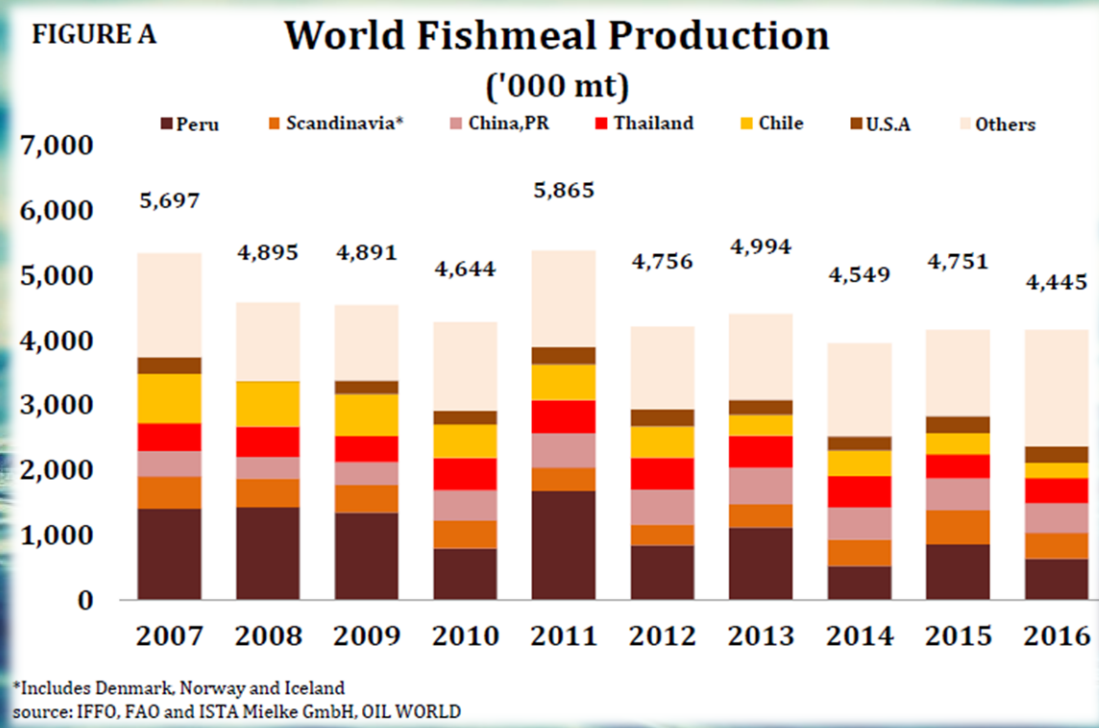


# “The continuing importance of fishmeal and fish oil in aquafeeds”

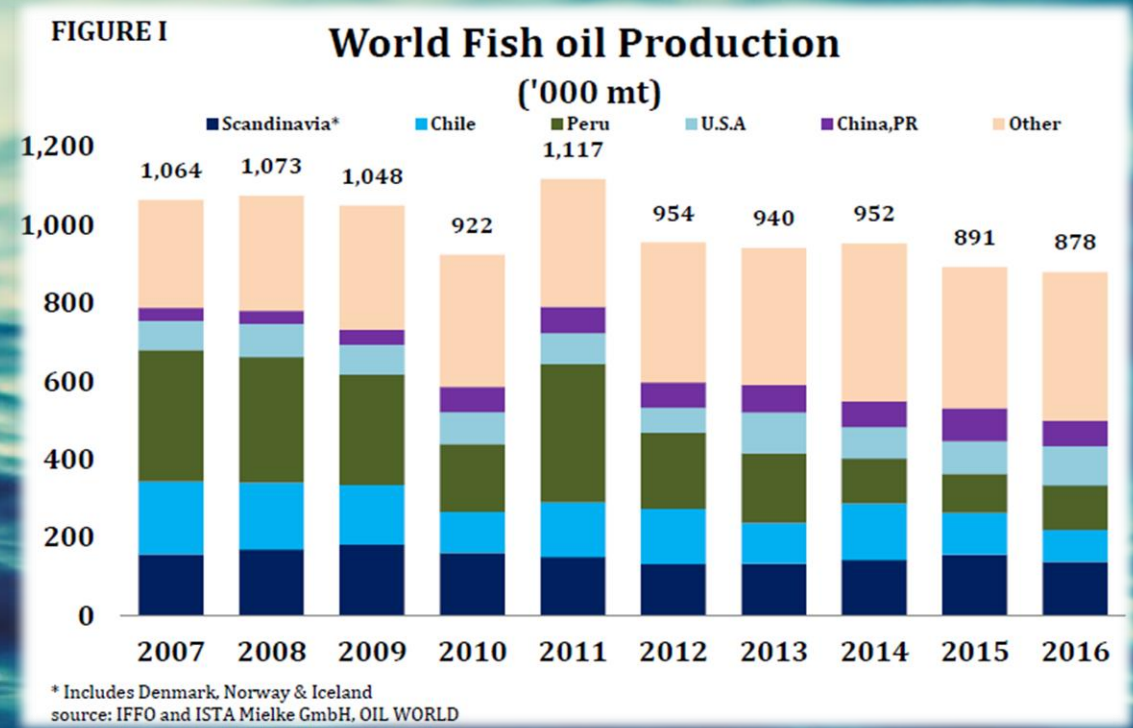


Dr Neil Auchterlonie,  
IFFO  
February 16<sup>th</sup> 2018

# Annual Global Production of FM & FO



**Fishmeal**  
c.5 million tonnes *p.a.*



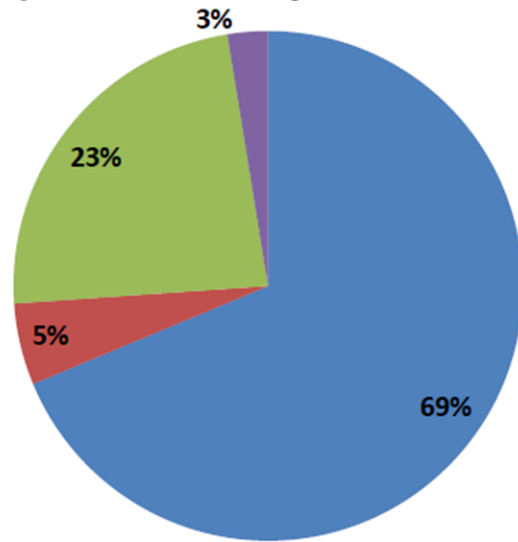
**Fish Oil**  
c.1 million tonnes *p.a.*

# FMFO by Market

FIGURE R

Use of Fishmeal by Market in 2016

