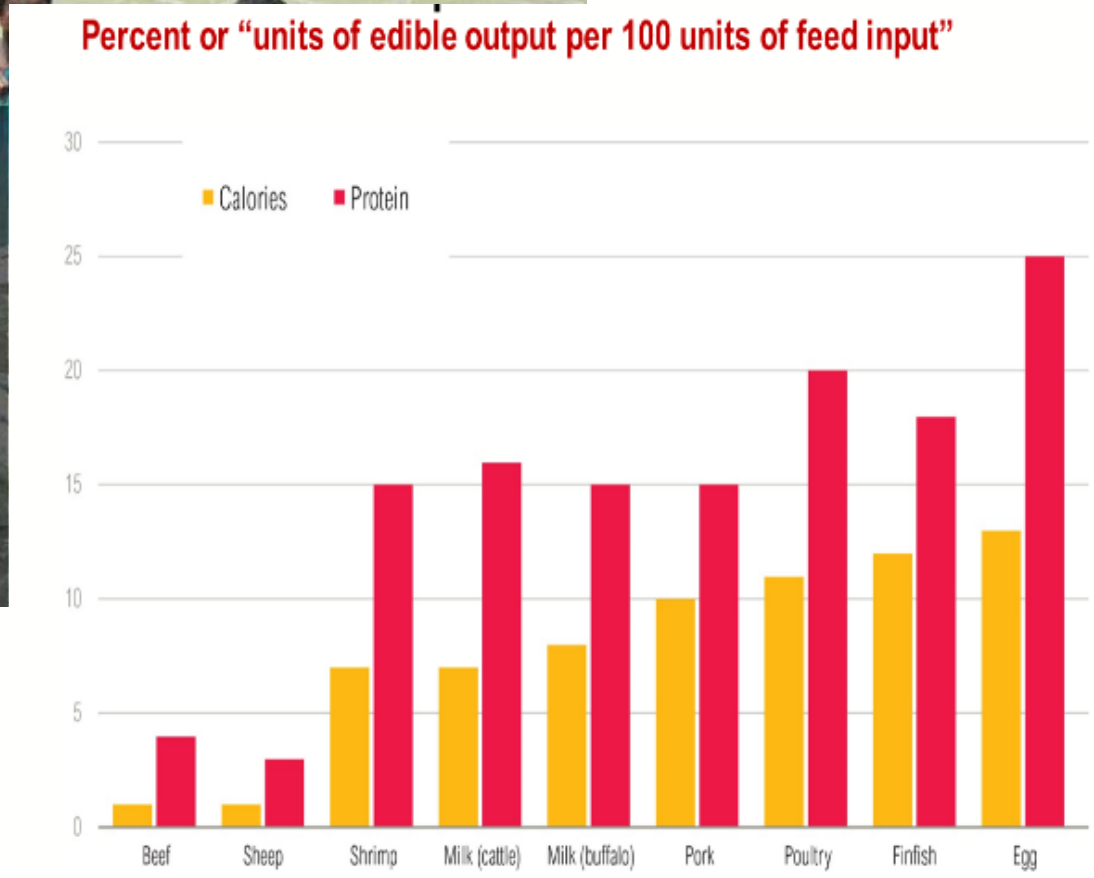
Minimizing waste production

Farmed fish → efficient convertors of feed protein/energy



WRI, 2014



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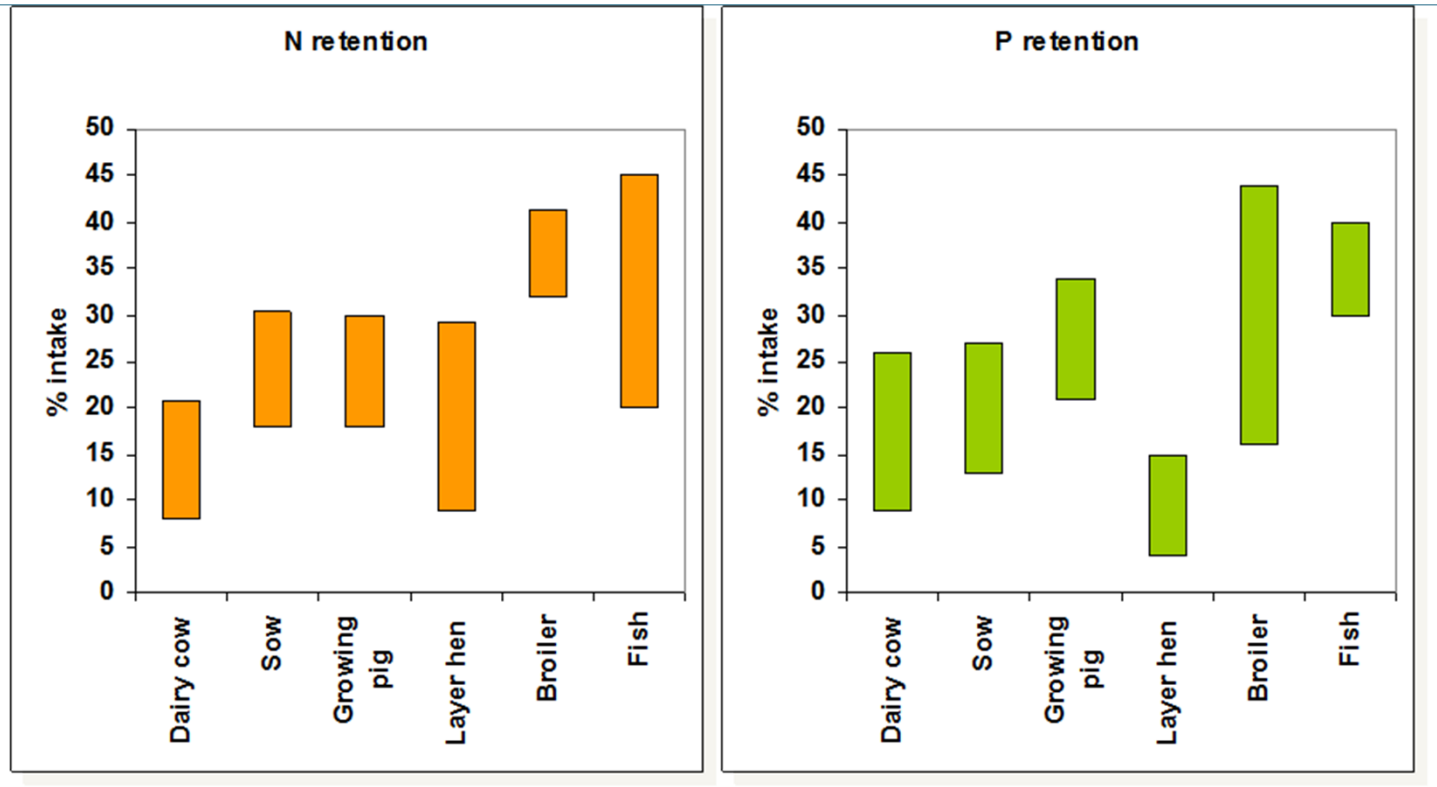
Minimizing waste production

