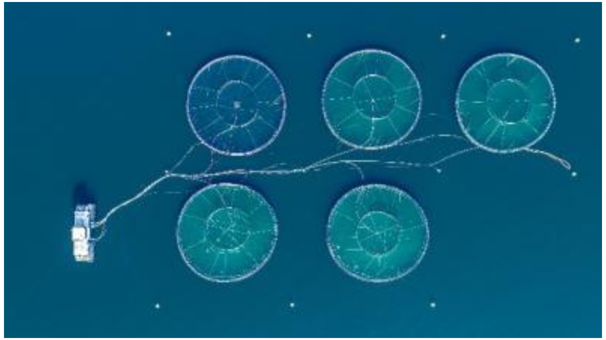
Sustainable marine ingredients and their role in fish nutrition, health and welfare

RSPCA/SSPO Nutrition Workshop at Aquaculture UK 2018



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Dr Neil Auchterlonie
Technical Director
IFFO

22nd May 2018

IFFO, The Marine Ingredients Organisation

www.iffo.net

- Technical support
- Lobbying
- Communications
- Market reports
- Conferences
- Standards

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Supply & Sustainability

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Average mass balance of marine ingredients

Whole fish/Crustaceans

Capture Fishery byproduct

Aquaculture byproduct

Raw material
(approx. 20 million tonnes per year)

5 million tonnes

14 million tonnes

1 million tonnes

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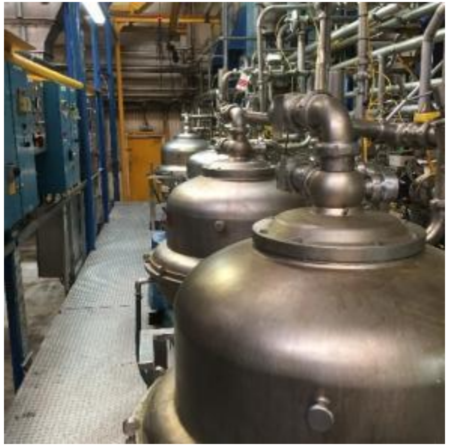
The Process…..



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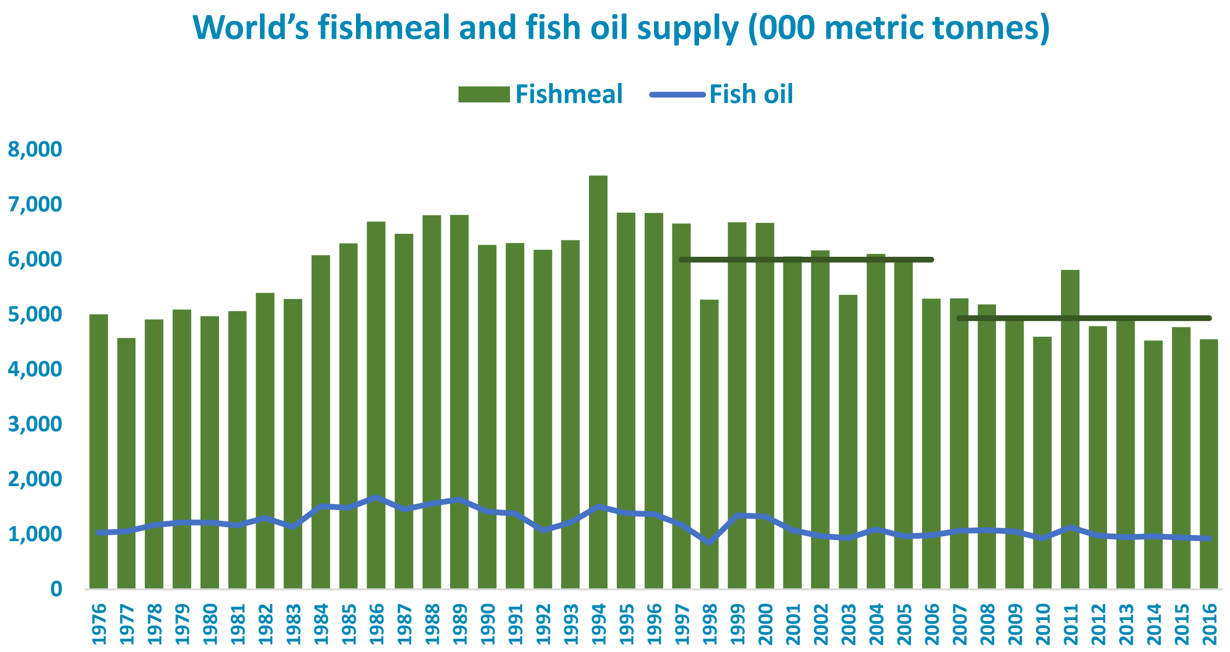

