FISH NUTRITION 101

Feeds & Feeding Strategies for Aquaculture

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WHY DO WE FEED FISH?

“The growth of a fish results from its consumption of food...” (Vasnetsov 1953)

Yes, but feed provides…

Energy

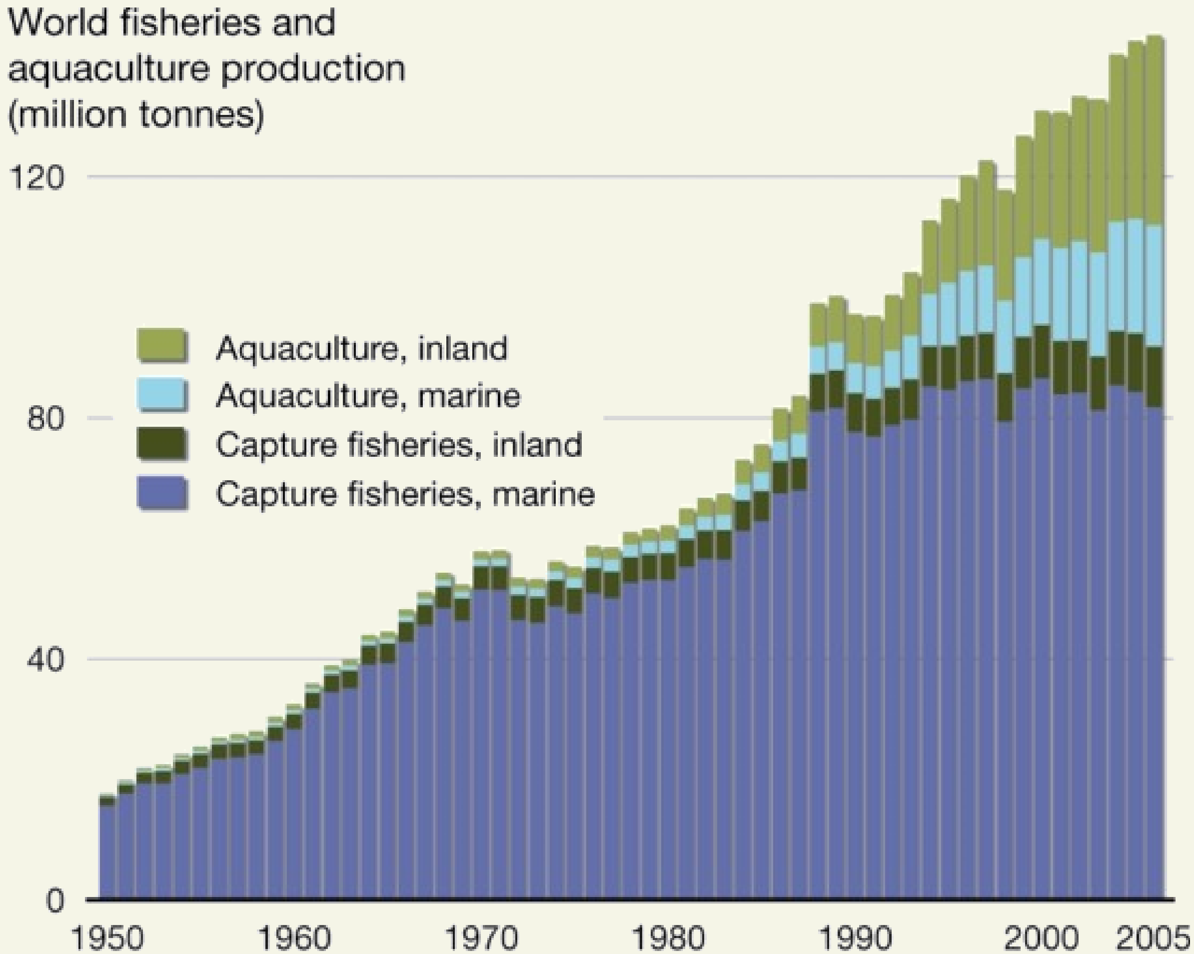
Biosynthetic building blocks

Essential nutrients

Amino acids, fatty acids, vitamins, and minerals

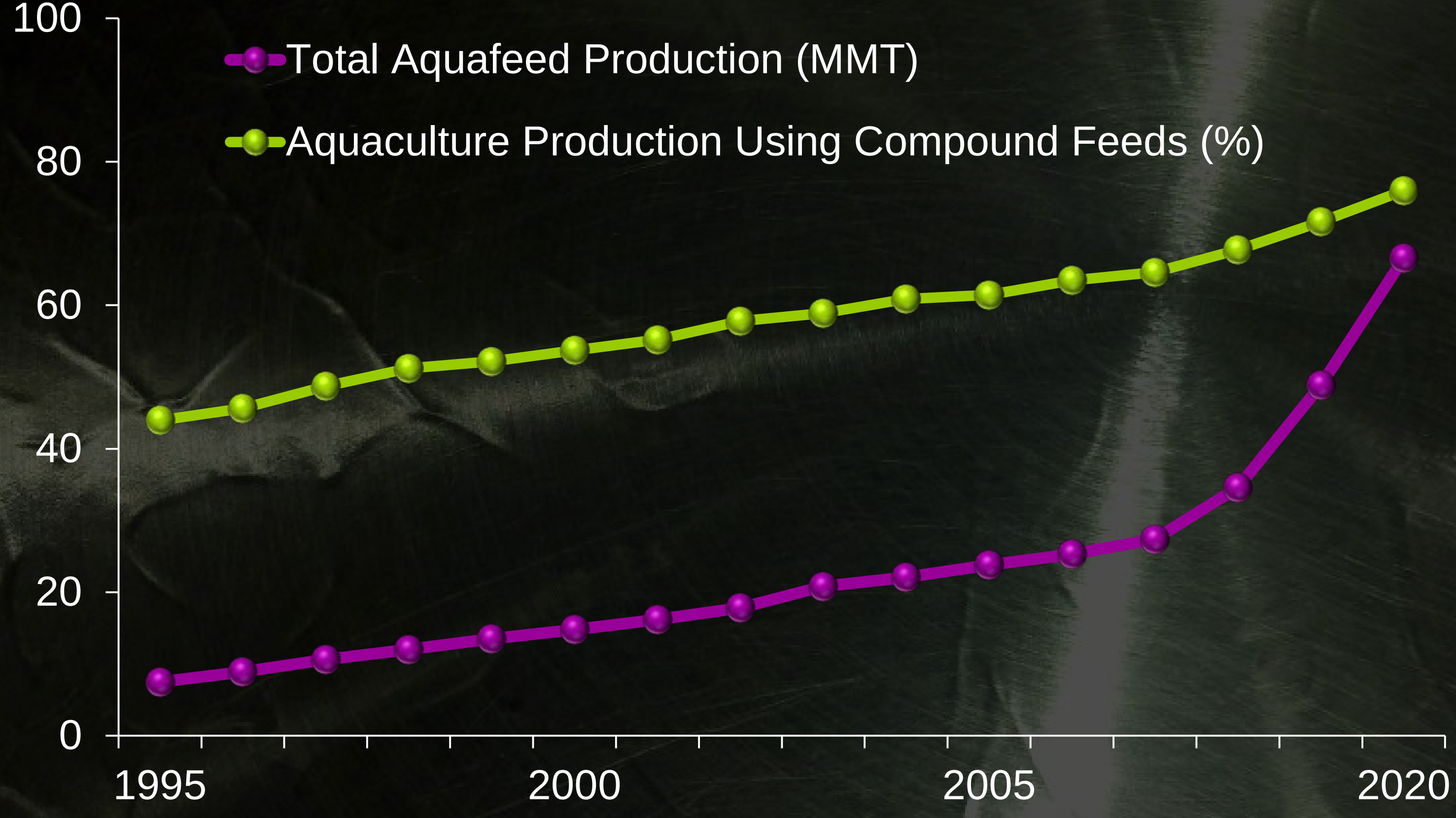
This presentation will cover the basics of fish nutrition and how feeds are formulated to provide fish with what they need

Aquaculture production has continually outstripped projections, and there is little reason to believe that it will not continue to do so. –World Bank 2006

