


## Reduced reliance on marine wild fishery resources: progress in combined replacement of fish meal and fish oil in fish feeds



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**At a global level, « seafood » supply from capture fisheries is at best stable while that from Aquaculture is continuously increasing**

**In 1980, Aquaculture supplied 9% of seafood; Now, nearly 50%**

**EU: 24% of the 23 kg per capita consumption of seafood comes from aquaculture**

**European aquaculture provides for healthy, nutritious and safe seafood produced with stringent sustainability goals**



**By 2030, predicted demand of 165 million tons (about 80 million more) of seafood will have to come from fish farming**

**This implies that we will need 2-3 million tons of more feeds per year**

**Until recently, most fish produced in Europe relied much on capture marine fishery derived ingredients (fish meal & fish oil) for feeds**

**Sustainable feeds for aquaculture should be less reliant on fishery derived ingredients**



**Formulated compound Aquafeeds in Europe : about 4 mio tons**

**= 1,6 mio Tons of proteins; 0,5-0,6 mio tons of fats**

**Aqua Feeds : nutrient dense, protein-rich, high-fat, high energy**

**ARRAINA aims at developing sustainable aquafeeds with low levels of FM & FO using alternative plant protein and lipid sources and analysing the consequences**

# Background

Several EU funded projects V framework  
Sustainable fisheries and aquaculture

**FISHMEAL REPLACEMENT**

**“PEPPA”**

**FISH OIL REPLACEMENT “RAFOA”**

**GUTINTEGRITY**

**FPPARS**

**PUFAFISH**

↓  
**FORM**

# PEPPA : Perspectives of Plant Protein Usage in Aquaculture

## General objectives

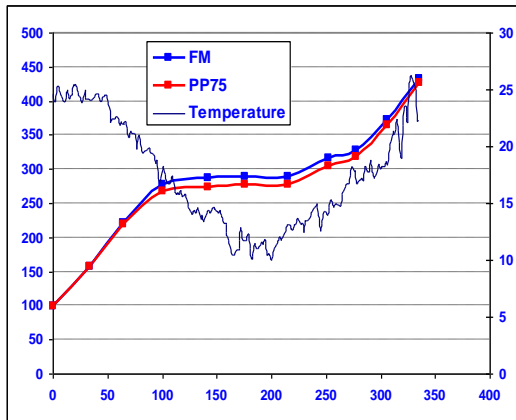
Replace the maximum amount of fish meal by plant protein sources in fish diets while improving muscle protein growth, fish quality, health, reproductive potential and environmental quality,

To understand the metabolic fates of dietary amino acids (AA) and carbohydrates as carbon-donors and as an energy source

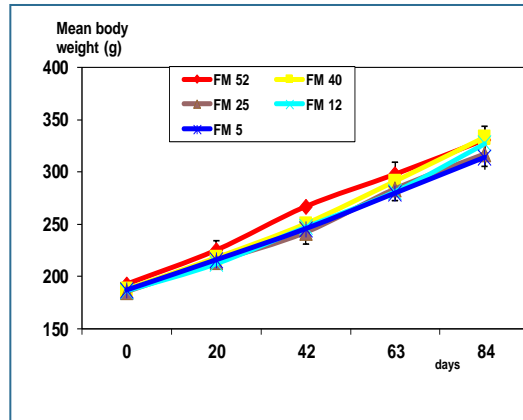
To strengthen our understanding of the relationships between nutritional factors and endocrine control of muscle growth and adiposity using cellular and molecular approaches.

# Fish meal replacement by a mixture of plant protein ingredients

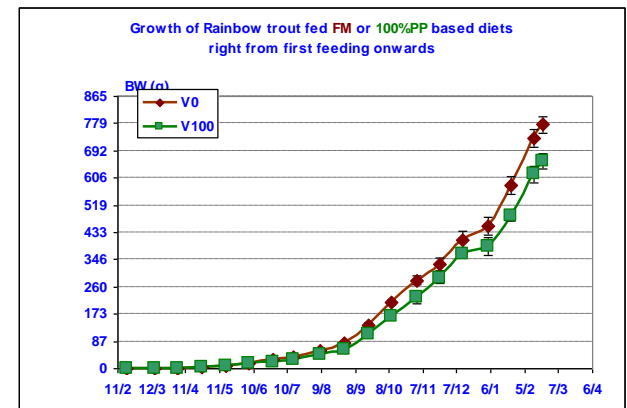
## Gilthead seabream



## European seabass



## Rainbow trout



# RAFOA

## OBJECTIVES

To replace as much as possible of the fish oil in farmed fish feeds with vegetable oils, without significantly compromising the health and welfare and growth performance of the fish, or its health promoting, taste and other acceptability characteristics to the consumer and processor;

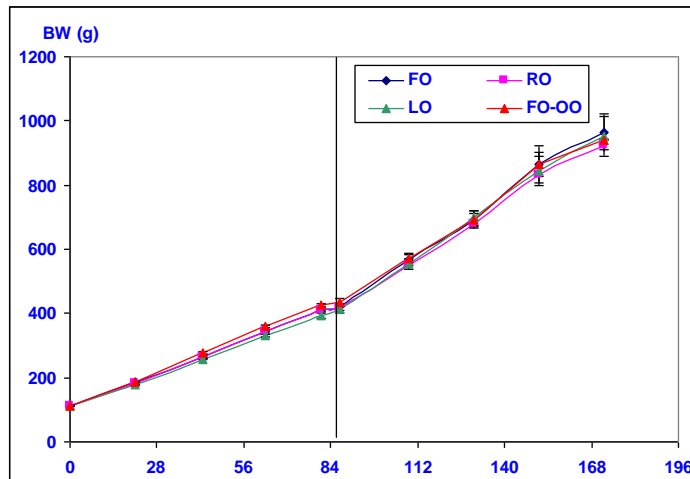
To underpin the findings by advancing current understanding of fish lipid nutrition.