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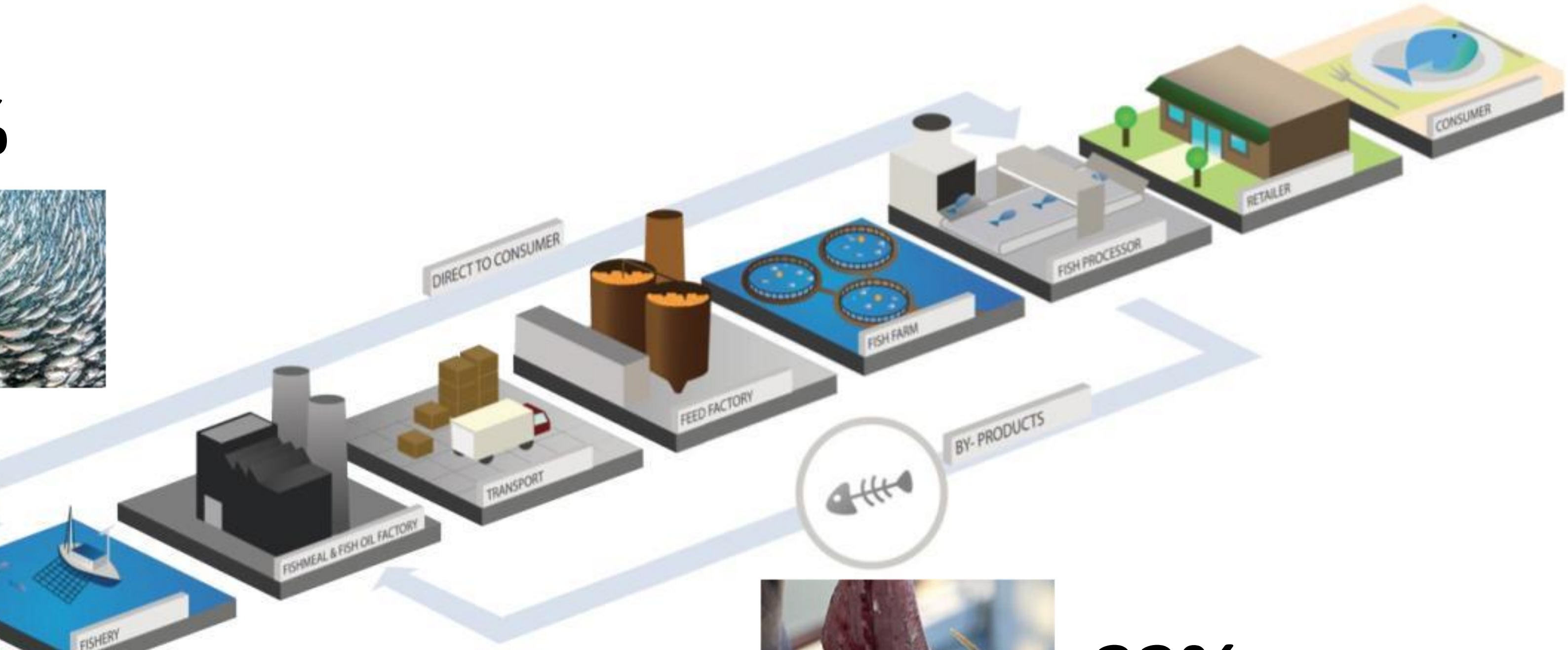
Marine Ingredients - The Supply Chain

67%



33%

Marine Ingredients - The Supply Chain (Certification)

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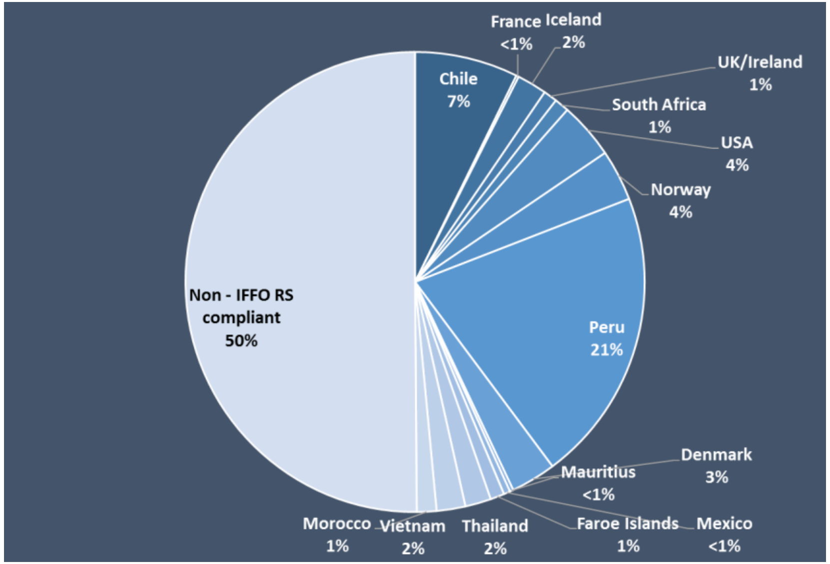
Sustainability: Certification of Fishmeal