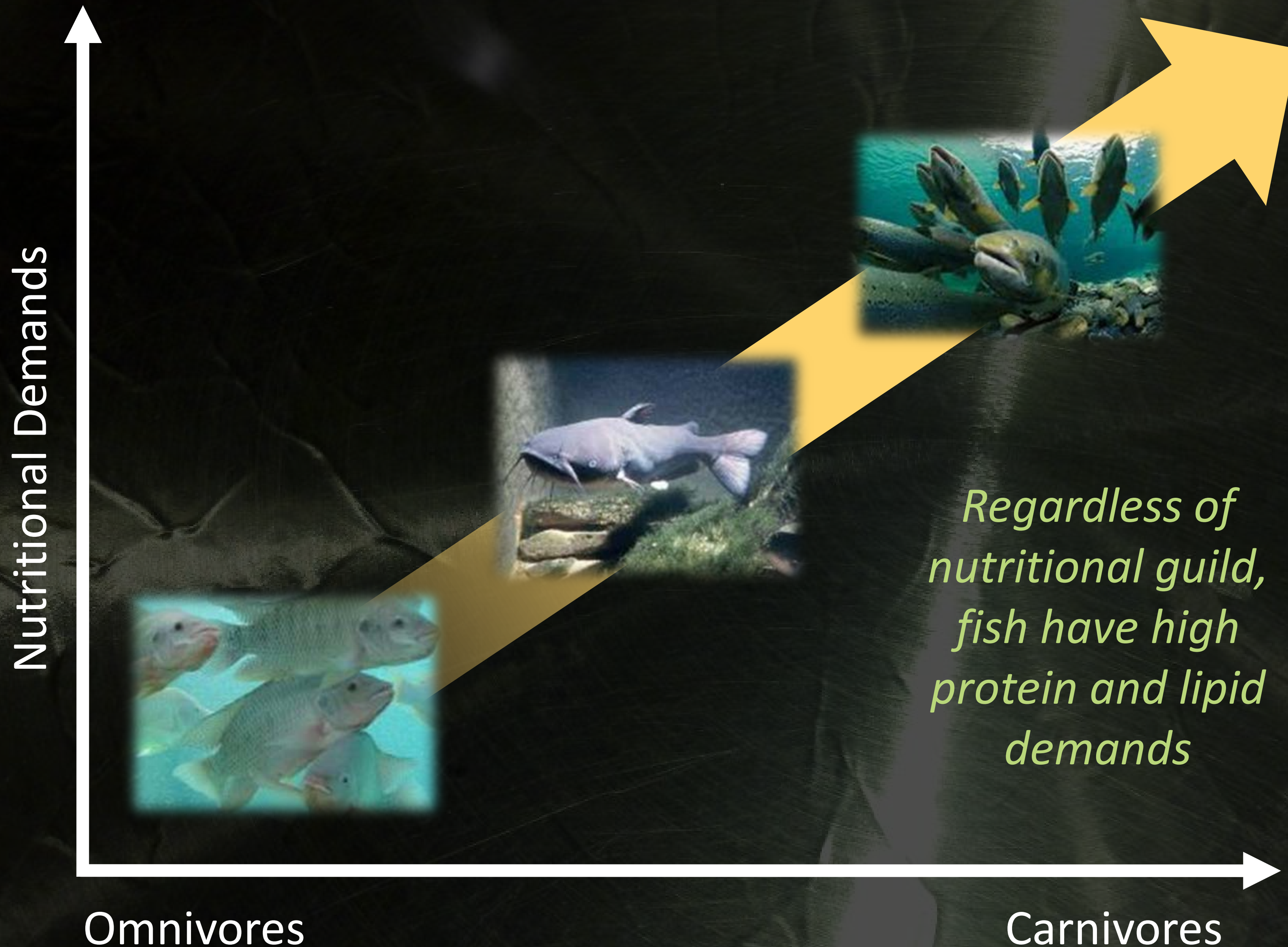


UNEP 2009

INCREASING GLOBAL RELIANCE ON COMPLETE FEEDS



Tacon and Metian 2008


Nutritional Demands
Regardless of nutritional guild, fish have high protein and lipid demands
Omnivores
Carnivores

Fish have high protein demands…

Species	Dietary Protein (%)
Asian sea bass	45
Atlantic halibut	51
Atlantic salmon	55
Tilapias	30-40
Pacific salmonids	40-45
Carps	31-43
Eels	40-45
Sea basses	45-50
Sea breams	50-55

Species	Dietary Protein (%)
Freshwater basses	35-47
Trouts	40-53
Flatfishes	50-51
Catfish	32-36
Beef cattle	7-18
Dairy cattle	12-18
Sheep	9-15
Swine	12-13
Poultry	14-28

…but require amino acids, not protein

Halver and Hardy, 2002

ESSENTIAL AMINO ACID REQUIREMENTS

Essential Amino Acids	Estimated Requirement (Rainbow Trout)	Fish Meal Composition
Arginine	3.3-5.9	6.2
Histidine	1.6	2.8
Isoleucine	2.4	4.2
Leucine	4.4	7.2
Lysine	3.7-6.1	7.8
Methionine	1.8-3.0	3.4
Phenylalanine	4.3-5.2	3.9
Threonine	3.2-3.7	4.2
Tryptophan	0.5-1.4	0.8
Valine	3.1	5.0

All data expressed as % crude protein

Halver and Hardy, 2002; Omega Protein, Inc., 2006

BASIS OF AMINO ACID DEMAND

Amino acids are/can be used for…

Synthesis of peptides, proteins, nucleic acids, amines, hormones, and other N-containing compounds

As a carbon source for intermediary metabolism

Energy production

Protein demand is higher for fish because of…

Greater carcass protein content

Lower energy requirements

Fish have high lipid demands too…

Species	Dietary Lipid (%)
Trout	18-20
Other salmonids	20-30
Tilapia	<10
Sea breams	10-15
Carp	<18
Sea basses	12-18
Yellow tail	11
Red drum	7-11
Grouper	13-14

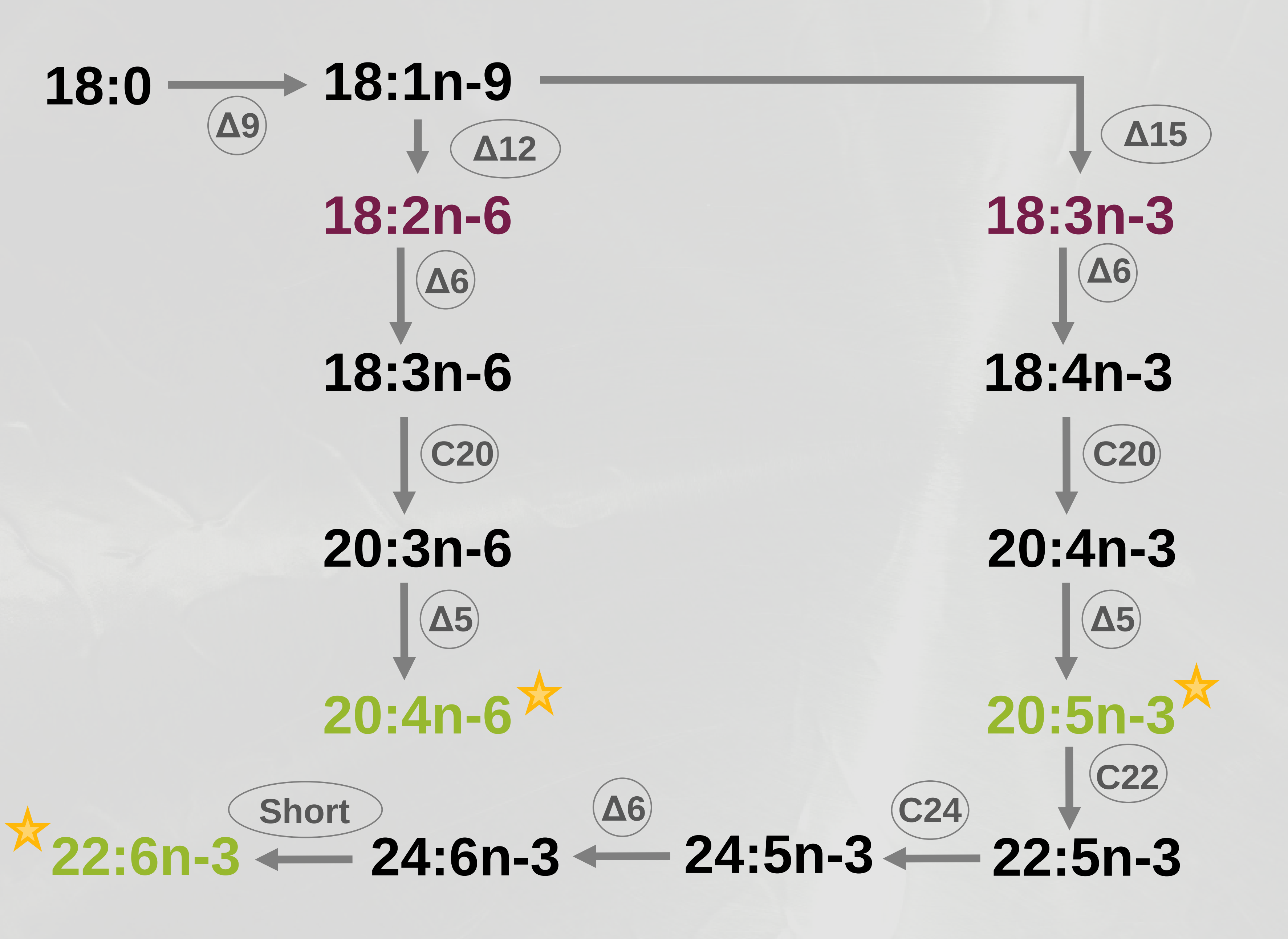
Species	Dietary Lipid (%)
Milk fish	7-10
Catfish	5-6
Turbot	<15
Sole	5
Beef cattle	1-2
Dairy cattle	1-2.5
Sheep	2.5-3
Swine	2-6
Poultry	~3

…but require fatty acids, not lipid

Guillaume et al. 2001


18:0
Δ9
18:1n-9
Δ12
Δ15
18:2n-6
18:3n-3
Δ6
Δ6
18:3n-6
18:4n-3
C20
C20
20:3n-6
20:4n-3
Δ5
Δ5
20:4n-6
20:5n-3
C22
Short
Δ6
C24
22:6n-3
24:6n-3
24:5n-3
22:5n-3


18:0
Δ9
18:1n-9
Δ12
Δ15
18:2n-6
Limited physiological functions
18:3n-3
Δ6
Δ6
18:3n-6
18:4n-3
C20
C20
20:3n-6
20:4n-3
Δ5
Δ5
20:4n-6
Distinct physiological functions
20:5n-3
C22
Short
Δ6
C24
22:6n-3
24:6n-3
24:5n-3
22:5n-3


18:0
Δ9
18:1n-9
Δ12
Δ15
18:2n-6
18:3n-3
Δ6
Δ6
18:3n-6
18:4n-3
C20
C20
20:3n-6
20:4n-3
Δ5
Δ5
20:4n-6
20:5n-3
C22
Short
Δ6
C24
22:6n-3
24:6n-3
24:5n-3
22:5n-3