Atlantic salmon, trout, sea bream and sea bass fed diets containing various blends of fish oil and vegetable oils including olive oil, linseed oil and rape seed oil, over the effective life spans of the species, namely from first feeding until the fish reach market size.

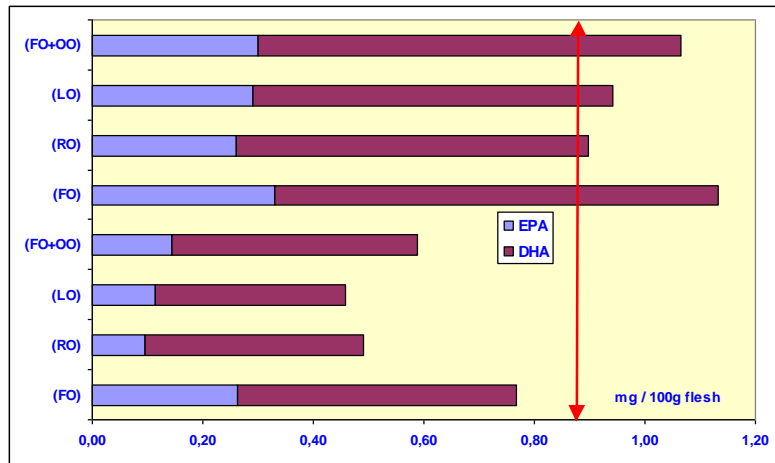
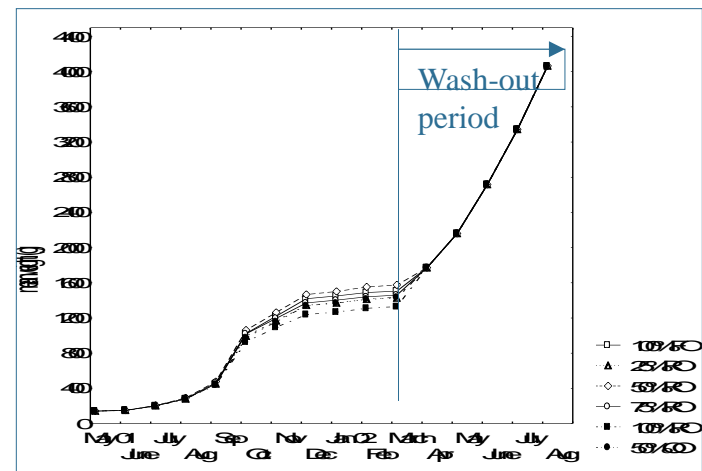


# Total replacement of Fish Oil by Veg Oils

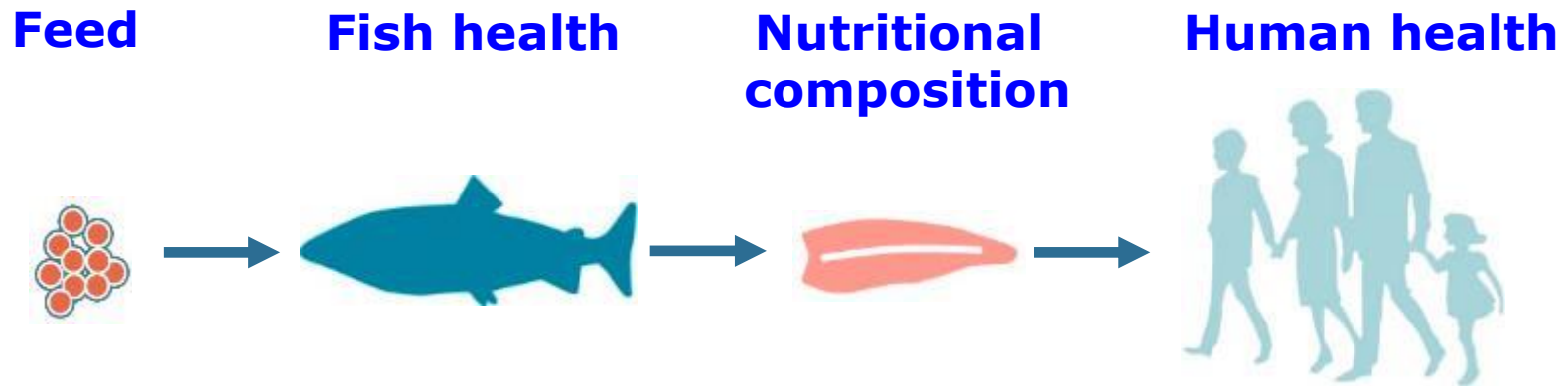
## Rainbow trout



## Atlantic salmon



**Finishing with FO to meet the RDA for EPA+DHA (0.87 g/d)**



**2006-2010**

**An integrated project (VI FP) covering all aspects from fish nutrition to human nutrition with partners from research & industry as well as producers**