- IFFO Responsible Supply
  - 132 certified sites
  - 17 countries
  - 18 fisheries
  - 129 byproducts
- Proportion of global annual production certified is significant
- An advanced programme: V2.0 developed in 2017

www.iffors.com

IFFO RS Certified factory statistics

Country	Sites	IFFO RS Species	MSC Species used
Peru	48	Anchovy	
Chile	20	2 x Anchovy, Common Sardine, Sardina Austral, Jack Mackerel, 4 by-product	
USA	5	Gulf menhaden, Atlantic menhaden 1 by-product	13 by-products
UK/Ireland	5	Boarfish, Blue Whiting & 40 by-products	Sand Eel
Iceland	11	Blue Whiting, Capelin & 2 by-products	NS Herring & SS Herring + 4 by-products
Norway	10	Blue Whiting, Sand Eel, Capelin & 11 by-products	Norway Pout, NS Sprat, NS Herring & SS Herring + 4 by-products
Denmark	3	Blue Whiting, Boarfish, Baltic Sprat, Herring (Baltic Sea), Herring (Bothnian Sea) 10 by-products	NS Herring & SS Herring, NS Sprat, Norway Pout, Sandeel, Skagerrak Herring+ 2 by-products
Faroe Islands	1	Blue Whiting, Capelin	NS Herring & SS Herring + 2 by-products
South Africa	5	Anchovy, Red eye herring, Anchovy by-catch, Multi Specie Pelagic Trawl, & 3 by-product	
France	1	12 by-products	7 by-product
Mauritius	1	4 by-products	
Mexico	2	Thread Herring, 6 by-products	
Morocco	3	3 by-products	
Thailand	6	25 by-products	
Vietnam	11	2 by-products	
Ecuador	2	8 by-products	
TOTAL	**134**	**17/132**	**6/32**

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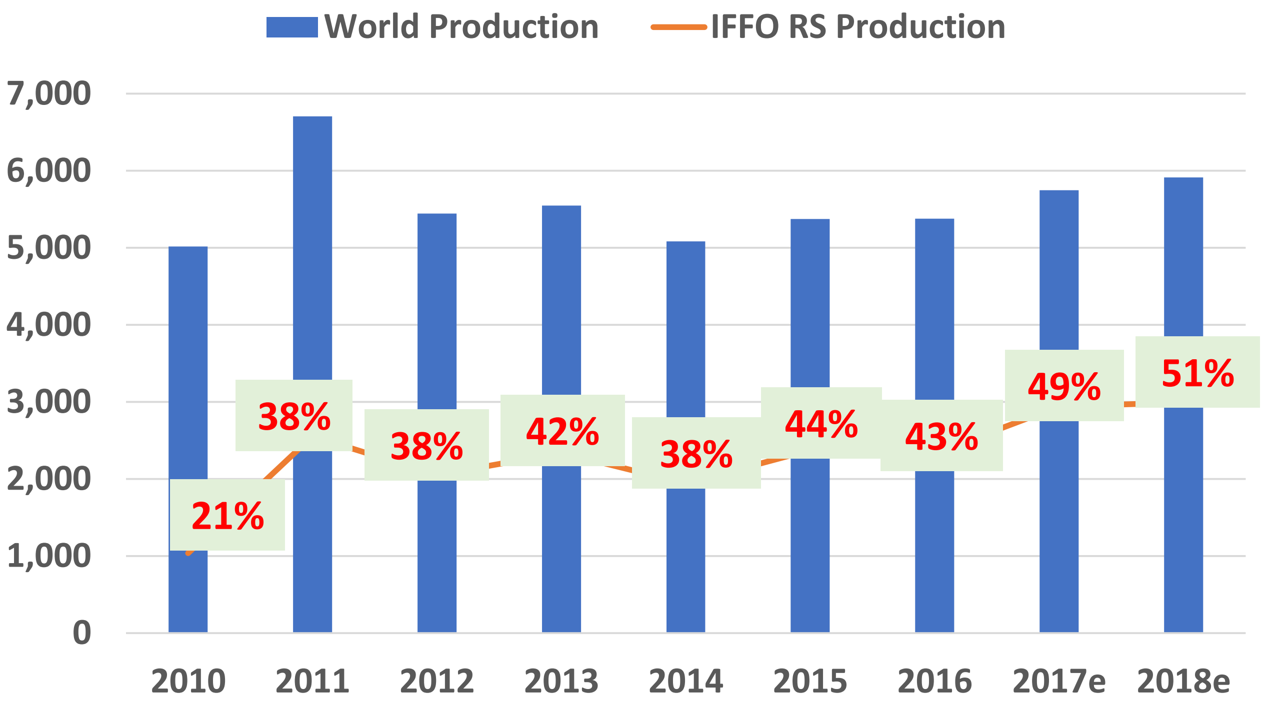
Estimated Projections: FM Certification Proportion of Annual Global Supply



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Science & Sustainability: Management of forage fish stocks

Lenfest Report (Little Fish; Big Impact):

- Published 2012;
- Funded by Pew;
- Precautionary in nature;
- Series of recommendations for low trophic level fishery management, based on level of information;
- Adopted ecosystem modelling techniques from the terrestrial environment;
- Questions over relevance to marine ecosystem, and especially predator-prey interactions.


