Defining Nutritional Specifications for Aquaculture Species

a. State-of the-art: What is required, how much and how do we know?

b. Empirical approaches and their limitations

c. Factorial nutrient requirement models and their limitations

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What Do Fish and Shrimp Require?

Traditional Essential Nutrients:

Same for all species:

Traditional

- 10 Essential amino acids
  - Fat and water soluble vitamins
  - Vitamin-like compounds (choline, *myo*-inositol)
  - Minerals

Nutrients with some aspects of essentiality that are species and life stage-specific:

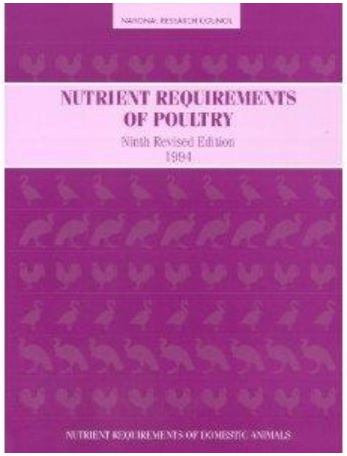
- Essential fatty acids ω-3, ω-6

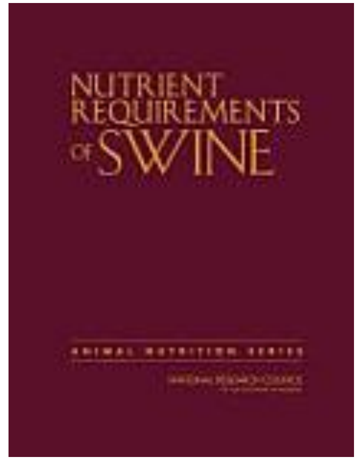
Nutrients for which essentiality is species and stage-specific:

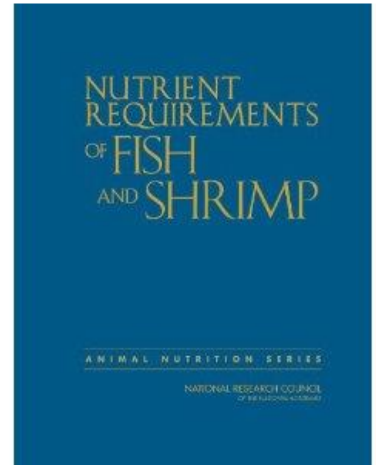
Novel

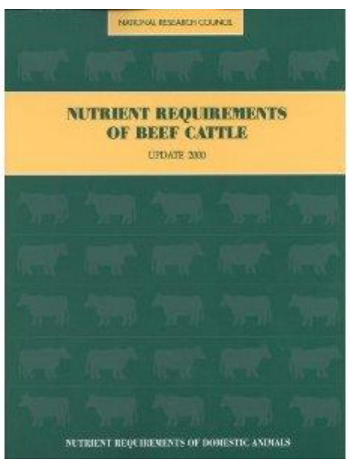
- Taurine
- Phospholipids (a very wide class of chemicals)
- Cholesterol ?
- Nucleotides ?
- Other compounds?

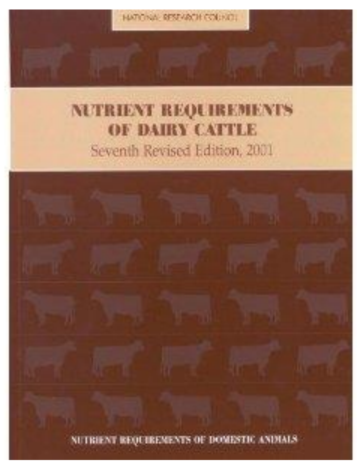
National Research Council (NRC) Nutrient Requirements of Animals Documents

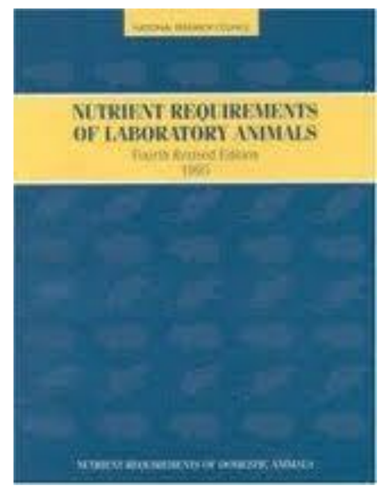












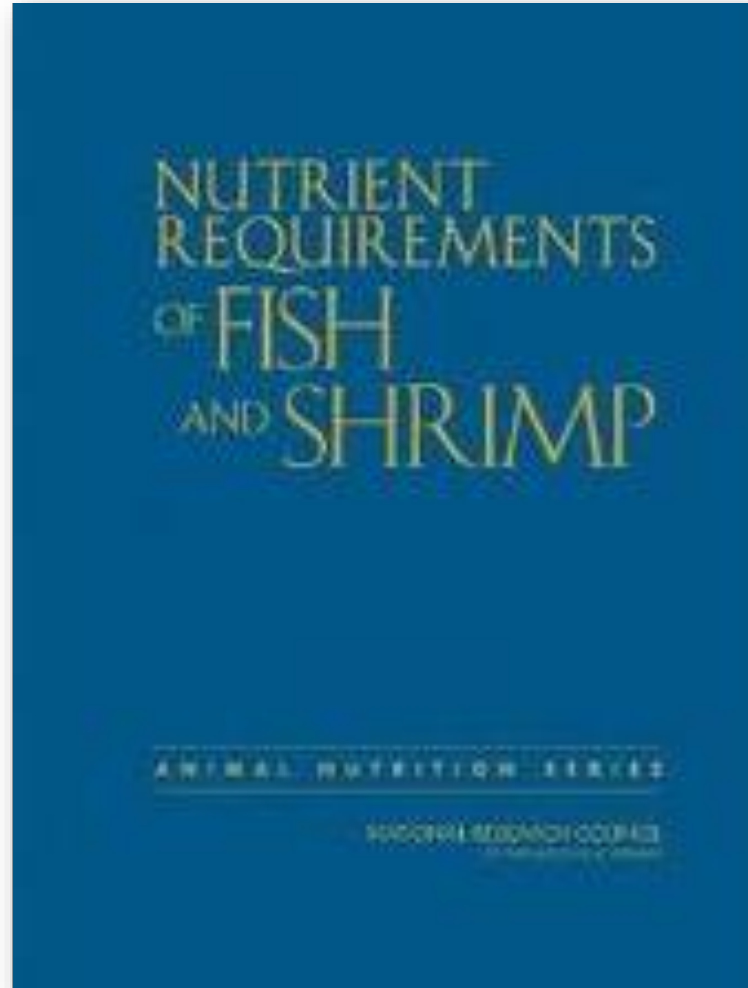
NRC Committee of Nutrient Requirements of Fish and Shrimp (2009-2011)

NRC 2011

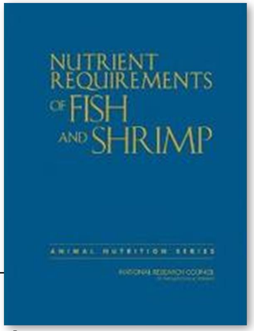
Review of state-of-the-art

Committee reviewed 1000s of papers

Imperfect document and recommendations represent best effort



NRC (2011) Essential Amino Acid Requirements of Different Fish Species ("Juvenile" Stage)



Amino Acids	Atlantic Salmon	Common Carp	Nile Tilapia	Channel catfish	Rainbow Trout	Asian Seabass	European Seabass	Japanese Flounder	Red Drum	Yellowtail
Arginine	1.8	1.7	1.2	1.2	1.5	1.8	1.8	2.0	1.8	1.6
Histidine	0.8	0.5	1.0	0.6	0.8	NT	NT	NT	NT	NT
Isoleucine	1.1	1.0	1.0	0.8	1.1	NT	NT	NT	NT	NT
Leucine	1.5	1.4	1.9	1.3	1.5	NT	NT	NT	NT	NT
Lysine	2.4	2.2	1.6	1.6	2.4	2.1	2.2	2.6	1.7	1.9
Methionine	0.7	0.7	0.7	0.6	0.7	0.8	NT	0.9	0.8	0.8
Met+Cys	1.1	1.0	1.0	1.0	1.1	1.2	1.1	NT	1.2	1.2
Phenylalanine	0.9	1.3	1.1	0.7	0.9	NT	NT	NT	NT	NT
Phe+Tyr	1.8	2.0	1.6	1.6	1.8	NT	NT	NT	NT	NT
Threonine	1.1	1.5	1.1	0.7	1.1	NT	1.2	NT	0.8	NT
Tryptophan	0.3	0.3	0.3	0.2	0.3	NT	0.3	NT	NT	NT
Valine	1.2	1.4	1.5	0.8	1.2	NT	NT	NT	NT	NT
Taurine	NR	NR	NT	NR	NR	R	0.2	R	R	R

Take home: We have reasonably good estimates for many species. Still major gaps.

Black Tiger shrimp (*P. monodon*)

The Black Tiger shrimp has been tested for several critical nutrient requirements over the last 15 years

FNRL

Summary of studies on essential amino acid requirements of Black tiger shrimp (*Penaeus monodon*) (source: NRC, 2011)

EAA	IBW g/shrimp	Diet CP %	DE kJ/g	Estimated Requirement	Model	Reference
Arg	0.02	40	ND	1.9% of diet 5.3% of CP	Broken line	Millamena et al., 1998
Arg	0.32	45	ND	2.5% of diet 5.5% of CP	Broken line	Chen et al., 1992
His	0.02	35–40	ND	0.8% of diet 2.2% of CP	Quadratic	Millamena et al., 1999
Isl	0.02	35–40	ND	1.0% of diet 2.7% of CP	Broken line	Millamena et al., 1999
Leu	0.02	35–40	ND	1.7% of diet 4.3% of CP	Quadratic	Millamena et al., 1999
Lys	0.02	40	ND	2.1% of diet 5.2% of CP	Broken line	Millamena et al., 1998
	2.4	34	ND	2.0% of diet 5.8% of CP	Factorial	Richard et al 2010
Met	0.02	37	15.1	0.9% of diet (w 0.4% Cys) 2.4% of CP	Broken line	Millamena et al., 1996
	2.4	34	ND	0.9% of diet (w 0.1-0.3% Cys) 2.9% of CP	Factorial	Richard et al. 2010
Phe	0.02	35–40	ND	1.4% of diet 3.7% of CP	Quadratic	Millamena et al., 1999
Thr	0.05	40	ND	1.4% of diet 3.5% of CP	Quadratic	Millamena et al., 1997
Trp	0.02	35–40	ND	0.2% of diet 0.5% of CP	Quadratic	Millamena et al., 1999

Factors Potential Affecting "Estimate" of Nutrient Requirement

Experimental conditions / errors

ex: Fish performance, variability of measurements

Parameter studied

e.g. growth, feed efficiency, nutrient gain, enzyme activity
histological analysis, tissue saturation

Lysine requirement to maximize weight gain = 2.2% diet
Lysine requirement to maximize protein gain = 2.4 to 2.6% diet

Mathematical/statistical model used and threshold value

e.g. broken-line vs. exponential, 95% of max. vs. 100% of max.

Feed composition

e.g. digestible energy content, digestible protein content

Mode of expression of requirement

e.g. % of diet, g/MJ DE, g/100 g protein, g kg BW-1 d-1

Developing "Scientifically Sound" Estimates of Essential Amino Acid Requirements of Fish and Shrimp (2009-2010)

Several hundred studies on the essential amino acid requirement of fish have been carried out and published (There seem to be a LOT of data available)

Many factors can potentially affect estimate of requirements

Need to review most of studies for this new NRC (Doing the work already!)

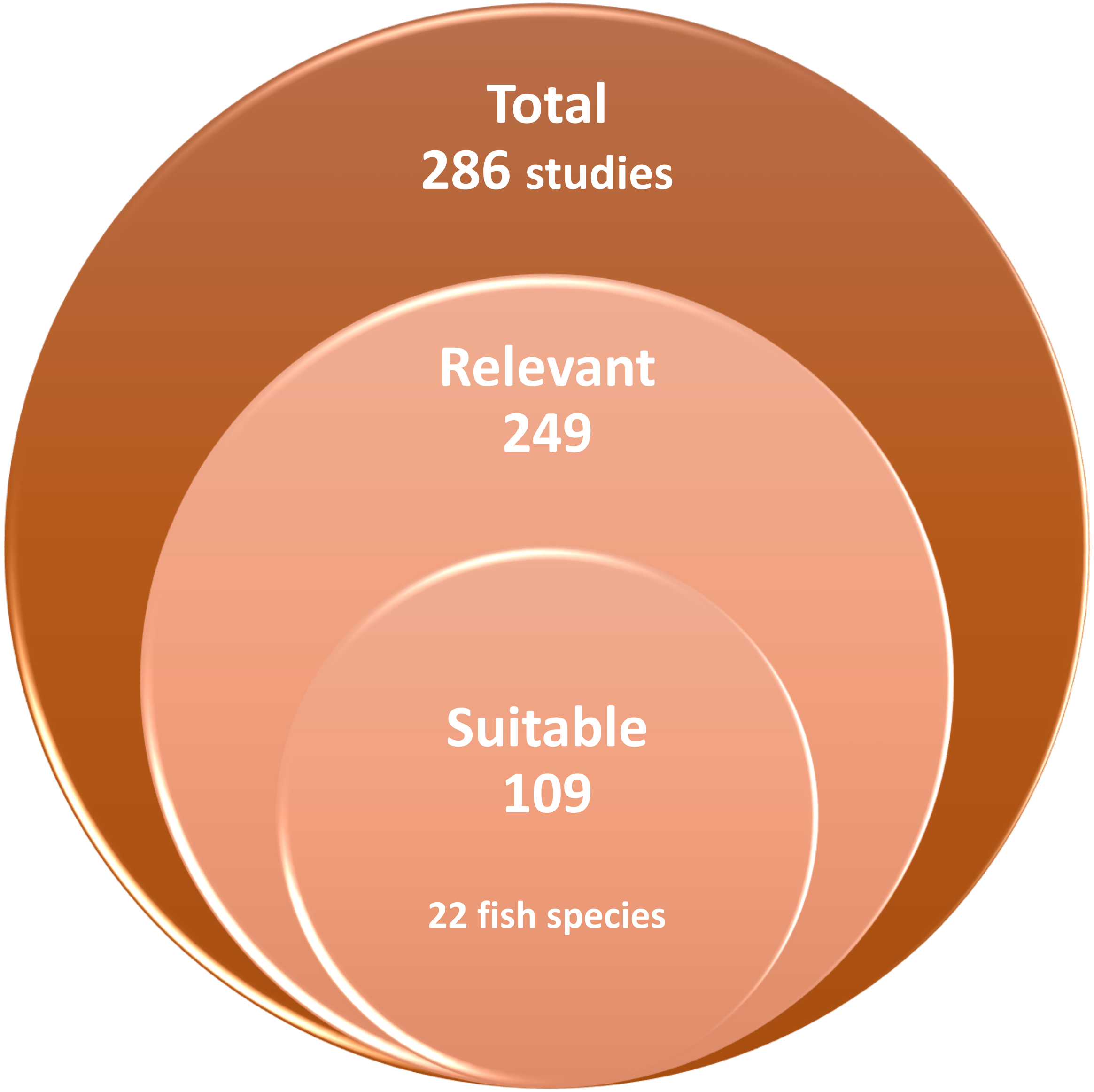
Why not integrate and analyze existing data across studies? Then we could:

1-) Get scientifically valid estimates of requirements for many species

2-) Can get a handle on source of variability in EAA requirements

Project: Meta-Analysis of Essential Amino Acid Requirements
Guillaume Salze, post-doctoral fellow