**Strategic goal: to tailor aquaculture feeds to produce high-quality fish with significantly **reduced use of both fish meal and fish oil****

# Studies undertaken



- Develop feeds with low levels of FM & FO
  - Develop and apply adequate integrative tools (husbandry, metabolic, molecular) to analyse the physiological or environmental consequences
  - Ensure that the Health & Welfare of farmed fish are ensured
  - Analyse flesh quality, sensory value and consumer response
  - Analyse Nutrient-Genotype Interactions
  - Analyse sustainability of such feeds mainly from terrestrial plant sources ....
- 
- Long-term growth studies with different species: Atlantic salmon, rainbow trout and gilthead seabream with low FM & low FO levels followed by finishing with high FM& FO level feeds
  - Studies with carps (Hungary, India) under pond culture conditions
  - Field level demonstration trials with Atlantic salmon, trout and seabream

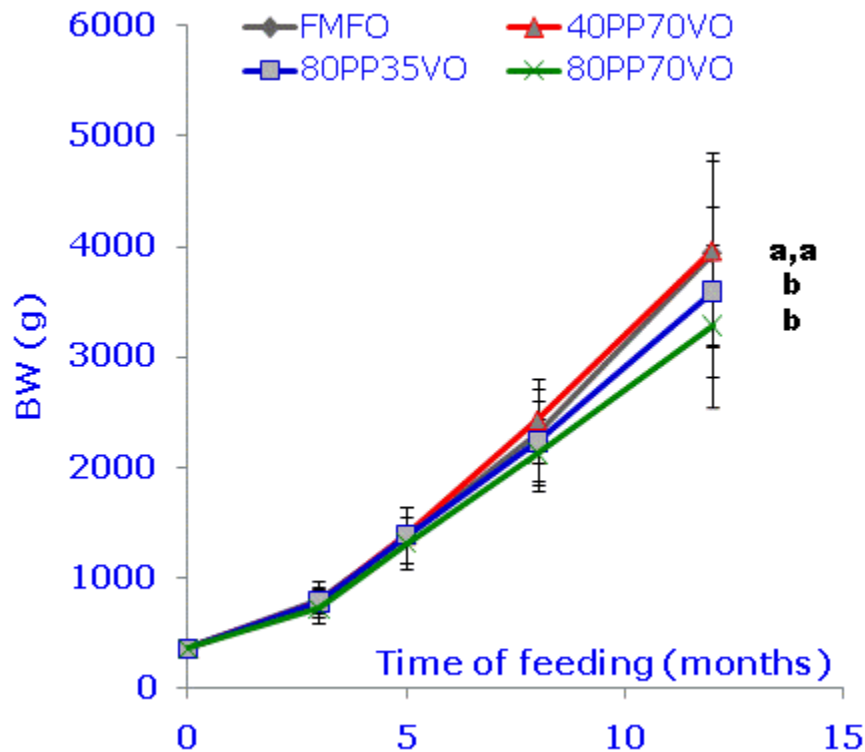
## Summary of target FM & FO levels



### Percent of Fish Meal and Fish Oil in Feeds of Fish Farmed in Europe and Aquamax targets for 2010

Species	2005 levels		Target levels demonstrated	
	FM	FO	FM	FO
Atlantic Salmon	35-47	25-33	12-16	8-12
Trout	30-35	20-25	5	5
Seabream	40-45	15-20	15	10
Carps	20-25	5-10	0	0

# Concomitant reduction in FM & FO: Atlantic salmon



**No difference in Feed or Protein efficiencies, Protein or fat retention**

**No health or welfare issues  
Healthy hind gut**

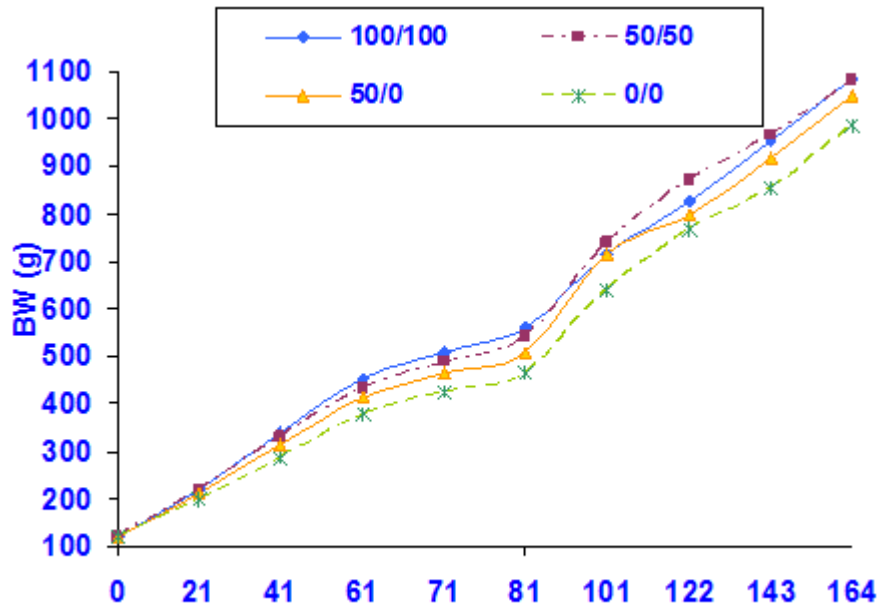
**Reduction in levels of Dioxins, PCBs,  
heavy metals and PAHs in salmon fillet fed  
PPVO feeds**

