"Marine Ingredients and their Continuing Importance in Aquafeeds"

Aquaculture UK 2017
University of Stirling

Dr Neil Auchterlonie, IFFO The Marine Ingredients Organisation

June 14th 2017

Fishmeal & Fish Oil in the Media…..!

Global Aquaculture Alliance

SeafoodSource

Algae-based aquafeed firms breaking down barriers for fish-free feeds

By Cliff White
Published on April 6, 2017

The future of aquaculture lies in fish-free feeds – and it isn't far away.

THE TIMES

Fish oil made from GM plant to be saviour of the oceans

Crop trial is a triumph

ScienceNordic

Health | Society & Culture | Environment | Technology | Agriculture & Fisheries | Natural Scie

Farmed fish don't need to eat fish

December 28, 2011 - 08:00

Article from Nofima The Norwegian Institute of Food, Fisheries and Aquaculture Research

Fish has traditionally been an important ingredient of feed in aquaculture, now new research shows how farmed rainbow trout can eat feed completely free of fishmeal, while growing fast in good health.

Keywords: Aquaculture, Marine research

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Dartmouth Team Makes Breakthrough Toward Fish-Free Aquaculture Feed

June 2, 2016 — Dartmouth College scientists have discovered that marine microalgae can completely replace the wild fish oil currently used to feed tilapia, the second most farmed fish in the world and the most widely farmed in the United States.

Feed Sustainability

Friday, 15 April 2016 • By Steven Summerfelt, Ph.D., Travis May, Curtis Crouse, M.S., John Davidson, M.S., Rick Barrows, Ph.D., Jason Mann, M.Sc. and Christopher Good, Ph.D., D.V.M.

Fishmeal-free Atlantic salmon feed formulation shows promise

Joint research between TCFFI, USDA and EWOS uses new diet for post-smolt to food-size fish Freshwater Institute's Atlantic salmon in ice on the way to processing. Photo by K. Sharrer. The objective of this project was to evaluate the effects of a fishmeal-free diet on Atlantic salmon post-smolt performance and fillet quality during growout to market-size in a commercial-scale,...

Feed navigator.com

Alltech focused on algae derived DHA for fish feed

By Aerin Einstein-Curtis
24-May-2016
Last updated on 24-May-2016 at 12:41 GMT

fishfarmingexpert.com

An appetite for insects

The prospects of including insect-derived material in aquafeeds has been greeted positively by the three largest salmon feed producers in the world.

Author: Magnus Petersen

Old articles

Salmon feeds that contain no wild-caught fishmeal will shortly be available to Australian farmers.

Fishmeal-free feed in the pipeline

Rob Fletcher

The news comes the commercial launch of a prawn feed – Perform Plus NoCatch – by Ridley Aquafeed, which contains no wild-caught fish.

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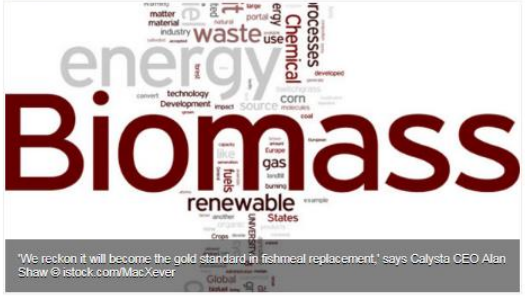
News, Events & Publications > News > Fishmeal-free breakthrough for Skretting

Fishmeal-free breakthrough for Skretting

4 May 2016

Calysta says gas to fishmeal replacement protein on path to commercialization

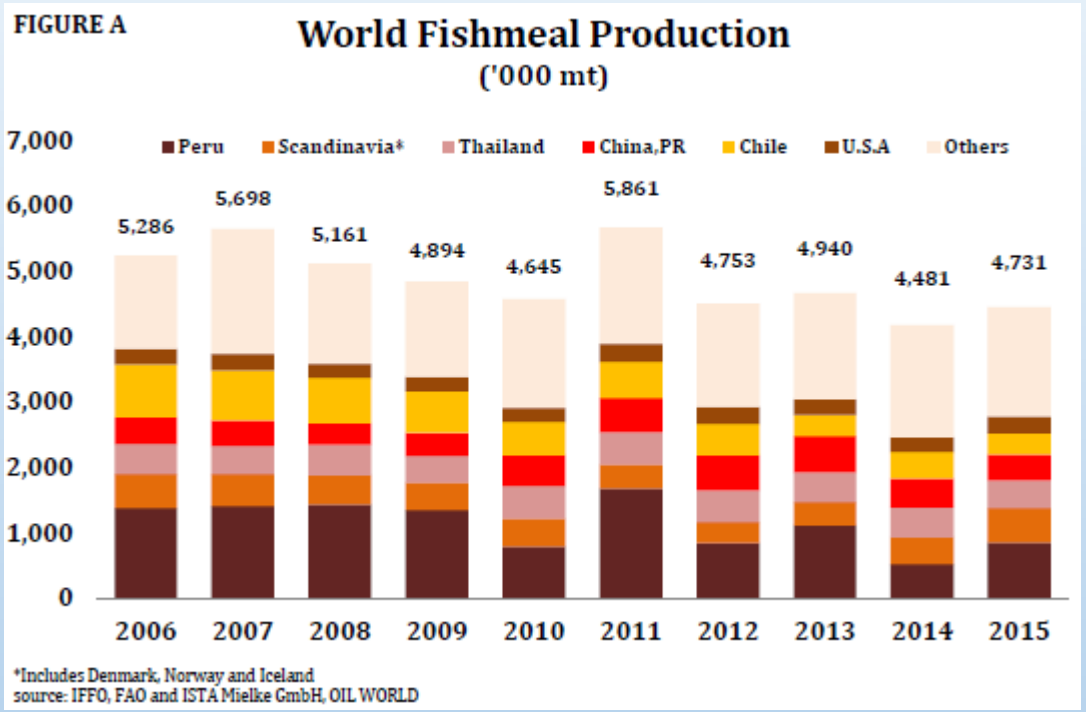
By Jane Byrne
14-Jan-2016
Last updated on 18-Jan-2016 at 09:17 GMT



"We reckon it will become the gold standard in fishmeal replacement," says Calysta CEO Alan Shaw © istock.com/MacXever