Ray Hilborn study disputes previous findings on forage fish

By Cliff White

Published on April 3, 2017

A new study has been published today by a scientific group led by University of Washington fisheries researcher Ray Hilborn that disputes previous findings on the impact of human and natural predation on forage fish such as anchovies,

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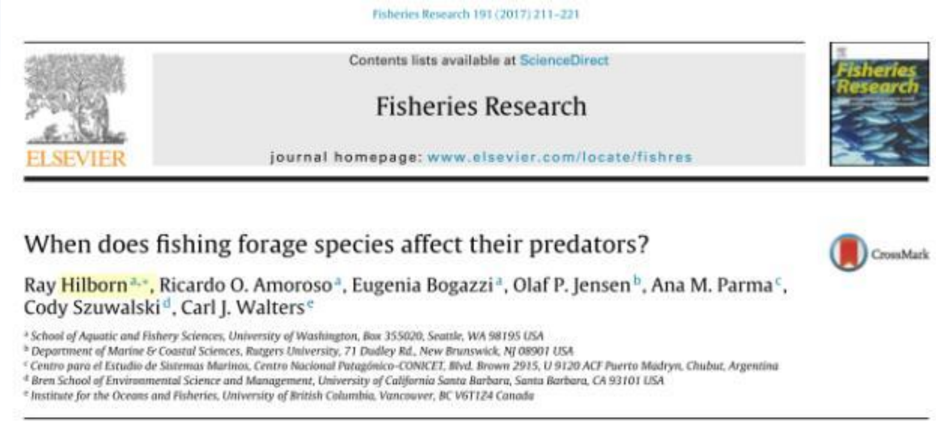
Science develops over time:


Fisheries Research 191 (2017) 211–221

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

ELSEVIER

When does fishing forage species affect their predators?

Ray Hilborn[a,*], Ricardo O. Amoroso[a], Eugenia Bogazzi[a], Olaf P. Jensen[b], Ana M. Parma[c], Cody Szuwalski[d], Carl J. Walters[e]

[a] School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195 USA
[b] Department of Marine & Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ 08901 USA
[c] Centro para el Estudio de Sistemas Marinos, Centro Nacional Patagónico-CONICET, Blvd. Brown 2915, U 9120 ACF Puerto Madryn, Chubut, Argentina
[d] Bren School of Environmental Science and Management, University of California Santa Barbara, Santa Barbara, CA 93101 USA
[e] Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC V6T1Z4 Canada

Lag time between science publication, and achieving changes in approach to regulation…….

"We show that existing analyses using trophic models have generally ignored a number of important factors including:

- *(1) the high level of natural variability of forage fish,*
- *(2) the weak relationship between forage fish spawning stock size and recruitment and the role of environmental productivity regimes,*
- *(3) the size distribution of forage fish, their predators and subsequent size selective predation*
- *(4) the changes in spatial distribution of the forage fish as it influences the reproductive success of predators"*

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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

<u>Key points:</u>

- Mainly pelagic species;
- Fishery management is straightforward;
- Fishing practices are generally benign (e.g. purse seine);
- Highly productive fisheries (environmental factors affect recruitment);
- Seasonal, high volume;
- Use as food:feed depends on market dynamics.

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Byproduct

- Globally 33% of total raw material – regionally variable;
- Europe shows higher recovery (estimated at 54% in 2016);
- Trend is increasing;
- More byproduct is available – logistical and practical issues with collection;
- Some differences from whole fish fishmeals: higher bone proportion (ash content); lower muscle (higher/variable oil yield); sometimes easier to collect and high quality (aquaculture) – usually challenging (capture fisheries & processing at sea);
- Some aquaculture byproduct finding unique markets.

UNIVERSITY OF STIRLING

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

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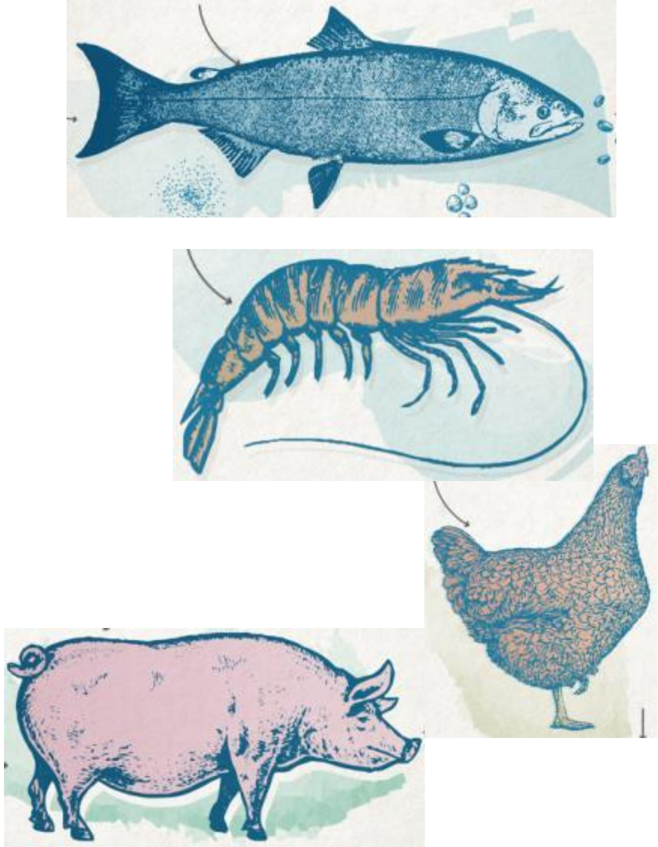
Nutrition