■ Aquaculture ■ Chicken ■ Pig ■ Other

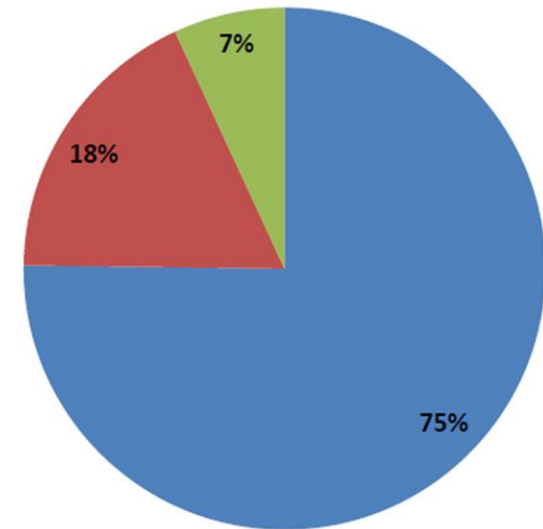


source: IFFO

FIGURE T

Use of Fish oil by Market in 2016

■ Aquaculture ■ Direct Human Consumption ■ Other

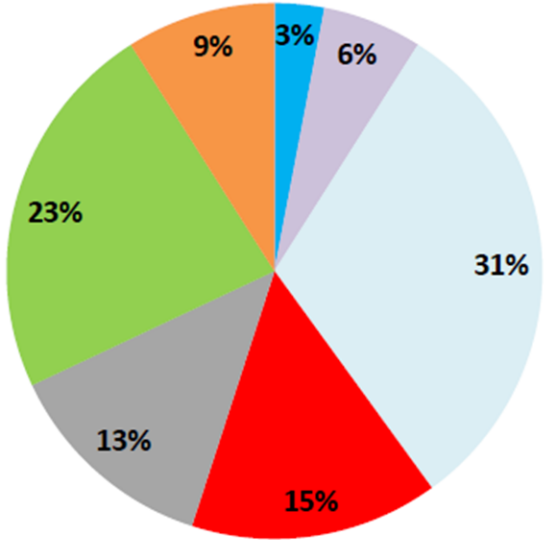


source: IFFO and FAO

# FMFO in Aquaculture

FIGURE Q Use of Fishmeal in Aquaculture in 2016

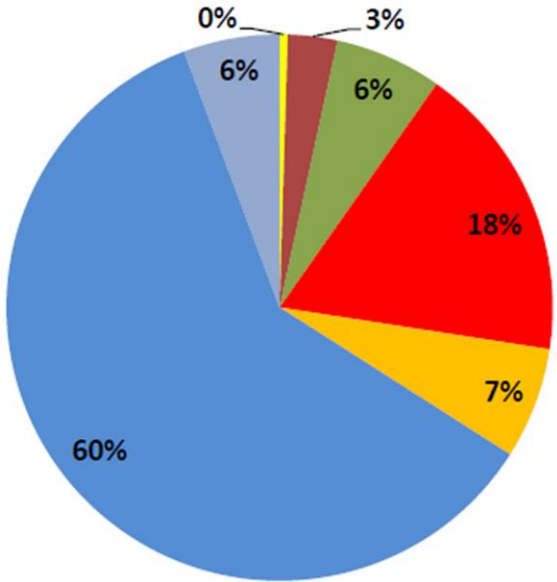
Cyprinids Eels Crustaceans Marine fish Other Salmonids Tilapias