**Lower growth and feed intake during the  
first 3 months in 80PP70VO group and no  
catch-up later on**

**Increased adiposity in issues  
Lipid metabolism variably affected**

**Possible to grow Atlantic salmon from 70 to 1400g with feeds with 15% FM  
1 kg fish protein obtained from plant protein and 0.5 kg fish meal protein !**

# Concomitant reduction in FM & FO: Rainbow trout



Even with a 0/0 FM/FO feed,  
reduction in growth of 20%

Lipid metabolism: reduced plasma lipids,  
cholesterol, VLDL & LDL

Increased body fat, lipogenesis (FAS)

No diet induced difference in oxidation  
capacities or lipid transport mechanisms

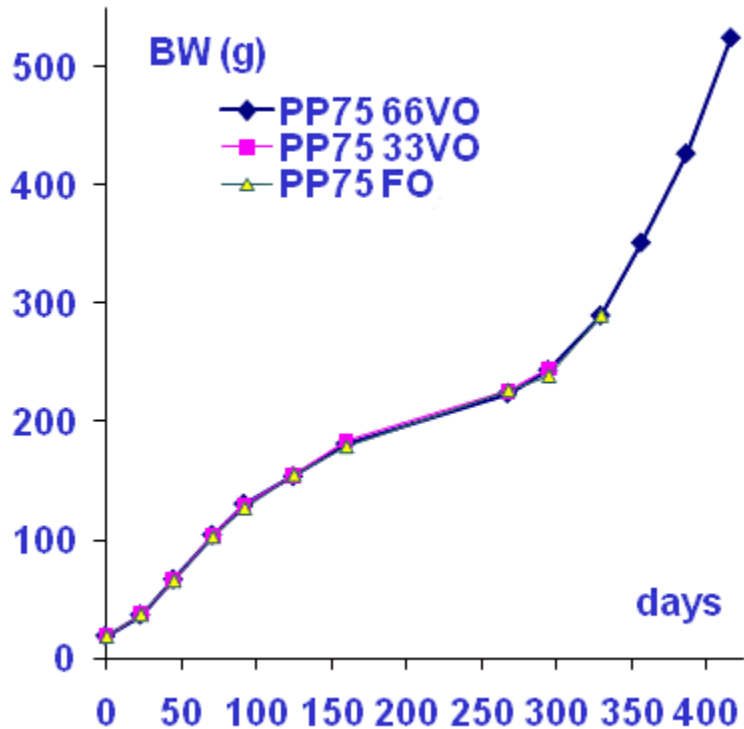
Muscle FA composition related to that of dietary  
FA profile

Sensory assessments similar but olfactive  
fingerprints distinct

Can tailor flesh EPA+DHA levels to meet the ISFAAL recommendations on w3 intake (3.5g/week)

After 3 wks of finishing, 300g fish previously fed with plant feedstuffs, or even 210g of trout provide the same after 12 weeks finishing with FO-enriched feed

# Concomitant reduction in FM & FO: Gilthead seabream



- No difference in growth, feed, protein efficiency or protein retention
- No adverse health issues

• PP75 100VO < PP50 100VO

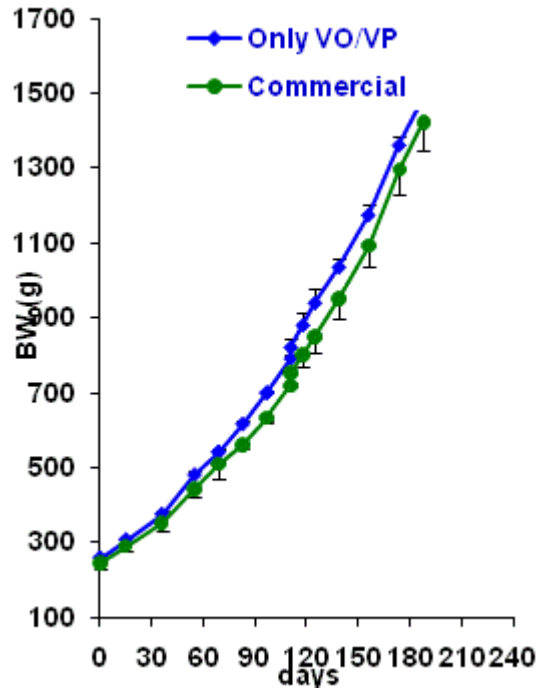
- Increased liver fat with 100VO
- Reduced contaminant levels

- Muscle FA profile reflects that of the diets
- Sensory properties similar but distinct olfactive fingerprints

- Gilthead seabream can be grown with feeds with low FM & FO with no adverse effects on growth or feed utilisation
- EPA+DHA requirement of Gilthead seabream <0.7% ?