- Essential in global protein production (not just fish);
- High protein level;
- High digestibility;
- Excellent amino acid balance (for carnivorous fish species);
- Rich in vitamins (especially B-group and vitamin D);
- Rich in minerals – Ca, Zn, Se, others;
- FO is a critical, and finite source of n-3s (EPA, DHA);
- Some compounds linked to growth performance still not identified ("Compound X")
- Some compounds linked to appetence and palatability (very important in hatchery feeds, for example);
- FMFO has moved towards strategic use (rather than commodity);
- FMFO is a high-value feed ingredient, used in smaller volumes in aquafeeds, but supplying critical nutritional qualities.



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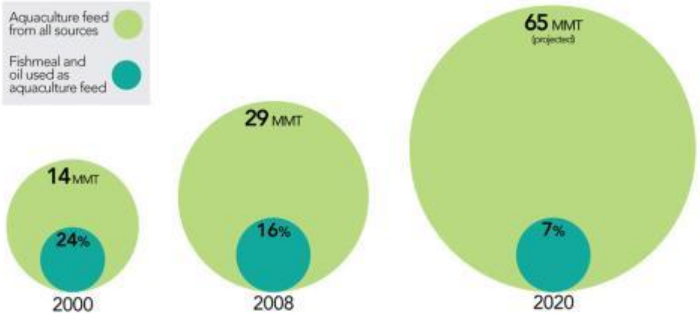
The Need for Feed

- Volume of feed production increasing to meet aquaculture growth demand;
- Fishmeal (FM) and fish oil (FO) annual production is finite;
- Important nutritionally (need to optimise use);
- Also important for quality of product;
- Other ingredients complement FMFO rather than replace;
- Need to manage key nutritional properties;
- Sustainability of sourcing is key consideration for producers.



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

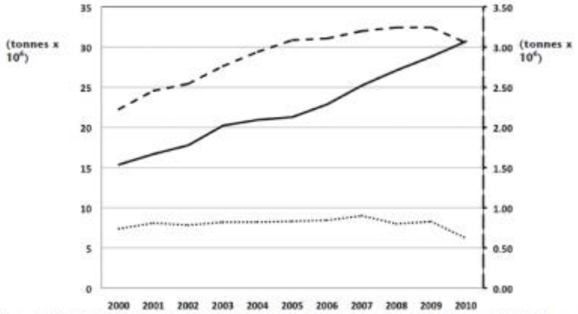


Figure 6. World fishmeal and fish oil consumption by aquaculture compared with growth in 'fed' aquaculture (millions of tonnes) during 2000-2010 (Solid line = Fed aquaculture; Broken line = Fish meal in aquaculture; Dotted line = Fish oil in aquaculture), (left hand vertical axis refers to fed aquaculture; right hand vertical axis refers to world fishmeal and fish oil consumption by fed aquaculture). (Shepherd & Jackson 2012, based on data from IFFO and FAO 2012a) (33,2)

Source: Shepherd, 2012

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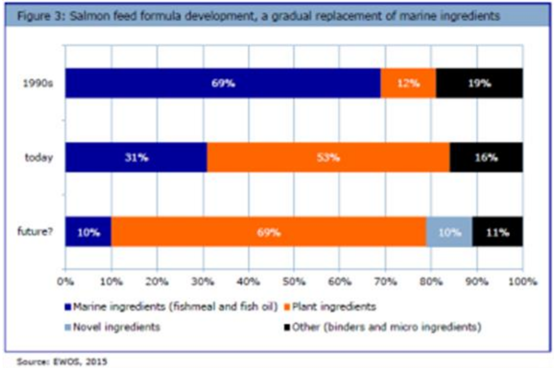
FMFO inclusion rates declining

- Some information is in the public domain, but this is a scenario that has principally been driven by the feed companies (commercial), based on accessible volume & price;
- It <u>**is not**</u> the result of eNGOs lobbying the industry on FIFO, FFDR or similar;
- It <u>**is**</u> constant improvement in developing better ways to use the nutritional contribution of a finite FMFO annual supply for best effect;
- It doesn't tell the whole story – grower diets have declined substantially, but inclusion rates in juvenile feeds often higher (but much lower volume of feed);
- Ties in with strategic use of FMFO (no longer commodities);
- Aligns with pig and poultry industries (use FMFO in feeds at key points in the production cycle).