source: IFFO and FAO

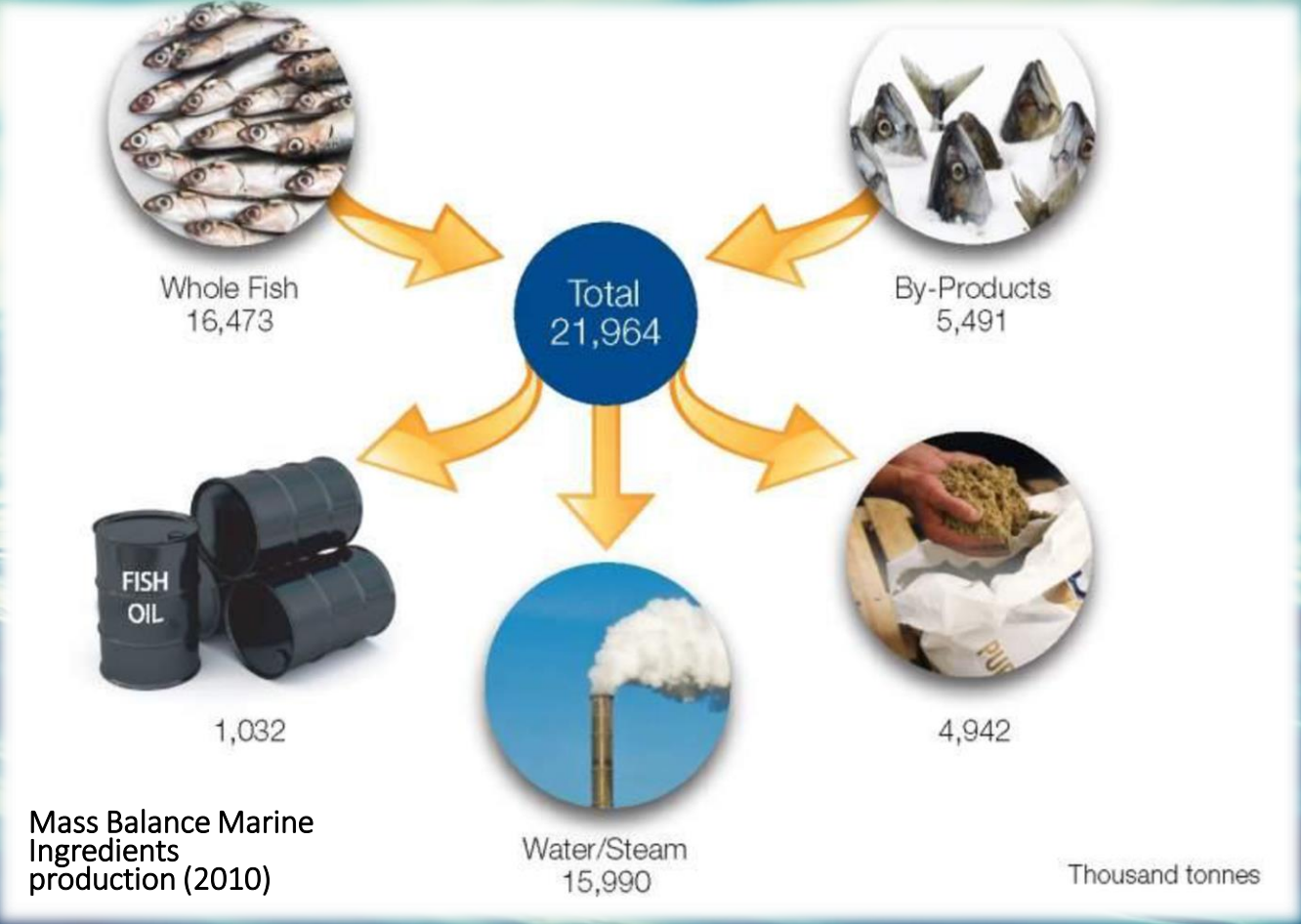
FIGURE S Use of Fish Oil in Aquaculture in 2016

Cyprinids Eels Crustaceans Marine fish Other Salmonids Tilapias



source: IFFO and FAO

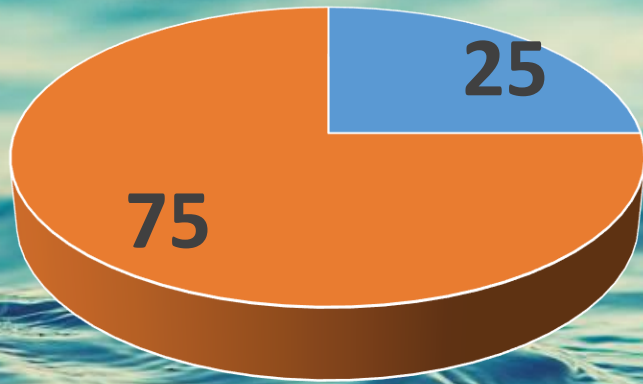
# Process:



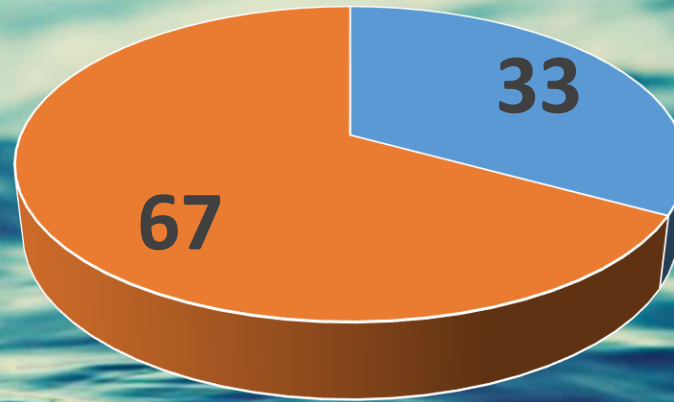
# Whole fish raw material sources:

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

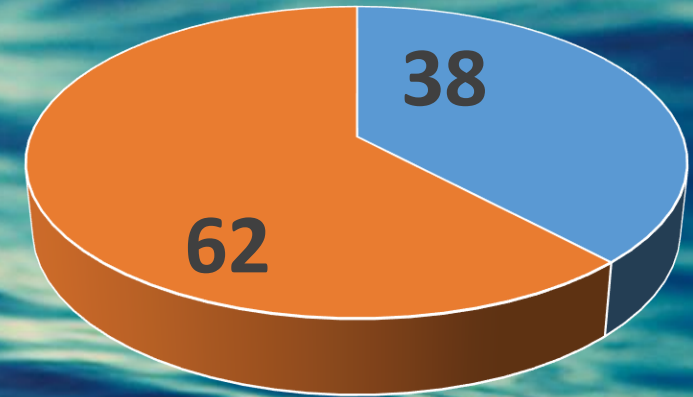
# Raw material: Whole fish & Byproduct proportions



Estimated by  
Shepherd, 2012



Calculated by Jackson &  
Newton, 2016



Predicted by FAO for  
2025 (2016)

# Marine ingredients are the foundation for modern fed aquaculture & facilitated technological development

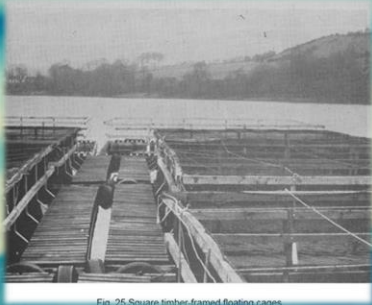


Fig. 26 Square timber-framed floating cages

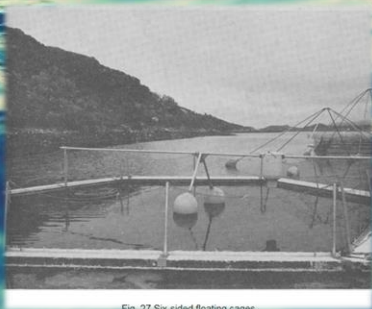
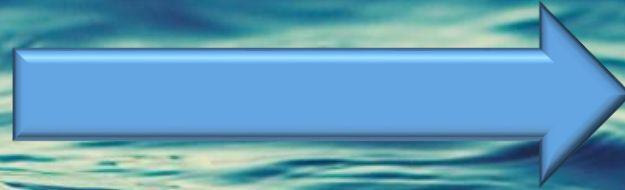