N & P retention in different farmed animals



WRI, 2014

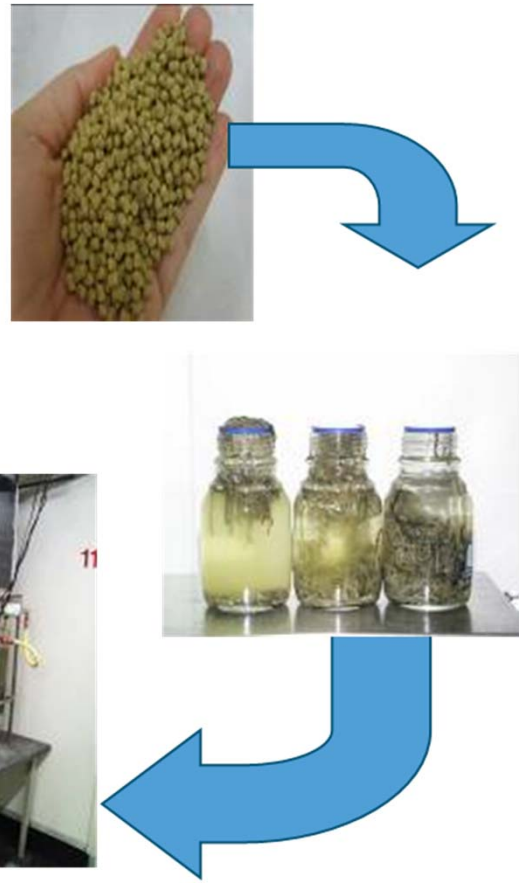
For fish

There is much room for improvement

Minimizing waste production

Fish nutrition ←→ faecal waste production (in RAS)

- Feeding level → amount of faeces (waste)
- Digestibility diet → amount of faeces (waste)
- Composition faeces → system performance
- Physical properties faeces (stability) → removal efficiency