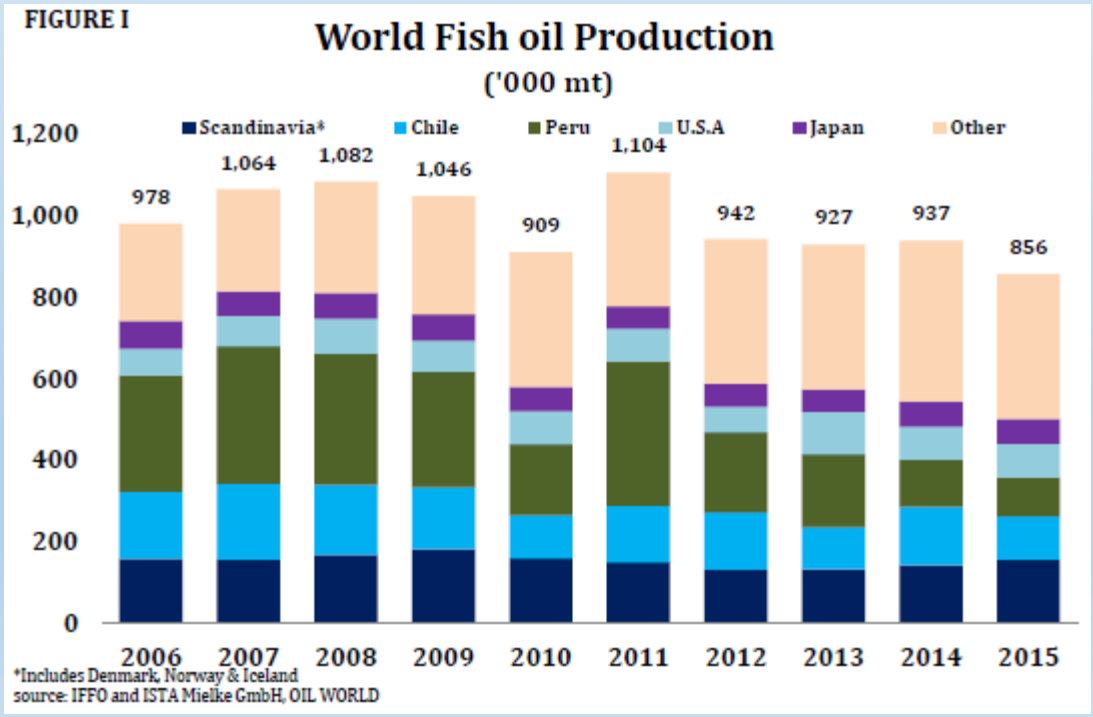
So…. What’s the real story?

Production

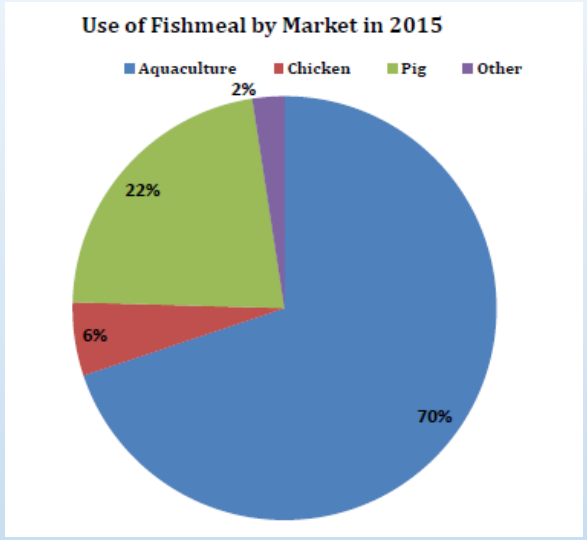


Fishmeal = c.5 million tonnes *per annum*

Fish Oil = c.1 million tonnes *per annum*



Markets



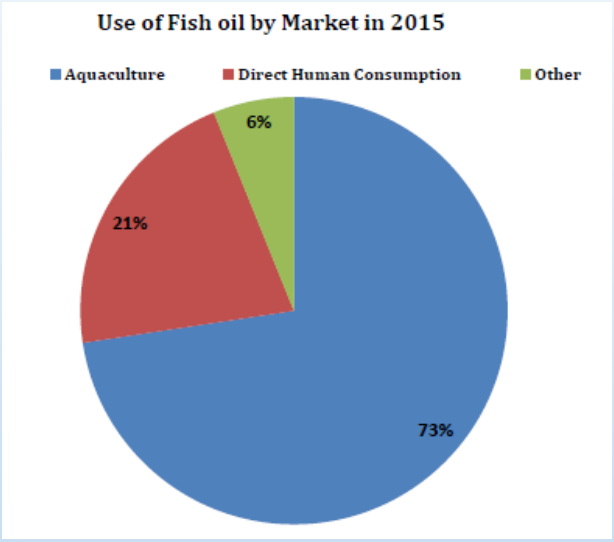


FIGURE Q

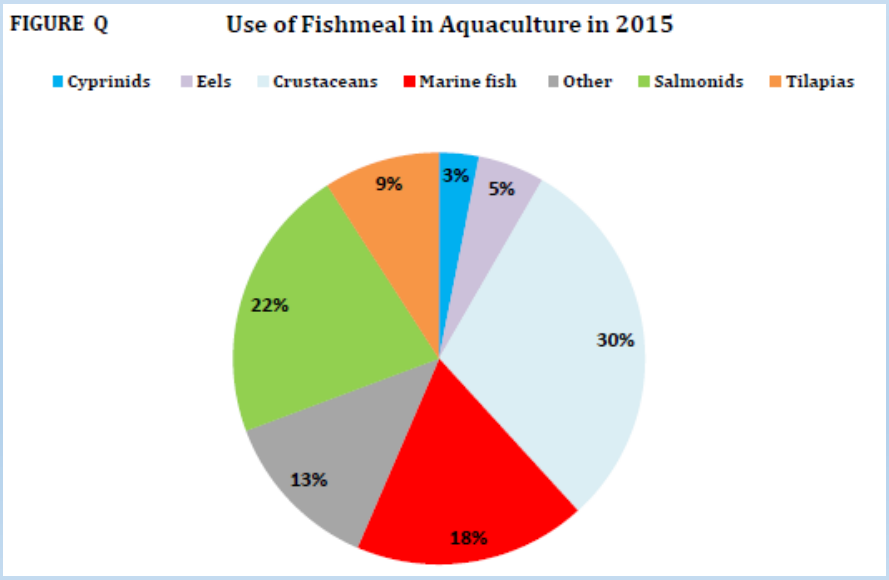
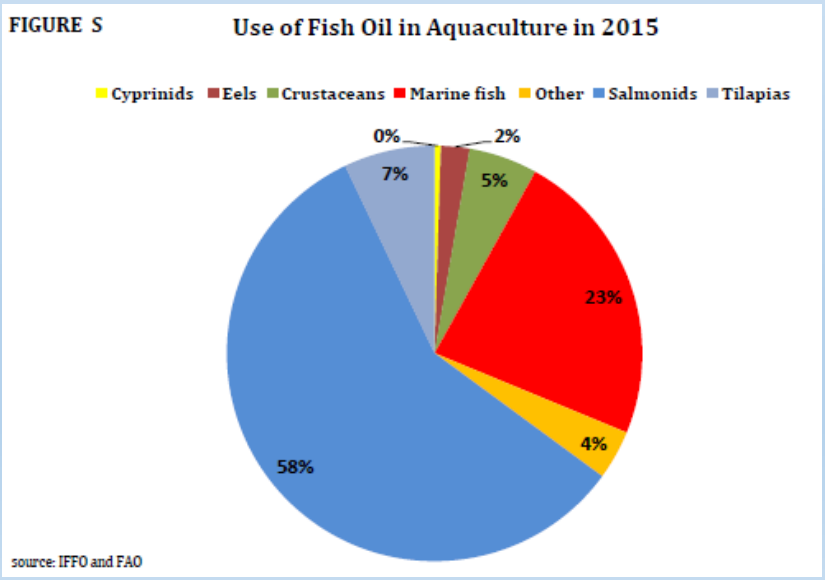