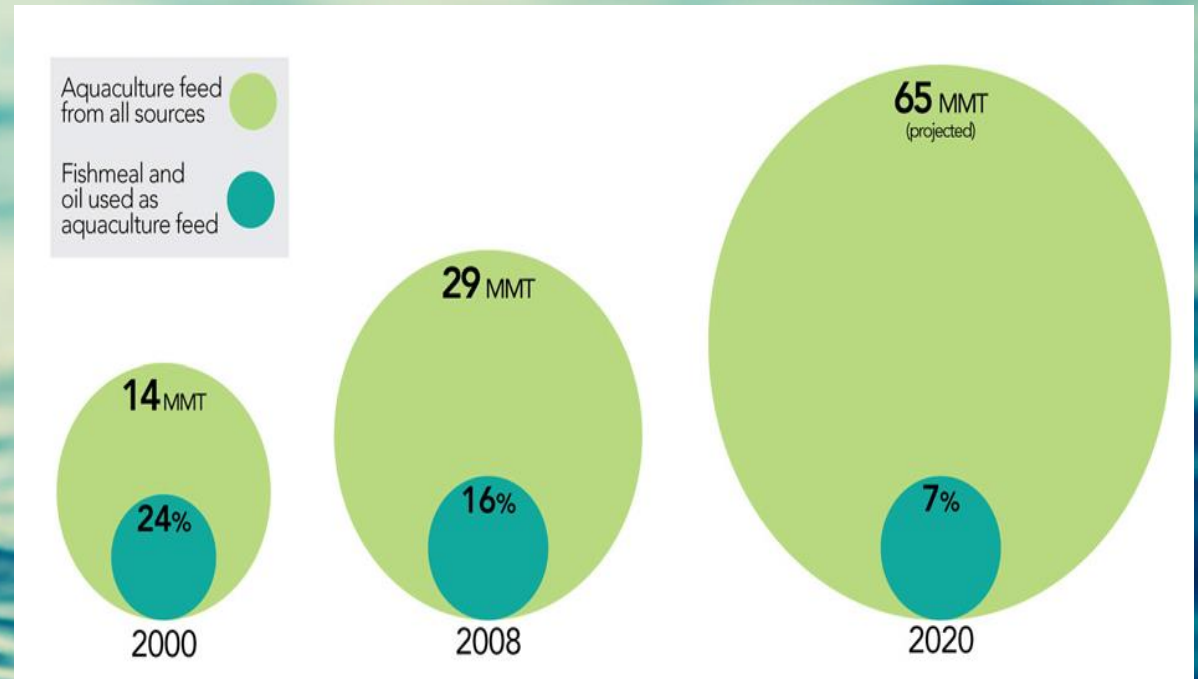
Fig. 27 Six-sided floating cages





# Aquaculture continues to grow....

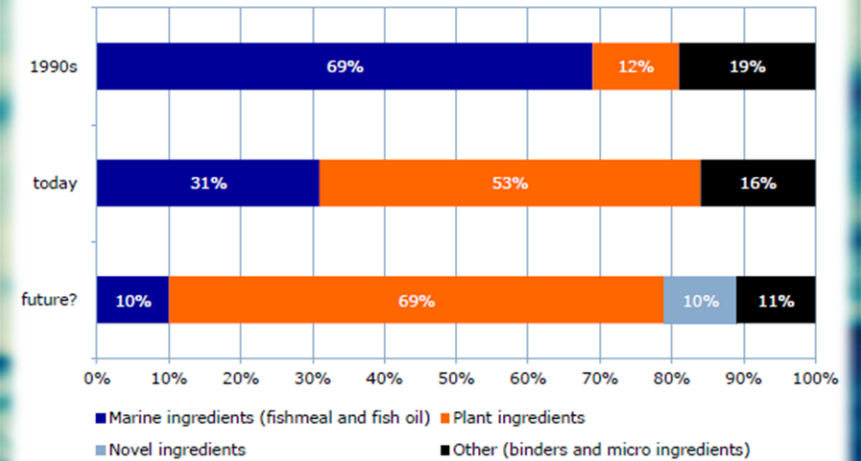
## More feed is required



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>

# FMFO inclusion rates declining

Figure 3: Salmon feed formula development, a gradual replacement of marine ingredients



Source: EWOS, 2015

Ingredient sources (% of the feed) 1990-2013

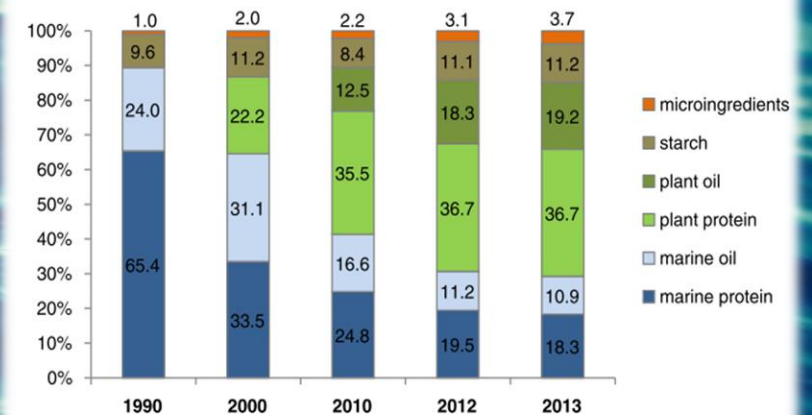


Fig. 1. Nutrient sources in Norwegian salmon farming from 1990 to 2013. Each ingredient type is shown as its percentage of the total diet.

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

# Nutritional importance:

- **Fishmeal**
  - Protein
  - Digestibility
  - Amino acid profile
  - Micronutrients
- **Fish oil**
  - Energy
  - LC polyunsaturated fatty acids (EPA & DHA)
- **Important factors for:**
  - Growth
  - Quality
  - Health

# 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, 2<sup>nd</sup> Edition, 1989, Ed. John E. Halver.

Table 3. Percentage of essential amino acids (EAA)<sup>1</sup> 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%) <sup>2</sup>	MM (55.6%) <sup>2</sup>	PBM (59.7%) <sup>2</sup>	BM (80%) <sup>2</sup>	SBM (48%) <sup>2</sup>
Arginine	3.82	3.60	4.06	3.08	3.08
Histidine	1.45	0.89	1.00	1.04	1.04
Isoleucine	2.66	1.64	1.64	1.64	1.64
Leucine	4.48	2.85	2.85	2.85	2.85
Lysine	4.72	3.08	3.08	3.08	3.08
Methionine + Cystine <sup>3</sup>	2.31	1.43	1.43	1.43	1.43
Phenylalanine + Tyrosine <sup>4</sup>	8.47	4.20	4.20	4.20	4.20
Threonine	1.89	1.89	1.89	1.89	1.89
Tryptophan	0.69	0.69	0.69	0.69	0.69
Valine	2.55	2.55	2.55	2.55	2.55

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

<sup>1</sup>Based on the EAA composition of each feedstuff we used and the 1973 NRC (National Research Council, Nutrient Requirements of Fish, National Academy of Sciences, Washington, DC).

<sup>2</sup>Percentage of total crude protein in feedstuff.

<sup>3</sup>Cystine can be synthesized from methionine.

<sup>4</sup>Tyrosine can be synthesized from phenylalanine.