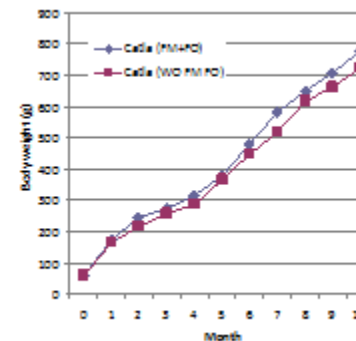
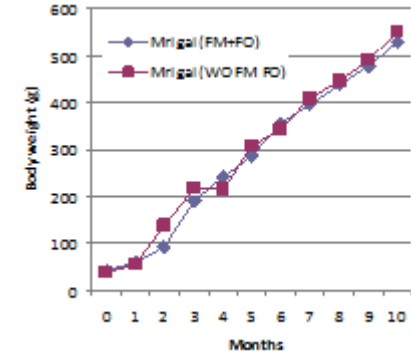
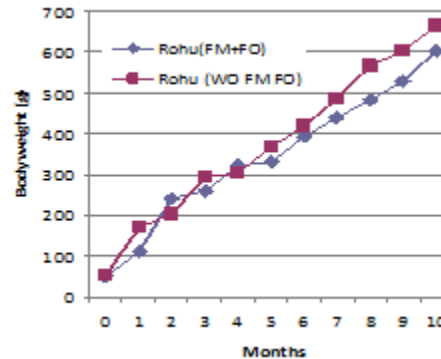
# Carps

## Common carp



Feeds with no FM or FO are as good as a commercial feed used for common carp culture;  
However, better growth with FM+FO inclusion; no adverse effects on fish health, growth or flesh quality

## Indian major Carps: Polyculture



With Indian major carps, under polyculture systems, no differences between groups fed feeds with or without FM& FO

Flesh FA compositions similar in both groups  
Contribution of natural food



# Analysis of nutrient x genotype interactions

## Objectives:

identify / exploit genotypes with enhanced ability to utilise plant feedstuffs

identify / exploit genotypes which maintain tissue n-3HUFA levels when fed diets with low n-3HUFA

## Models

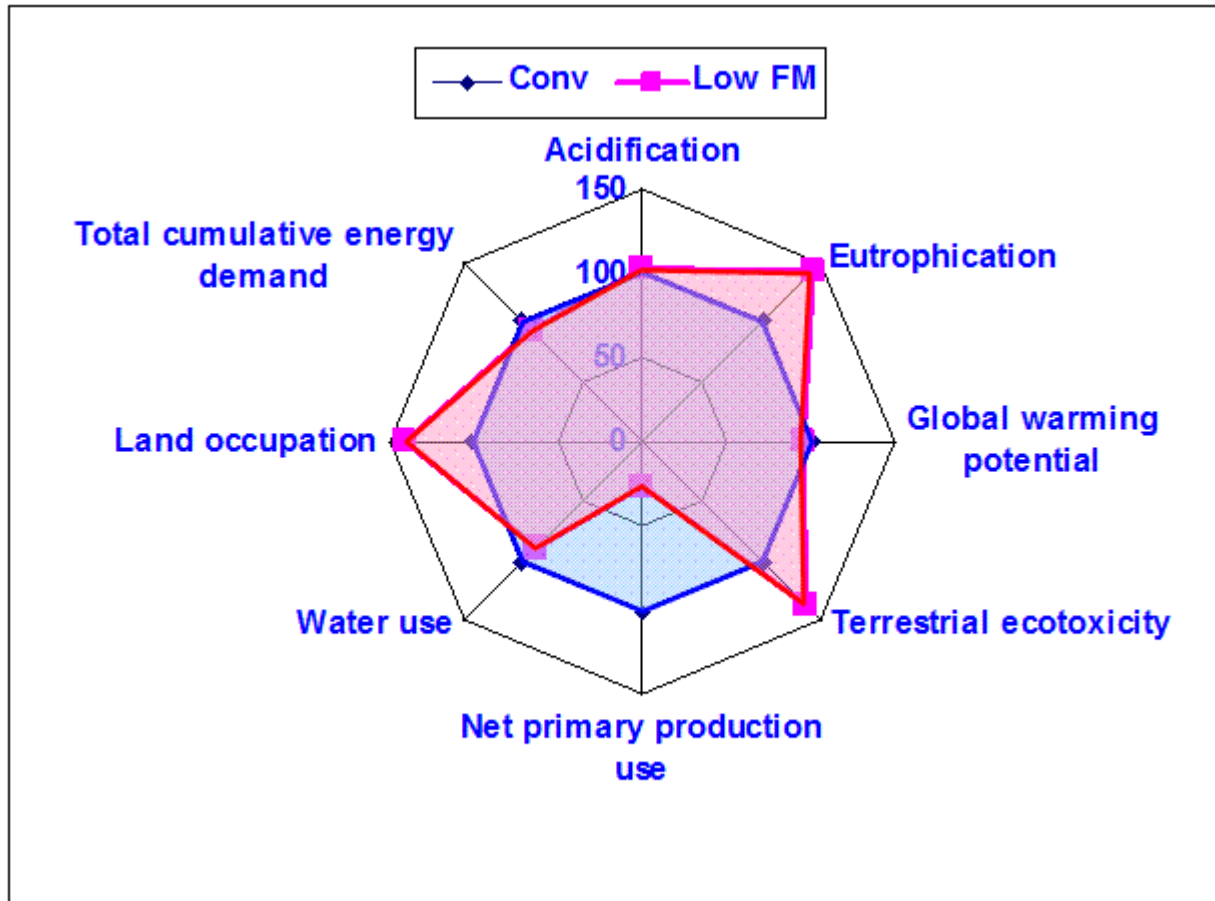
Lean and fat strains of Atlantic salmon, rainbow trout