FIGURE S

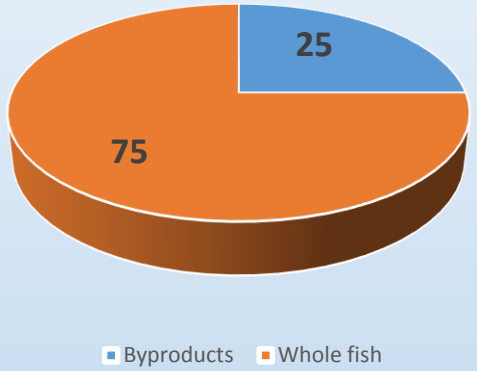


Process:

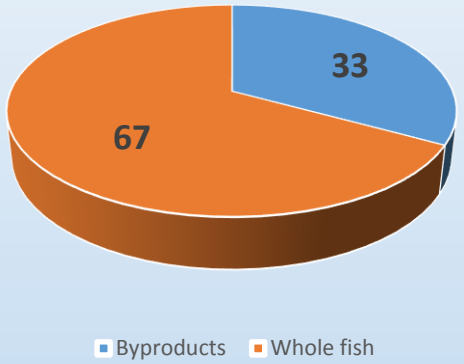
Mass Balance Marine Ingredients production (2010)

Raw material

Estimated by Shepherd, 2012



Calculated by Newton, 2016



Predicted by FAO for 2025 (2016)

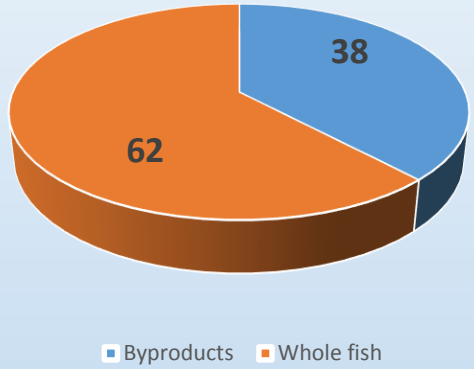


TABLE 2
FISHMEAL PRODUCTION (TONNES ,000)

Region	From Whole fish	From By-product	Total	% from By Product
Europe	320	381	701	54
Asia (exc China)	580	454	1,034	44
China	281	152	433	35
M East	42	13	55	23
CIS	57	27	84	32
Africa	146	60	206	29
S. America	1,532	289	1,821	16
N. America	170	118	288	41
Oceania	2	14	16	85
Totals	3,131	1,508	4,639	33

UNIVERSITY OF STIRLING

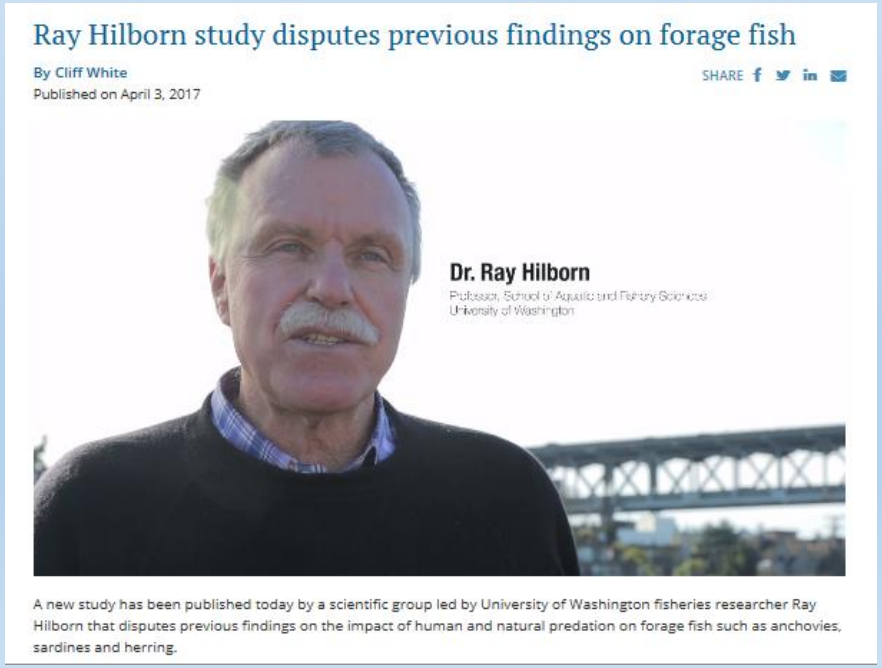
Project to model the use of fisheries by-products in the production of marine ingredients with special reference to omega-3 fatty acids EPA and DHA, Jackson A and Newton RW, IFFO and University of Stirling, July 2016

FAO (2016) “non-official estimates for FM production from byproduct are 25-35%”

Whole fish raw material sources:

INDUSTRIAL GRADE FORAGE	Landings tonnes
Gulf menhaden (*Brevoortia patronus)*	479,000
Atlantic menhaden *(Brevoortia tyrannus)*	212,000
Sand-eel (*Ammodytes spp.)*	486,500
Total 1,175,000 tonnes of which 100% converted	
FOOD GRADE FORAGE	
Peruvian anchovy (*Engraulis ringens*)	8,468,000
Japanese anchovy *(Engraulis japonicus*)	1,567,000
South African anchovy (*Engraulis encrasicolus*)	228,000
Sprat *(Sprattus sprattus)*	262,000
Blue whiting *(*Micromesistius poutassou)	678,500
Capelin *(Mallotus villosus*)	958,500
Total 12,162,000 tonnes of which an estimated 90% was converted	
PRIME FOOD FISH	
Atlantic herring (*Clupea harengus)*	656,500
European sardine *(Sardina pilchardus)*	639,000
Chilean jack mackerel (*Trachurus murphyii*)	1,870,000
Japanese jack mackerel *(Trachurus japonicas)*	320,000
Chub mackerel *(Scomber japonicus)*	1,403,500
Californian sardine (*Sardina sagax caerulea*)	556,000
South African sardine (*Sardina sagax)*	263,000
Total 5,708,000 tonnes (average landings 2001 – 2006) of which an unknown percentage was converted	

after Wijkström, 2011



Marine ingredients are the foundation for modern fed aquaculture

- Fishmeal and fish oil feeds met farmed species nutritional needs in the early, developing industry
- Allowed development of technology in other areas, e.g. systems, farmed fish health, and therefore supported overall industry development
- Constraints in supply appeared once industry had reached sufficient scale
- Partial substitution in feeds prompted by economics (not sustainability) – especially for trout (profit margins)
- "***Fishmeal and fish oil are still considered the most nutritious and digestible ingredients for farmed fish feeds***" (FAO, 2016)

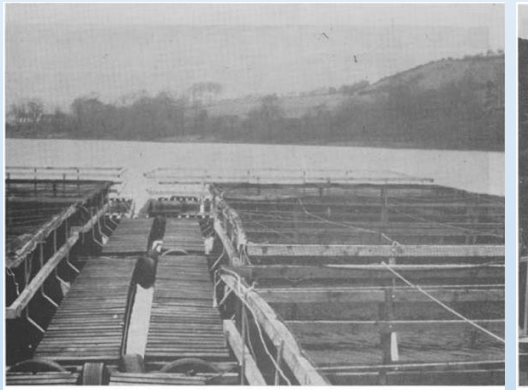


Fig. 25 Square timber-framed floating cages

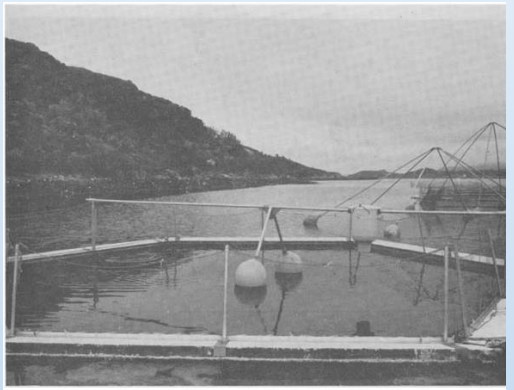
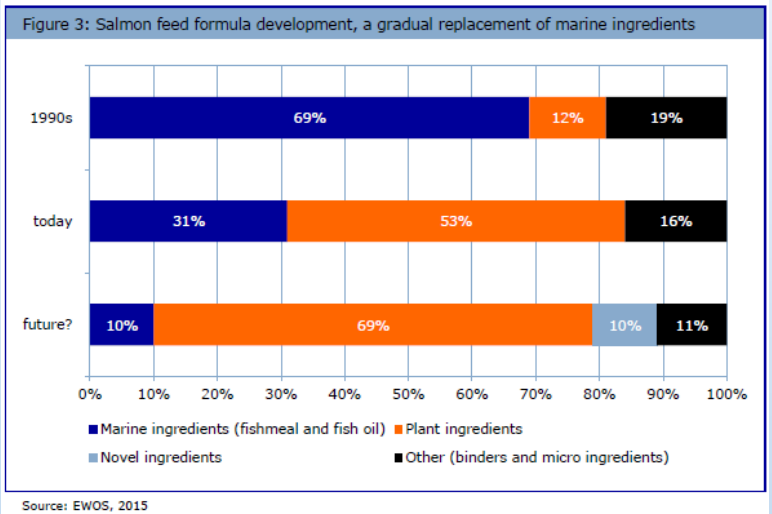
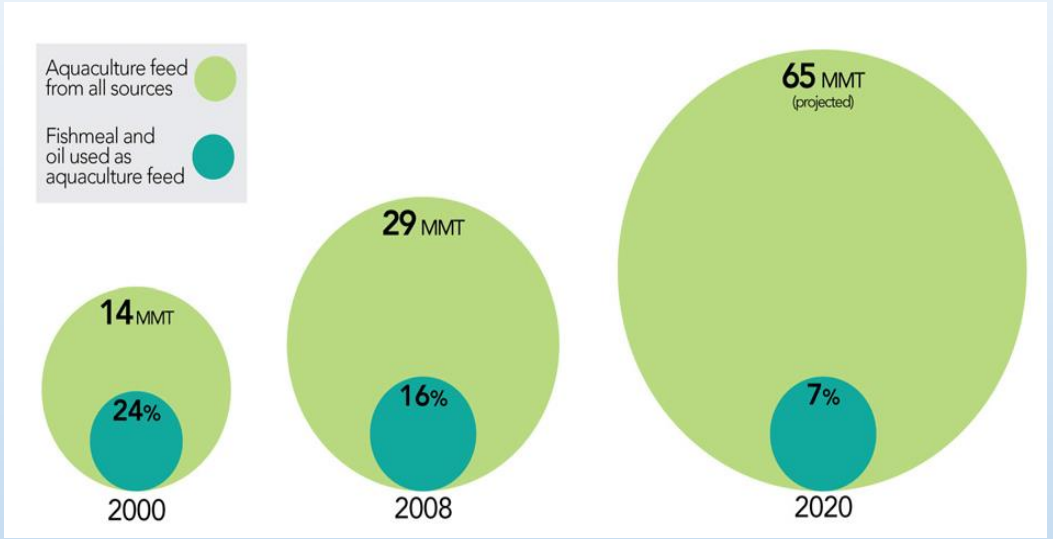