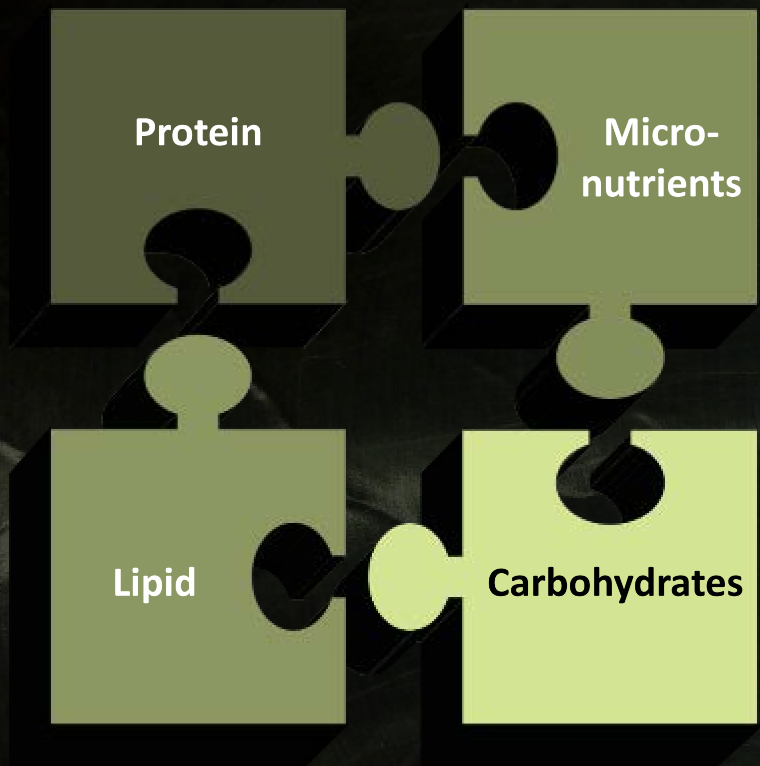
ESSENTIAL FATTY ACID REQUIREMENTS

Species	Advanced Juvenile/ Adult Requirement	Fish Oil Composition
Rainbow trout	18:3n-3 (0.7-1.0%) n-3 LC-PUFA (0.4-0.5%)	18:2n-6 (~1.7%)
Common carp	18:2n-6 (1.0%) 18:3n-3 (0.5-1.0%)	18:3n-3 (~2.0%)
Tilapia	18:2n-6 (0.5-1.0%)	
Various Pacific salmonids	18:2n-6 (1.0%) 18:3n-3 (1.0%)	20:5n-3 (~13%)
Gilthead seabream	n-3 LC-PUFA (0.9-1.9%)	22:6n-3 (~15%)
Red seabream	22:6n-3 (0.5%) 20:5n-3 (1.0%)	
Striped jack	22:6n-3 (1.7%)	LC-PUFA (~30%)

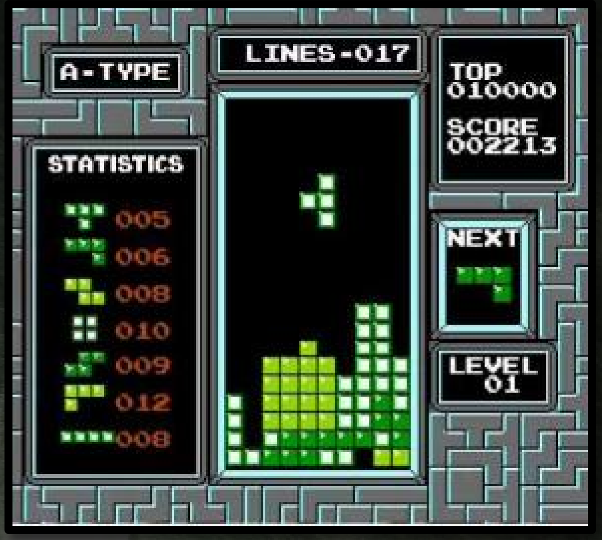
All values reported as % of dry diet

Halver and Hardy 2002

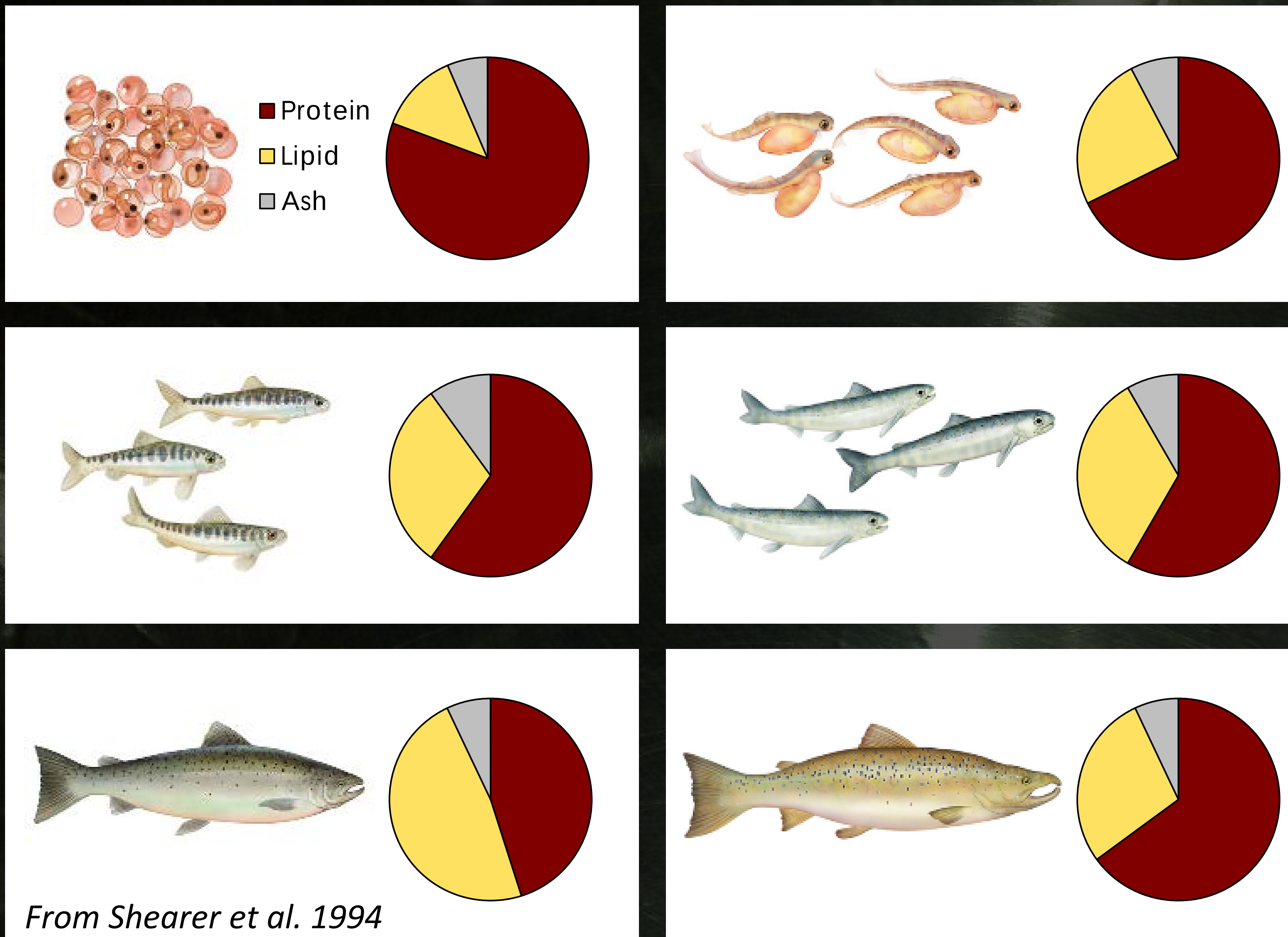
GROWTH HAPPENS WHEN LIMITING RESOURCES BECOME AVAILABLE AND IS AS FAST AS THE SLOWEST PROCESS



All the building blocks must be available before new molecules or tissues can be synthesized