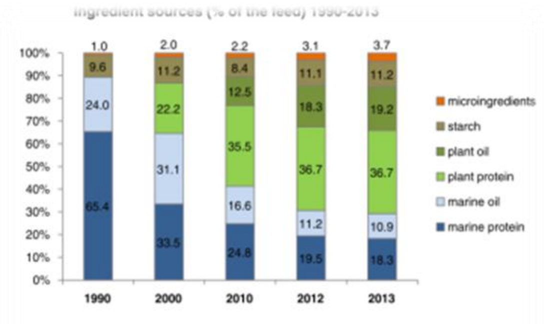


Fig. 1. Nutrient sources in Norwegian salmon farming from 1990 to 2013. Each ingredien

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

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Sustainability: FCRs declining

Table 1. Feed use and efficiencies (1995 and 2007)

Species group	Percentage on feeds*	Average FCR†	Average % fishmeal in feed‡	Average % fish oil in feed‡	Total feeds used§
Shrimp					
1995	75	2.0	28	2	1,392
2007	93	1.7	18	2	5,603
Salmon					
1995	100	1.5	45	25	806
2007	100	1.3	24	16	1,923
Marine fish					
1995	50	2.0	50	15	498
2007	72	1.9	30	7	2,311
Chinese carp (nonfilter feeding)					
1995	20	2.0	10	0	1,970
2007	47	1.7	5	0	8,578
Tilapia					
1995	70	2.0	14	1	984
2007	82	1.7	5	0	3,590

Data are from ref. 2.

*Estimated percentage of total species-group production fed on compound aquafeeds.

†Estimated average species-group economic FCR (total feed fed/total species group biomass increase), also known as EFCR.

‡Also known as fish inclusion rates.

§Total compound aquafeeds used for species group (thousand tons).

Naylor et al., (2009) www.pnas.org/cgi/content/full/0905235106/DCSupplemental

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FIFO

	2000	2010	2015
Crustaceans	0.91	0.45	0.46
Marine Fish	1.48	0.88	0.53
Salmon & Trout	2.57	1.38	0.82
Eels	2.98	1.81	1.75
Cyprinids	0.07	0.03	0.02
Tilapias	0.27	0.18	0.15
Other Freshwater	0.60	0.15	0.13
Aquaculture total	0.63	0.33	0.22

- Lowering in response to decreasing inclusion rates;
- Making more feed with the same amount of FMFO annually.

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Fishmeal as a Protein Source:

- High crude protein levels (65%-72%);
- High digestibility;
- High bioavailability;
- Some variability (as a product);
- Quality can depend on raw material sources & processing;
- Amino acid profile is an important part of the overall nutritional contribution.

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Amino acid profile

“All finfish studied to date have been shown to require the same 10 amino acids which are considered essential for most animals. These include arginine, histidine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.”

From: Robert P. Wilson, “Amino Acids and Proteins, in Fish Nutrition, 2nd Edition, 1989, Ed. John E. Halver.

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 [illegible] crude protein in the meal (in parenthesis).

Essential Amino Acid	FM (64.5%)[2]	MM (55.6%)[2]	PBM (59.7%)[2]	BM (8[illegible]	[illegible]
Arginine	3.82	3.60	4.06	[illegible]	[illegible]
Histidine	1.45	0.89	1.[illegible]	[illegible]	[illegible]
Isoleucine	2.66	1.64	[illegible]	[illegible]	[illegible]
Leucine	4.48	2.8[illegible]	[illegible]	[illegible]	[illegible]
Lysine	4.72	[illegible]	[illegible]	[illegible]	[illegible].08
Methionine + Cystine[3]	2.31	[illegible]	[illegible]	[illegible]	1.43
Phenylalanine + Tryosine[4]	[illegible]	[illegible]	[illegible]	8.47	4.20
Threoni[illegible]	[illegible]	[illegible]	[illegible].94	3.76	1.89
Try[illegible]	[illegible]	[illegible]	0.46	1.04	0.69
[illegible]	[illegible]	[illegible]2	2.86	7.48	2.55

[illegible] ...ne EAA composition of each feedstuff we[illegible] ...3 NRC (National Research Council, Nutrient Req[illegible] ..., National Academy of Sciences, Washington, DC).
[2]Percen[illegible] total crude protein in feedstuff.
[3]Cystine c[illegible]n be synthesized from methionine.
[4]Tyrosine can be synthesized from phenylalanine.

“Fishmeal contains the profile of amino acids that most closely meets the amino acid requirements of fish.”