## Studies

Low FM + high or low FO feeds over long-term

# Life cycle analysis as a tool to assess the overall environmental impacts

## Comparing low FM trout feed against a conventional feed



Increased use of terrestrial plant products

*Increased impacts mostly linked with agricultural practices*

*Eutrophication*

*Ecotoxicity*

*Land Occupation*

*Net primary production use is reduced*

# Fish-In Fish-Out (FIFO) Ratios

**Global yield from wild fish: FM = 23 – 25 %; FO = 4 - 5 %**

$$\text{FIFO} = \frac{\text{FM, \% in feed}}{\text{FM yield from wild fish}} + \frac{\text{FO, \% in feed}}{\text{FO yield from wild fish}} \times \text{Feed Gain ratio}$$

Species	2006	Post-Aquamax
Atlantic salmon	➤ 7	3.6
Rainbow trout	6	1.5
Seabream	4.5	3.0
Carps	1.5	0.0

**Results of the “Aquamax” project show significant reduction in FM and FO usage even in “FIFO” ratio is calculated in its most stringent form**

## Outcomes

**Significant proportions of FM and FO can be replaced by plant-based alternative protein (amino acid) and fat (fatty acid) sources in fish feeds**

**Results confirm that in all species there are no serious issues as regards growth, nutrient utilisation or physiological well-being**

**Achieved despite specific constraints and addressing issues of importance in the European context:**

**No terrestrial animal products, No GM products ...**

**Fish health and welfare issues, Nutritional value, Food safety issues (Least-risk!), Environmental sustainability, Social equity...**

**Number of issues pointed out at the level of fish as a biological system**

**Life stages**



**Studies on five major species of fish  
with different biological cycles**

**Over the Full Life Cycle**

**Improve knowledge on nutrient requirements**

**Develop novel nutrient delivery vectors**

**Undertake Long-term trials with low FM/FO feeds**

**Ensure growth, physiological well-being, health of fish**

**Ensure nutritional value, quality and food safety**

**Prepare fish for the novel feeds**

- **Knowledge & Innovation , Original research, EU advance**  
Consolidated nutrient requirement database  
Confer flexibility in choice of feedstuffs  
Assess Produce: Predictive tools / Biomarkers  
Prepare the fish for the future : programming ?
- **Science & Industry close links**  
consortium of 10 RTD & 11 industry / SMEs  
feed companies, producers,  
environment, certification
- **CFP: ensure sustainable seafood production, environmental standards**
- **Strengthen EU skills and competence towards sustainable Blue Growth**  
Training courses, booklets, innovation workshops





## What was Done / Achieved ?

Studies undertaken with five major species of fish having different life cycles

Improved knowledge on nutrient requirements

Long-term trials with low FM/FO feeds in link with producers

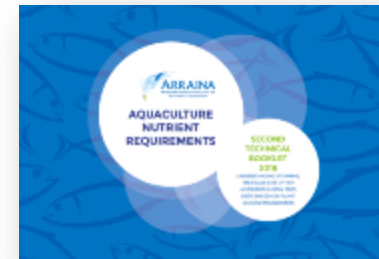
Confer flexibility in the choice of feedstuffs for the aquafeed Industry