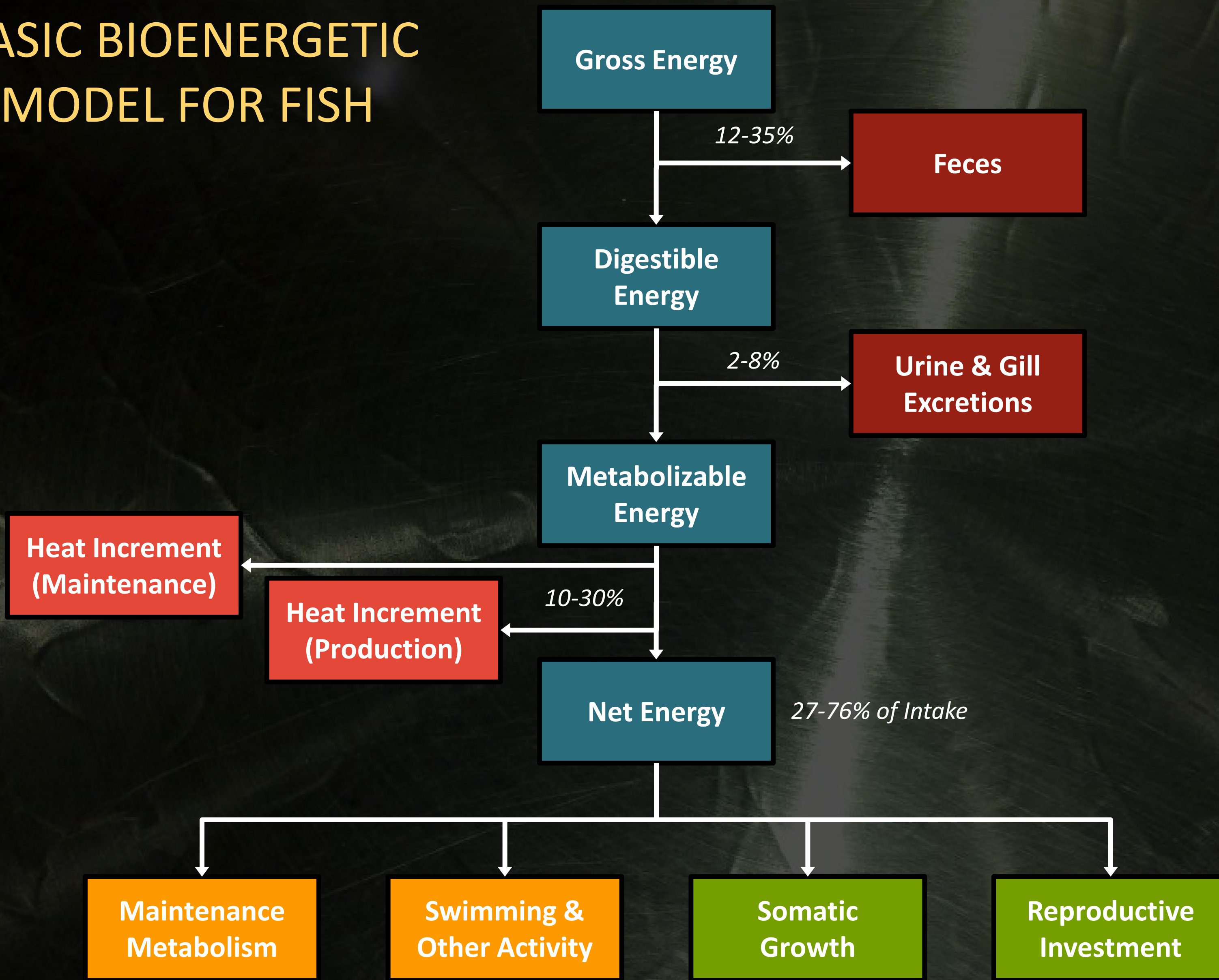


PROXIMATE COMPOSITION OF ATLANTIC SALMON



From Shearer et al. 1994

BASIC BIOENERGETIC MODEL FOR FISH



WHAT AFFECTS BIOENERGETICS & GROWTH?

Energy Intake	Feed composition, feeding rate, feeding frequency
Excretions	Gastric evacuation rate, life stage, feed digestibility, feed protein vs. CHO vs. lipid content, limiting factor for growth
Heat Increment	Water temperature, nutrient intake vs. demand, number and type of transformations to be made
Routine Metabolism	Life stage, body size, temperature, normal behavior and activity levels
Retained Energy Investment	Life stage, overall reproductive strategy, season

THINKING SMALL AND THINKING BIG

Higher resting metabolic rate

Higher energy expenditures

Higher feeding rates (e.g. 5%)

Higher maintenance demand

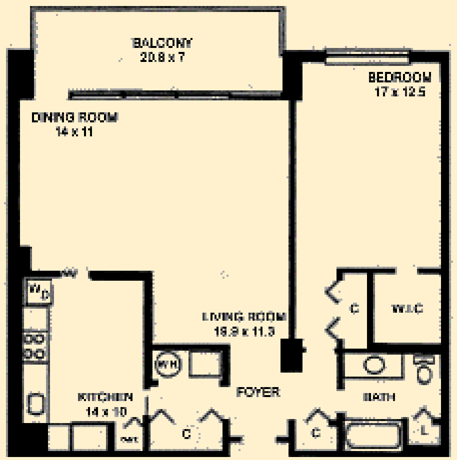
Lower resting metabolic rate

Lower energy expenditures

Lower feeding rates (e.g. 3%)

Lower maintenance demand

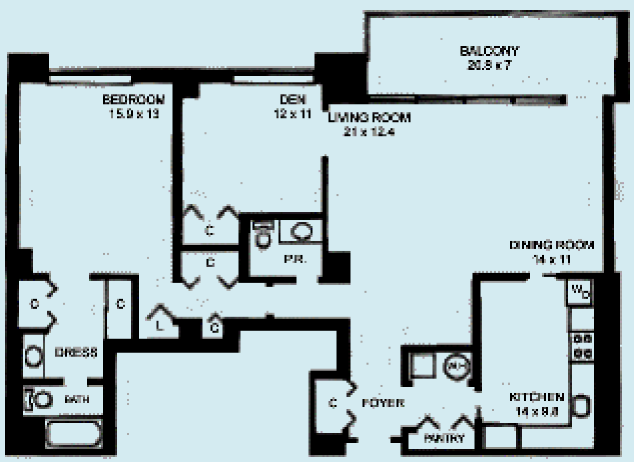
SMALL VS. LARGE FISH METABOLISM—AN ANALOGY



Size = 1043 ft^2

Construction cost = $102K

Cost per ft^2 = $98



Size = 1209 ft^2

Construction cost = $115K

Cost per ft^2 = $95

Tocher 2003, Li et al. 2008

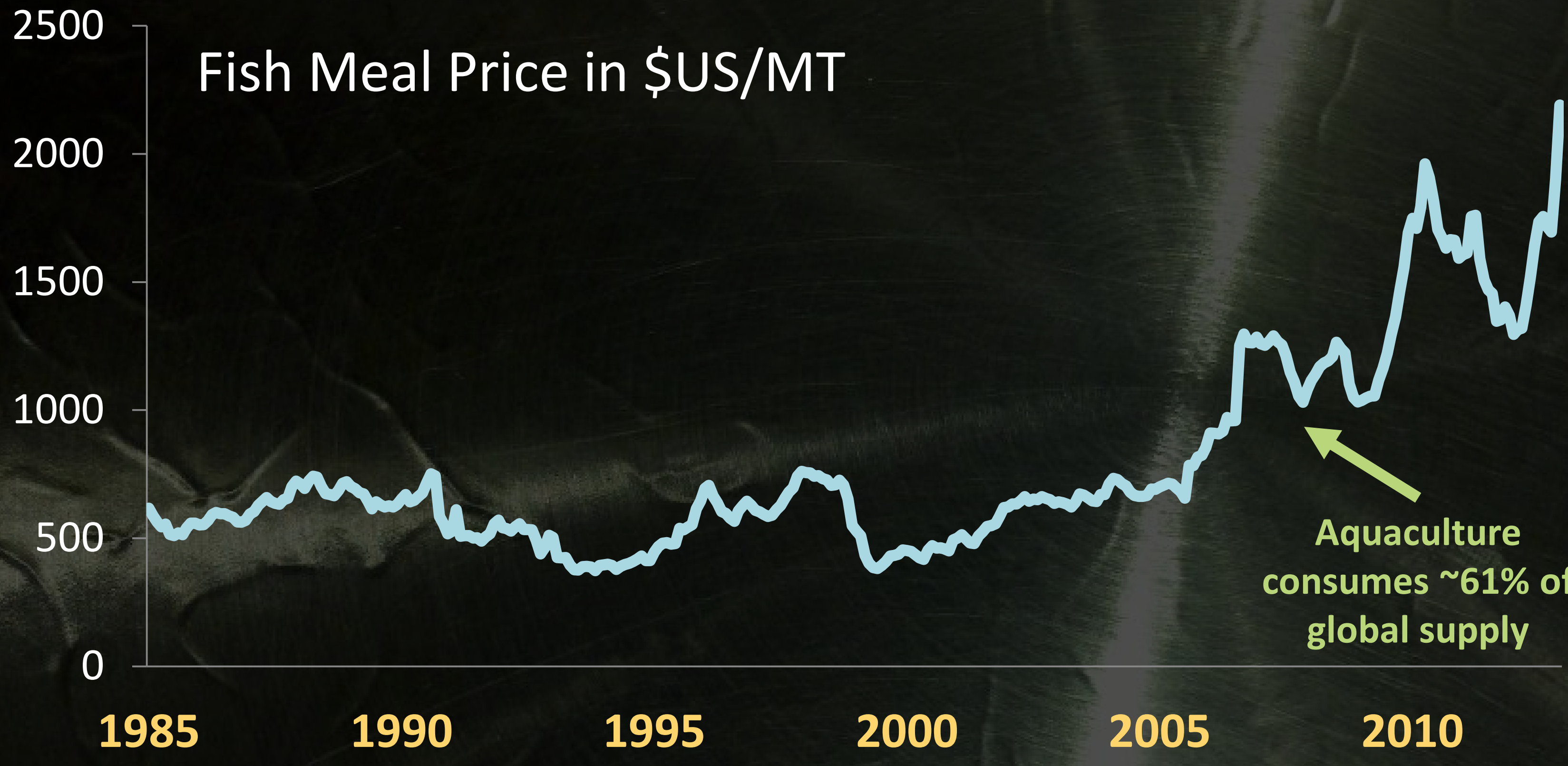
HOW DO I KNOW WHAT TO FEED?