Fig. 27 Six-sided floating cages

Source, FAO:
http://www.fao.org/docrep/field/003/T5817E/T5817E01.htm

Aquaculture continues to grow, resulting in lower inclusion rates (supply ≠ demand)…





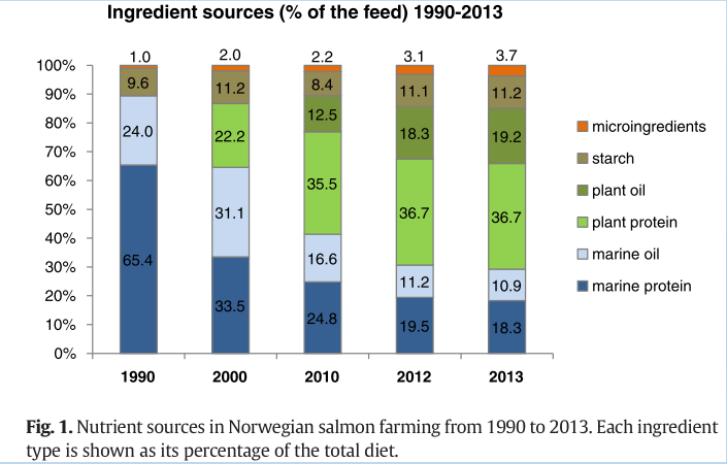


Fig. 1. Nutrient sources in Norwegian salmon farming from 1990 to 2013. Each ingredient type is shown as its percentage of the total diet.

Ytrestoyl, et al. (2015) Aquaculture 448 365–374
http://dx.doi.org/10.1016/j.aquaculture.2015.06.023

1990
- **Fishmeal – 63.8%**
- **Fishoil 23.4%**

2000
- **Fishmeal – 37.5%**
- **Fishoil – 30.7%**

2010
- **Fishmeal – 25.6%**
- **Fishoil – 17%**

Source: Fry, J.P. et al., 2016. Environmental health impacts of feeding crops to farmed fish. *Environment International*, 91, pp.201–214. Available at: http://dx.doi.org/10.1016/j.envint.2016.02.022

Reduction in inclusion rates driven mostly by price, not by sustainability concerns/certification……

Nutritional importance:

- Fishmeal
  - High in protein
  - Excellent digestibility
  - Amino acid profile (meets requirements for carnivorous fish species)
  - Micronutrients – vitamins and minerals
- Fish oil
  - Energy provision
  - LC polyunsaturated fatty acids (EPA & DHA)
- Important factors for:
  - Growth
  - Quality
  - Health

Table 3. Percentage of essential amino acids (EAA)[1] in fishmeal (FM), rendered meat meal (MM), poultry by-product meal (PBM), blood meal (BM), soybean meal (SBM). Percentage of crude protein in the meal (in parenthesis).

Essential Amino Acid	FM (64.5%)[2]	MM (55.6%)[2]	PBM (59.7%)[2]	BM (89.2%)[2]	SBM (50.0%)[2]
Arginine	3.82	3.60	4.06	3.75	3.67
Histidine	1.45	0.89	1.09	5.14	1.22
Isoleucine	2.66	1.64	2.30	0.97	2.14
Leucine	4.48	2.85	4.11	10.82	3.63
Lysine	4.72	2.93	3.06	7.45	3.08
Methionine + Cystine[3]	2.31	1.25	1.94	2.32	1.43
Phenylalanine + Tryosine[4]	4.35	2.99	3.97	8.47	4.20
Threonine	2.31	1.64	0.94	3.76	1.89
Tryptophan	0.57	0.34	0.46	1.04	0.69
Valine	2.77	2.52	2.86	7.48	2.55

[1]The percentage values for the EAA composition of each feedstuff were taken from the 1993 NRC (National Research Council, Nutrient Requirements of Fish, National Academy of Sciences, Washington, DC).
[2]Percentage of total crude protein in feedstuff.
[3]Cystine can be synthesized from methionine.
[4]Tyrosine can be synthesized from phenylalanine.

UF IFAS Extension UNIVERSITY of FLORIDA

The Benefits of Fish Meal in Aquaculture Diets

R. D. Miles and F. A. Chapman[2]

Importance of micronutrients – Minerals

- Requirements *vs.* optimal growth/health?
- Fishmeal as source of calcium, phosphorus, selenium, zinc & others

Mineral requirements of fish

Macrominerals (g/kg diet)	Microminerals (mg/kg diet) (trace elements)
Calcium	Iron
Phosphorus*	Manganese*
Sodium	Copper
Potassium*	Zinc*
Chlorine	Cobalt
Magnesium*	Selenium*
Sulfur	Iodine*
	Molybdenum

* Required in the diet, but not always supplemented in practical feeds

Extract from: Ronald W. Hardy, University of Idaho, Fish Nutrition Research Differences and similarities with livestock nutrition and what the future holds. Part I.: http://www.pitt.edu/~super4/33011-34001/33021.ppt

Importance of micronutrients – Vitamins

- Requirements *vs.* optimal growth/health?
- Different requirements for fish?
- Fishmeal as source of B-group vitamins;
- Fish oil as source of vitamin A, D.

"Unfortunately, limited research effort has been directed to characterize the pathological changes associated with disorders linked to nutrient deficiencies in fish"

Lall, S. and Lewis-McCrea, L.M. (2007) Role of nutrients in skeletal metabolism and pathology in fish – An overview. Aquaculture 267, 3-19 doi:10.1016/j.aquaculture.2007.02.053

Vitamin requirements of salmon and growing chickens (IU or mg/kg dry diet)

Vitamin	Salmon/trout	Chickens
Vitamin A	2500	1500
Vitamin D	2400	200
Vitamin E	50	16
Vitamin K	unknown	0.5
Thiamin	1	1.3
Riboflavin	7	3.6
Pyridoxine	6	3.0
Pantothenic acid	20	10
Niacin	10	11
Biotin	0.15	0.10
Folic acid	2	0.25
Vitamin B_{12}	0.01	0.003
Ascorbic acid	50	not required
Choline	800	500
myo-Inositol	300	not required

*values in yellow are lower for chickens

Extract from: Ronald W. Hardy, University of Idaho, Fish Nutrition Research Differences and similarities with livestock nutrition and what the future holds. Part I.: http://www.pitt.edu/~super4/33011-34001/33021.ppt

Marine Ingredients & Aquafeed Palatability

- Often overlooked
- Important = feed intake
- Fishmeal known to play an important role

"Poor palatability is a limiting factor for replacing fishmeal with other protein sources in aquaculture"

Journal of Ocean University of China
June 2016, Volume 15, Issue 3, pp 561–567

Palatability of water-soluble extracts of protein sources and replacement of fishmeal by a selected mixture of protein sources for juvenile turbot (*Scophthalmus maximus*)

Authors Authors and affiliations

Chun Dong, Gen He ✉, Kangsen Mai, Huihui Zhou, Wei Xu

"The feed-palatability issue may be overcome, perhaps through the inclusion of krill meal"

Wilding, T. A., Kelly, M. S. and Black, K. D. (2006) Alternative marine sources of protein and oil for aquaculture feeds: state of the art and recommendations for further research. The Crown Estate, 63 pages, December 2006. ISBN (10): 0-9553427-4-0, ISBN (13): 978-0-9553427-4-5.