# Importance of micronutrients – Minerals

## Mineral requirements of fish

### Macrominerals (g/kg diet)

Calcium  
Phosphorus\*  
Sodium  
Potassium\*  
Chlorine  
Magnesium\*  
Sulfur

### Microminerals (mg/kg diet) (trace elements)

Iron  
Manganese\*  
Copper  
Zinc\*  
Cobalt  
Selenium\*  
Iodine\*  
Molybdenum

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

**Table 3:** The mineral and trace element contents of feed meals

	Anchovy		Herring		Menhaden		Tuna		Salmon	Jack Mackerel	White fish	Sandeel	Soya	Canola/ rapeseed
	Mean	Range	Mean	Range	Mean	Range	Mean	Range			Mean	Mean	Mean	Mean
Calcium %	3.89	2.79-5.60	2.05	1.32-3.54	5.23	3.94-6.82	8.36	5.82-12.6	3 - 4		7.66	2.8	0.29	0.17
Chlorine %	1.41		1.01		0.55		1.01				1.25		0.03	0.04
Magnesium %	0.25	0.16-0.33	0.12	0.09-0.13	0.15	0.13-0.17	0.23	0.16-0.30	0.15 - 2.0		0.17	0.2	0.29	0.41
Phosphorus (total) %	2.54	1.85-3.55	1.90	1.01-2.29	2.93	2.39-3.67	4.44	3.28-6.59	2 - 3		4.80	2.2	0.60	1.17
Phosphorus (available) %			1.90								4.80		0.24	
Potassium %	0.75	0.39-0.84	1.16	0.84-1.38	0.71	0.60-1.10	0.73	0.58-0.84	2 - 3		0.87	0.2	1.97	1.39
Sodium %	0.95	0.48-1.49	0.57	0.29-1.03	0.38	0.25-0.44	0.74	0.52-1.17	0.4 - 0.5		1.04	1.0	0.03	0.04
Sulphur %	0.54		0.46				0.68				0.48			0.30
Aluminum mg/kg	77.2	48.0-190	33.0	22.5-97.5	352	161-615	150	98.0-180				82		
Barium mg/kg	5.40	2.00-10.9	3.00	2.0-15.0	20.4	4.9-51.5	4.52	2.0-6.5						
Boron mg/kg	13.7	9.00-19.8	6.30	4.45-8.45	14.1	12.2-19.8	16.4	11.1-21.5						
Chromium mg/kg	10.2	6.6-23	4.20	3.0-6.2	11.0	8.5-13.1	17.6	11.9-21.5						
Copper mg/kg	8.30	5.0-13.8	5.40	4.6-8.8	10.9	6.6-17.5	10.6	8.00-15.4	2 - 3		6.45	4.2	43	19
Iron mg/kg	237	150-725	138	105-255	491	250-670	362	235-450	70 - 80		241	208	93.0	208
Manganese mg/kg	9.73	4.3-21.1	3.07	2.0-4.25	36.3	21.1-65	8.53	7.10-15.0	15 - 20		11.2	12	38	21
Selenium mg/kg	1.38	1.18-1.73	2.31	1.73-3.43	2.19	1.22-3.98	4.47	3.40-6.20	0.8 - 0.9		1.56	2.5	0.35	0.06
Strontium mg/kg	87.8	36.5-161	71.0	22.8-171	63.4	37.5-96	> 200							
Zinc mg/kg	108	90-146	122	105-132	147	133-169	212	151-273	200 - 250		95	108	56	61
Iodine mg/kg									2 - 3					

# Importance of micronutrients – 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 <sub>12</sub>	0.01	0.003
Ascorbic acid	50	not required
Choline	800	500
myo-Inositol	300	not required

\*values in yellow are lower for chickens

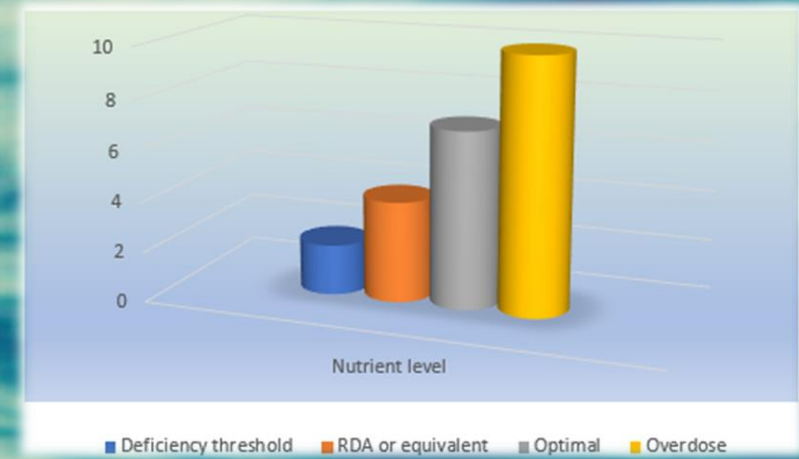




# Fish nutrition studies are based on identification of levels that avoid deficiency

*“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



**What about optimisation?**

**How do requirements change with species?**

**With farming system?**

**With life cycle stage?**

**With specific pathogen challenge?**

**Scope for customised diets....**

# Reducing FMFO in aquafeeds has repercussions.....

## SCIENTIFIC OPINION

ADOPTED: 25 January 2017

doi: 10.2903/j.efsa.2017.4713

### **Safety of vitamin D<sub>3</sub> addition to feedingstuffs for fish**

EFSA Panel on Additives and Products or Substances used in Animal Feed (FEEDAP),  
Guido Rychen, Gabriele Aquilina, Giovanna Azimonti, Vasileios Bampidis,  
Maria de Lourdes Bastos, Georges Bories, Andrew Chesson, Pier Sandro Cocconcelli,  
Gerhard Flachowsky, Jürgen Gropp, Boris Kolar, Maryline Kouba, Marta López-Alonso,  
Secundino López Puente, Alberto Mantovani, Baltasar Mayo, Fernando Ramos, Maria Saarela,  
Roberto Edoardo Villa, Pieter Wester, Lucio Guido Costa, Noël Dierick, Paola Manini,  
Jordi Tarrés-Call and Robert John Wallace