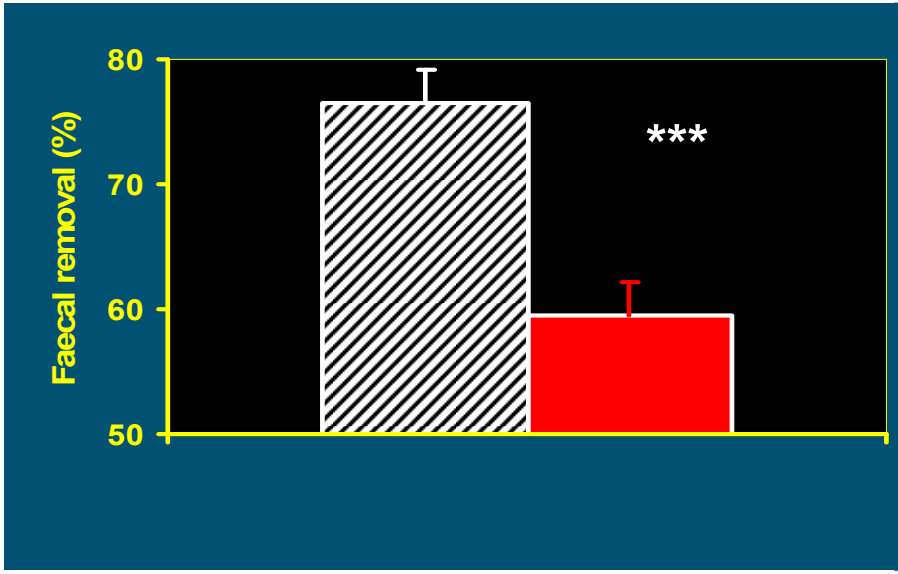


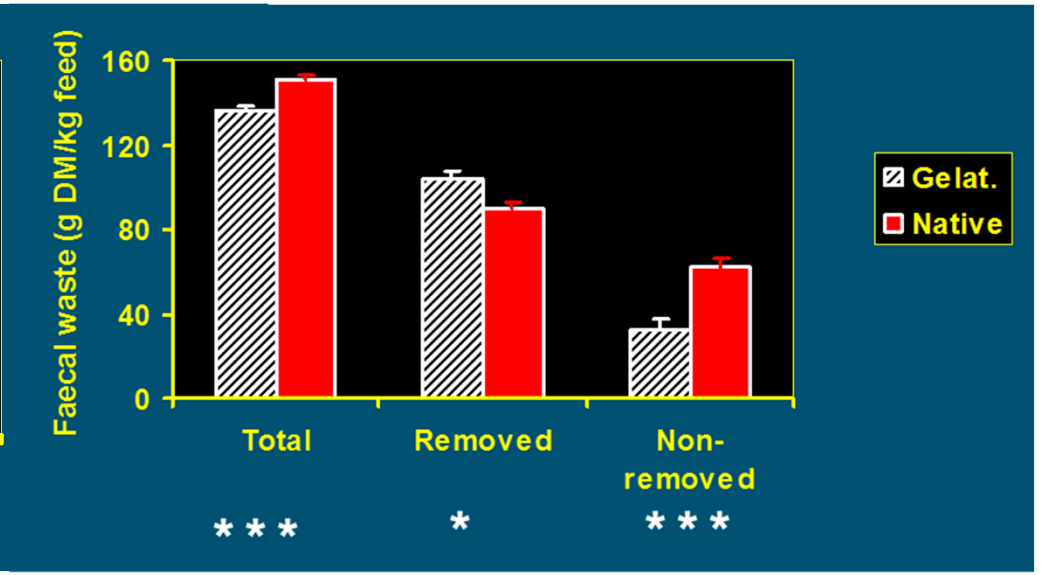
Minimizing waste production

Phd: Amirkolaie A.K. 2005. Dietary carbohydrate and faecal waste in the Nile Tilapia (*Oreochromis niloticus* L.)

Aim thesis: Does feed composition affect faeces stability?

Minimizing waste production





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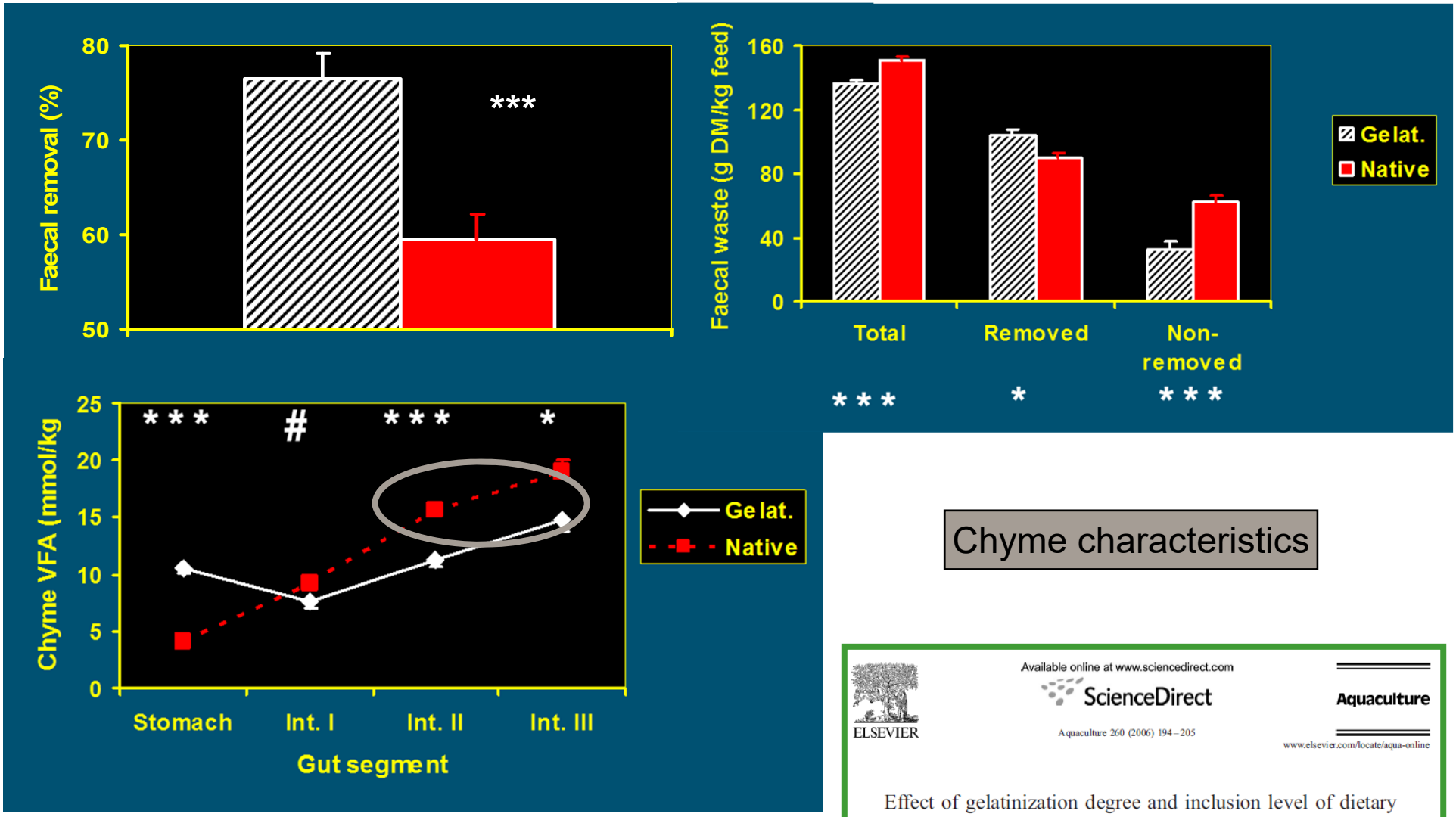
Minimizing waste production