UF | IFAS Extension

The Benefits of Fish Meal in Aquaculture Diets
R. D. Miles and F. A. Chapman[2]

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Substitution: It isn't "like for like"

Table 4: The vitamin contents of feed meals

	Anchovy	Herring	Menhaden	Tuna	Salmon	Jack Mackerel	White fish	Sandeel	Soya	Canola/ Rapeseed
	Mean	Mean	Mean	Mean			Mean	Mean	Mean	Mean
Biotin mg/kg	0.25	0.46	0.18	0.20			0.08		0.25	0.97
Choline mg/kg	4404	4833	3112	2994			3750		2804	2764
Folic acid mg/kg	0.18	0.4	0.12				0.43		3.6	1.4
Niacin (nicotinic acid, Vitamin B_3)mg/kg	97.5	106	55	144			54.5		27	41
Panthothenic acid (vitamin B_5) mg/kg	12.2	24.0	8.6	7.7			12.5		14.5	13.7
Pyridoxine (Vitamin B_6) mg/kg	4.07	4.24	4.66				4.61	3.0	8	7.0
Riboflavin (vitamin B_2) mg/kg	6.85	8.50	4.8	6.79			7.8	7.0	3.55	3.3
Thiamin (vitamin B_1) mg/kg	0.10	0.40	0.6				1.7	1.0		6.6
Vitamin B_{12} mg/kg	0.27	0.34	123	0.31			0.08	0.28		
Vitamin E (tocopherol) mg/kg	5.00	22.1	12.0	5.6			8.9	8.0		16
Vitamin K mg/kg		2.2								

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Importance of micronutrients: Minerals

Generalisation?
Different species,
different requirements?

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

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Importance of micronutrients: Vitamins

Interesting to see that salmon/trout have higher requirements than chicken for many vitamins!

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

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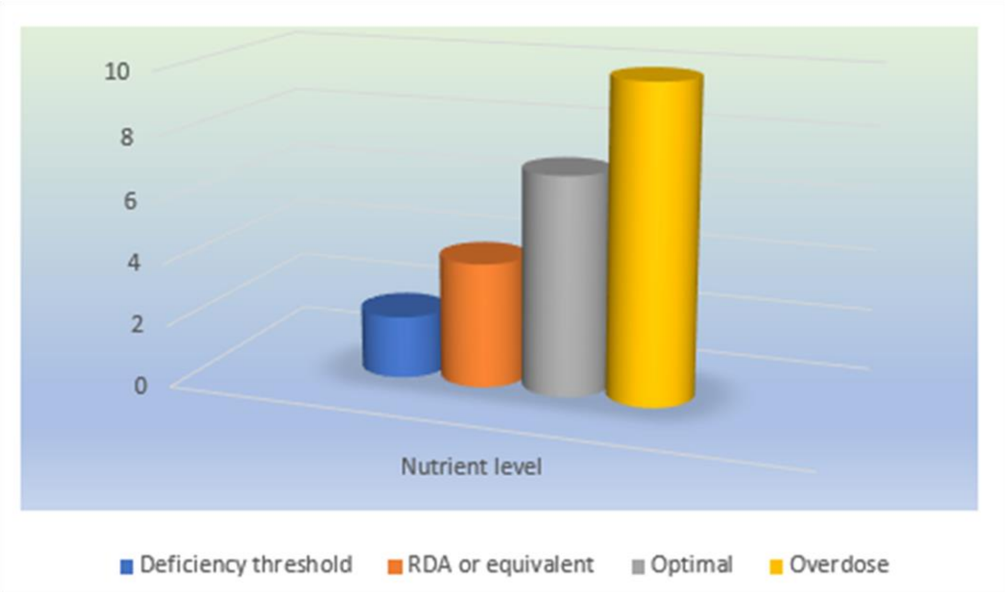
Fish nutrition studies are (largely) based on identification of levels that avoid deficiency

"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



So, what about (nutritional) optimisation in aquafeeds?

How do requirements change with species?

With farming system?

With life cycle stage?

With specific pathogen challenge?

How does this relate to growth performance? Survival? Welfare status?

Scope for customisation of diets….