Meta-Analysis of Essential Amino Acid Requirements of Fish



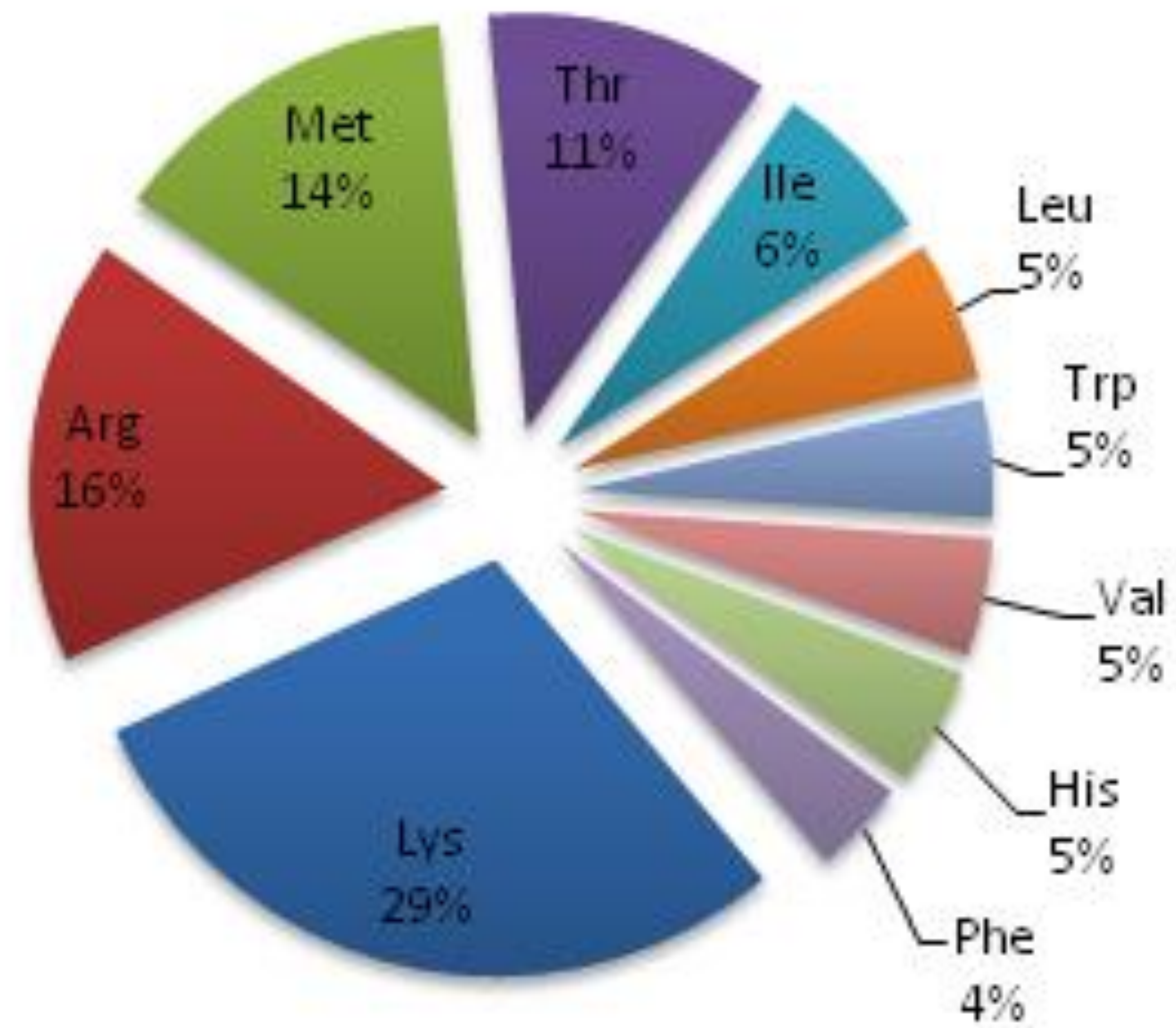
Main causes of rejection:

1) Key piece(s) of information missing in paper and preventing calculation of parameter(s) deemed important

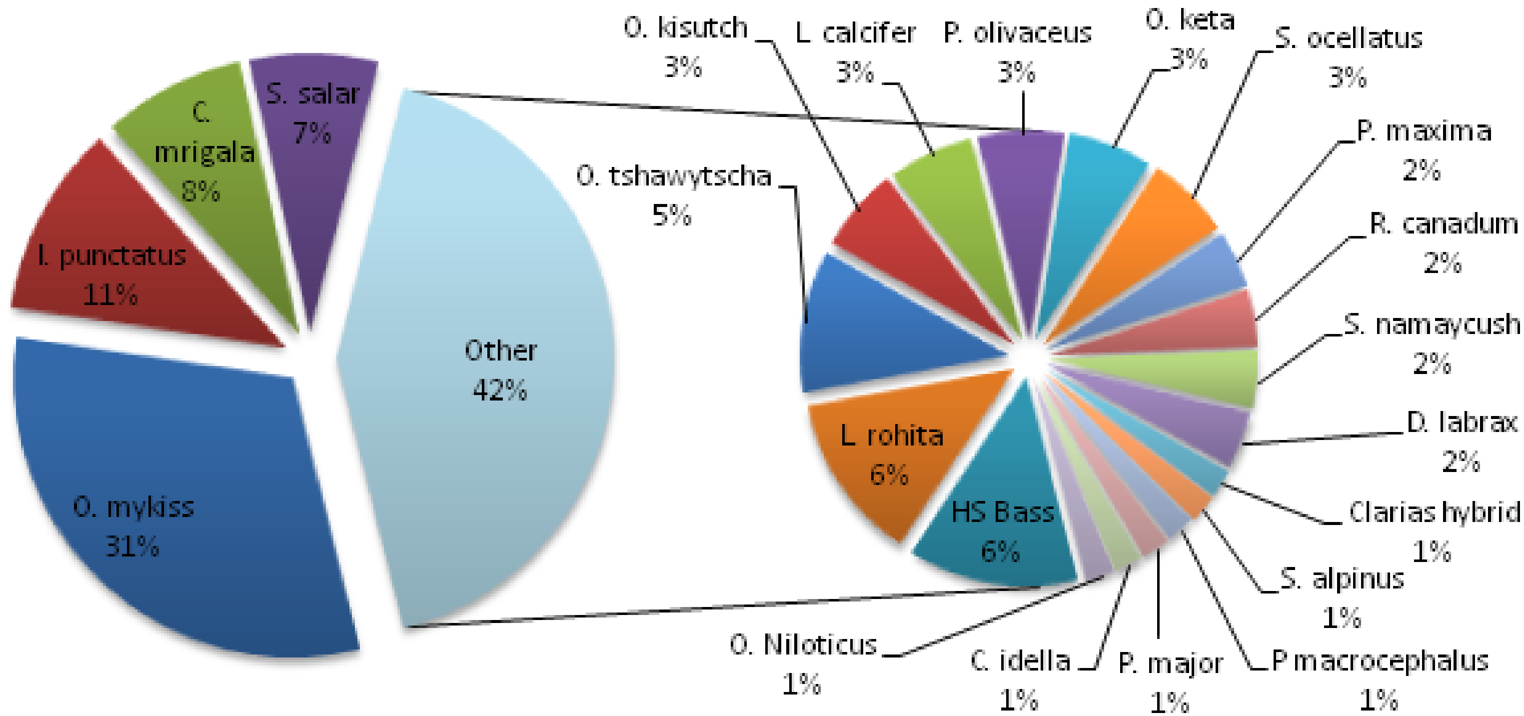
2) Insufficient graded EAA levels (or inappropriate design for goal of meta-analysis)

3) Poor growth or feed efficiency achieved in study

109 Studies on Essential AA Requirements: Breakdown by EAA

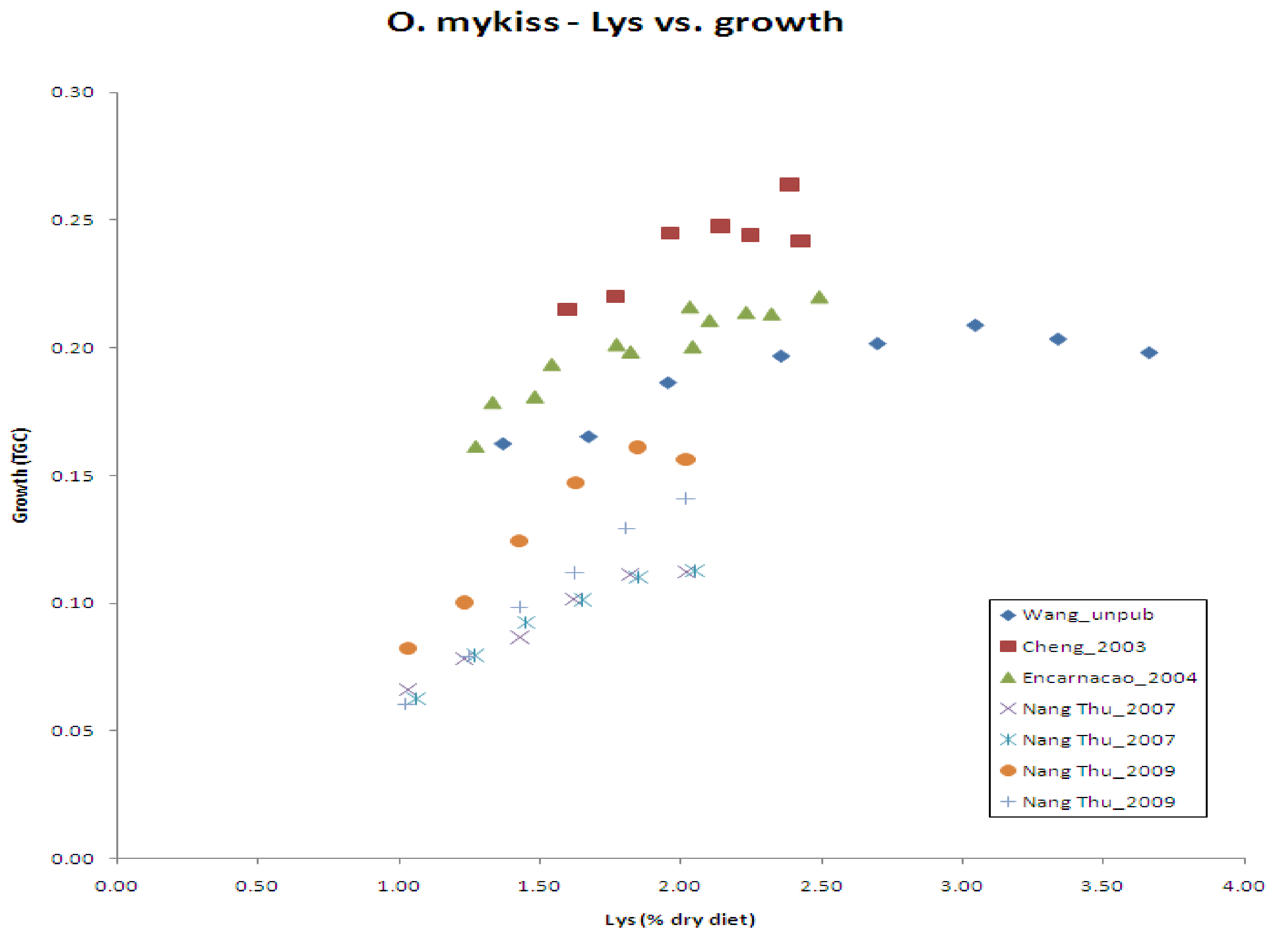


109 Studies on 10 Essential Amino Acids: 22 Species Represented!



22 species represented,

Too many species = dilution of research efforts



Estimating Essential Nutrient Requirements Across Studies is not Simple. Reference values are not always very robust.

Essential Amino Acid Requirements of Different Fish Species

Amino Acids	Atlantic Salmon	Common Carp	Nile Tilapia	Channel catfish	Rainbow Trout	Asian Seabass	European Seabass	Japanese Flounder	Red Drum	Yellowtail
Arginine	1.8	**1.7**	1.2	1.2	1.5	1.8	1.8	2.0	1.8	1.6
Histidine	0.8	0.5	**1.0**	0.6	**0.8**	NT	NT	NT	NT	NT
Isoleucine	1.1	**1.0**	**1.0**	0.8	**1.1**	NT	NT	NT	NT	NT
Leucine	1.5	1.4	1.9	1.3	1.5	NT	NT	NT	NT	NT
Lysine	2.4	**2.2**	**1.6**	1.6	**2.4**	2.1	2.2	2.6	1.7	1.9
Methionine	0.7	0.7	0.7	0.6	0.7	0.8	NT	0.9	0.8	0.8
Met+Cys	1.1	1.0	1.0	1.0	1.1	1.2	1.1	NT	1.2	1.2
Phenylalanine	0.9	1.3	1.1	0.7	0.9	NT	NT	NT	NT	NT
Phe+Tyr	1.8	2.0	1.6	1.6	1.8	NT	NT	NT	NT	NT
Threonine	1.1	**1.5**	1.1	0.7	**1.1**	NT	1.2	NT	0.8	NT
Tryptophan	0.3	0.3	0.3	0.2	0.3	NT	0.3	NT	NT	NT
Valine	1.2	**1.4**	**1.5**	0.8	1.2	NT	NT	NT	NT	NT
Taurine	NR	NR	NT	NR	NR	R	0.2	R	R	R

Based on review and "mathematical analysis" (cough! cough!) of hundred of studies!

A lot remained executive decisions by the committee of experts (and me)!

Source: NRC (2011)

Pacific white-legged shrimp (*L. vannamei*)

Essential Amino Acid Requirements

Nutrient	Rainbow Trout	Kuruma prawn	Tiger shrimp	Pacific white legged shrimp
	% diet	*Marsupenaeus japonicus*	*Penaeus monodon*	*Litopenaeus vannamei*
Arginine	1.5	1.6	1.9	
Histidine	0.8	0.6	0.8	
Isoleucine	1.1	1.3	1.0	
Leucine	1.5	1.9	1.7	
Lysine	2.4	1.9	2.1	1.6
Methionine	0.7	0.7	0.7	
Met+Cys	1.1	1.0	1.0	
Phenylalanine	0.9	1.5	1.4	
Phe+ Tyr	1.8	R	R	
Threonine	1.1	1.3	1.4	
Tryptophan	0.3	0.4	0.2	
Valine	1.2	1.4	R	

What? Only one value?

NRC (2011)

Mineral Requirements

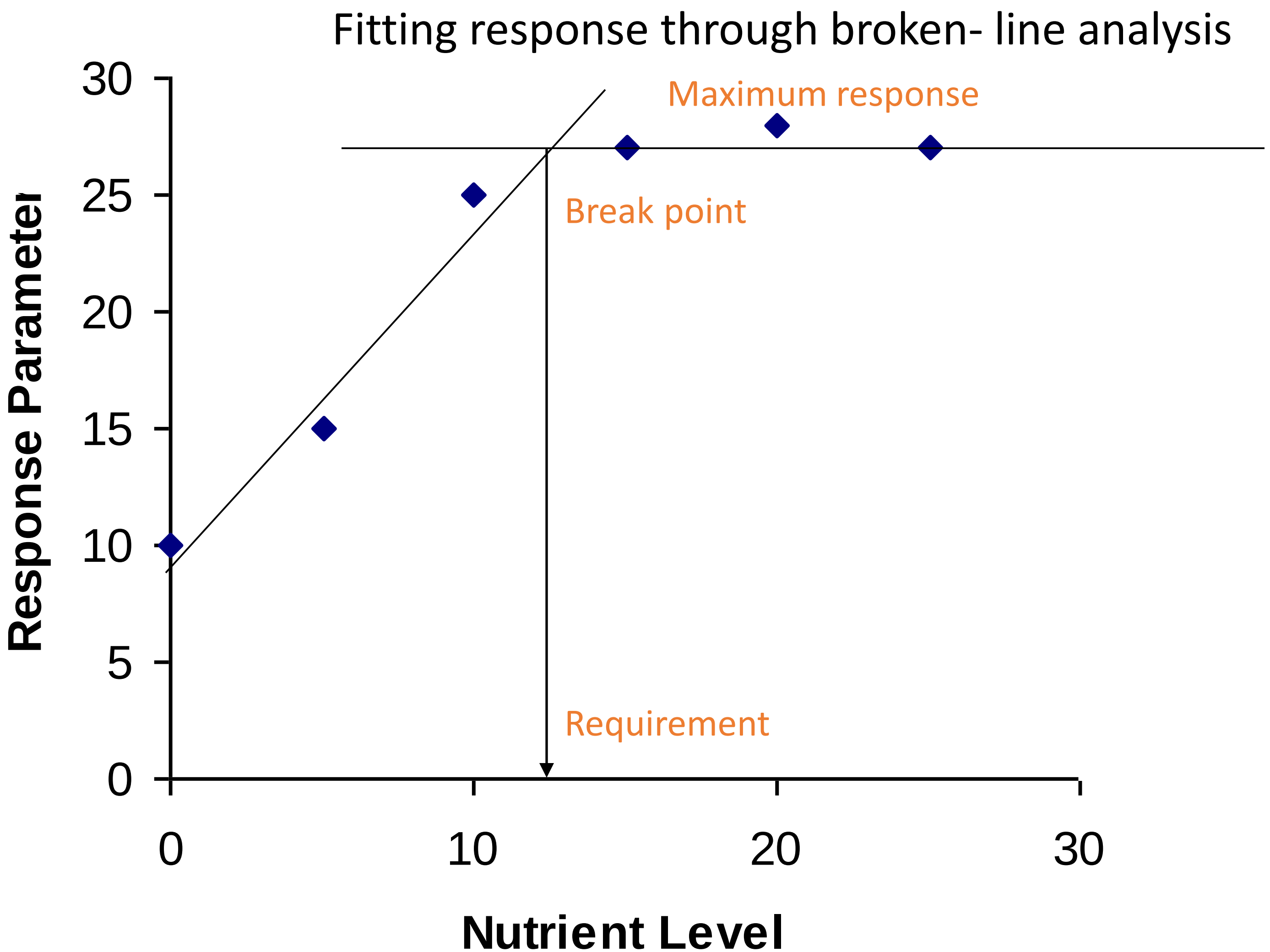
Nutrient	Kuruma prawn	Tiger shrimp	Pacific White legged shrimp	Fleshy prawn
	Marsupenaeus japonicus	*Penaeus monodon*	*Litopenaeus vannamei*	*Fennero-penaeus chinensis*
Macro minerals % diet				
Calcium			R	
Chlorine				
Magnesium	0.3		0.26-0.35	
Phosphorus	1.0	0.7	0.3-0.7	
Potassium	1.0	1.2	R	
Sodium				
Micro minerals mg/kg diet				
Copper	R	10-305	16-32	25
Iodine				
Iron	R	R	R	R
Manganese	R		R	
Selenium			0.2-0.4	
Zinc				15

Not very informative!