Develop micronutrient mix adapted for low FM/FO feeds

Develop feeds with improved nutrient availability

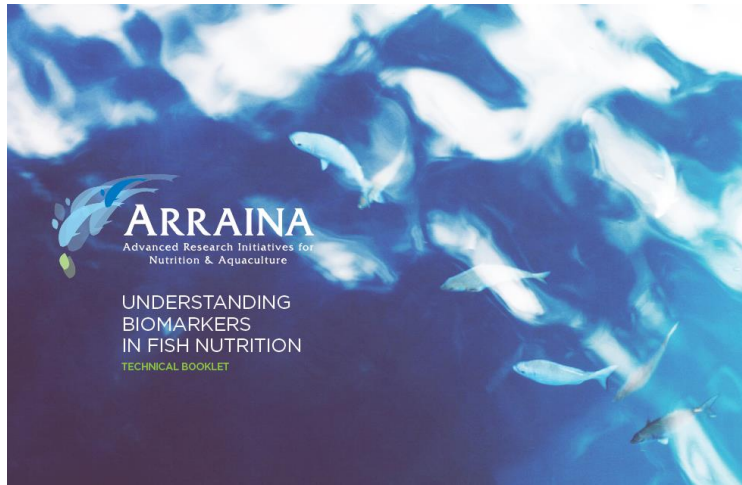
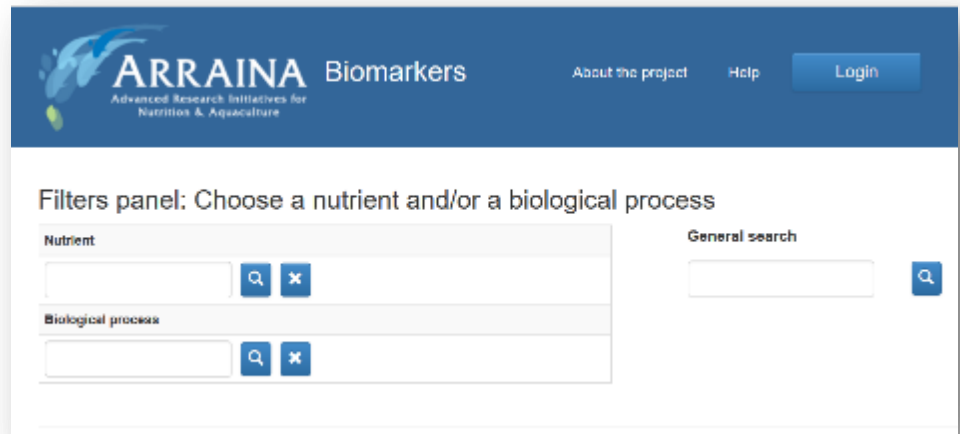
Web-based tool to assess environmental impacts of feeds