Chyme characteristics

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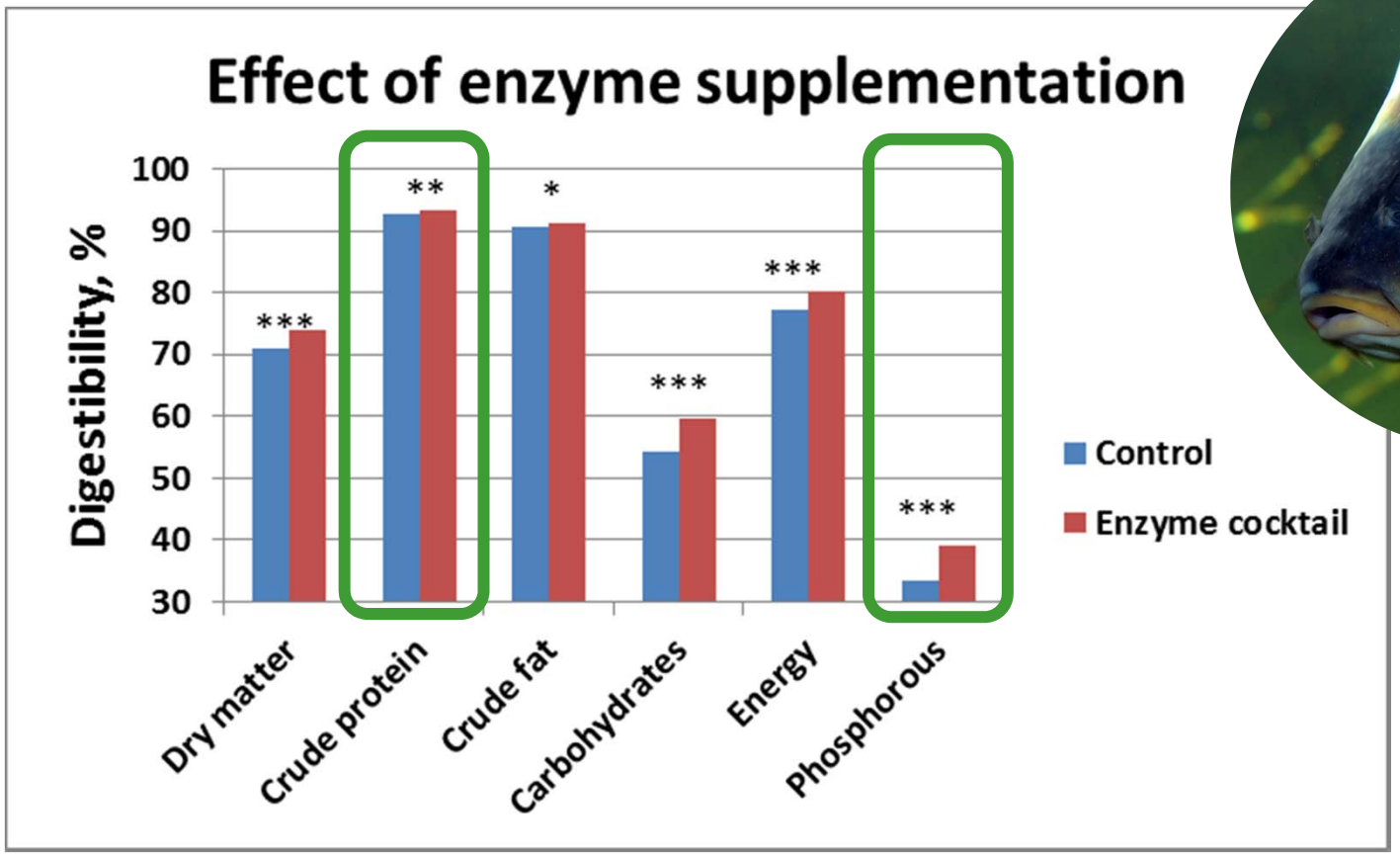
Minimizing waste production