- Feed as little protein and lipid as needed
  - *Minimize feed costs and effluents*
- Nutrient requirement or demand studies
  - *Published results*
  - *Previous experience with different feeds*
- Requirements of different lifestages or species
  - *Carnivores vs. omnivores*
  - *Effects of water temperature*
  - *Larvae vs. juveniles vs. broodstock*

Typical Feeds	High Energy (Carnivorous)	Medium Energy (Carnivorous)	Low Energy (Omnivorous)
Fish meal	25-50	20-40	0-20
Soy products	0-15	25-35	30-50
Gluten products	5-20	15-20	15-20
Cereal grains	10-18	20-25	30-45
Fats/oils	20-30	5-10	2-5
Other	3-5	3-5	3-5
Current price ($USD/MT)	**>1500 -- <500**		

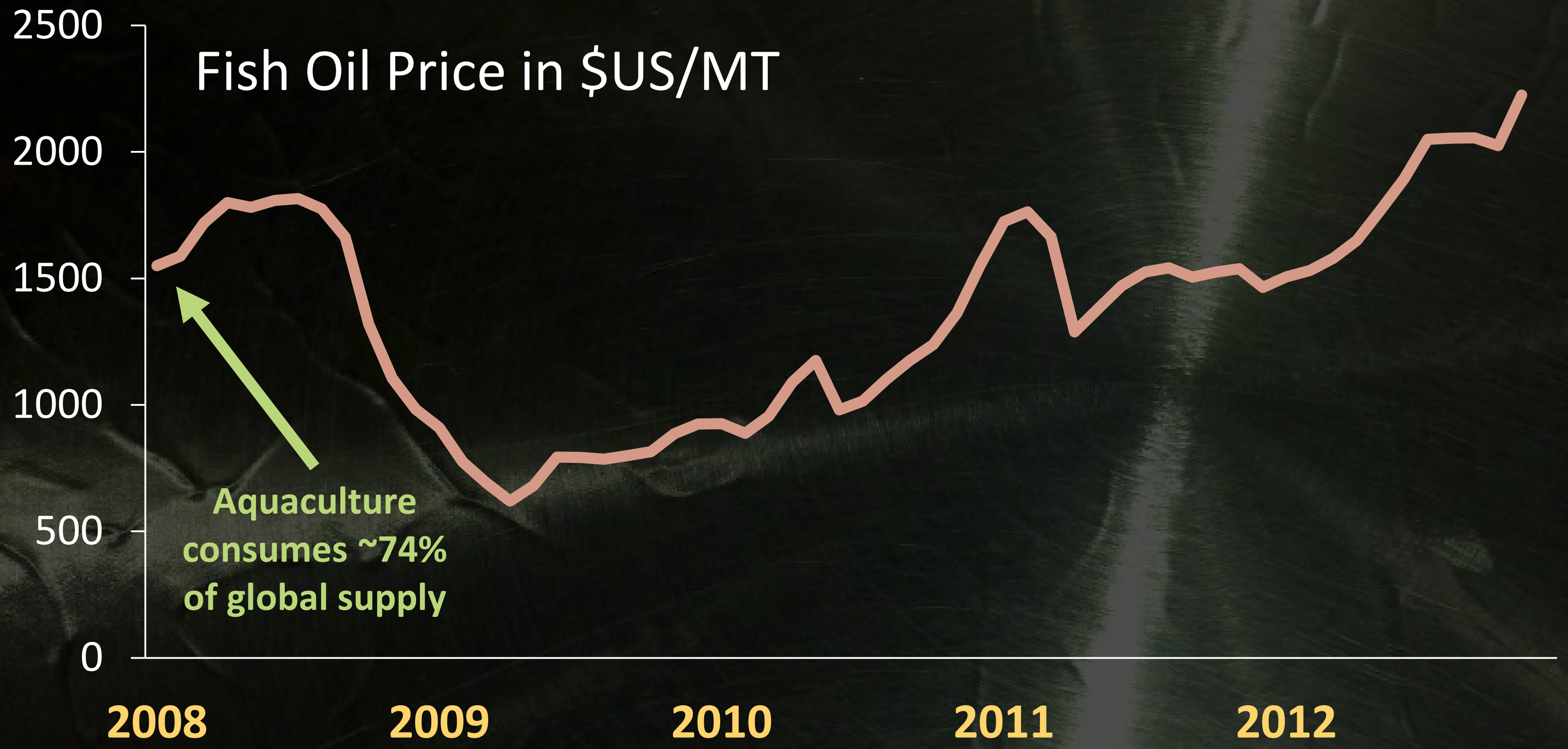
"…while the inclusion level of fish meal in feed is 25 percent, it actually accounts for 43 percent of raw material costs and 32 percent of total production costs. Alternative proteins such soybean, wheat and corn gluten, which can make up 45 percent of volume, account for 19 percent of raw material costs." (Seafood Source 2010)

WHAT WILL LIMIT THE GROWTH OF AQUACULTURE?



"…much research has focused on finding replacements for fish meal…Partial replacements have been achieved. However, no dramatic breakthroughs have been reported, and the share of fish meal and fish oil used in aquaculture is increasing…" (FAO 2008)

WHAT WILL LIMIT THE GROWTH OF AQUACULTURE?



"…given the difficulty in replacing fish oils…it is clear that competition for fish oil is likely to be a more serious obstacle for some sections of the aquaculture industry." (FAO 2008)

Marine Feedstuffs

?

Alternative Feedstuffs

Lower feed costs →

EAA, EFA, etc. may be low or absent →

← High levels of EAA, EFA, etc.

← Palatable, nutrient dense, highly digestible

← Maintain integrity of product

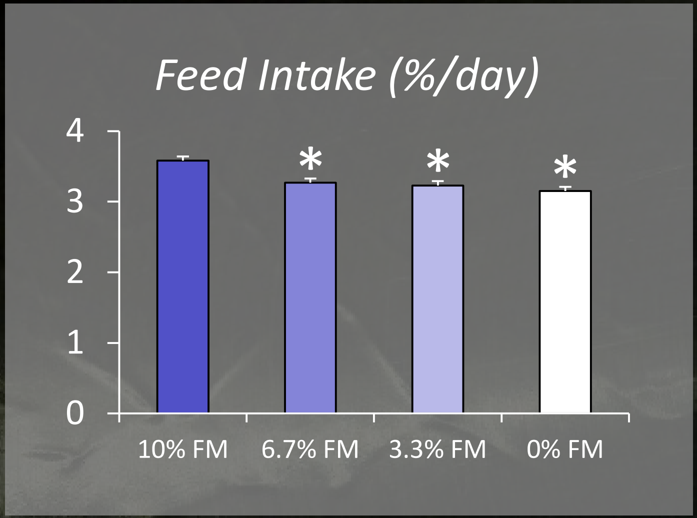
Readily available, sustainable →

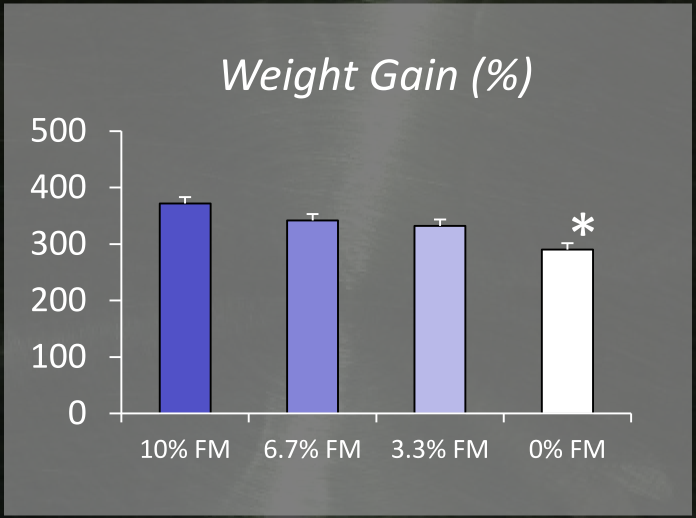
Decreased cost of production →

Safer products? →

REPLACING FISH MEAL…PRODUCTION EFFECTS

Case study with soy protein concentrate in HSB feeds



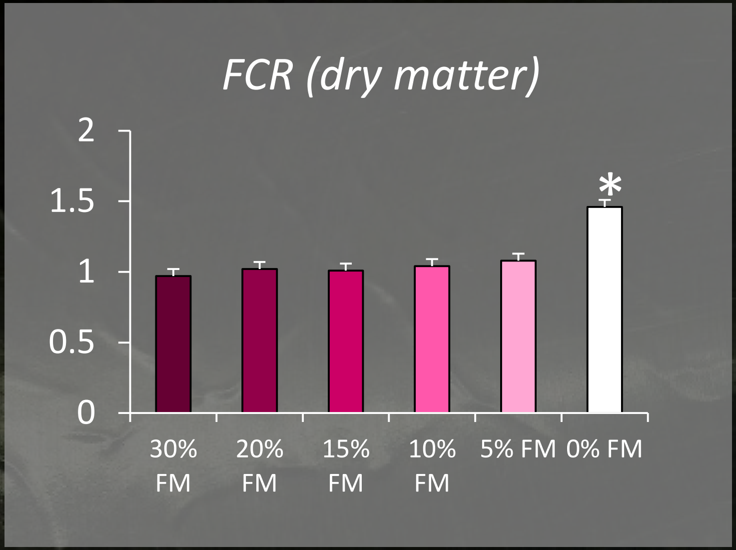


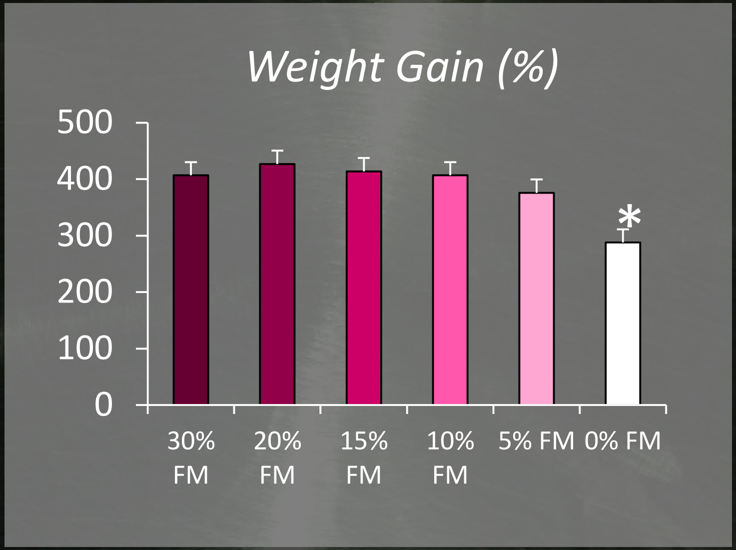
Fish meal sparing can reduce the palatability of feeds, especially for carnivorous fish