Validated through a “Proof of Concept” challenge





## Tools / biomarkers for assessing physiological status

**ARRAINA Biomarkers**  
Advanced Research Initiatives for  
Nutrition & Aquaculture

About the project Help Login

Filters panel: Choose a nutrient and/or a biological process

Nutrient

Biological process

General search

Or environmental consequences

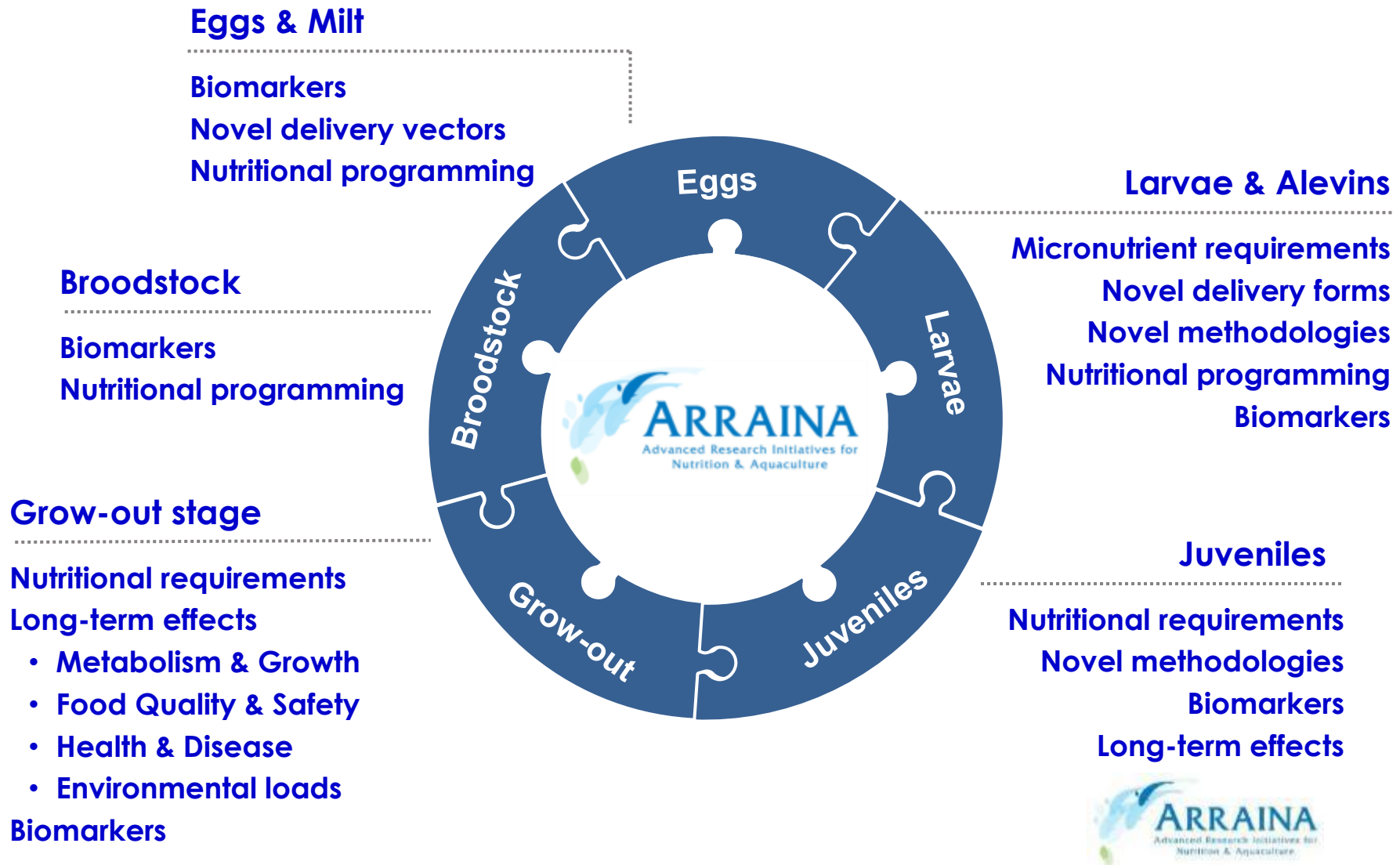


**wastEst** – a modeling tool to compare the  
environmental impact of different fish  
feed formulations

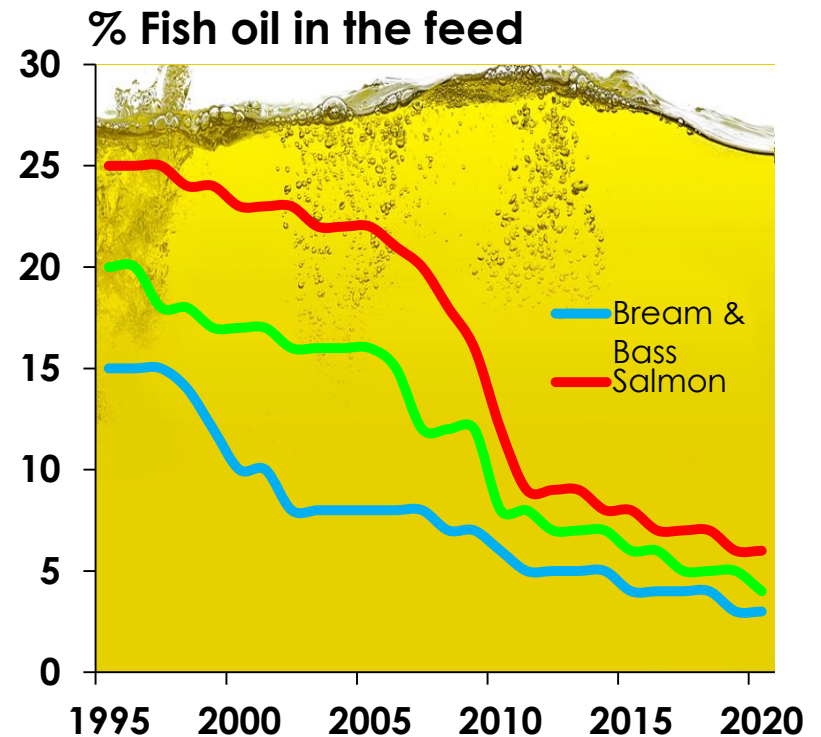
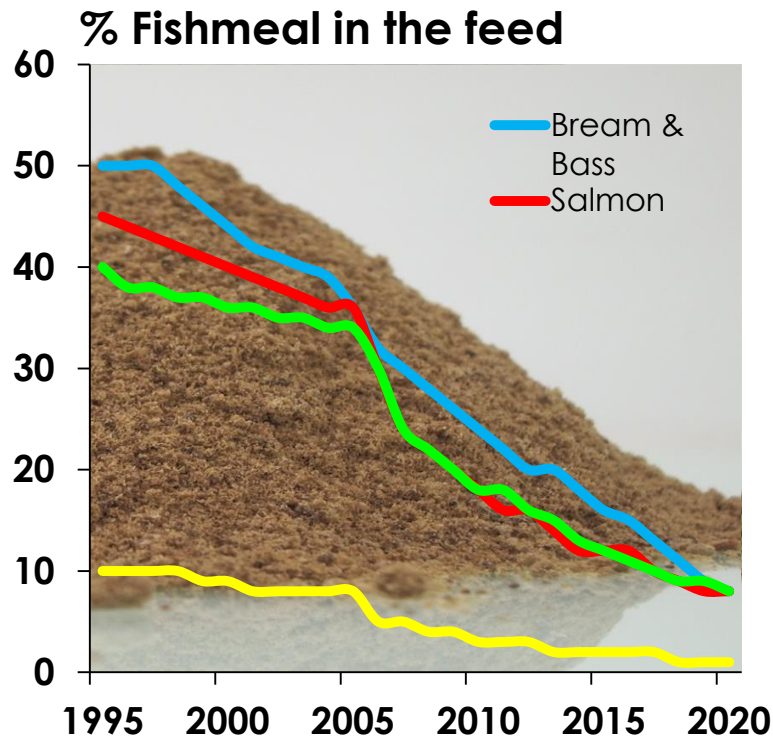


# Under scenarios of alternative feeds...

In all five species, specific knowledge gaps are being tackled



# Sustainable feeds for aquaculture should be less reliant on fishery derived ingredients



(Recalculated by Sachi Kaushik from Tacon & Metian, 2008, 2015; FAO, 2014)



Consortium of 10 RTD & 11 industry / SMEs, feed companies, farmers..  
Stakeholder advisory board (FEAP, FEFAC, EAS, ASC, IUCN)

## What Next ?

Validate results across the sector

Confirm the high resource efficiency of fish farming sector

Integrate information gained here for other initiatives

Develop future feeds for “Marine agronomy”?

Assert EU lead in the fish feed industry

Feed / Breed Interactions

Prepare / Programme fish for the future ?