ARRAINA
Advanced Research Initiatives for Nutrition & Aquaculture



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Minimizing waste production

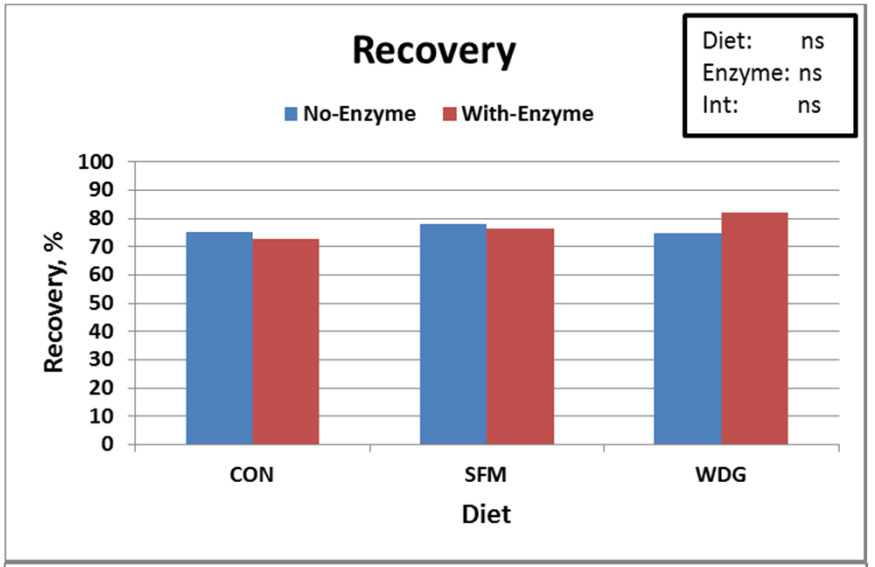
- **Recovery (stability)**

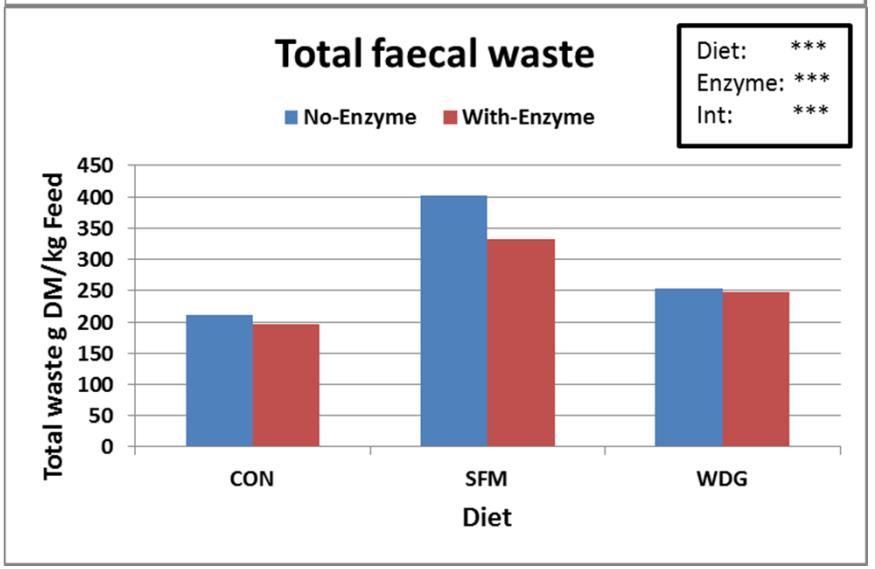
  not affected (73←→82%)

- **Total faecal waste amount:**

  enzyme effect diet dependent

  SFM diet 17% less faeces





Content presentation

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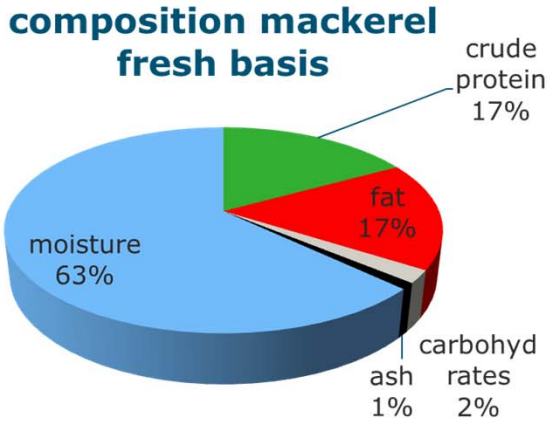
Do fish drink? Chyme conditions & digestion

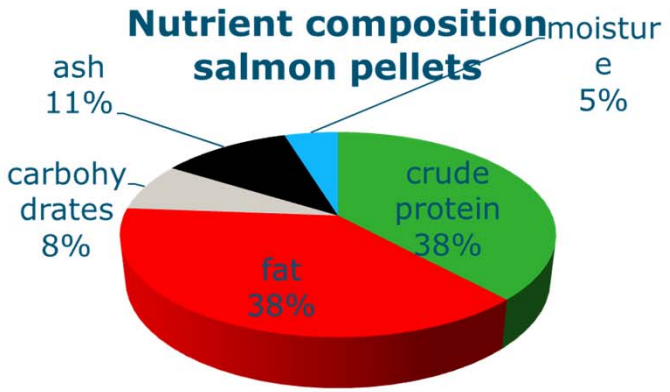
- Drinking...

?

Do fish “drink” water?

Do fish drink? Chyme conditions & digestion





Moisture content

Do fish drink? Chyme conditions & digestion

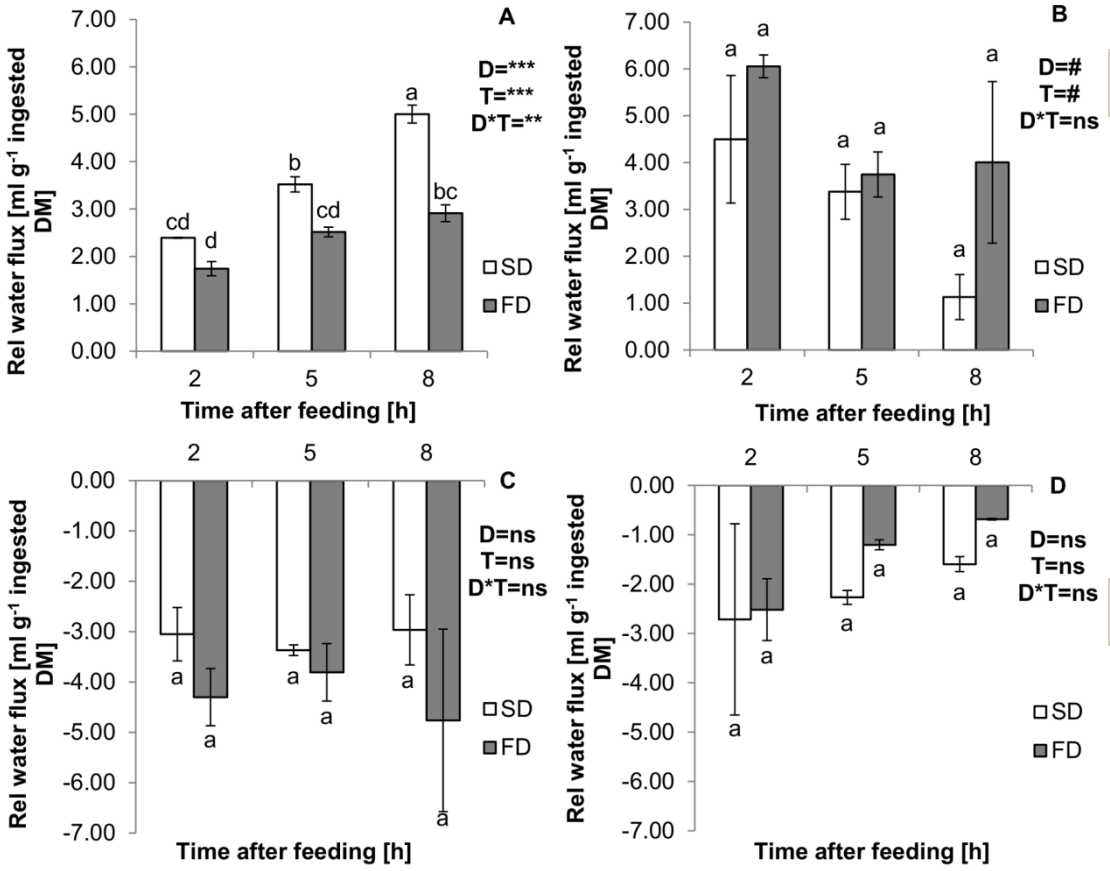
Water flux in the intestine with time after feeding