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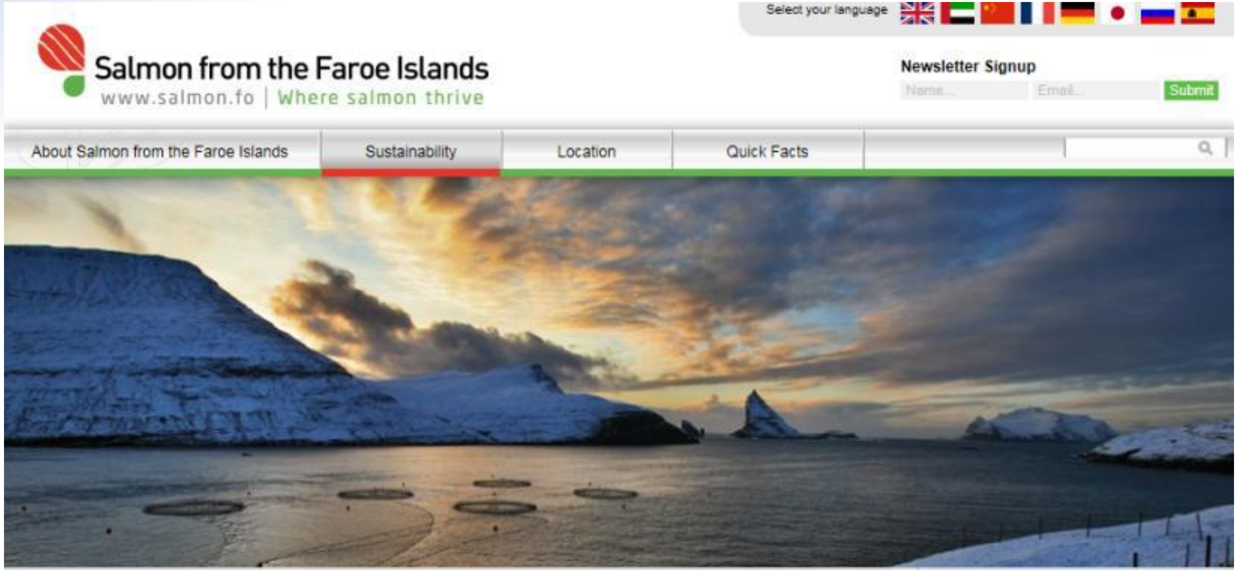
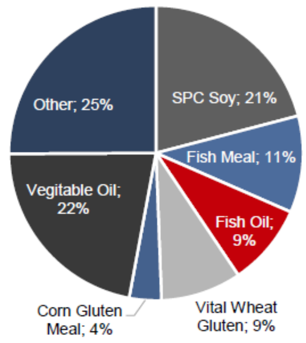
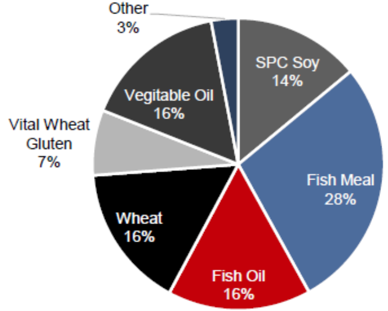
Case study – Faroe Islands



Standard feed recipe 2016E[1]



Feed recipe Bakkafrost 2015



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

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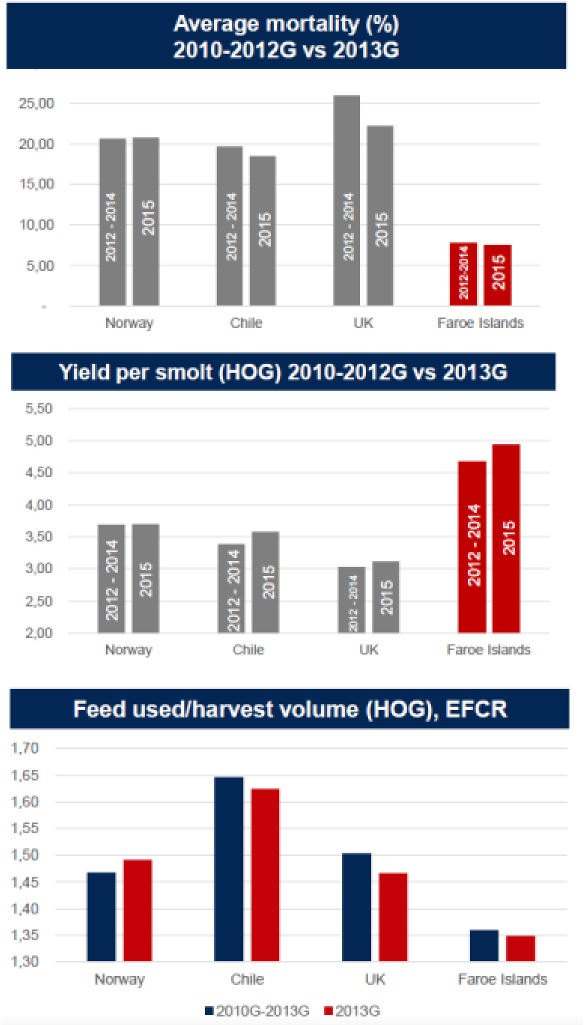
Performance?

- Mortality rate ↓
- Yield ↑
- FCR ↓

Anecdote (not science) but assume meeting needs for:

- Nutrition? ☑
- Health? ☑
- Welfare? ☑



Bakkafrost data:

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

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Prompts questions:

- Are we seeing the point at which marine ingredient inclusion rates are reaching a (lower-limit) threshold?
- What are the links with fish health, growth and welfare?
- What about the nutritional quality of the end product? [We already know about declining n-3 content, but what about other (micro-)nutrients?]
- What is the scope for customisation of diets for optimisation of different species in different systems, and to particular life-stage needs?

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"Fishmeal and fish oil are still considered the most nutritious and digestible ingredients for farmed fish feeds"

(FAO, 2016)

Questions?

Email: nauchterlonie@iffo.net