Fish Nutrition - alternatives

- Protein:
  - Soybean
  - Wheat
  - Bloodmeal
  - LAPs
  - Insect
  - Algae
- Oil:
  - Canola
  - Camelina (future?)
  - Algae

Different amino acid profiles – may require supplementation to meet nutritional needs….

Table 2. Plant ingredients used in Norwegian salmon feed production in 2010 and 2013 (Nofima, 2014).

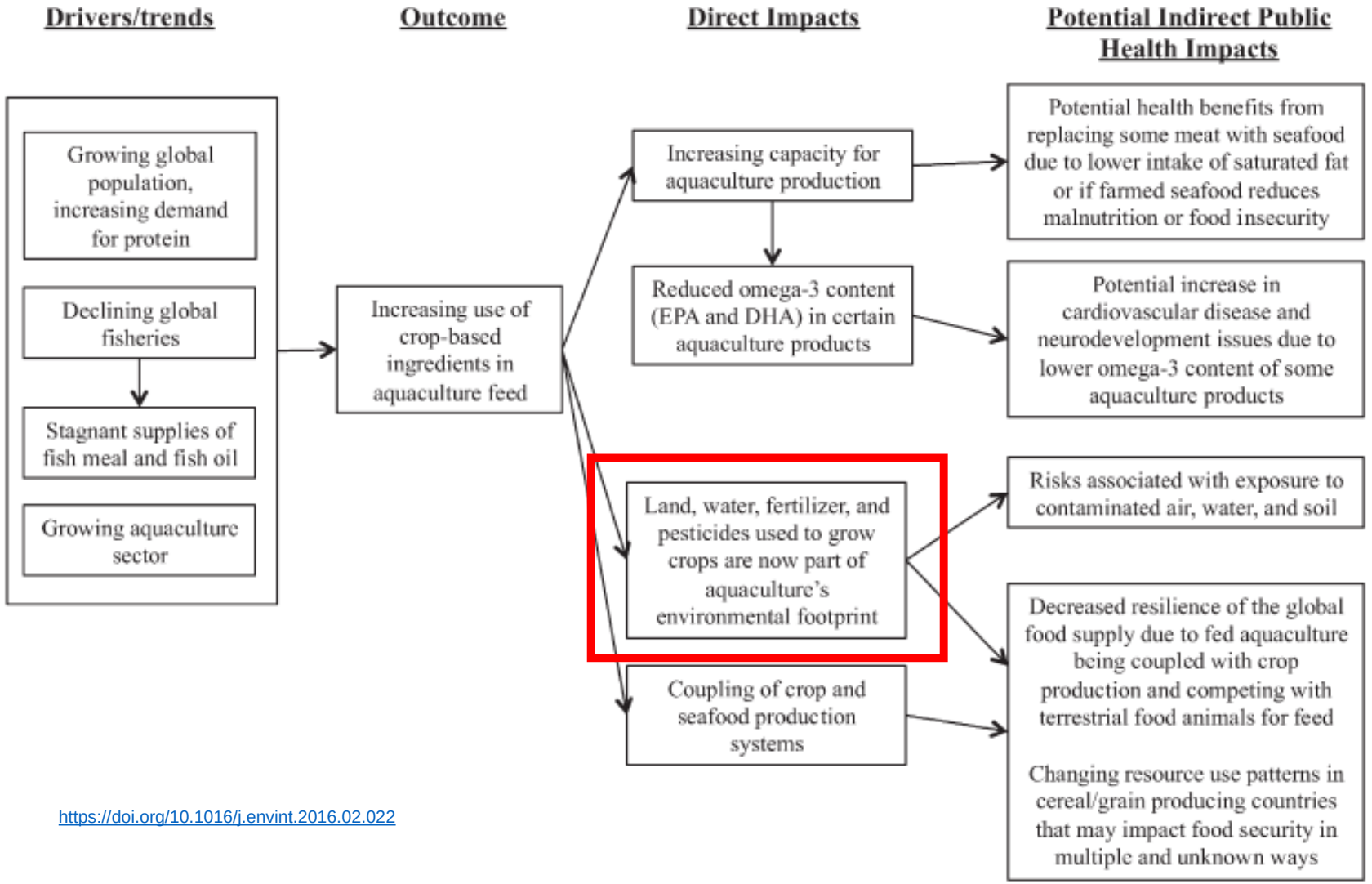
Plant ingredients (tonnes)		2012	2013
Protein sources	Soy protein concentrate	346 730	364 980
	Wheat gluten	94 137	99 348
	Sunflowermeal	97 137	65 039
	Peaprotein concentrate	12 936	7917
	Fababeans	30 753	24 971
	Dehulled horse beans	4442	
	Maize	12 509	28 640
Sum plant protein sources		*598 861*	*590 896*
Oil sources	Rapeseed oil	298 991	309 497
	Other plant oils	0	0
Sum plant oil		*298 991*	*309 497*
Binders	Wheat	161 432	158 992
	Pea	16 466	22 055
	Tapioca	3396	
Sum plant ingredients		**1 079 146**	**1 081 439**

Taken from: Shepherd C J1, Monroig O2 and Tocher D R2. 2015. **Production of high quality, healthy farmed salmon from a changing raw material base, with special reference to a sustainable Scottish industry.** A study commissioned by the Scottish Aquaculture Research Forum (SARF), http://www.sarf.org.uk/cmsassets/documents/216181-554802.sarfsp007.pdf