NRC (2011)

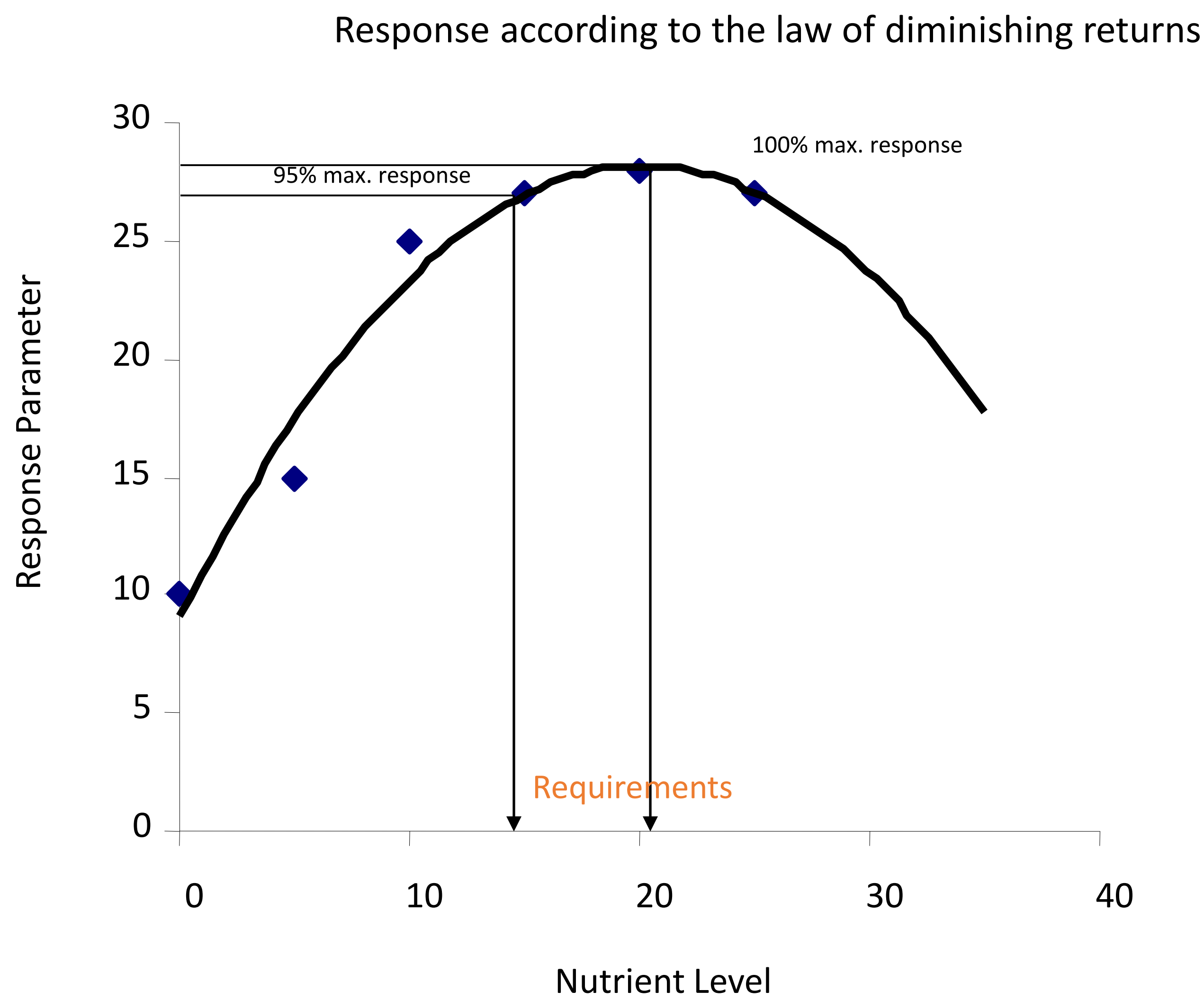
How are we coming up with these numbers?

Analyzing the response



Assuming a constant linear response up to requirement

Polynomial (Quadratic) Function



The “threshold selected by the investigator can have dramatic impact on the estimate of requirement

Aquaculture Research

Aquaculture Research, 2008, **39**, 1498–1505 doi: 10.1111/j.1365-2109.2008.02018.x

Dietary threonine requirement of fingerling Indian major carp, *Labeo rohita* (Hamilton)

Shabihul Fatma Abidi & Mukhtar A Khan
Fish Nutrition Research Laboratory, Department of Zoology, Aligarh Muslim University, Aligarh 202 002, India

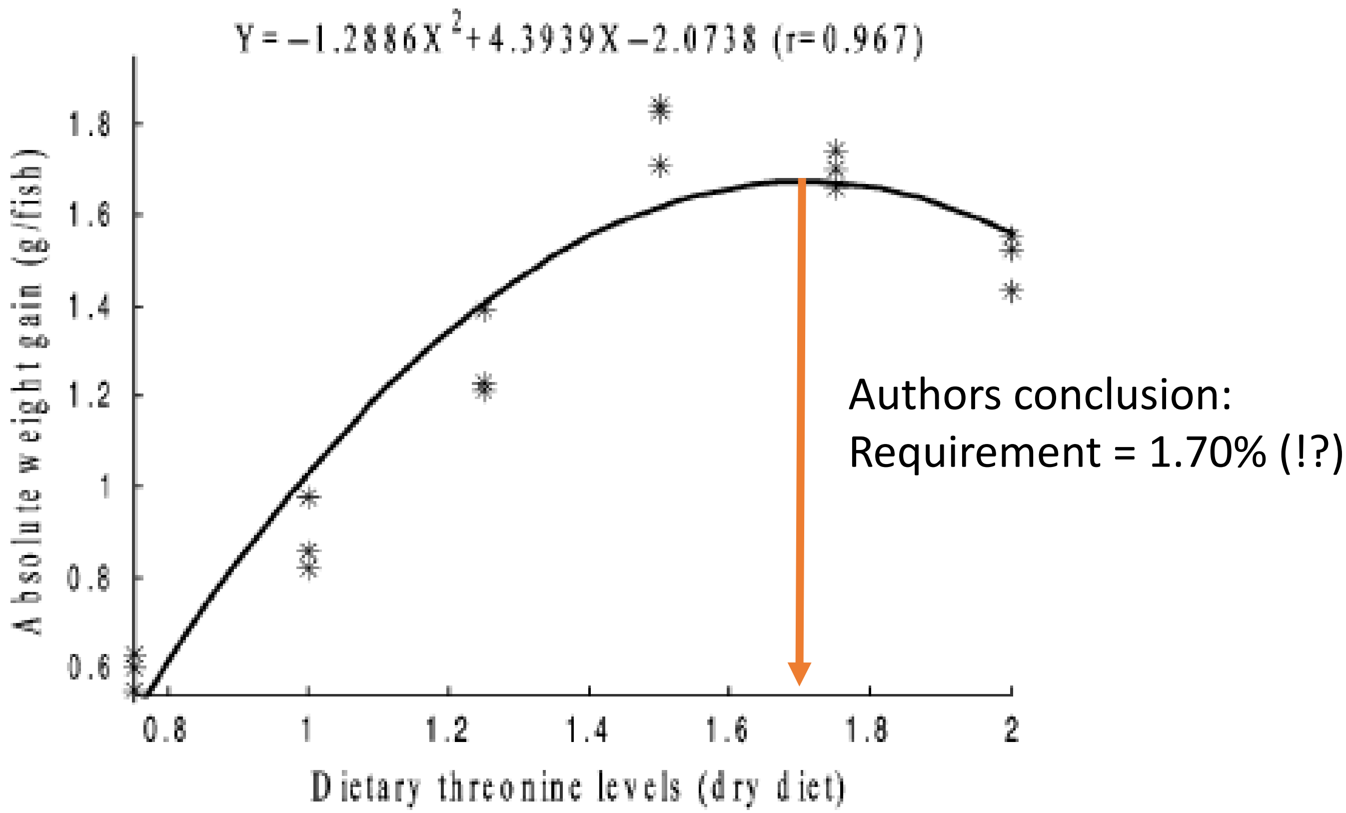
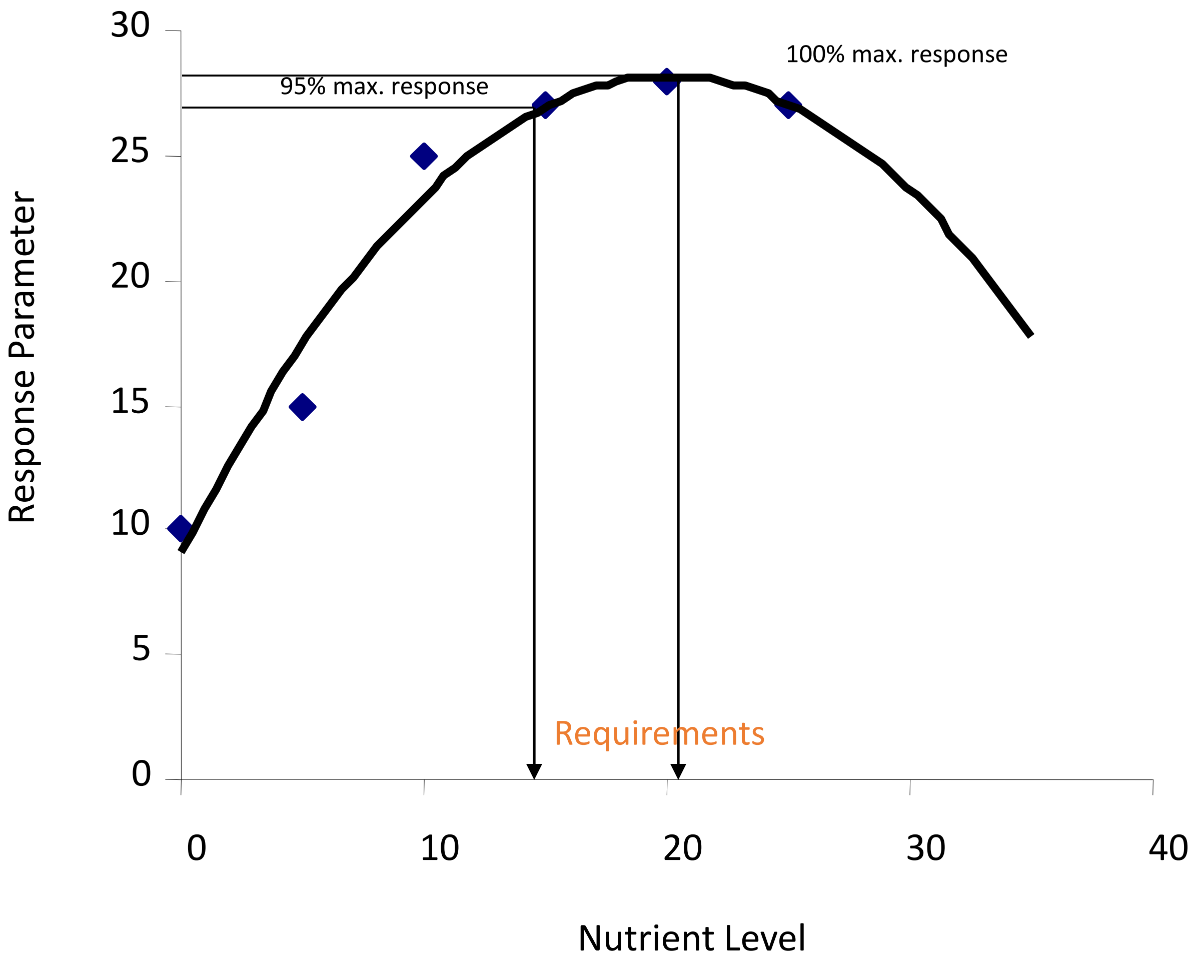


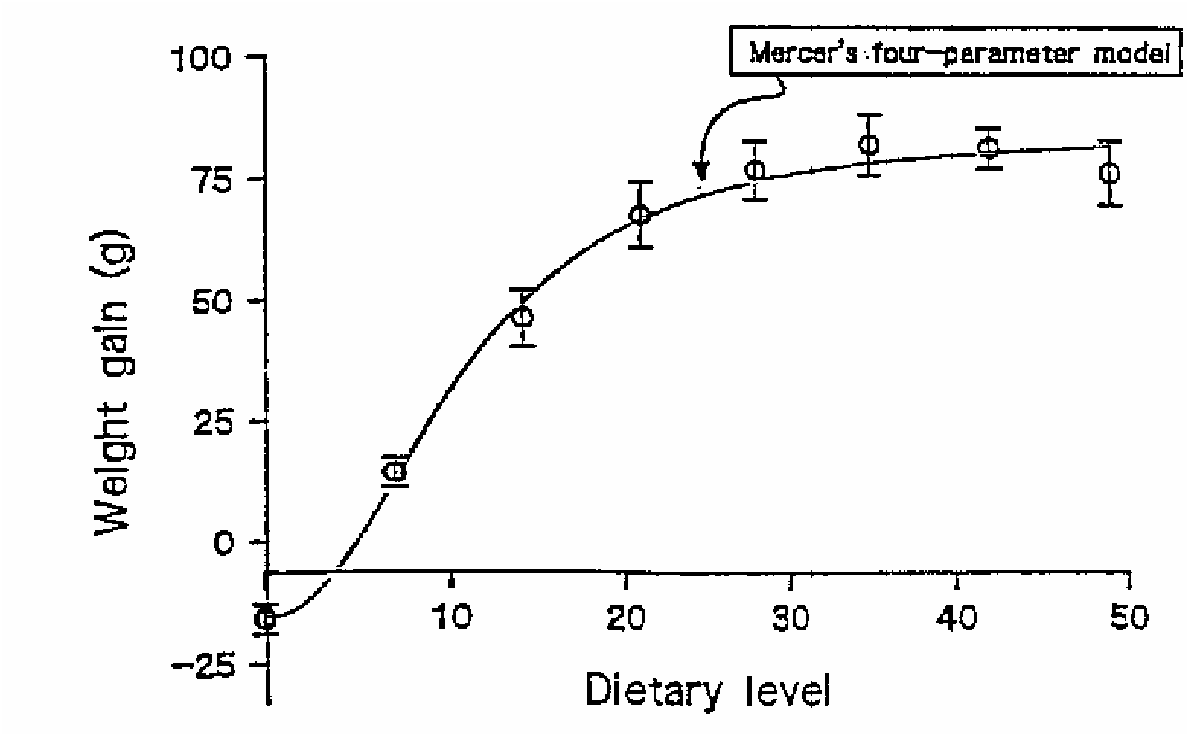
Figure 1 Second-degree polynomial relationship of absolute weight gain to dietary threonine levels.