stomach

Prox. intestine

Mid intestine

Distal intestine



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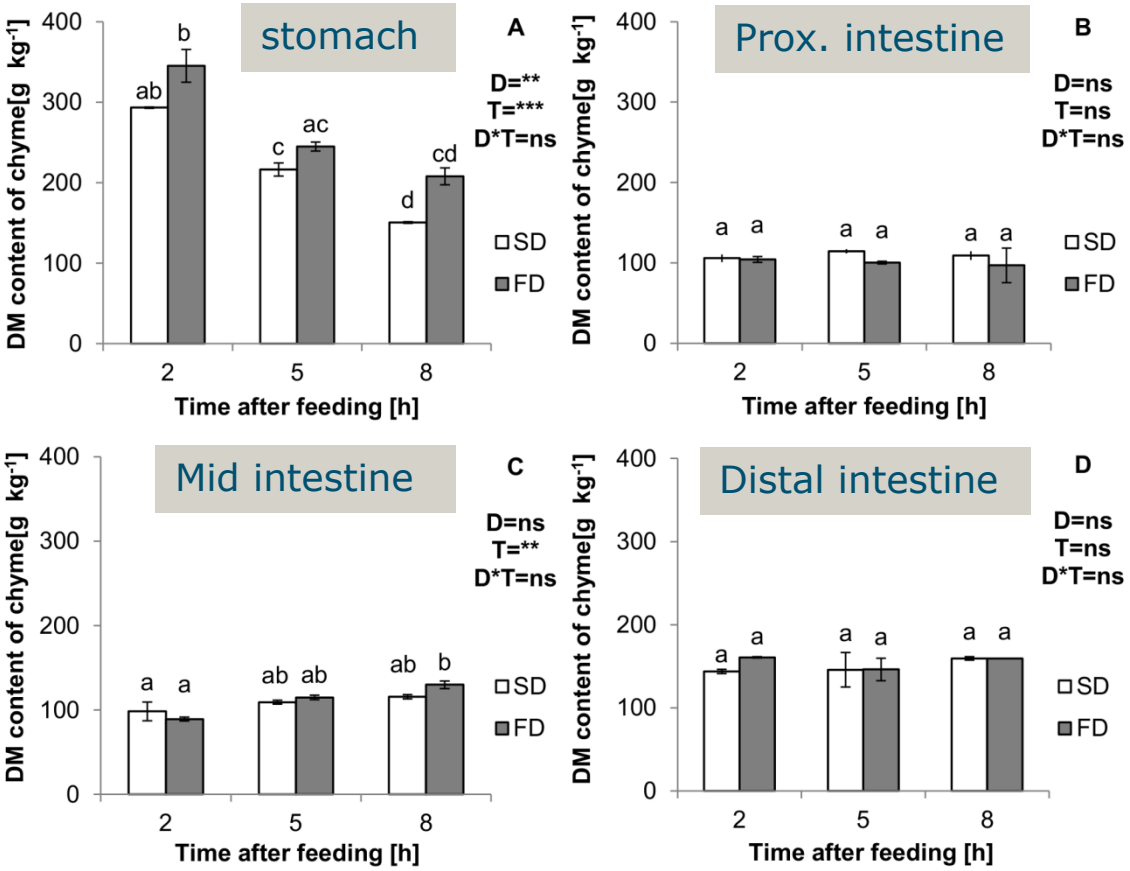
Do fish drink? Chyme conditions & digestion