Blaufuss and Trushenski 2011

REPLACING FISH MEAL…PRODUCTION EFFECTS

Case study with soybean meal in HSB feeds



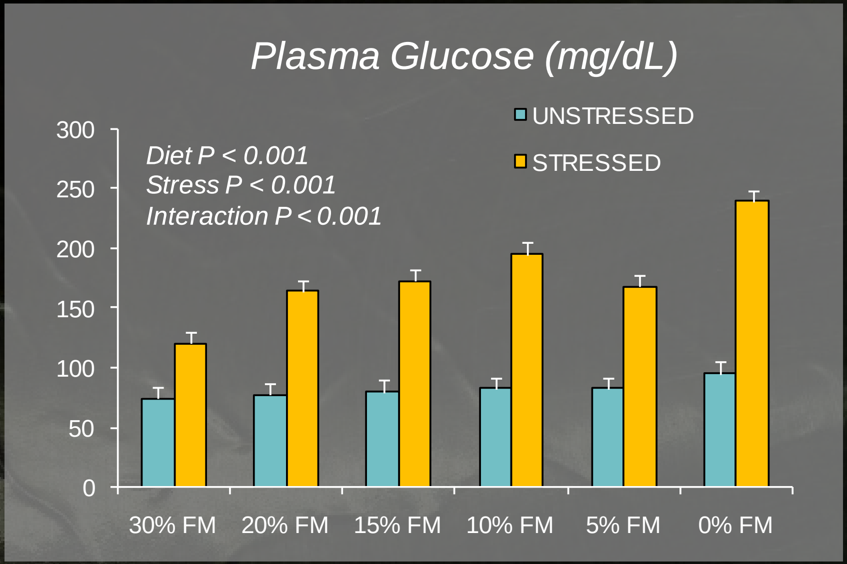


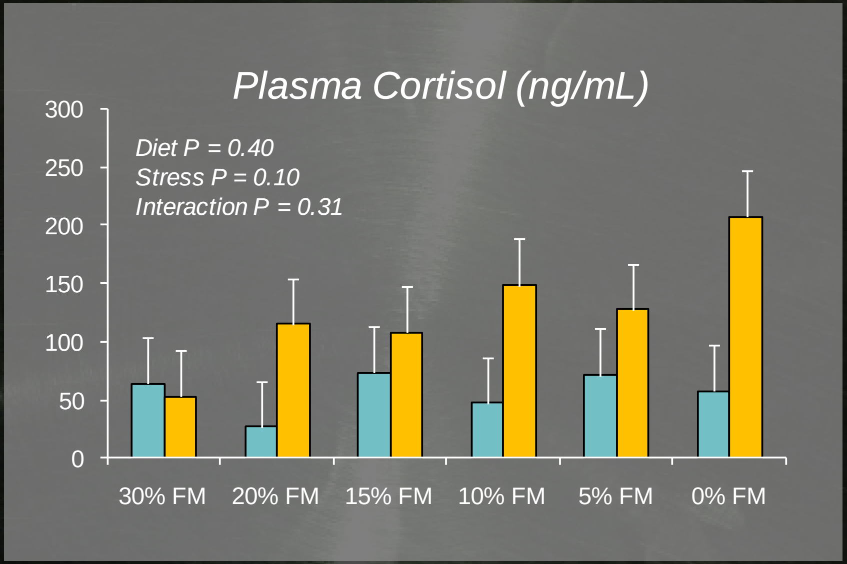
Even when intake is good, EAA deficiencies and utilization problems can still develop with reduced fish meal feeds

Laporte and Trushenski 2011

REPLACING FISH MEAL…STRESS EFFECTS

Case study with soybean meal in HSB feeds



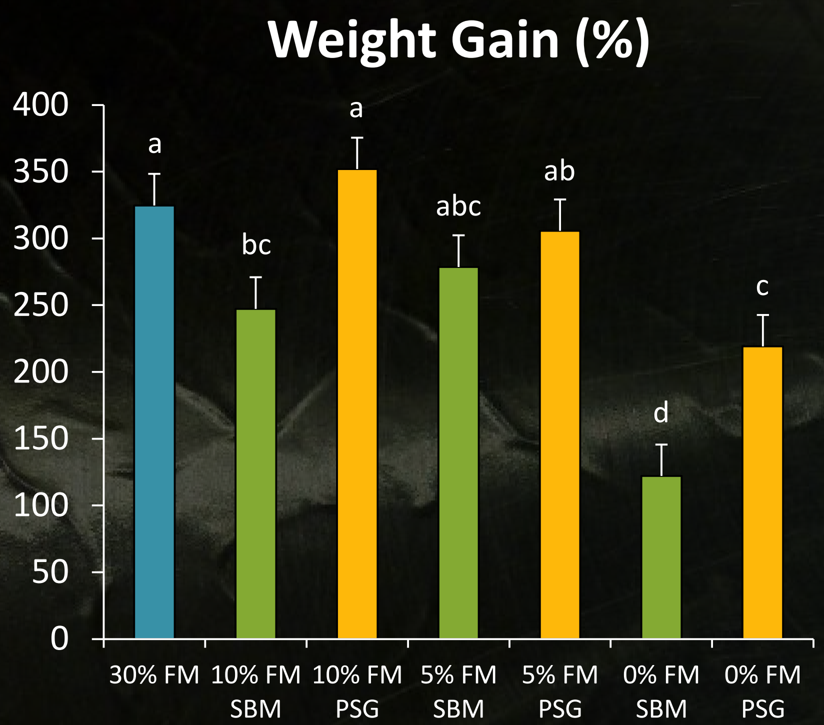


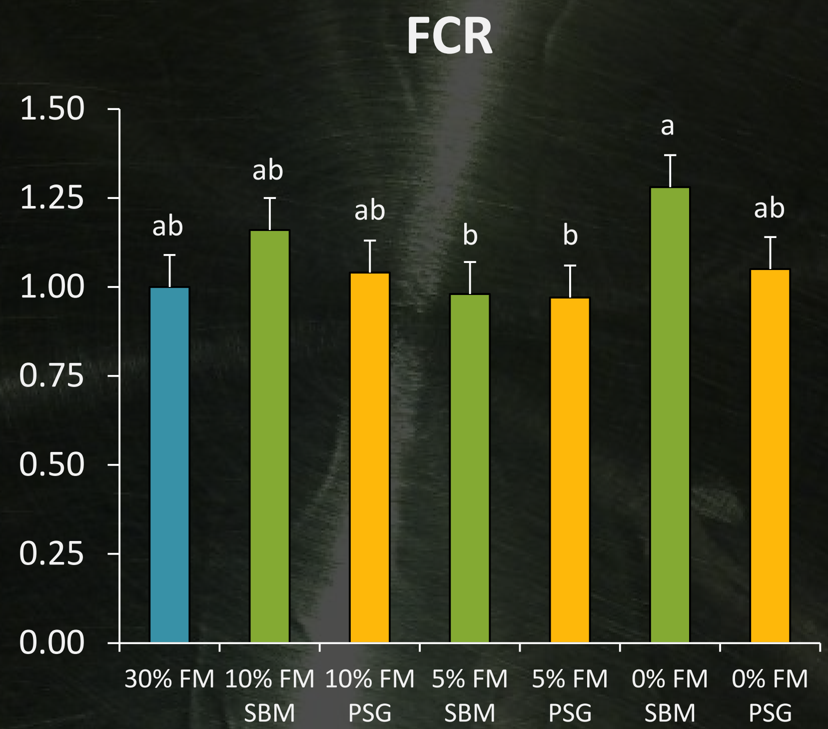
Fish meal sparing may lead to unintended consequences in terms of livestock resilience

Laporte and Trushenski 2011

FISH MEAL REPLACEMENT…SOLUTIONS

Case study with PepSoyGen in HSB feeds



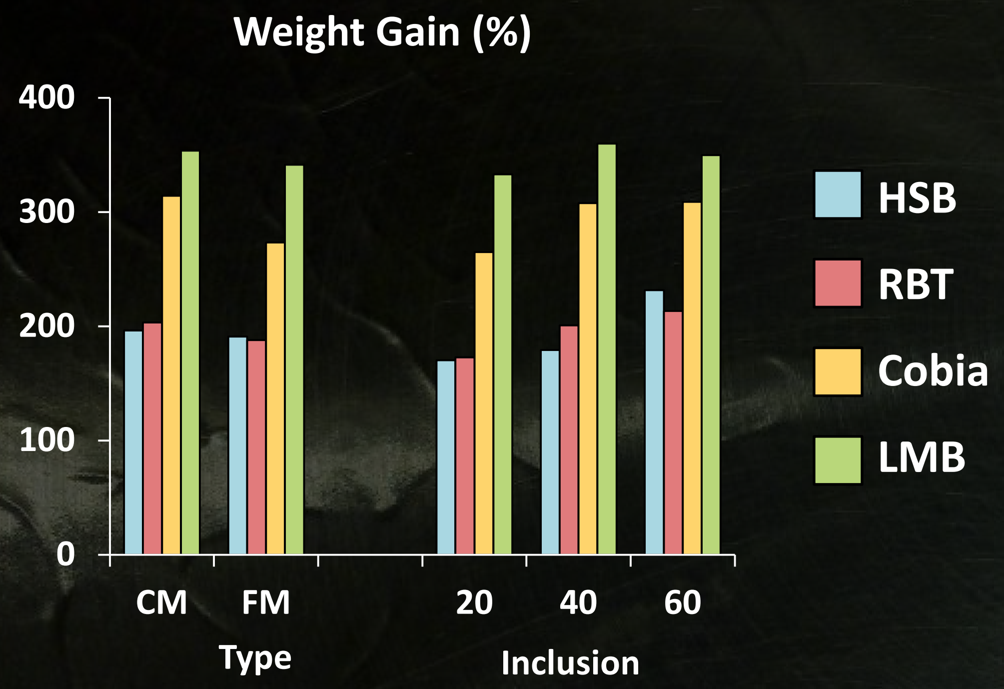


Fermented soybean meal outperformed traditional soybean meal at all levels of inclusion in HSB feeds