# Marine Ingredients & Aquafeed Palatability

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

Glencross, B. R., Blyth, D., Irvin, S., Bourne, N., Campet, M., Boisot, P., Wade, N.  
Glencross, B. R., Blyth, D., Irvin, S., Bourne, N., Campet, M., Boisot, P., Wade, N. (2011) 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): 0-7551-0274-0. ISBN (13): 978-0-9553427-4-5

Contents lists available at ScienceDirect  
Aquaculture  
journal homepage: www.elsevier.com/locate/aqua-online  
An evaluation of the complete replacement of both fishmeal and fish oil in diets for juvenile Asian seabass, *Lates calcarifer*  
Glencross B<sup>a</sup>, David Blyth<sup>b</sup>, Simon Irvin<sup>b</sup>, Nicholas Bourne<sup>a</sup>, Marcel Campet<sup>c,1</sup>, Pascal Boisot<sup>d</sup>, Nicholas M. Wade<sup>a</sup>  
<sup>a</sup>2000 AgriScience Flagship, PO Box 2511, Brisbane, QLD 4001, Australia  
<sup>b</sup>2000 AgriScience Flagship, 441 North St, Warrnambool, VIC 3240, Australia  
<sup>c</sup>1000 AgriScience Flagship, 441 North St, Warrnambool, VIC 3240, Australia  
<sup>d</sup>1000 AgriScience Flagship, 441 North St, Warrnambool, VIC 3240, Australia

***“Poor palatability is a limiting factor for replacing fishmeal with other protein sources in aquaculture”***

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

***“...it has also been determined that a critical threshold of 15% fishmeal was pertinent to barramundi, based on a diet balanced for digestible protein, energy and amino acids using a plant protein concentrate as the alternative (Glencross et al., 2011)...”***

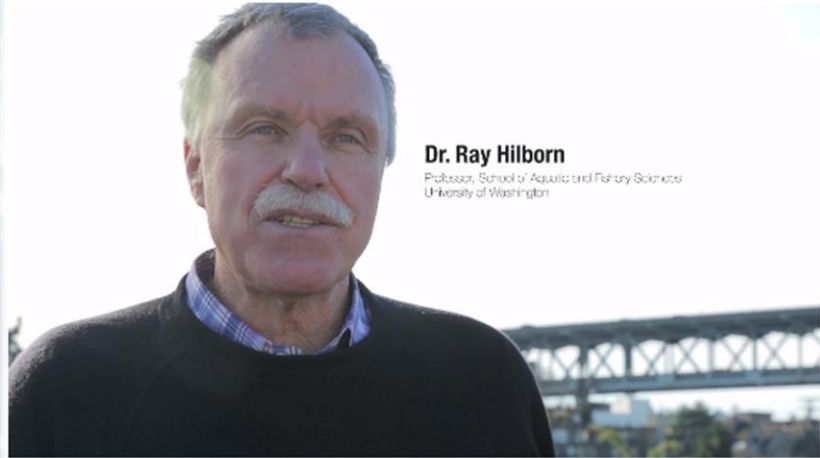
# Sustainability: Management of forage fish stocks



## Ray Hilborn study disputes previous findings on forage fish

By Cliff White  
Published on April 3, 2017

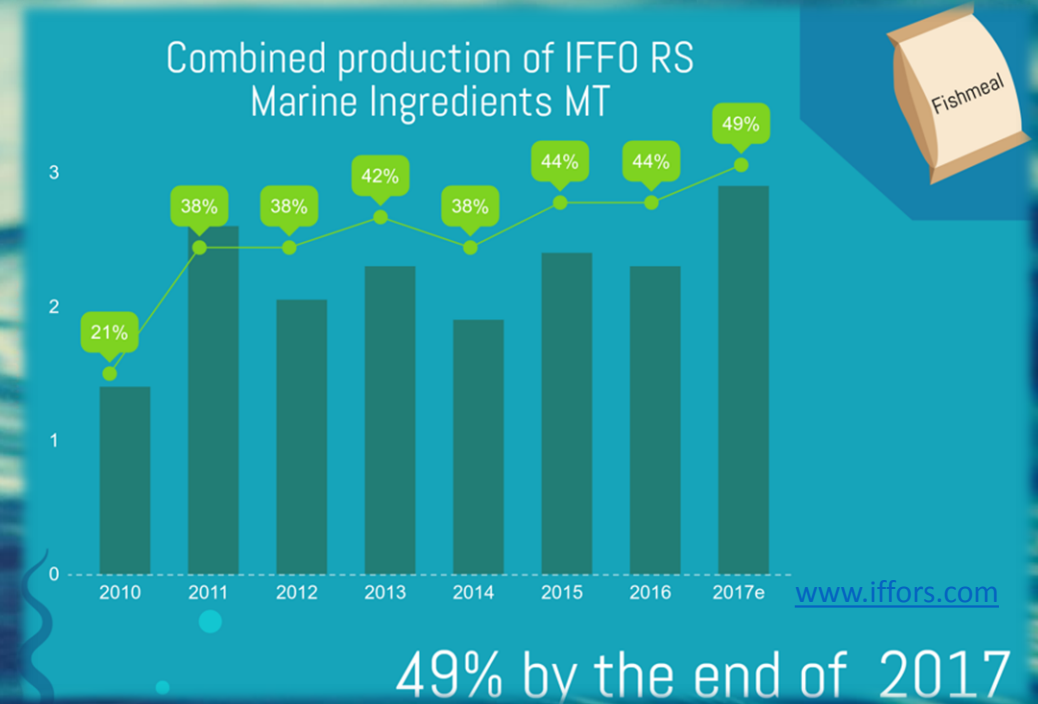
SHARE [f](#) [t](#) [in](#) [e](#)