Polynomial (Quadratic) Function



Response according to the law of diminishing returns

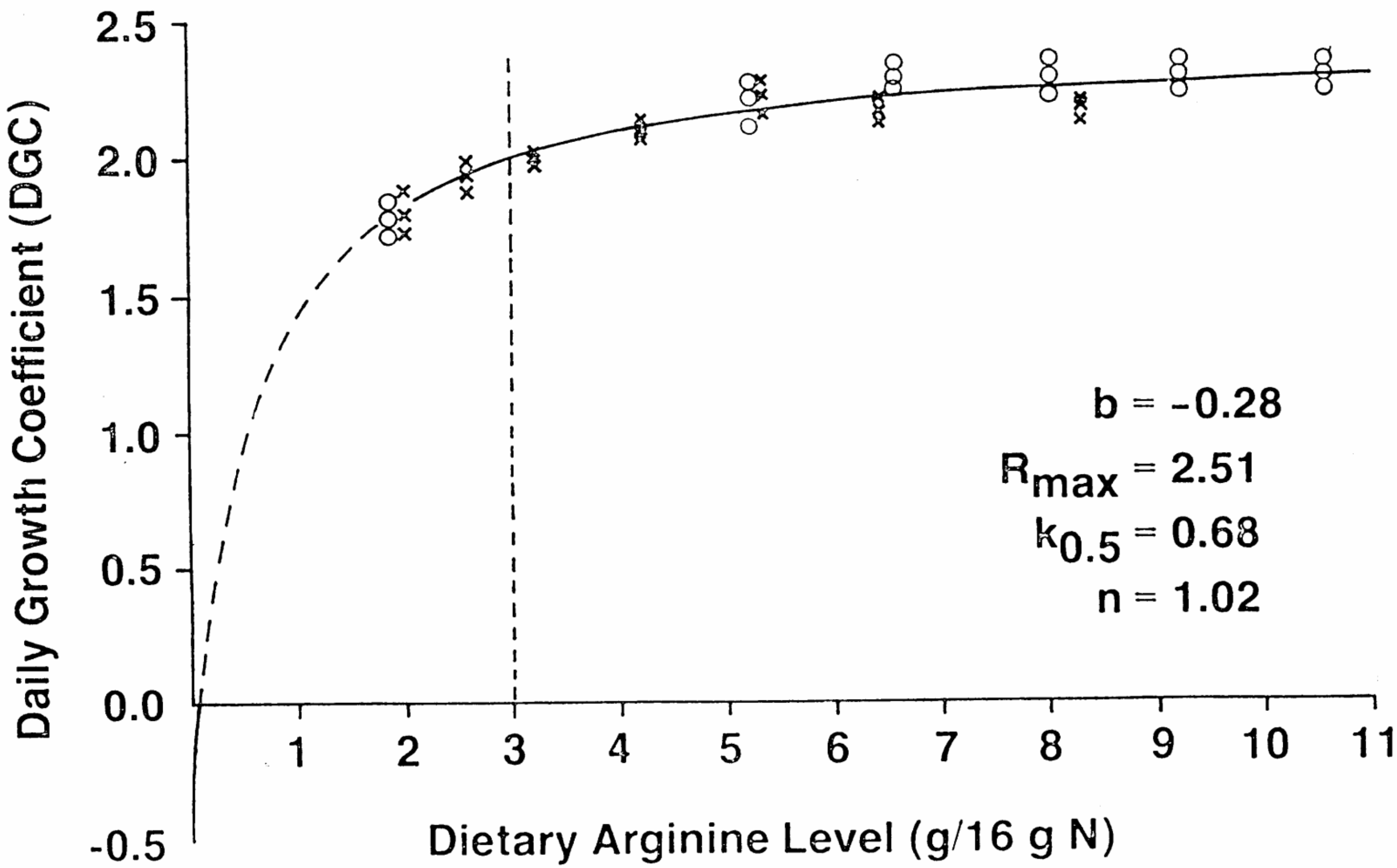
Four (4) Parameter Logistic Equation (Nutritional Kinetic Model)



$$r = \frac{R_{max} + [b(1 + c) - R_{max}]\, e^{-kI}}{1 + c \cdot e^{-kI}} .$$

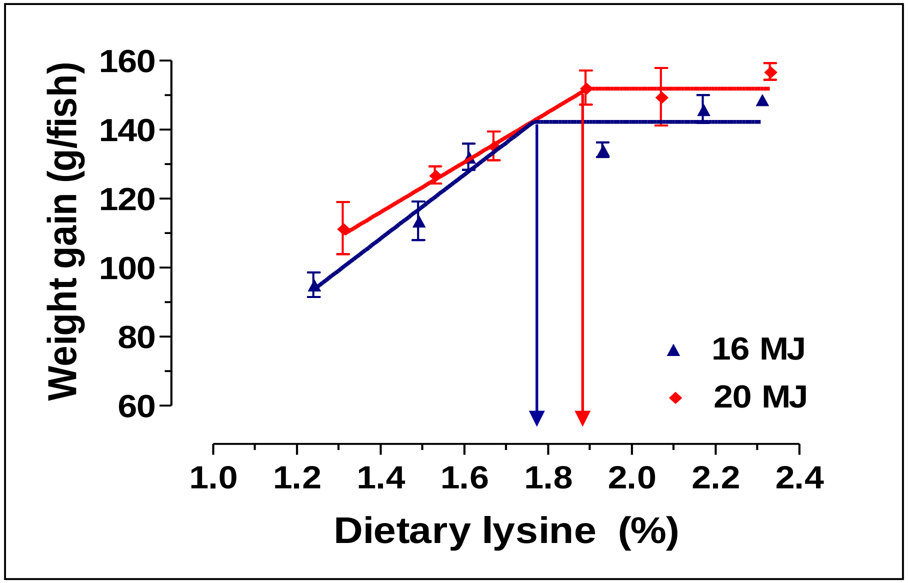
Response according to the law of diminishing returns

Nutritional Kinetic Model = an asymptotic function



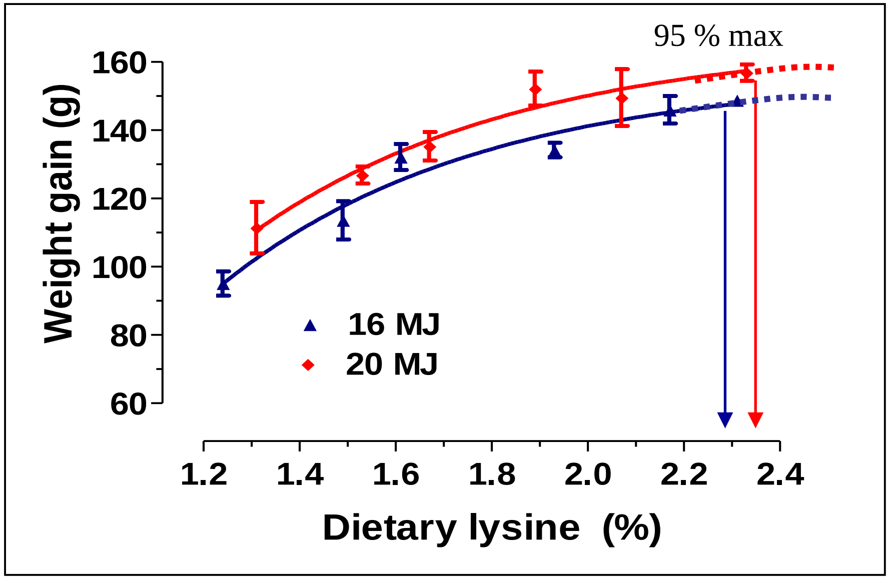
$$r = \frac{R_{max} + [b(1 + c) - R_{max}]\, e^{-kI}}{1 + c \cdot e^{-kI}} .$$

Model Adopted Can Significantly Affect Estimate of Requirement



Broken line model

= 1.8% diet



Nutritional kinetic model

= 2.3% diet

British Journal of Nutrition (2010), **103**, 984–995 doi:10.1017/S0007114509992844

Maintenance and growth requirements for nitrogen, lysine and methionine and their utilisation efficiencies in juvenile black tiger shrimp, *Penaeus monodon*, using a factorial approach

Lenaïg Richard[1,2], Pierre-Philippe Blanc[2], Vincent Rigolet[2], Sadasivam J. Kaushik[1] and Inge Geurden[1]*

[1]*INRA, UMR 1067 Nutrition, Aquaculture and Genomics, F-64310 St-Pée-sur-Nivelle, France*

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(Received 18 June 2009 – Revised 28 September 2009 – Accepted 12 October 2009 – First published online 30 November 2009)

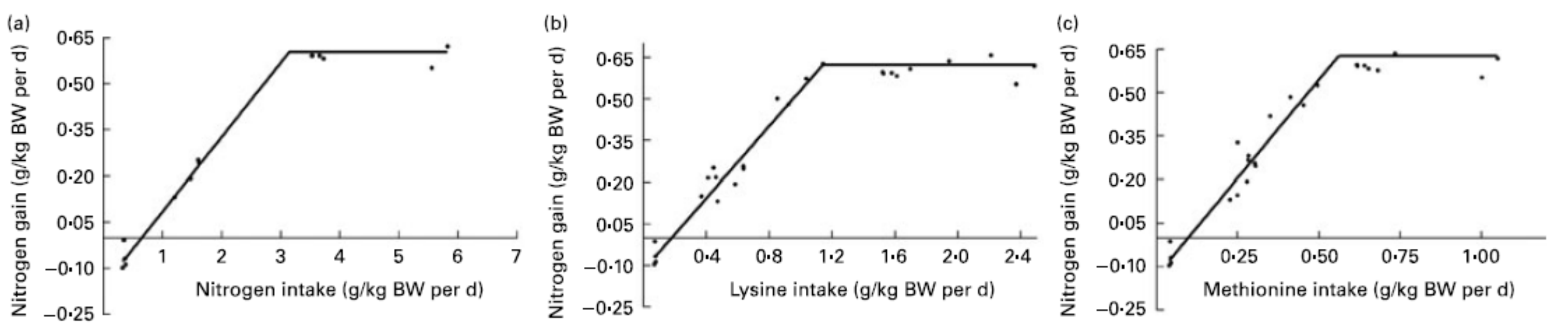
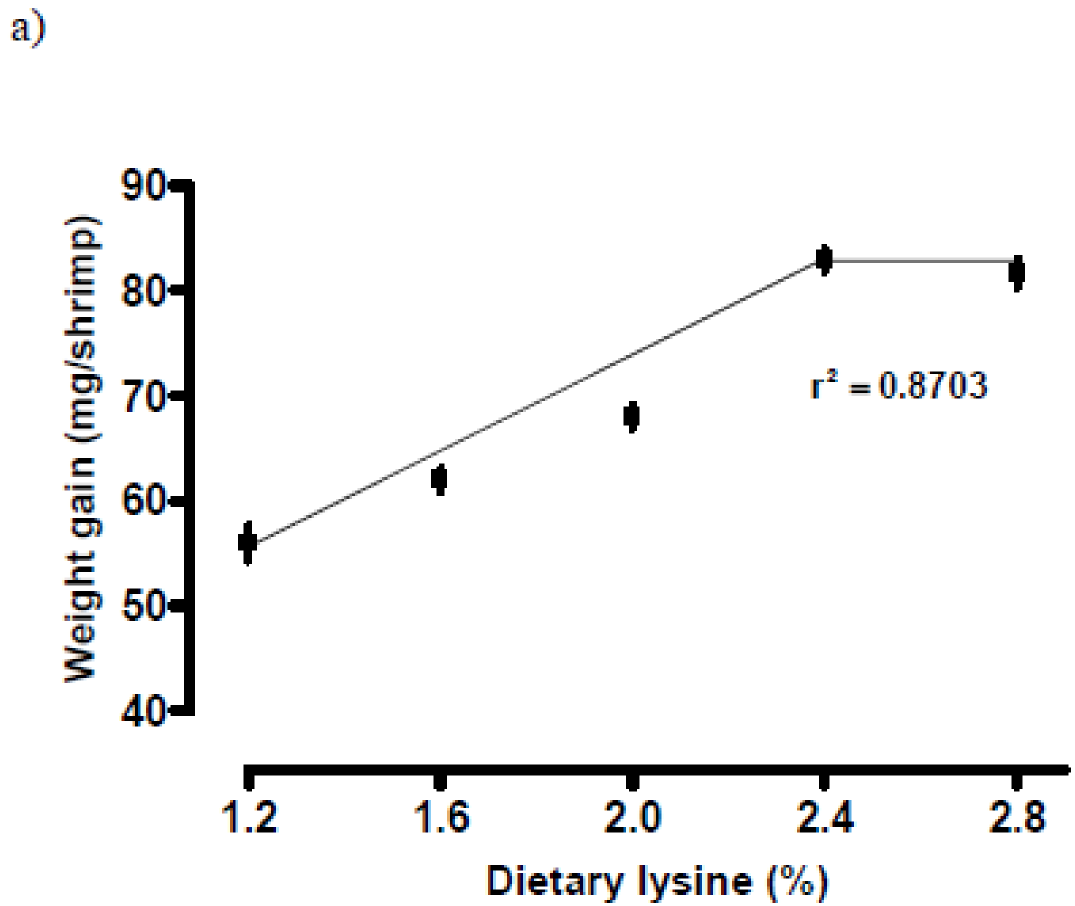


Fig. 2. Linear broken line regressions (broken line model) of nitrogen gain *v.* nitrogen intake (a), lysine intake (b) and methionine intake (c) in juvenile *Penaeus monodon*. The parameters of the regression equations and the requirement estimates are summarised in Tables 5 and 6. BW, body weight.

Good growth response can be achieved with synthetic amino acids
Solid and highly relevant studies can be conducted using standard methodology

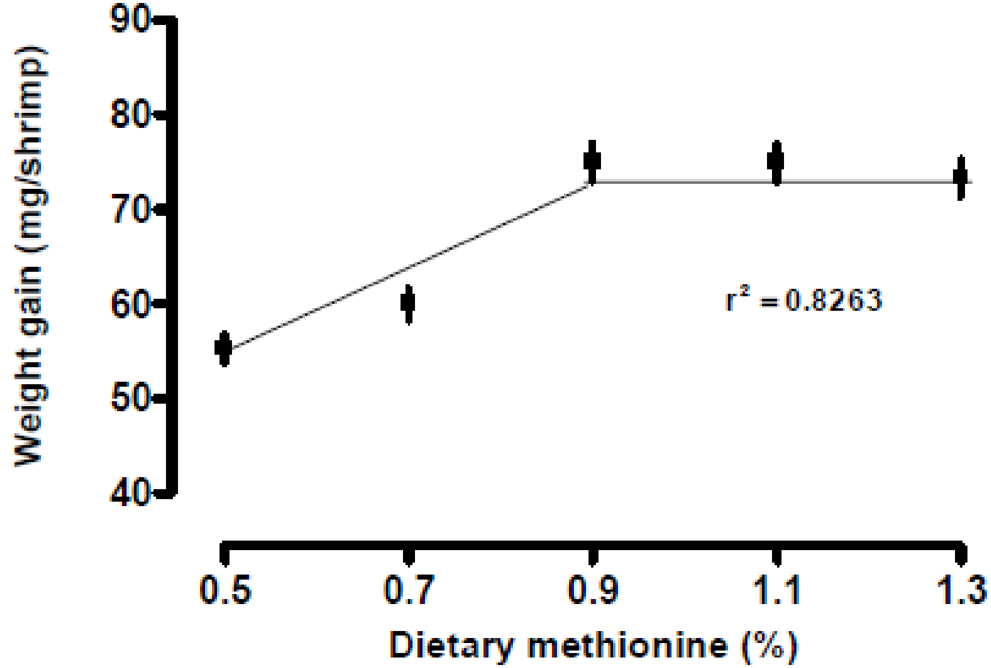
Response Atlantic ditch shrimp (*Palaemonetes varians*) to graded levels of dietary lysine



Palma et al. (submitted)

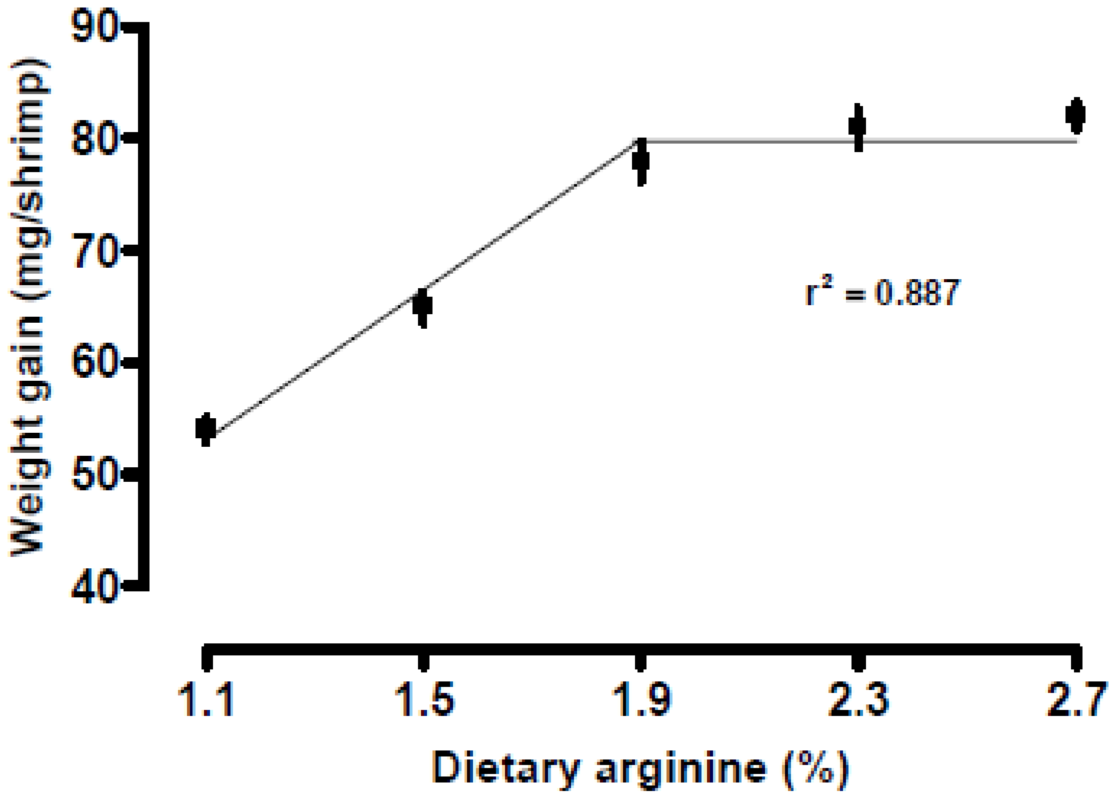
Response Atlantic ditch shrimp (*Palaemonetes varians*) to graded levels of dietary methionine

b)



Palma et al. (submitted)

Response Atlantic ditch shrimp (*Palaemonetes varians*) to graded levels of dietary arginine