Table C3. Range of antinutrients present in some common plant ingredients

	Ingredient					
Antinutrient	Soybean meal	rapeseed meal	Lupin meal	Pea	Faba bean	Sunflower meal
Proteinase inhibitors	X	X	X	X	X	X
saponins	X		X	X		X
phytic acid	X	X		X		
Lectins	X			X	X	
Glucosinolates		X				
phytoestrogens	X		X			
phytosteerols	X					
antivitamins	X			X		
Alkaloids			X		X	
allergens	X					
arginase inhibitor						X
cyanogens				X		
Tannins		X		X	X	
Vicine/convicine					X	

Changing Impacts as aquaculture grows…

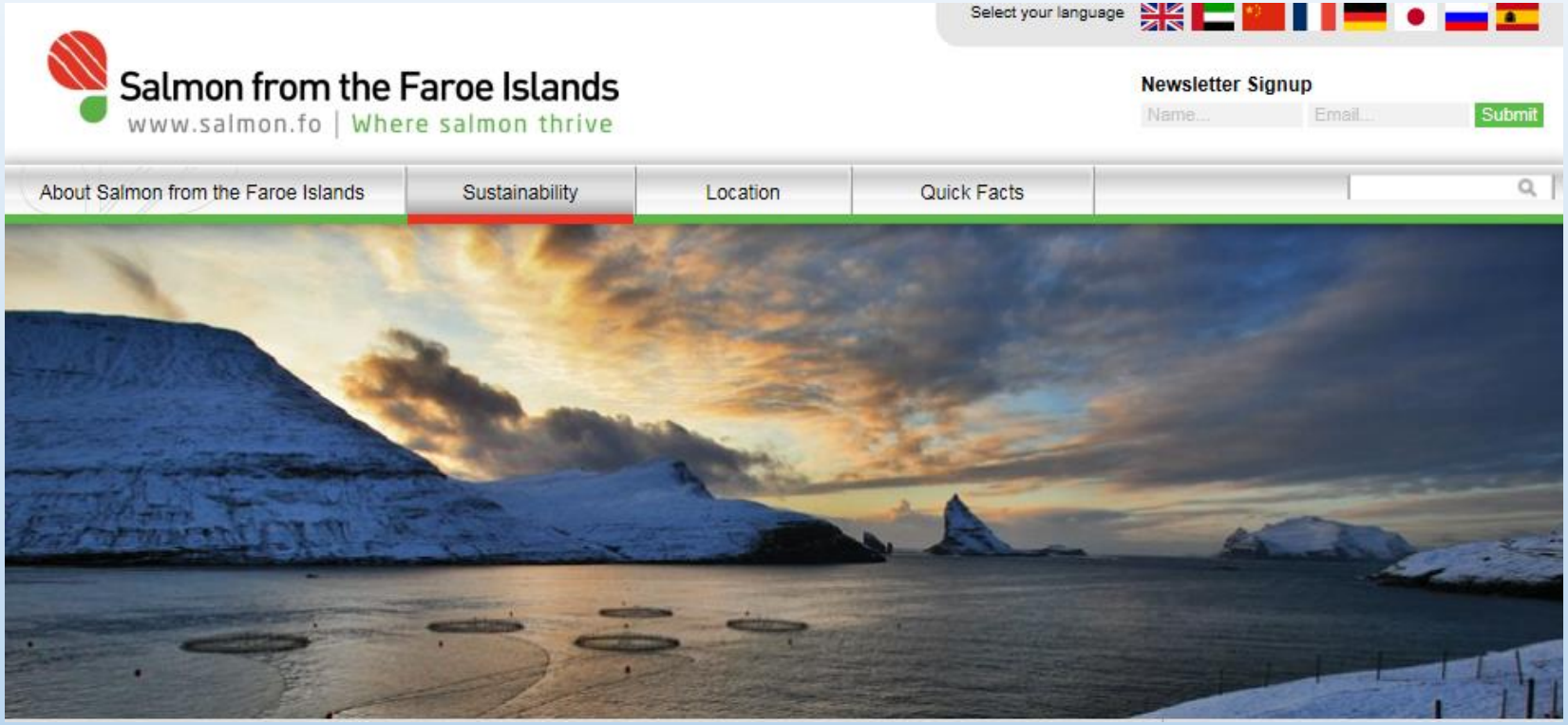


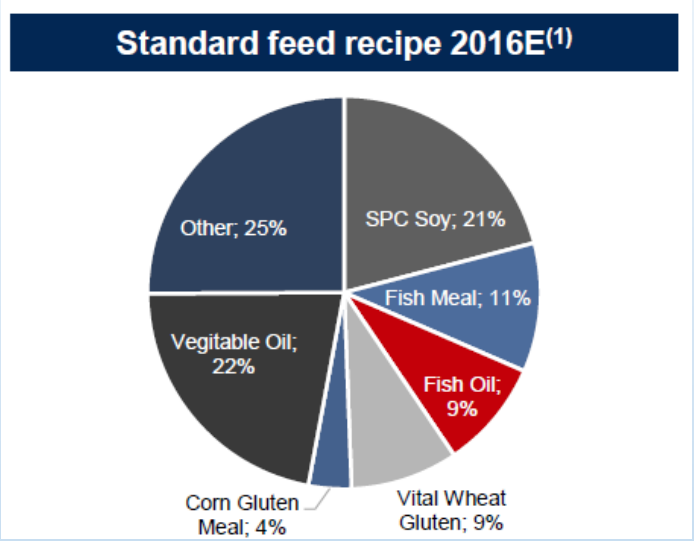
https://doi.org/10.1016/j.envint.2016.02.022

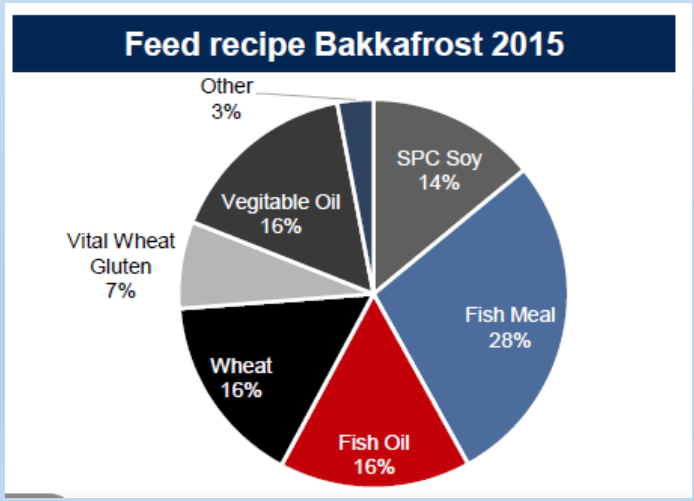
Summary Comparison: Marine vs Terrestrial Ingredients