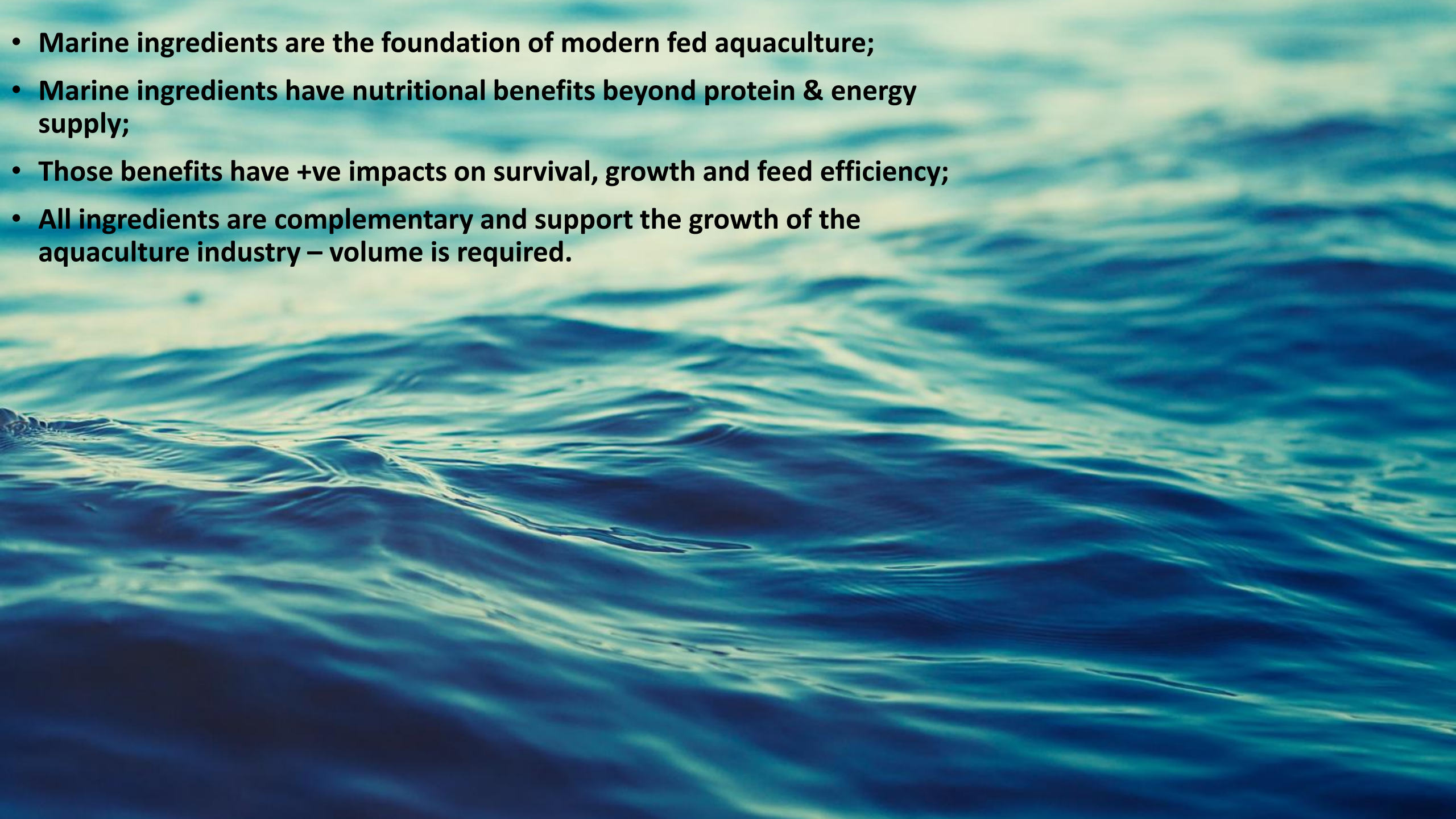
A new study has been published today by a scientific group led by University of Washington fisheries researcher Ray Hilborn that disputes previous findings on the impact of human and natural predation on forage fish such as anchovies, sardines and herring.

# Sustainability: Certification

- **IFFO Responsible Supply**
  - 132 certified sites
  - 17 countries
  - 18 fisheries
  - 129 byproducts
- Proportion of global annual production certified is significant



- **Marine ingredients are the foundation of modern fed aquaculture;**
- **Marine ingredients have nutritional benefits beyond protein & energy supply;**
- **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.**



***“Fishmeal and fish oil are still considered the most nutritious and digestible ingredients for farmed fish feeds”***

**(FAO, 2016)**







# Questions?

Email: [nauchterlonie@iffo.net](mailto:nauchterlonie@iffo.net)

Web: [www.iffo.net](http://www.iffo.net)