Dry matter content digesta with time after feeding



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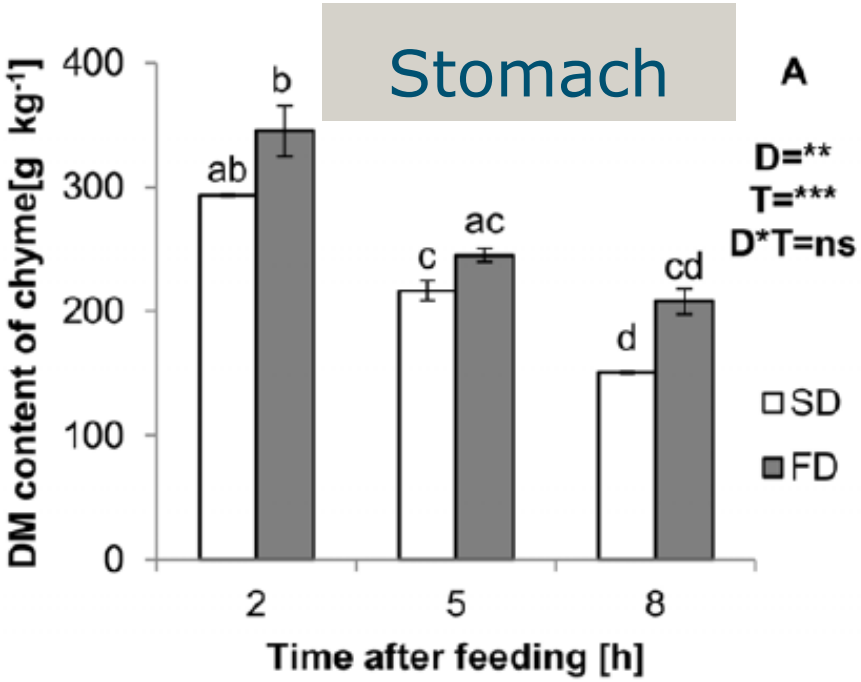
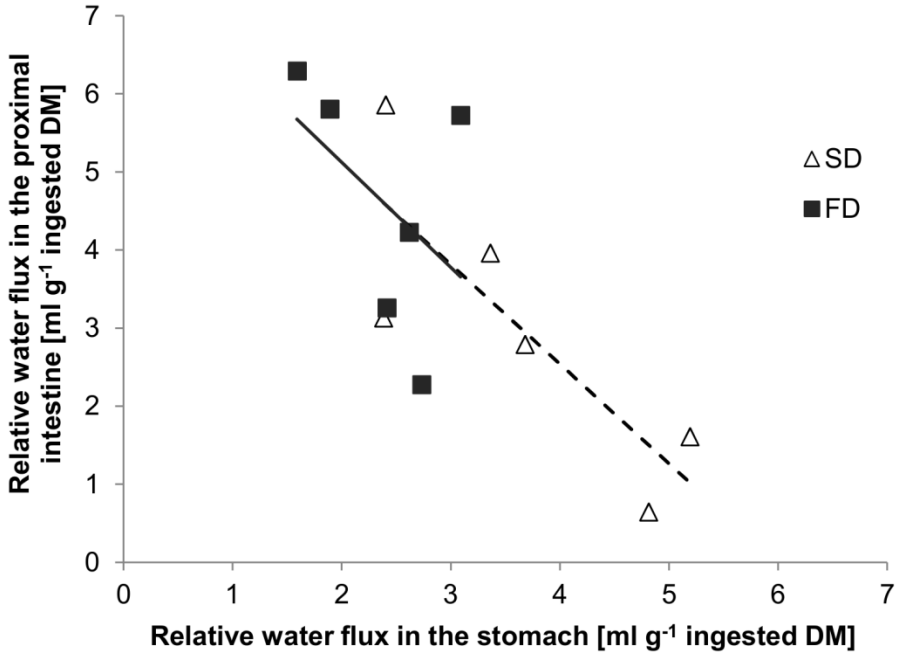
Do fish drink? Chyme conditions & digestion

Water balance, water flux :

If low in stomach → high in proximal part intestine





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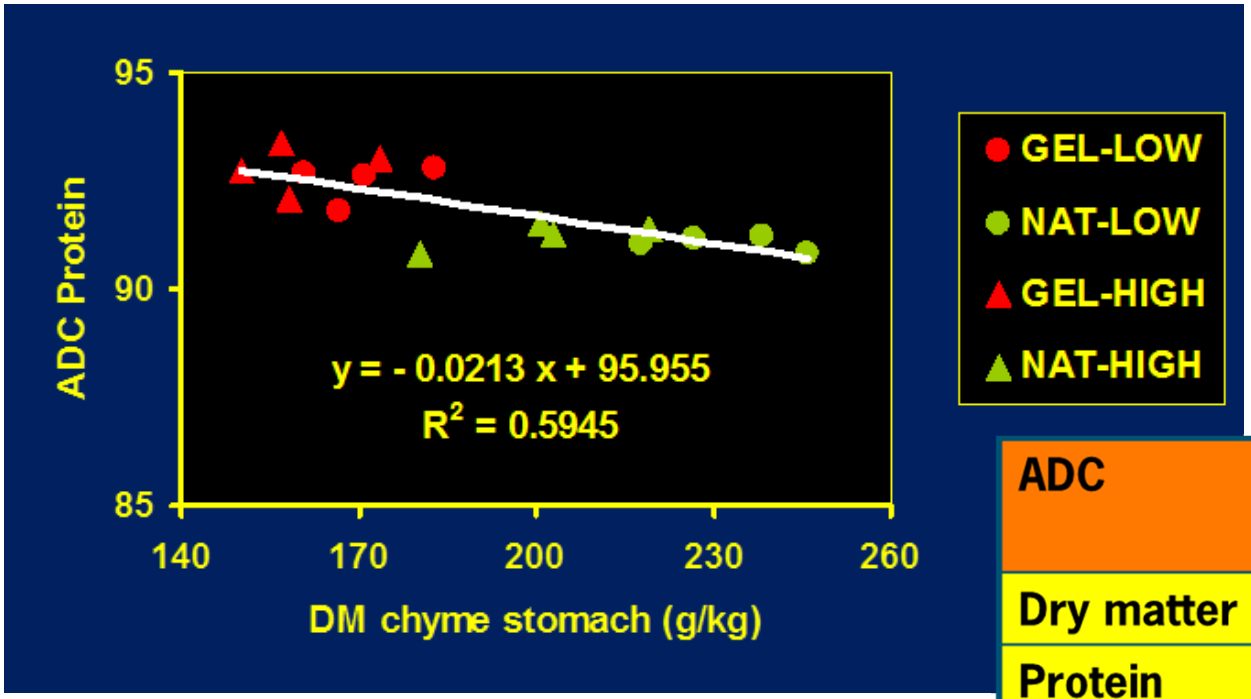

ADC	Chyme DM Stomach	Chyme DM Intestine I
Dry matter	-0.74***	-0.79***
Protein	-0.77***	-0.64**
Fat	-0.80***	-0.88***
Starch	-0.86***	-0.61*
Ash	0.57*	0.42ns

- Correlations between ADC and chyme DM content
- Current research topic: nutrition ←→ gut physiology