Rombenso et al. 2013

FISH MEAL REPLACEMENT…SOLUTIONS

Case study with Asian carp meal in aquafeeds

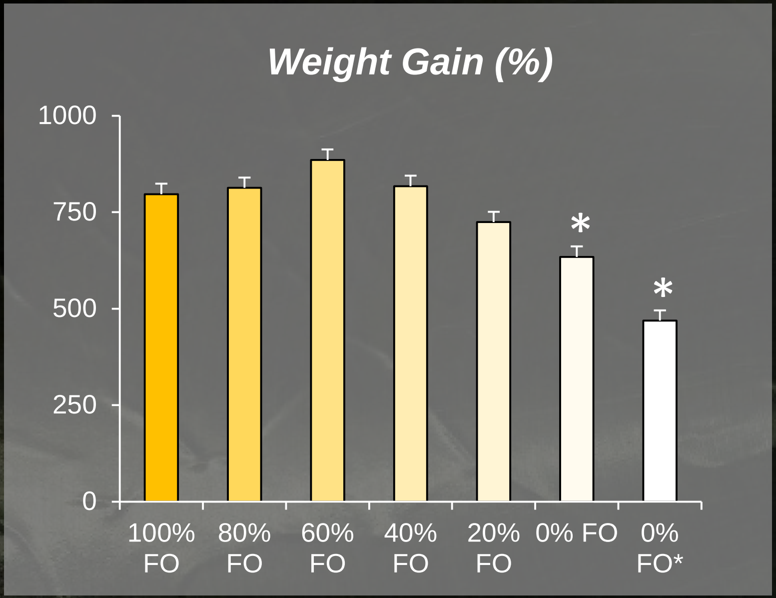


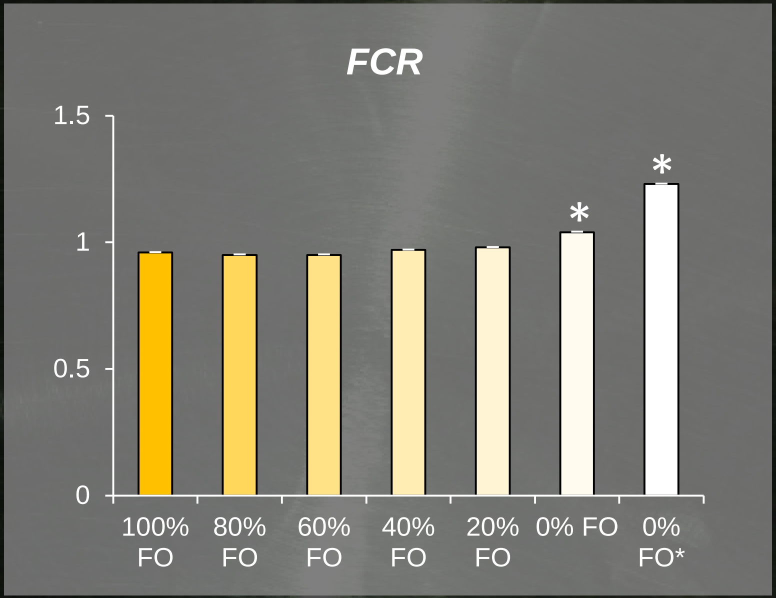
Results show excellent utilization, high value of Asian carp meal in aquafeeds

Bowzer et al. 2013, in press, in preparation

REPLACING FISH OIL…PRODUCTION EFFECTS

Case study with canola oil in HSB feeds



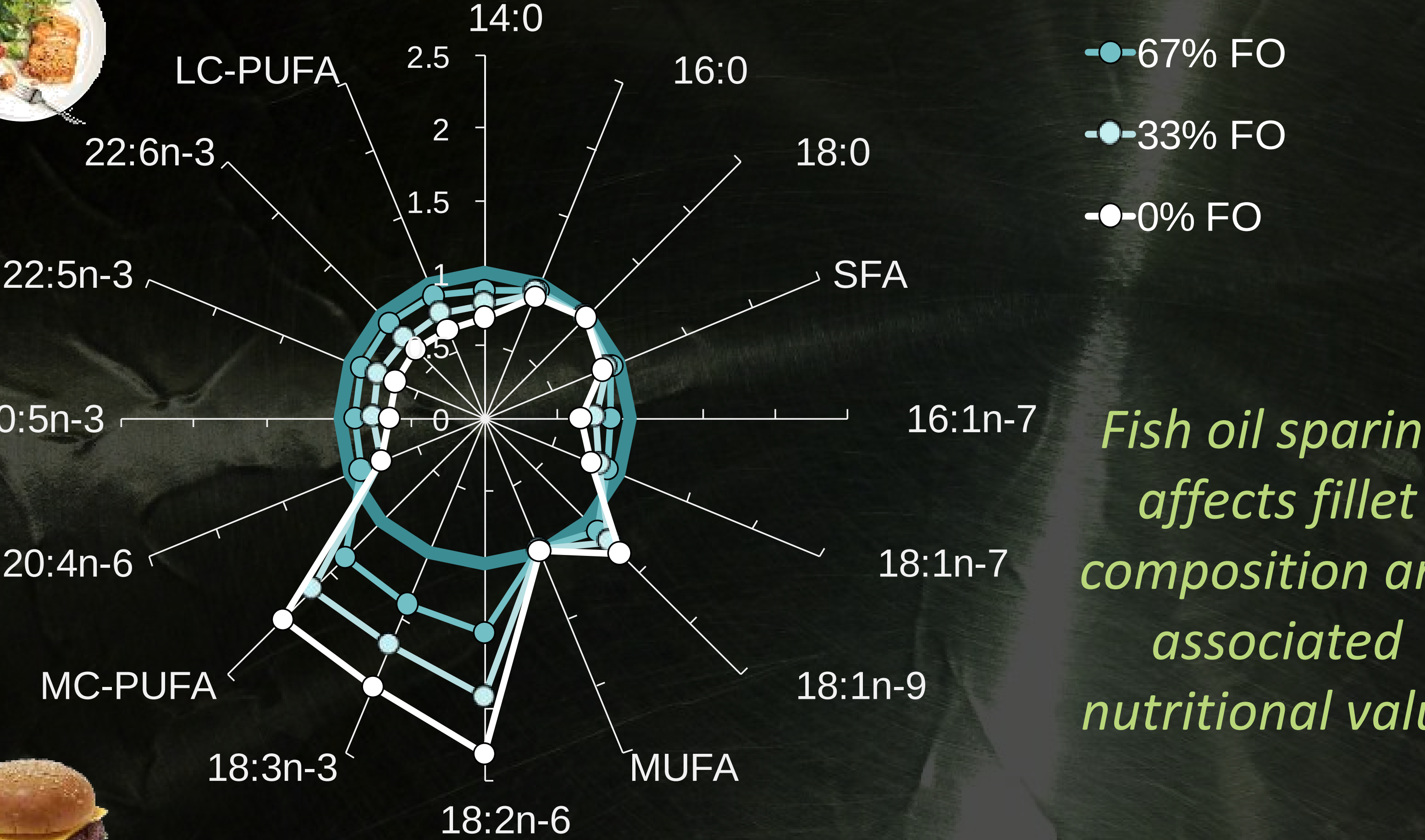


EFA deficiencies associated with fish oil replacement can lead to impaired production

Lewis and Kohler 2008

REPLACING FISH OIL…FILLET EFFECTS

Case study with soy oil in cobia feeds



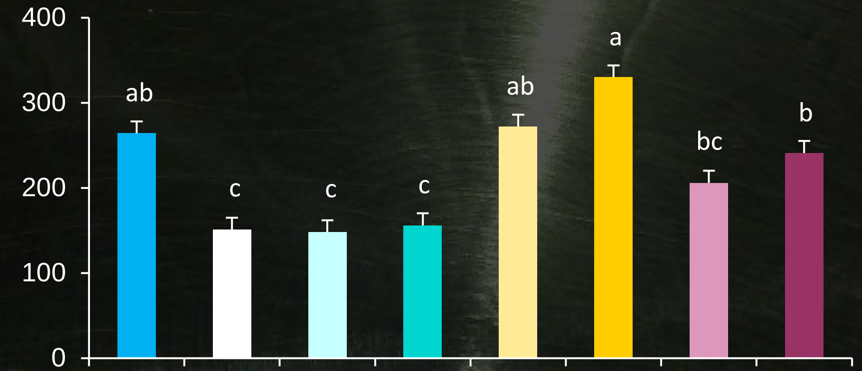
Fish oil sparing affects fillet composition and associated nutritional value