Good growth response can be achieved with synthetic amino acids
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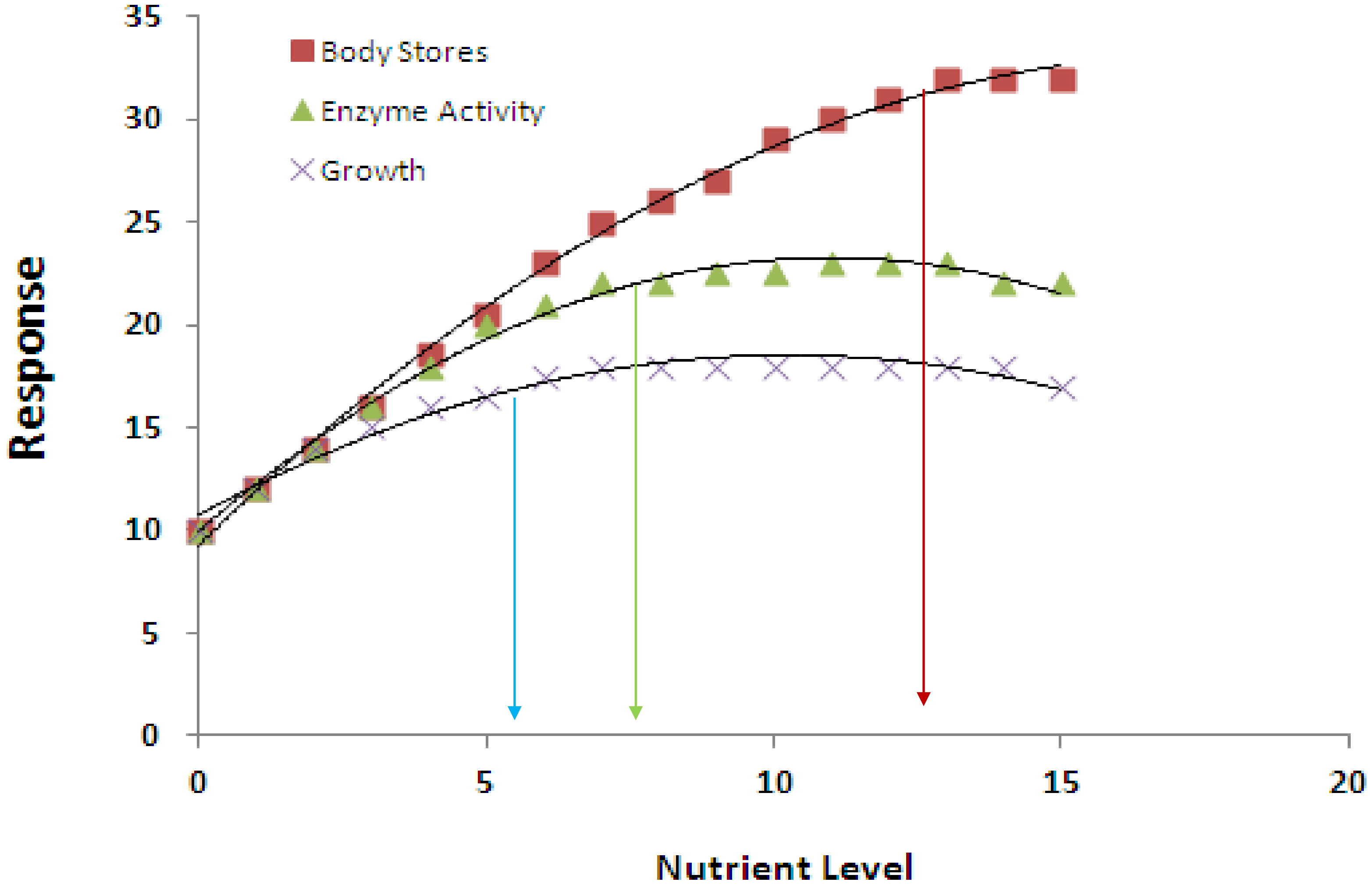
Palma et al. (submitted)

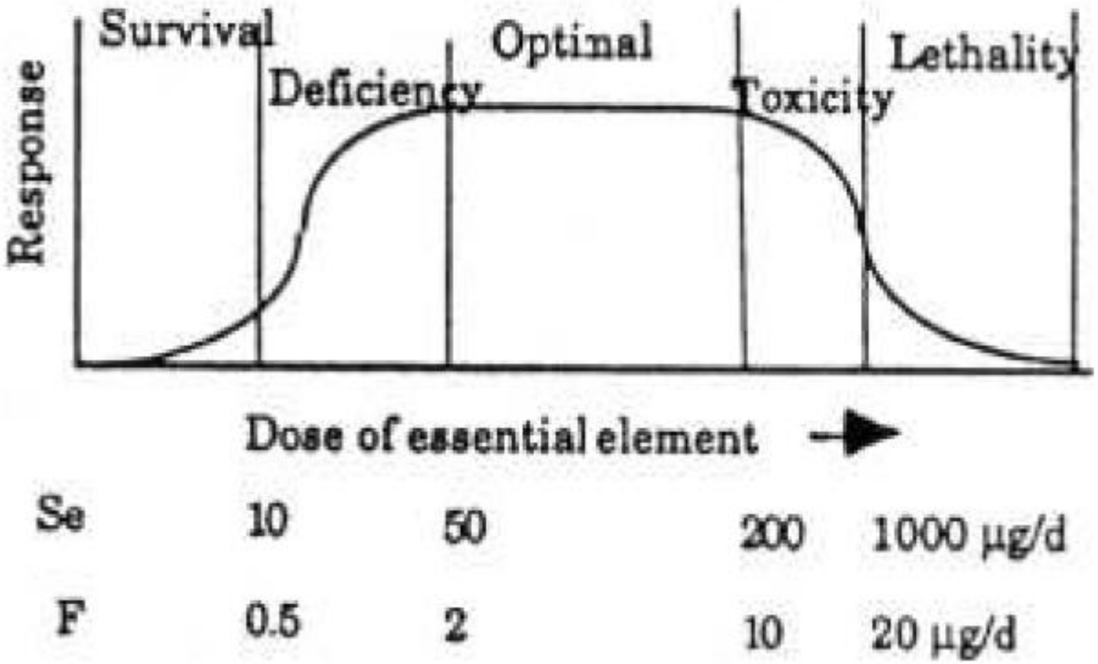
Different Parameters May Yield Different Estimates of Requirement



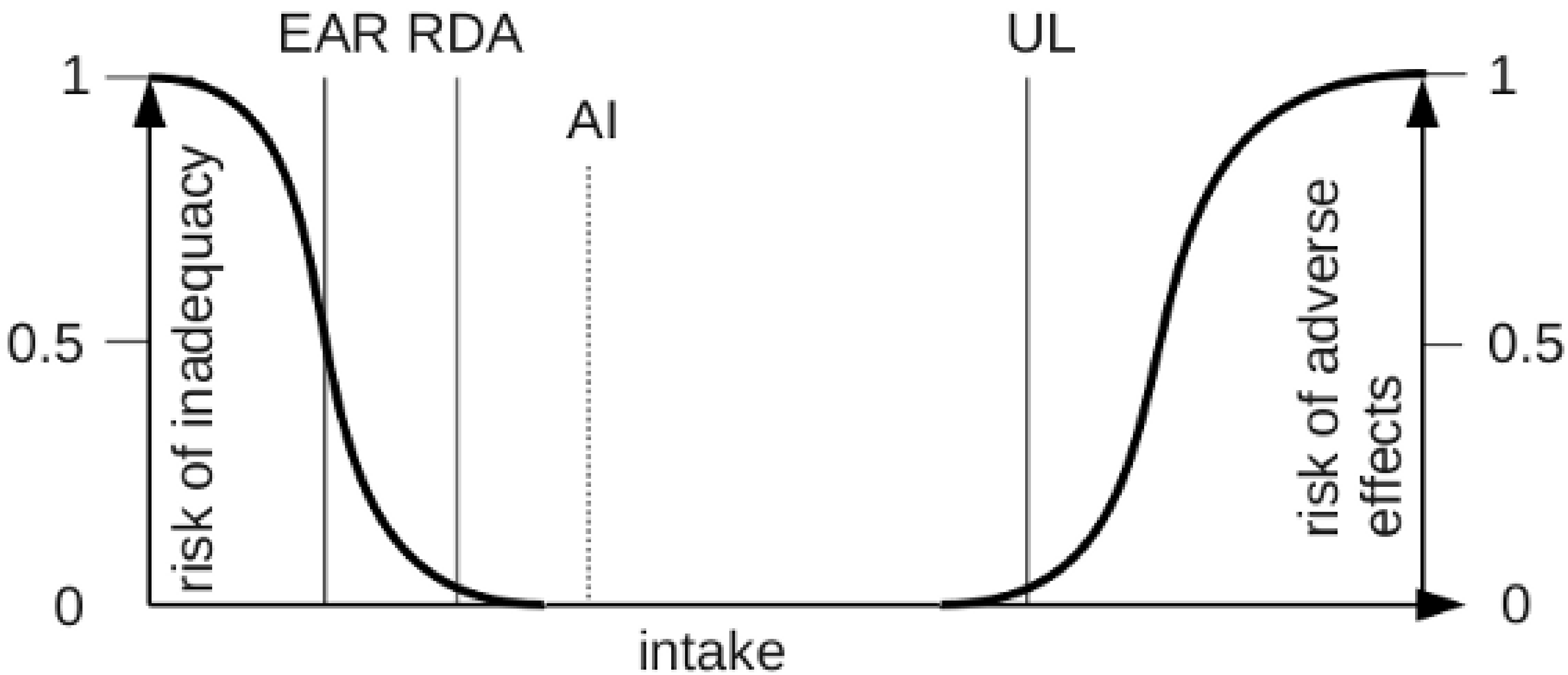
Different Models, Different Parameters = Different Estimates of Requirement

	Model			
Criteria	**Four parameter logistic**	**Exponential**	**Polynomial**	**Broken line**
Weight gain	2.11	2.68	2.23	2.19
Protein deposition	2.44	3.15	2.41	2.22

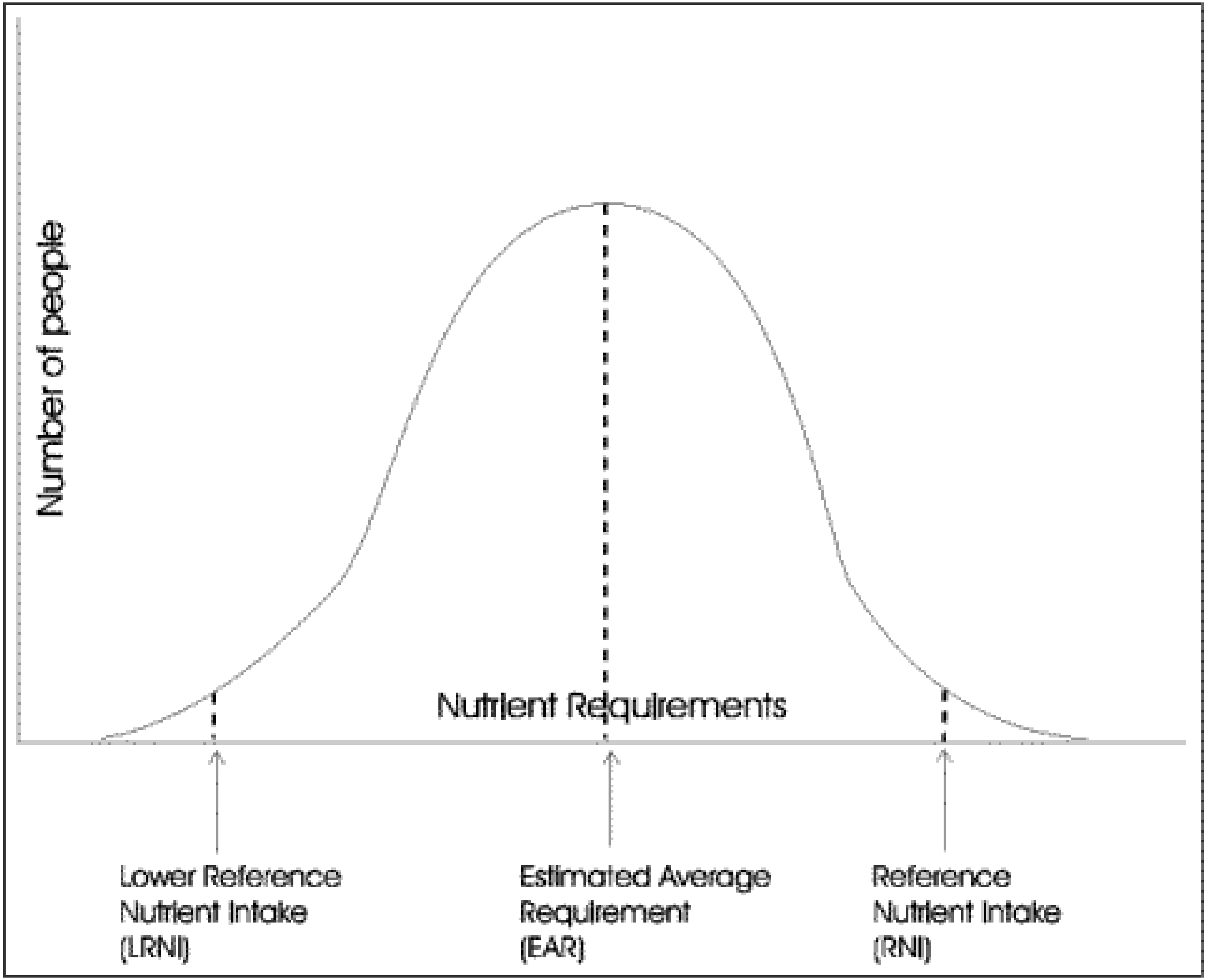
Dosis facit venom



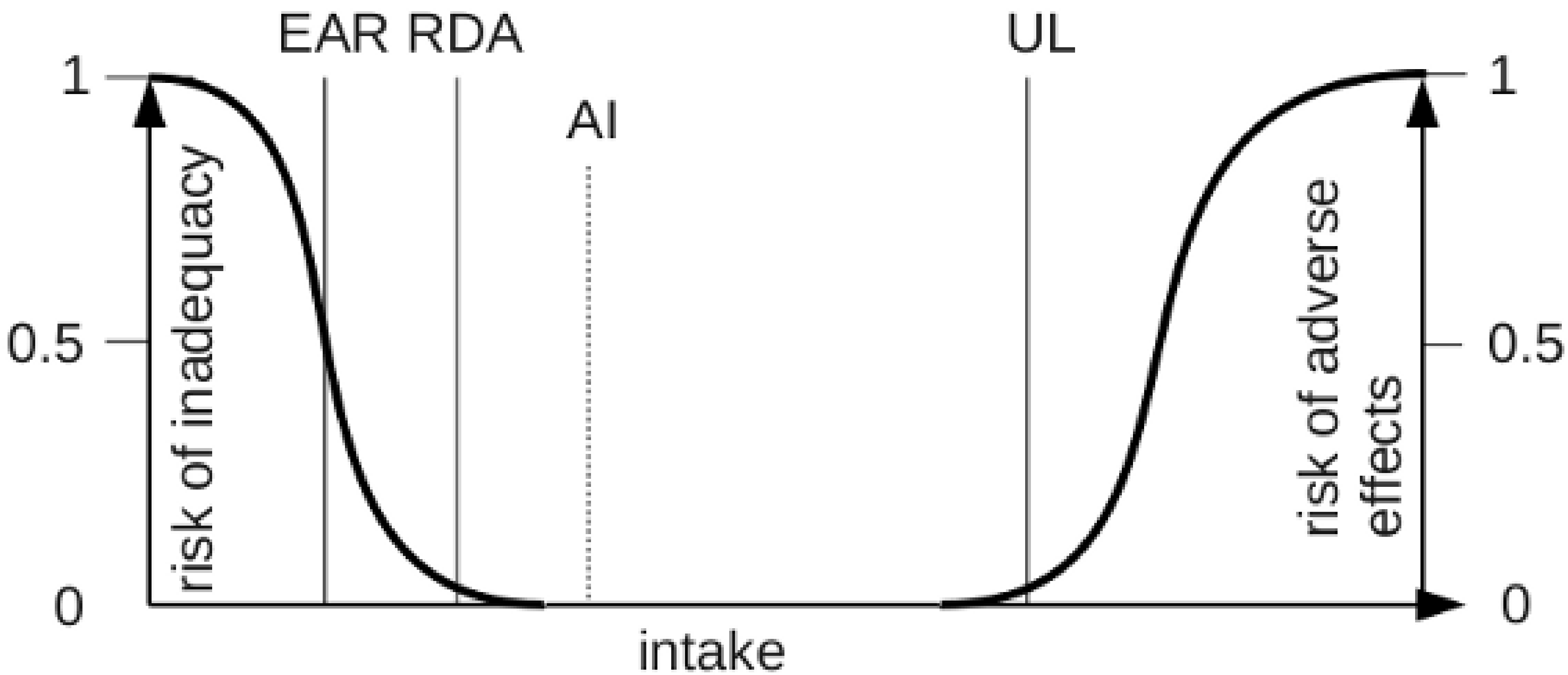
- ***How is uptake and ecosystem and tissue/organismal concentration controlled ?***



Estimated average requirement (EAR)
Recommended dietary allowance (RDA)
Adequate intake (AI)
Tolerable upper intake level (UL)



Note: This is a theoretical curve. This type of curve is based on numerous assumptions that are very difficult, almost impossible, to verify