Group	Parameter	Fishmeal	Vegetable meals	Land Animal Proteins
Market	Price	🔴	🟢	🟢
Market	Consumer acceptance	🟢	🟡	🟡
Market	Sustainability perception	🔴	🟢	🟡
Nutritional	Protein content	🟢	🟡	🟢
Nutritional	Energy content	🟢	🟡	🟢
Nutritional	Antinutritional factors	🟢	🔴	🟢
Nutritional	Digestibility	🟢	🟡	🟢
Nutritional	Micronutrients	🟢	🟡	🟡
Environmental	Water use	🟢	🟡	🟡
Environmental	Energy use	🟡	🟡	🟡
Environmental	GHG	🟢	🟡	🟡
Environmental	Fertiliser use	🟢	🔴	🔴
Environmental	Pesticide (& medicine) use	🟢	🔴	🔴
Environmental	Land use	🟢	🔴	🔴

Case study – Faroe Islands





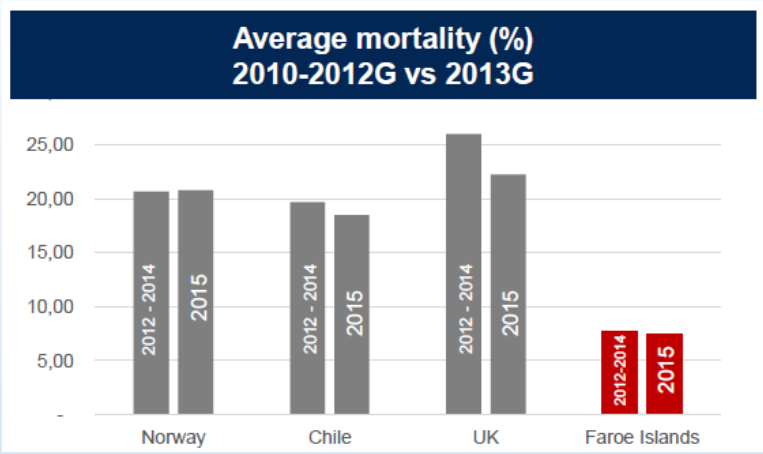


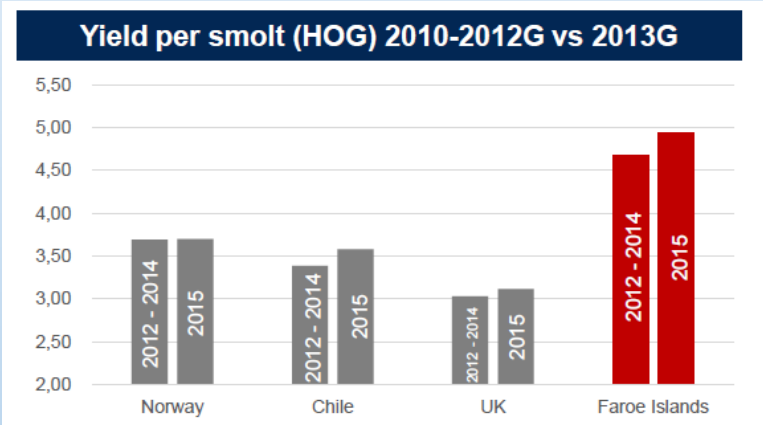
Bakkafrost data:

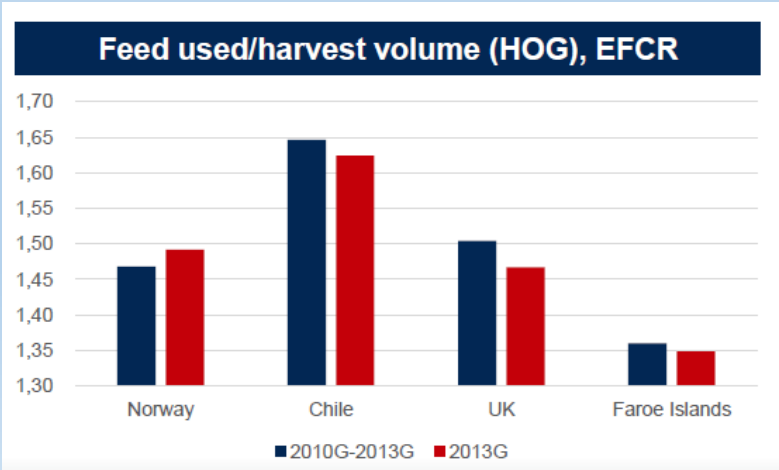
https://dsrqhvon5mja8.cloudfront.net/media/1542/bakkafrost-presentation-cmd-7-june-2016.pdf

Performance?

- Mortality rate
- Yield
- FCR





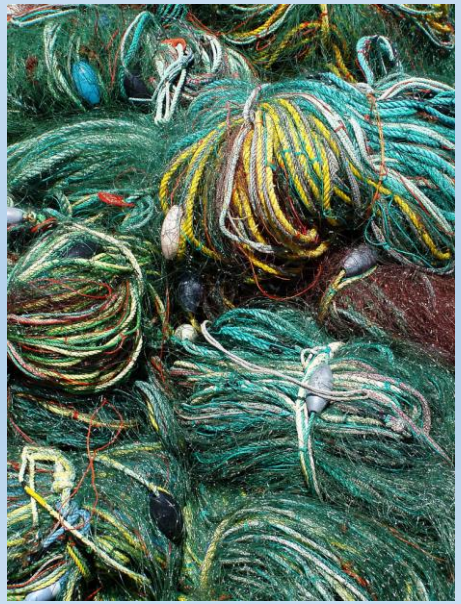


Bakkafrost data:

https://dsrqhvon5mja8.cloudfront.net/media/1542/bakkafrost-presentation-cmd-7-june-2016.pdf

Summary

- Marine ingredients are the foundation for modern fed aquaculture;
- Marine ingredients have nutritional benefits;
- Those benefits have +ve impacts on survival, growth and feed efficiency;
- All ingredients are complementary and support the growth of the aquaculture industry – volume is required;
- Measurable sustainability impacts cover all ingredients;
- Environmental impacts for marine ingredients differ from those of terrestrial ingredients (it is not a case of sustainability credentials).



“AWANIO”

As Well As.....

Not

Instead Of.....