Trushenski et al. 2011

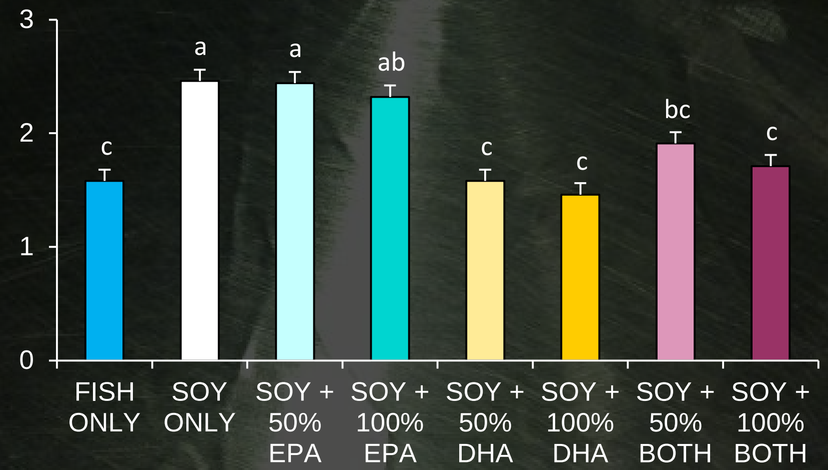
REPLACING FISH OIL…SOLUTIONS

Case study defining EFA requirements of cobia

Weight Gain (%)



FCR (dry matter)



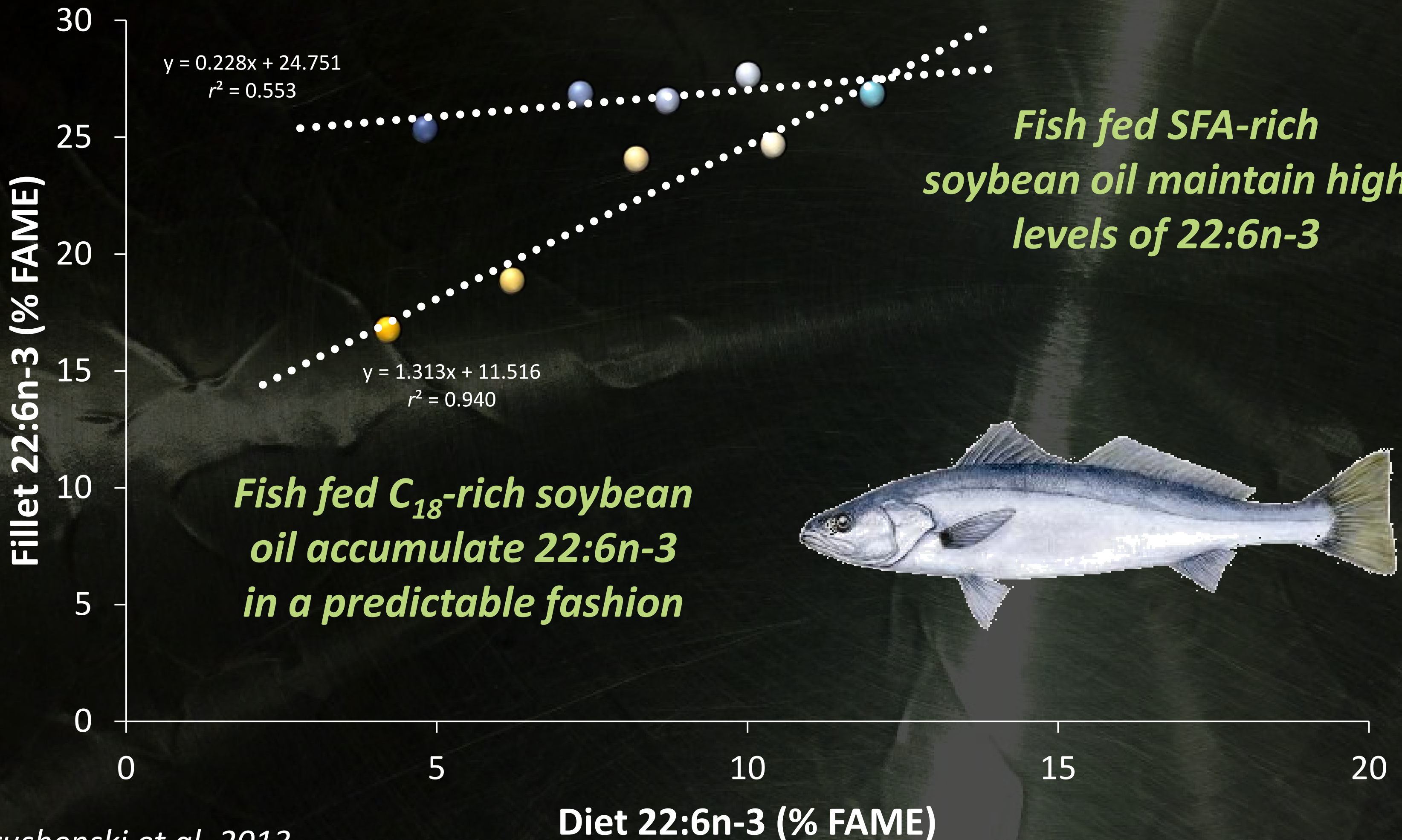
DHA is crucial, EPA is dispensable for growth performance of cobia

0.8-1.2% DHA required to maintain growth

Trushenski et al. 2012

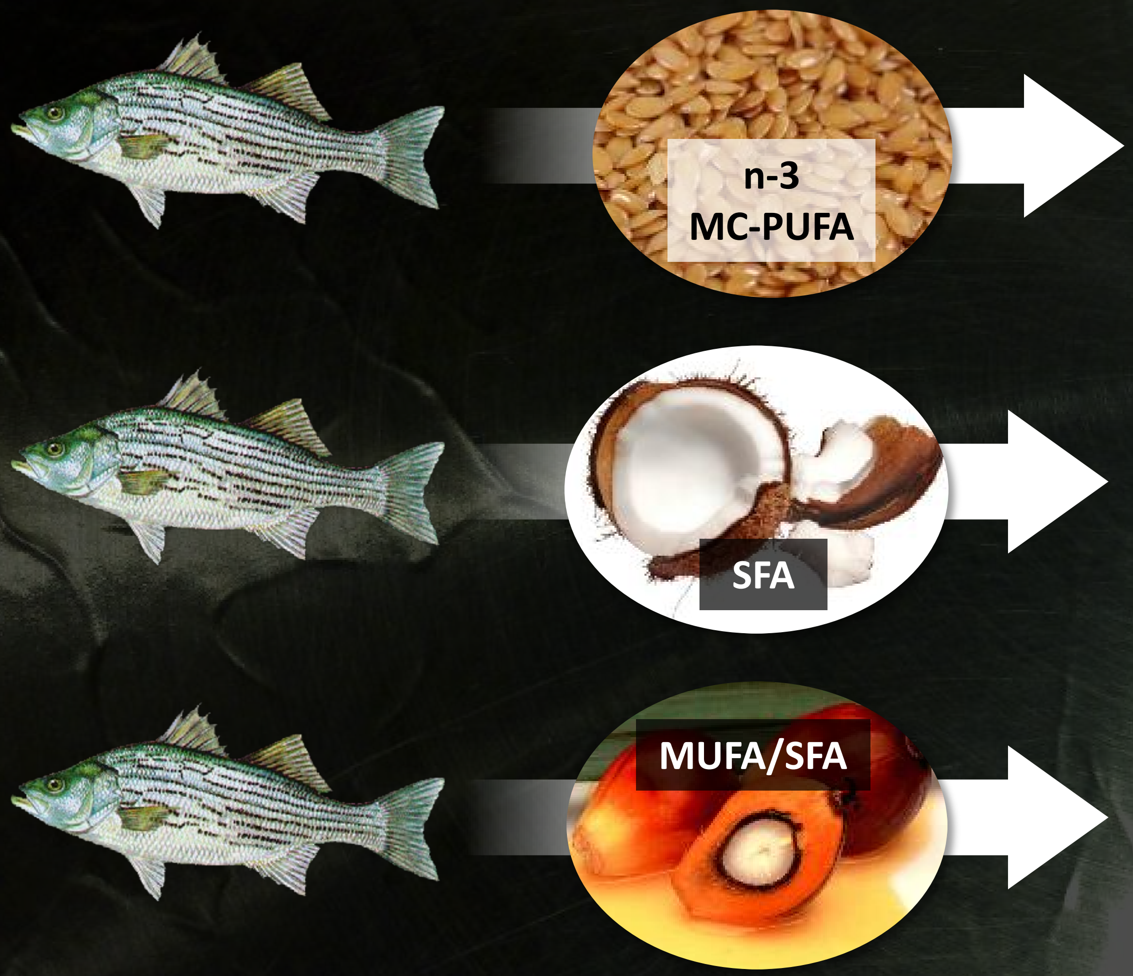
REPLACING FISH OIL…SOLUTIONS

Using SFA-rich oils to spare fish oil in white seabass feeds



Trushenski et al. 2013

POTENTIAL SOLUTIONS FROM RECENT STUDIES



No growth effects

Substantial LC-PUFA loss

Trushenski and Boesenberg 2009

No growth effects

Limited LC-PUFA loss

Trushenski et al. 2008

No growth effects

Limited LC-PUFA loss

Trushenski 2009

THE CHALLENGES…

Fish meal and oil are finite resources which aquaculture increasingly monopolizes

Sources of amino acids abound, but may be improperly balanced, unpalatable

> *Alternative proteins impact production performance, livestock resilience*

Sources of essential fatty acids can be limiting

> *Alternative lipids affect fillet nutritional value, reproductive performance*

THE OPPORTUNITIES…

Seafood demand continues to rise

Roughly half of seafood consumed is farm-raised

Food security for 9 billion people by 2050

Seafood provides 1/3 of the population with 15% or more of daily protein—aquaculture grows by 7-9% annually

Aquaculture produces protein efficiently

Swine
3 to 1

Beef Cattle
8 to 1

Poultry
2 to 1

Fish
1-2 to 1

Strategic use of resources solves problems