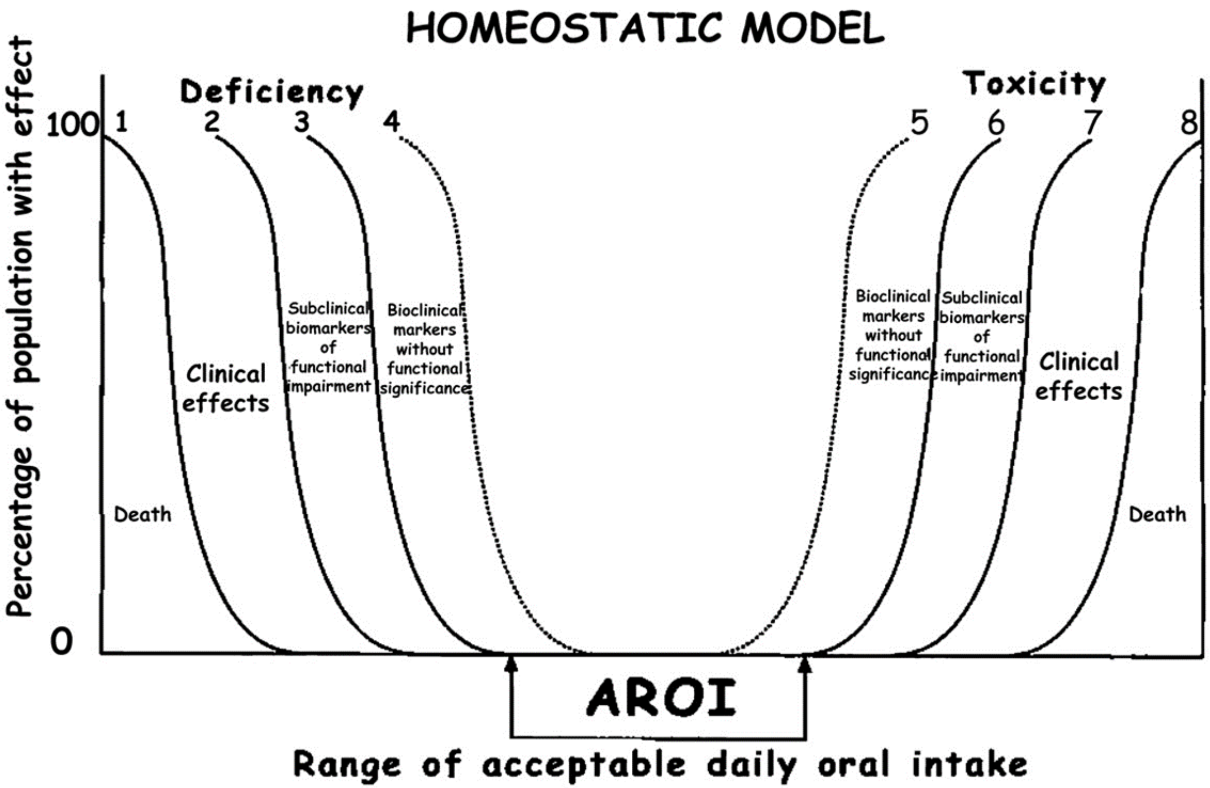
Estimated average requirement (EAR)
Recommended dietary allowance (RDA)
Adequate intake (AI)
Tolerable upper intake level (UL)

Objectives in Animal Nutrition?

Business models? Producing and selling "xyz" (milk, meal, fish fillets, egg)

Selling feed ingredients or additives or nutrients

Hinging on the profitability and sustainability (long term outlook) of the business model



Where on this graph do you want to be?

As an animal producer? feed manufacturer? vitamin supplier?

Table 9.2 Vitamin requirement of salmonids.

Vitamin	**Requirement**
Fat-soluble vitamins	
Vitamin A, IU/kg	2,500
Vitamin D, IU/kg	2,400
Vitamin E, IU/kg	50
Vitamin K, mg/kg	1
Water-soluble vitamin, mg/kg	
Riboflavin	4
Pantothenic acid	20
Niacin	10
Vitamin B12	0.01
Biotin	0.15
Folate	1.0
Thiamin	1
Vitamin B6	3
Vitamin C	50
Vitamin-like compounds, mg/kg	
Choline	1,000
myo-Inositol	300

Critical Reviews in Food Science and Nutrition, 49:361–368 (2009)

ISSN: 1040-8398
DOI: 10.1080/10408390802067290

Taylor & Francis
Taylor & Francis Group

Stability of Vitamins during Extrusion

MIAN N. RIAZ,[1] MUHAMMAD ASIF[1] and RASHIDA ALI[2]
[1]Food Protein R & D Center, Texas A&M University College Station, TX.
[2]H. E. J. Research Institute of Chemistry, University of Karachi, Pakistan.

Table 3 Typical losses of different vitamin during Pelleting and extrusion.

Vitamins	Mineral/Vitamin premix	Pelleting (70°C)	Pelleting (90°C)	Extrusion (80°C)	Canning	Storage
Vitamin A	1% / m	10%	30–40%	30%	Up to 70%	6–7% / m
Vitamin D	10% / m	15%	35%	25%	–	10% / m
Vitamin E	2% / 6 m as acetate	10%	15%	10%	–	–
Vitamin K	34–38% / m	20%	40%	50%	–	50% in compound feed
Vitamin B_1	50% / 3 m	15%	50%	50%	Up to 70%	5–20% / m
Vitamin B_2	5–40%	10%	15%	20%	–	2–10% / m
Vitamin B_6	20% / m	10%	30%	5–25%	3–5%	2–5% / m
Niacin	2–4% / m	5%	10%	10–30%	5%	1–2%
Pantothenic acid	1–8% / m	10%	20%	10–20%	–	0–5% / m
Choline	10% / 6 m	5%	5%	Low	NSR	3% / 6 m
Folic acid	10–40% p m	5–20%	45%	50%	50%	10–50% / m
Biotin	5% / m	10%	35%	15–25%	NSR	1–2% / m
Vitamin C	1–2% / m	40%	85%	90%	–	2–5% / m

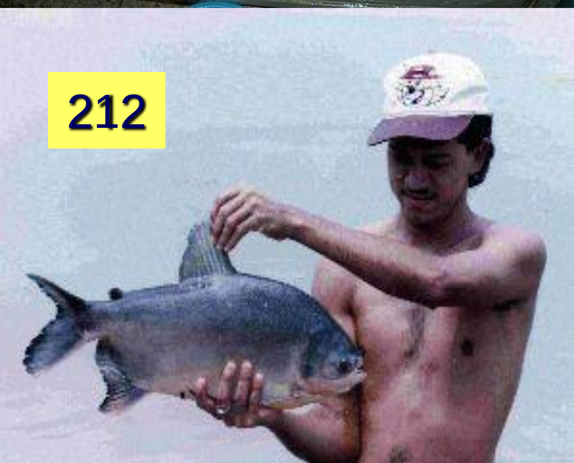
NSR = No significant reduction.
Source: Charlton and Ewing (2007).
m = Month.

Shrimp feeding on pelleted artificial diet

Requirement vs. Recommendation/ Specification

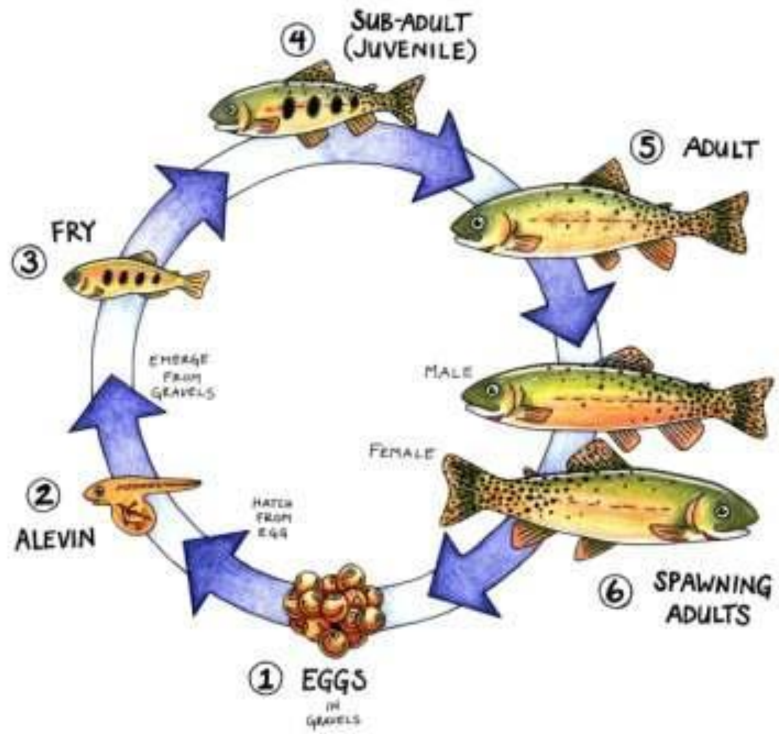
Requirement:	Minimum amount necessary for maximum growth young, fast- growing fish are in general used Parameters other than growth may be used
Recommendation/ Specification :	Requirement + safety margin for losses + margin for other sources of variations = Matter of Opinion (scientific or not)

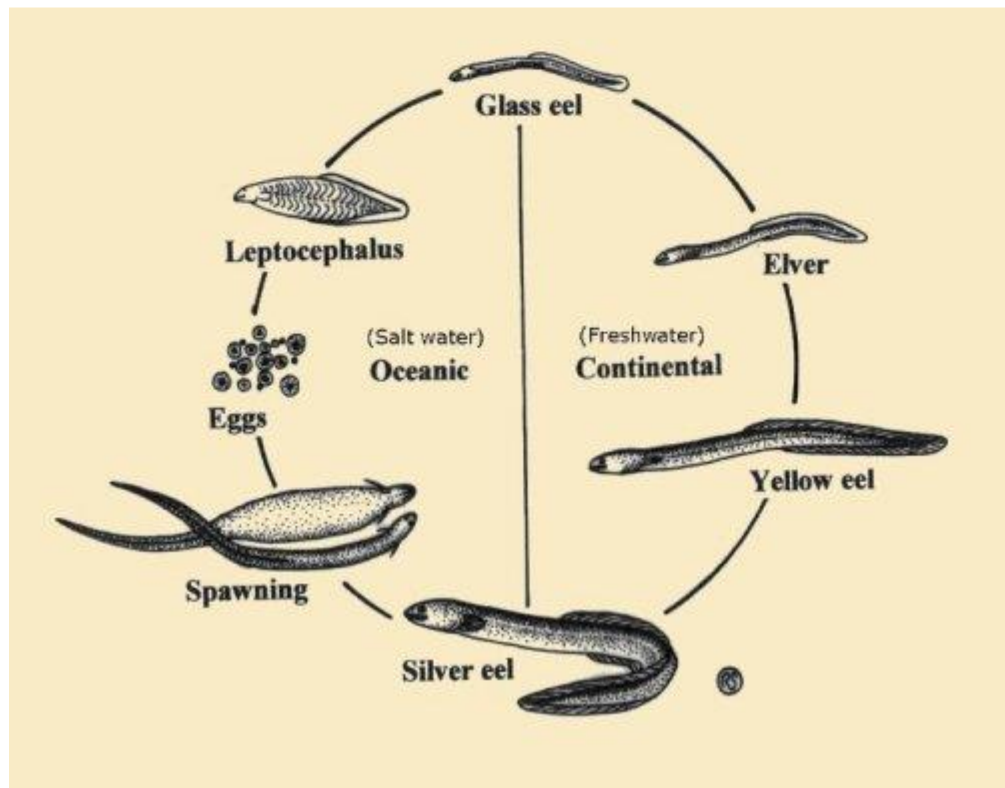
AQUACULTURE = Diversity of Species



Slide courtesy of Dr. A.J. Tacon

Differences Between Different Life Stages or Weight Ranges



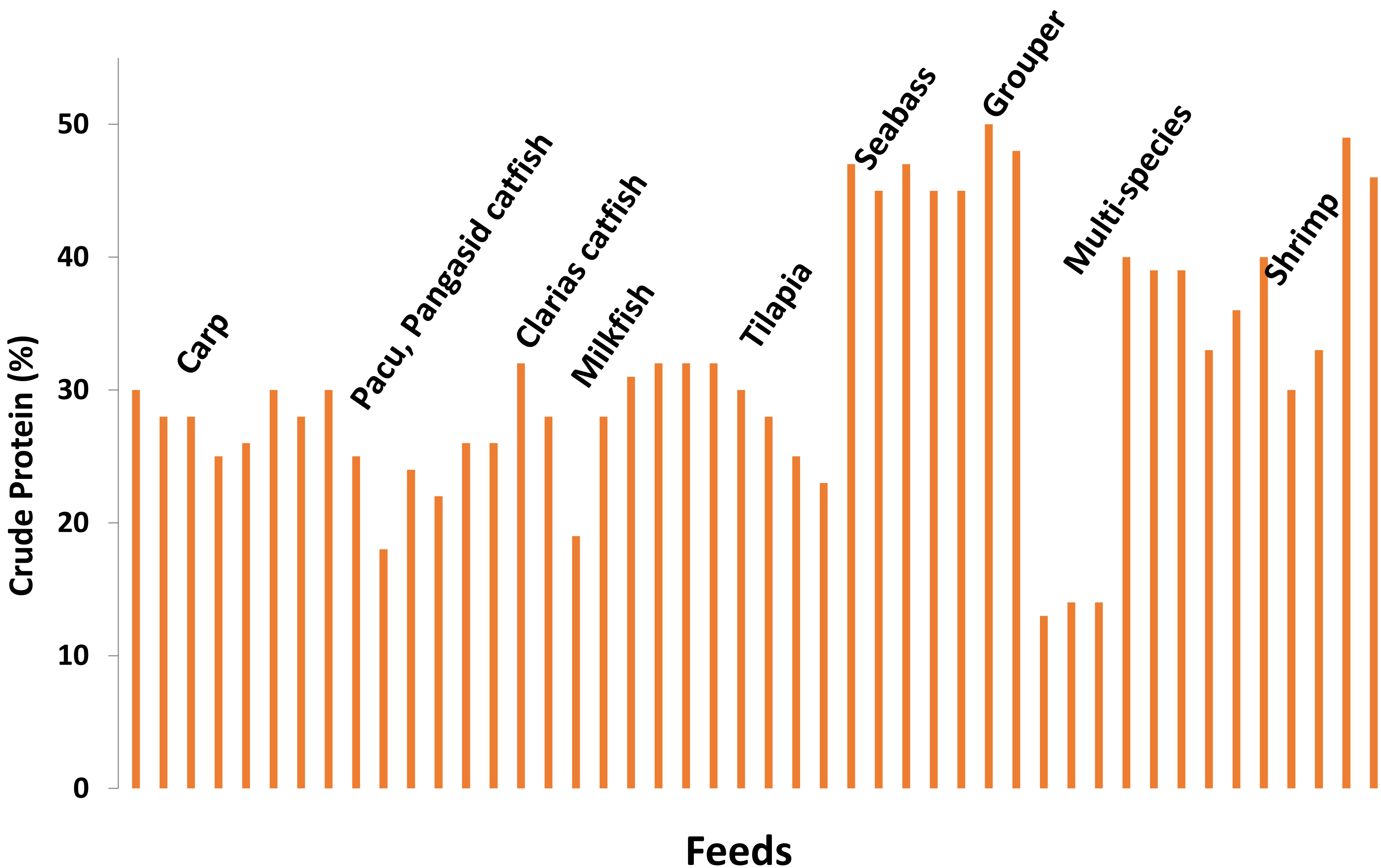


Feed is not "Feed"

Atlantic salmon (Azevedo, 1998)