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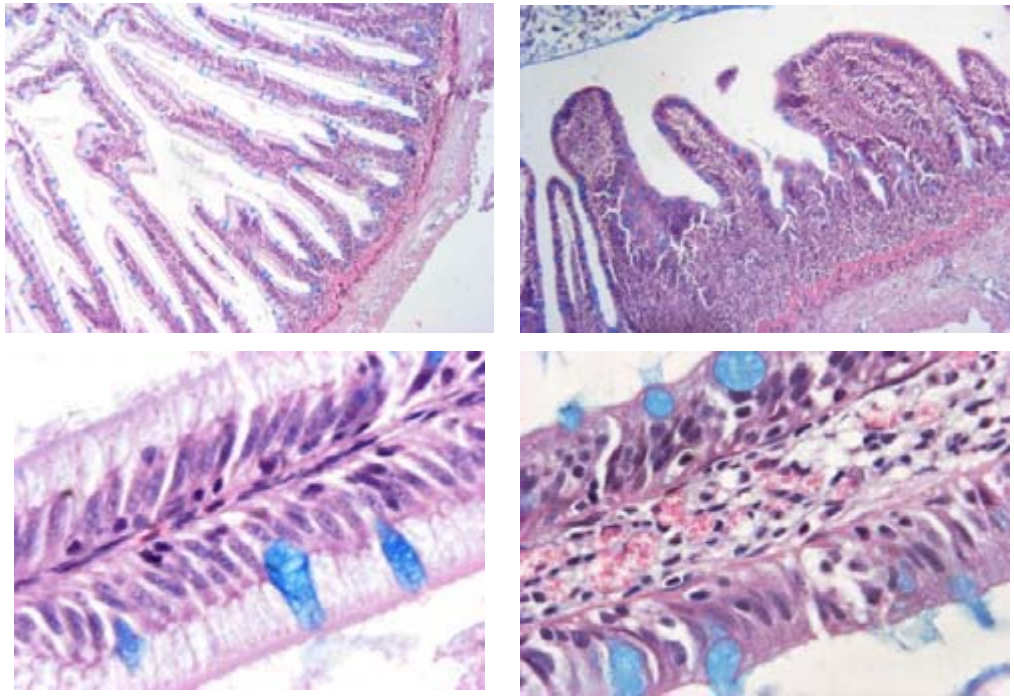
Enteritis in Salmonids and other fish

Soy bean meal induced enterites in salmonids



Fishmeal diet

20% Soybean meal diet

Location 2nd gut segment:

- Mucosal folds
- Sub-epithelail mucosa
- Lamina propria → wider
- Eosinophilic granulocytes
- Supranuclear vacuoles

Cause → still not clear

- Saponine?
- .....

Uran, 2008

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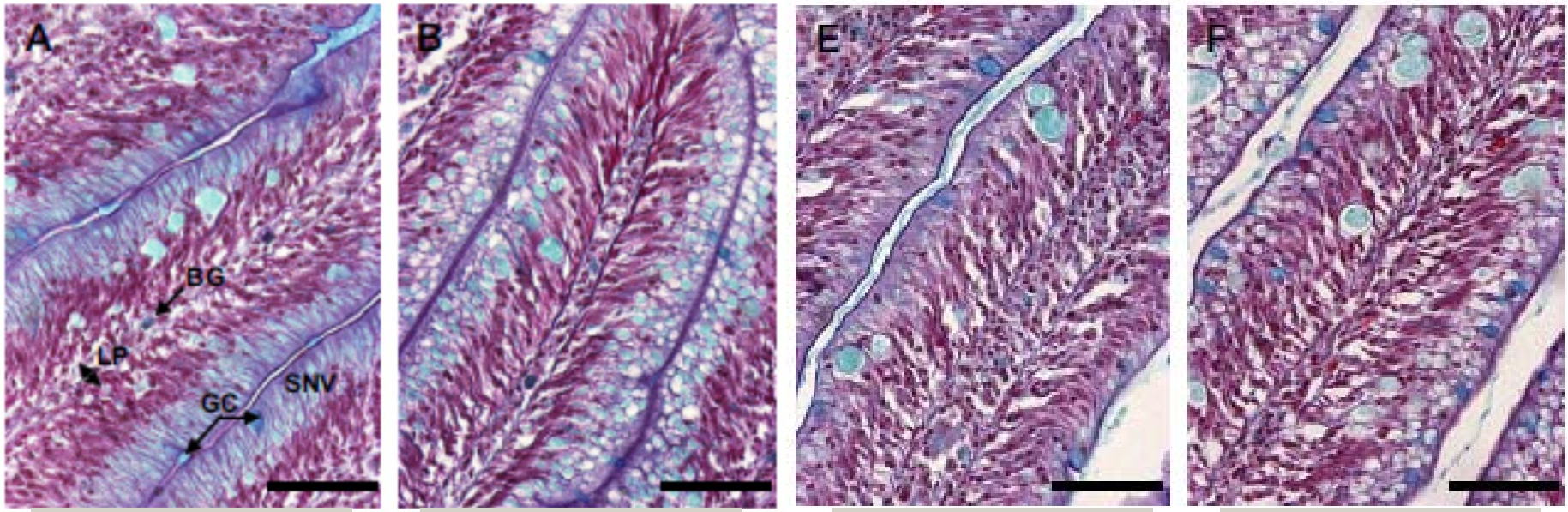
Enteritis in Salmonids and other fish

Soybean meal induced enterites in other fish?



Week 0 | Week 1 | Week 4 | Week 5

Also in carp:

- Naive carp → fed SBM
  → enterites distal intestine

But in carp:

- Disappears with time

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Uran et al. (2008)

Thank you

Johan.Schrama@wur.nl

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