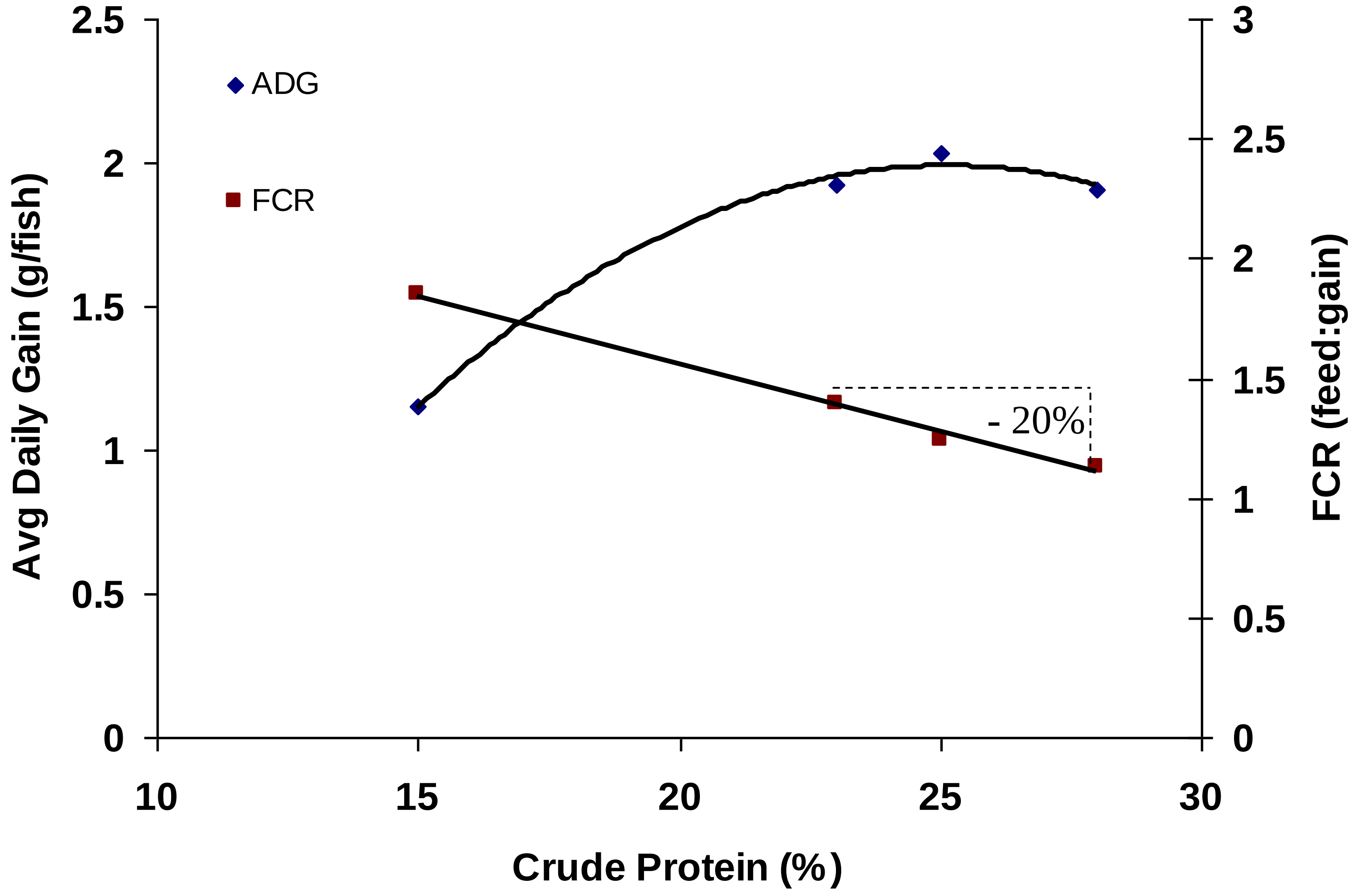
	Regular	HND
DP, %	37	44
DE, MJ/kg	18	22
DP/DE, g/MJ	20	20
Weight gain, g/fish	33.4	33.6
Feed efficiency, G:F	1.09	1.33
FCR, F:G	0.92	0.75

Protein Levels of Aquaculture Feeds Produced by a "Generalist" Aquaculture Feed Manufacturer



How you adapt the nutrient composition of feed of different chemical composition?
Multiple contradictory opinions / approaches

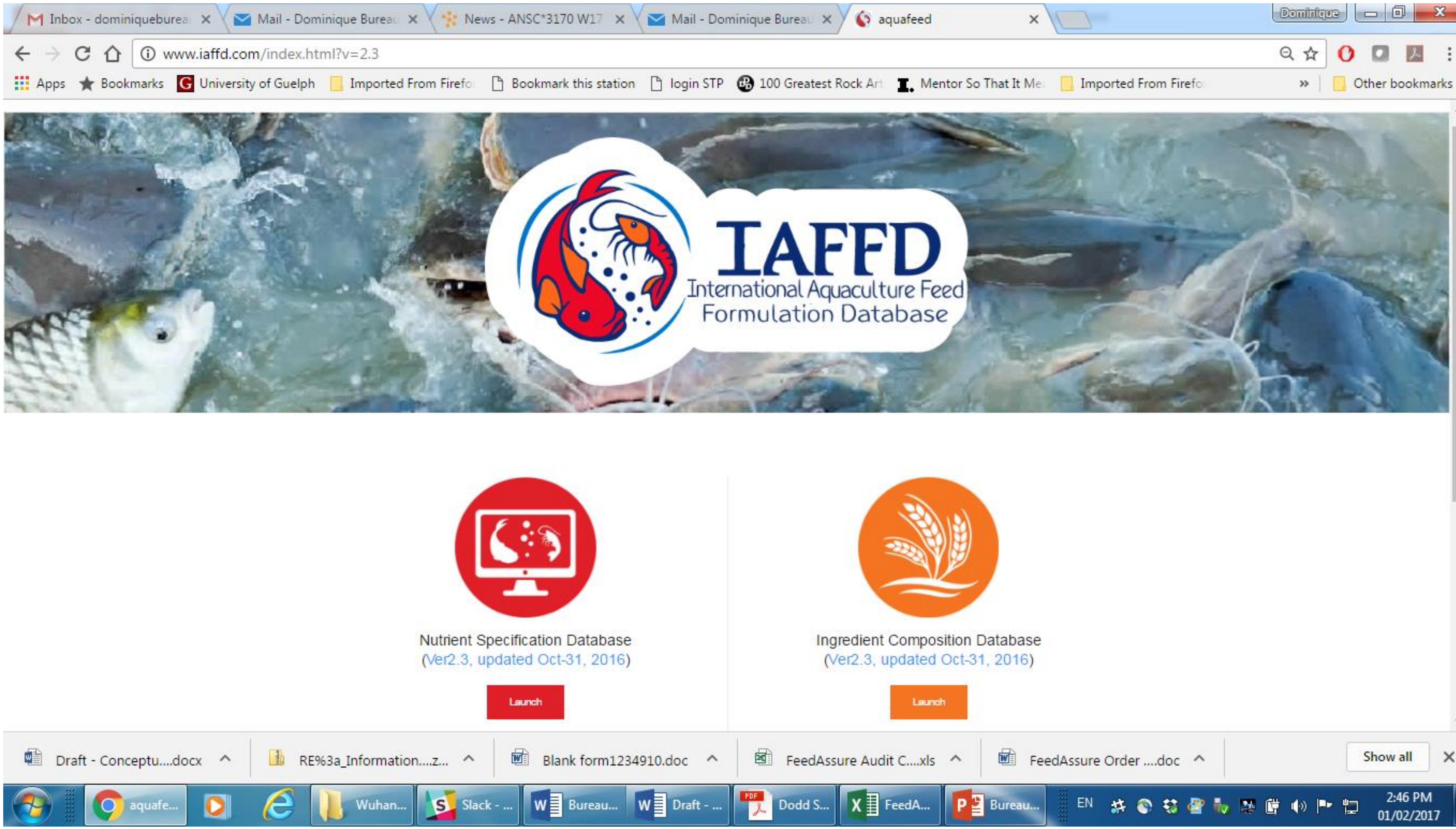
Daily Weight Gain and Feed Conversion Ratio of Nile Tilapia Fed Commercial Feeds with Different Nutrient Densities



Data from a commercial cage culture operation in SE Asia

Current Challenge:

Developing Nutritional Specifications for Different Species, Life Stages, Weight Ranges and Feed Types



http://iaffd.com/

A very large scale effort : Investment > USD 150,000 (direct) + USD 150,000 (indirect)
> 20 people worked on this project at the University of Guelph
Reviewed and compiled information from > 1000 documents
Best effort but also an imperfect one

IAFFD
International Aquaculture Feed
Formulation Database

Scope : 30 Species

1 Tilapia (Oreochromis, Tilapia and Sarotherodon spp.)
2 Pangasius (Pangasius spp.)
3 Milkfish (Chanos chanos)
4 Asian sea bass/Barramundi (Lates calcarifer)
5 Grass Carp (Ctenopharygodon idella)
6 Common Carp (Cyprinus carpio)
7 Whitelegged Pacific Shrimp (Litopenaeus vannamei)
8 Black Tiger Shrimp (Penaeus monodon)
9 African/Walking Catfish (Clarias spp.)
10 Pompano (Trichinotus spp.)
11 Snappers (Lutjanus spp.)
12 Groupers (Epinephelus, Mycteroperca, Plectropomus spp.)
13 Siganids (Siganus spp.)
14 Cobia (Rachycentron canadum)
15 Gourami (Osphronemus spp.)
16 Rohu (Labeo rohita)
17 Catla (Catla catla)
18 Mrigal (Cirrhinus cirrhosus)
19 Snakehead (Channa spp.)
20 Pacu (Piaractus mesopotamicus)
21 Freshwater Prawn (Macrobrachium spp.)
22 Rainbow Trout (Oncorhynchus mykiss)
23 Sturgeon (Acipenser spp.)
24 Abalone (Haliotis spp.)
25 Gilthead sea bream (Sparus aurata)
26 European sea bass (Dicentrarchus labrax)
27 Atlantic salmon (Salmo salar)
28 King/Chinook salmon (Oncorhynchus tshawytscha)
29 Gibel carp (Carassius auratus)
30 Channel catfish (Ictalurus puntatus)

IAFFD

International Aquaculture Feed Formulation Database

Nutritional Specifications

ASNS

This part of the project involved developing nutritional specifications for a large number of commercially important aquaculture species in Asia.

This was approached in three different, complementary ways:

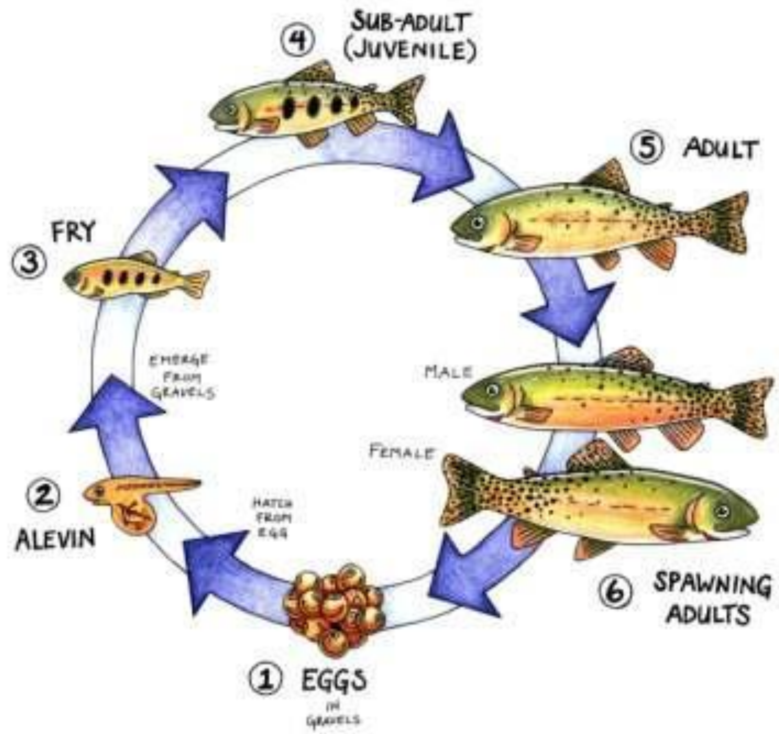
1) Reviewing the scientific and technical literature

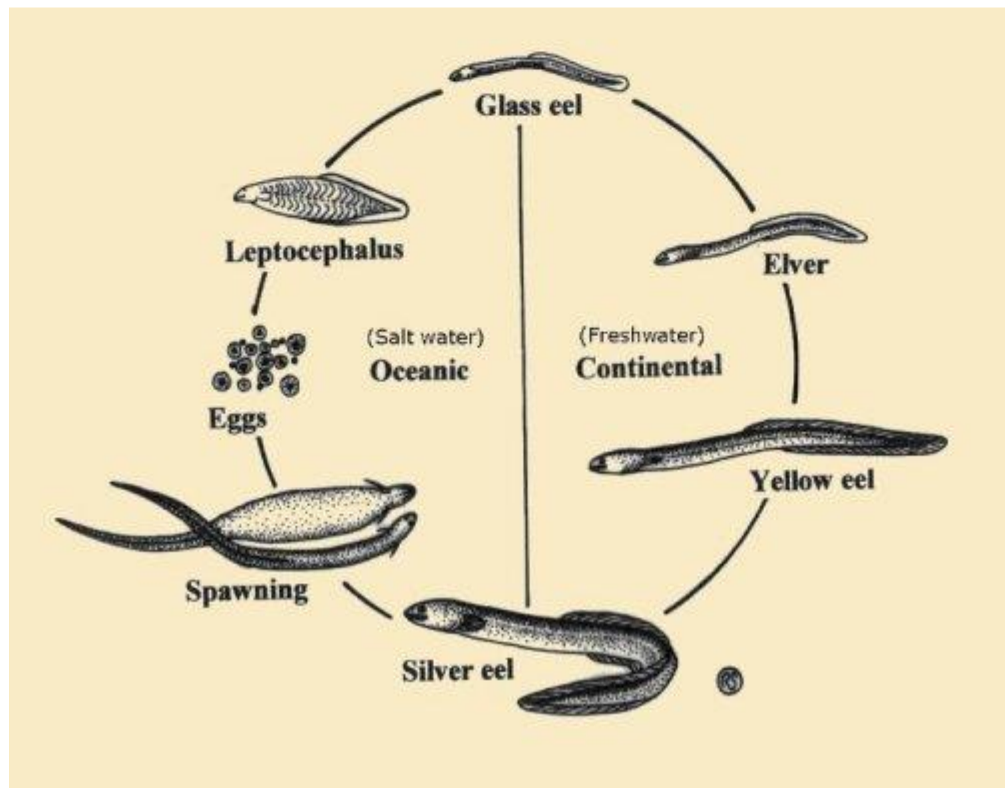
    Compiled information / specific data from about 1000 papers

2) Advanced nutritional modeling used to generate nutritional specification for 24 species (groups of species) and 3 to 7 life stages or weight ranges

Many "blank" for many parameters = insufficient information, need to be the focus of future efforts = Important to include now so that we start paying attention to these parameters.

Differences Between Different Life Stages or Weight Ranges

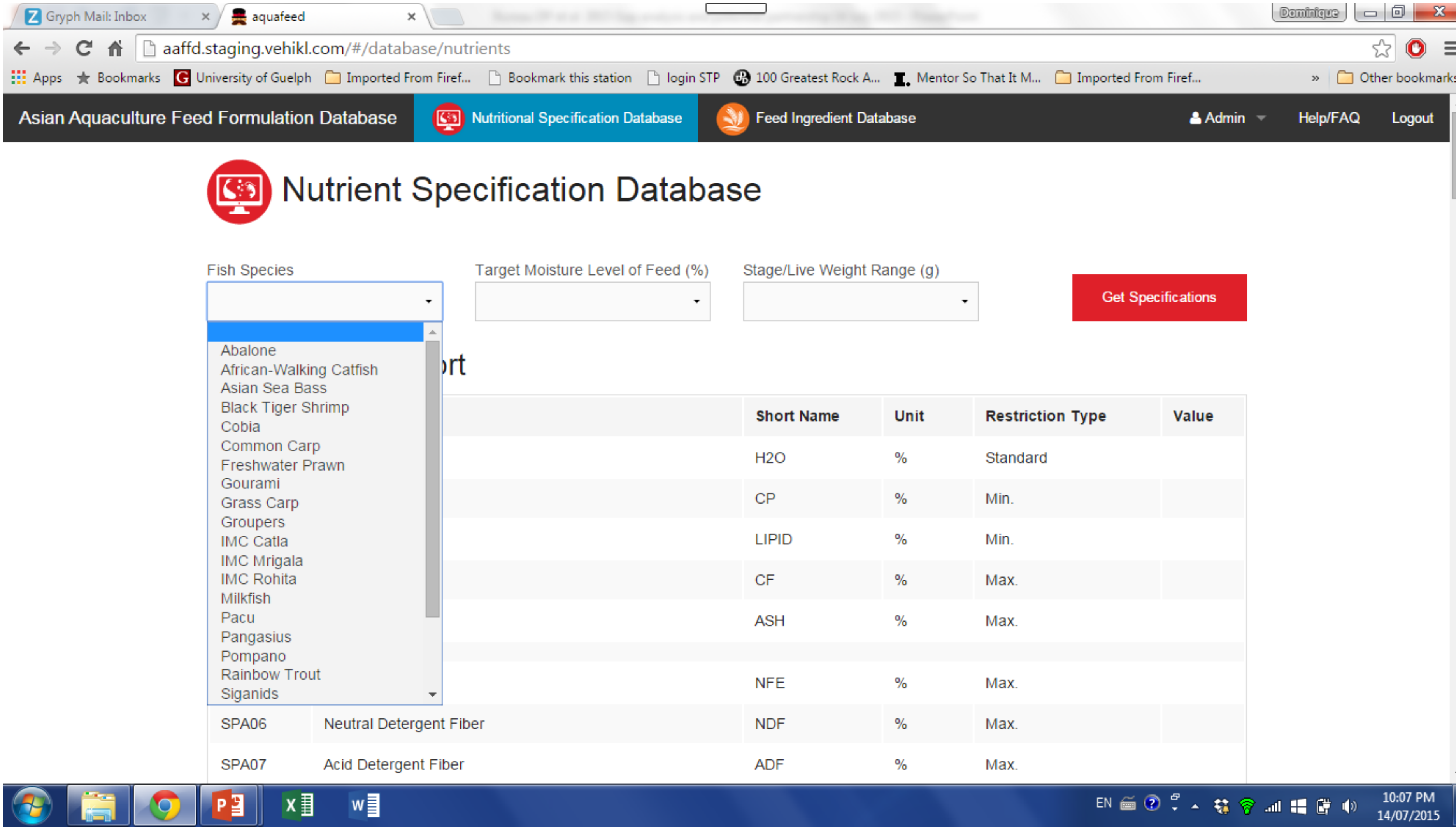




Changing Nutritional Specifications as a Function of Life Stage / Live Weight

Tilapia

				Specifications for Stage / Live Weight Range (g)					
				101_1	**101_2**	**101_3**	**101_4**	**101_5**	**101_6**
				Starter	**Fry**	**Pre-grower**	**Grower1**	**Finisher**	**Brood**
NutrSpecification	**Short Name**	**Unit**	**Restriction Type**	**< 5 g**	**5-50 g**	**50-200 g**	**200-500 g**	**500-1500 g**	**>1500 g**
Moisture	H2O	%	Minimum	10.0	10.0	10.0	10.0	10.0	10.0
Crude Protein	CP	%	Minimum	37.0	34.9	32.9	30.4	28.5	28.2
Crude Lipids	LIPID	%	Minimum	8.4	8.6	8.8	9.7	11.3	12.2
Crude Fibre	CF	%	Maximum	0.0	0.0	0.0	0.0	0.0	0.0
Ash	ASH	%	Maximum	0.0	0.0	0.0	0.0	0.0	0.0
NFE	NFE	%	Maximum	0.0	0.0	0.0	0.0	0.0	0.0
NDF	NDF	%	Maximum	0.0	0.0	0.0	0.0	0.0	0.0
ADF	ADF	%	Maximum	0.0	0.0	0.0	0.0	0.0	0.0
Starch	STARC	%	Minimum	16.3	17.0	17.7	18.4	18.5	18.3
Dig CP -fish	DP	%	Minimum	34.1	32.1	30.2	28.0	26.3	25.9
Dig GE (DE) - fish	DE kcal	kcal	Minimum	3442	3384	3338	3318	3361	3406
DE Fish Carni		kcal	Minimum	0.0	0.0	0.0	0.0	0.0	0.0
DE Fish Omni		kcal	Minimum	3442	3384	3338	3318	3361	3406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University of Guelph
Imported From Firef...
Bookmark this station
login STP
100 Greatest Rock A...
Mentor So That It M...
Imported From Firef...
Other bookmarks
Asian Aquaculture Feed Formulation Database
Nutritional Specification Database
Feed Ingredient Database
Admin
Help/FAQ
Logout
Nutrient Specification Database
Fish Species
Target Moisture Level of Feed (%)
Stage/Live Weight Range (g)
Get Specifications
Abalone
African-Walking Catfish
Asian Sea Bass
Black Tiger Shrimp
Cobia
Common Carp
Freshwater Prawn
Gourami
Grass Carp
Groupers
IMC Catla
IMC Mrigala
IMC Rohita
Milkfish
Pacu
Pangasius
Pompano
Rainbow Trout
Siganids
rt
Short Name
Unit
Restriction Type
Value
H2O
%
Standard
CP
%
Min.
LIPID
%
Min.
CF
%
Max.
ASH
%
Max.
NFE
%
Max.
SPA06
Neutral Detergent Fiber
NDF
%
Max.
SPA07
Acid Detergent Fiber
ADF
%
Max.
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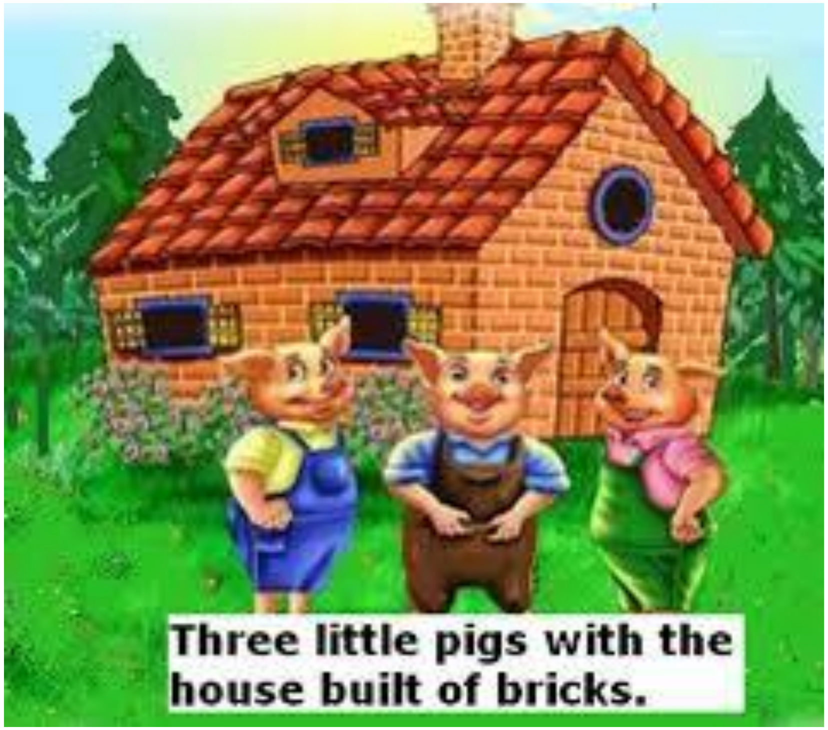
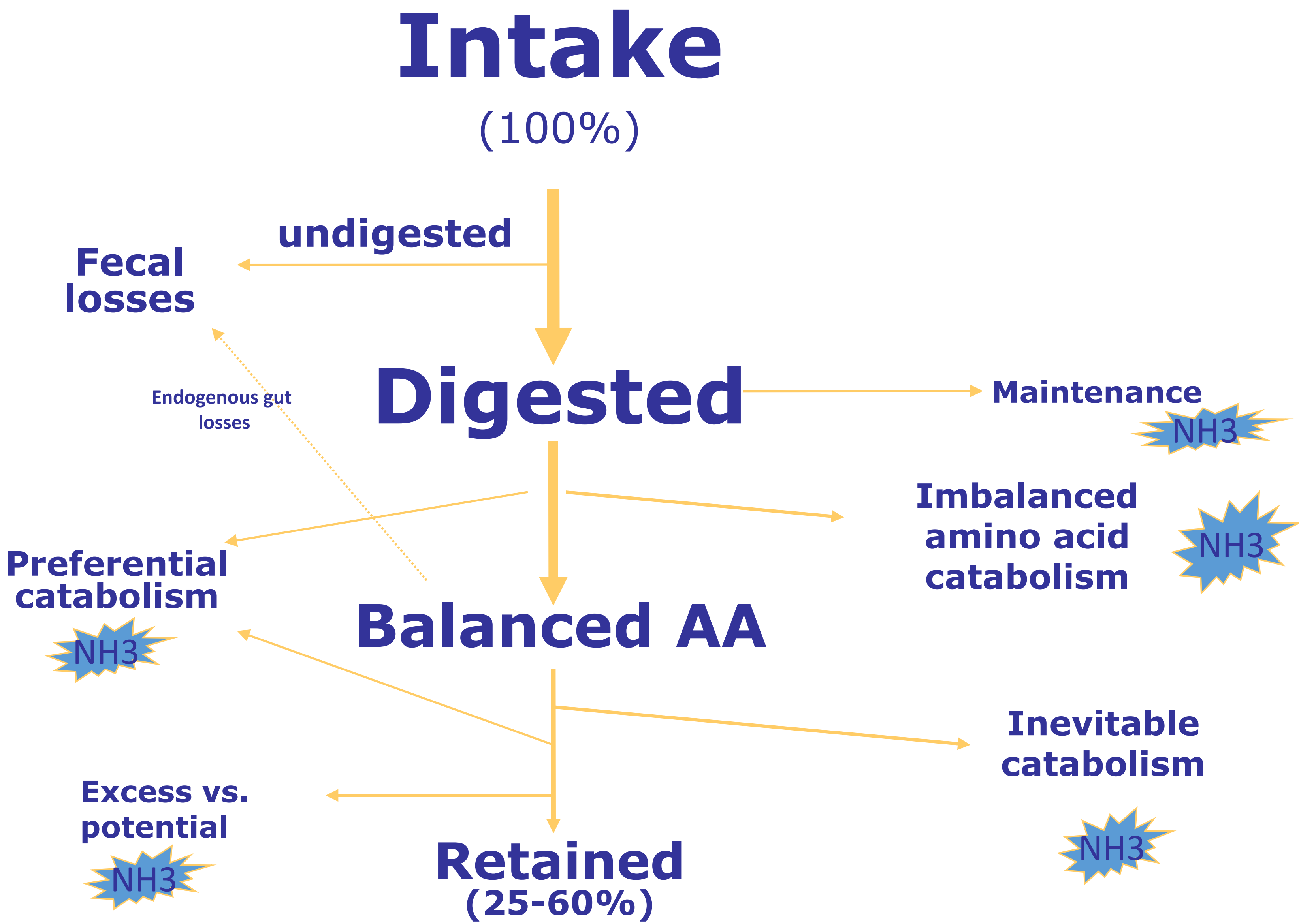


How much material (brick, mortar, roofing tiles, etc.) did the little pig need to build his brick house?

If we can approach construction/ engineering this way,
Why can’t we apply the same ideas to nutrition???

Factorial Amino Acid Utilization Scheme



Intake

mg fish/day

Fecal losses

Endogenous gut losses

Digestible Amino Acid Requirement

mg fish/day

Maintenance

mg fish/day

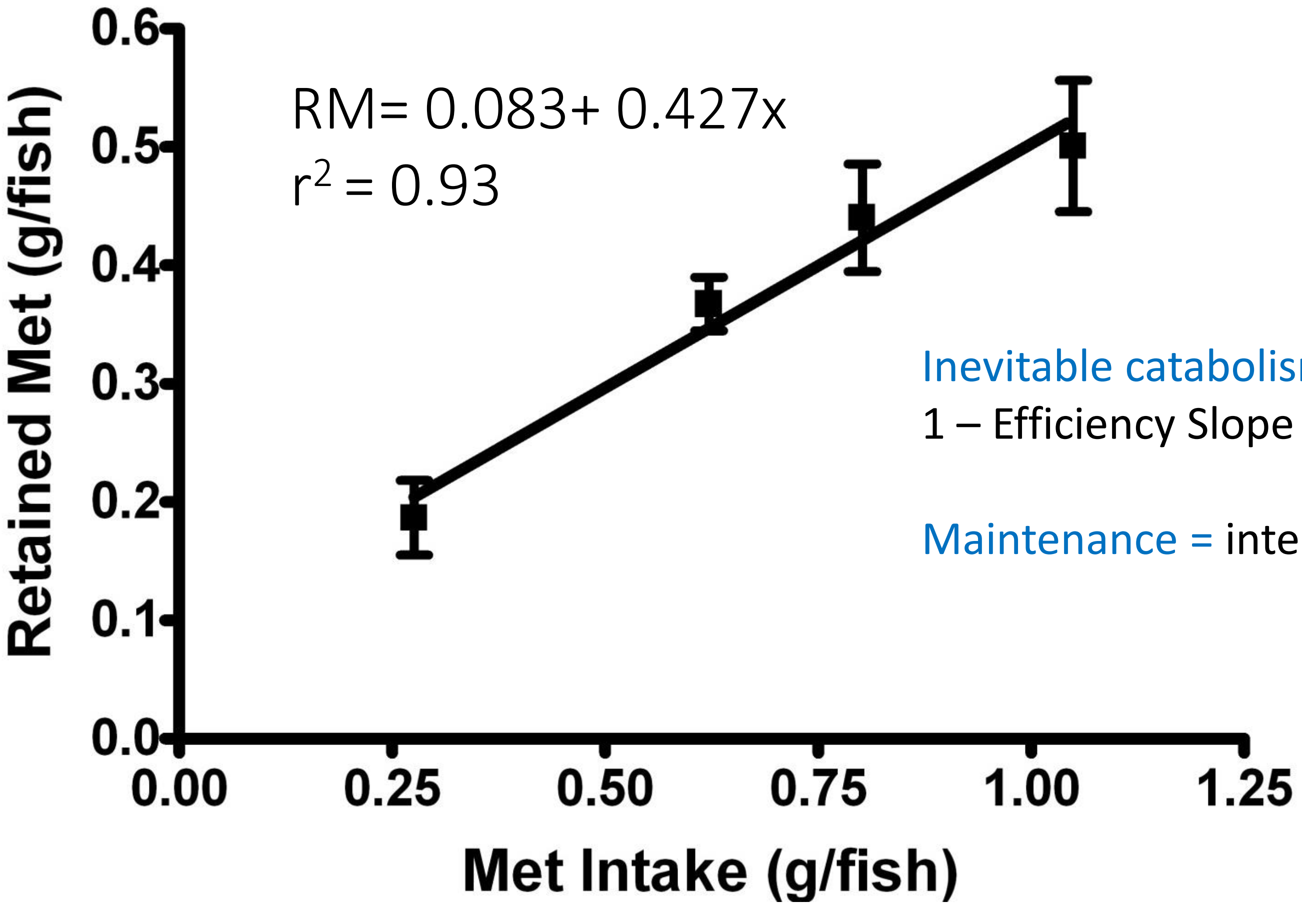
Inevitable catabolism

mg fish/day

Retained

mg fish/day

Efficiency of Retention

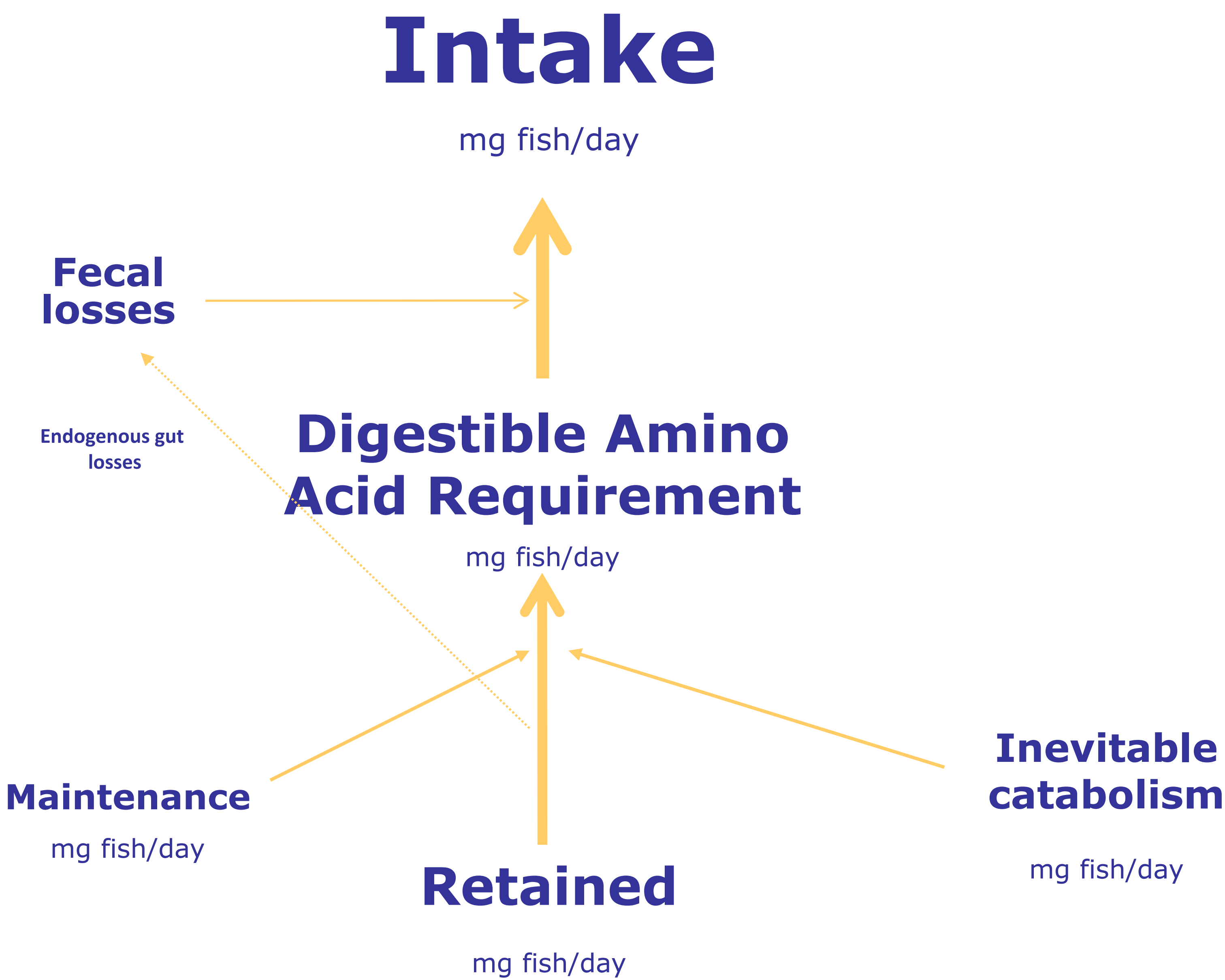


Inevitable catabolism =
1 – Efficiency Slope

Maintenance = intercept

Retained methionine (g/fish) vs. methionine intake (g/fish)

Factorial Amino Acid Requirement Model



Factorial Model of Amino Acid Requirement Model

Absolute EAA (e.g. Met) Requirement
(g per fish per day)

Divided by

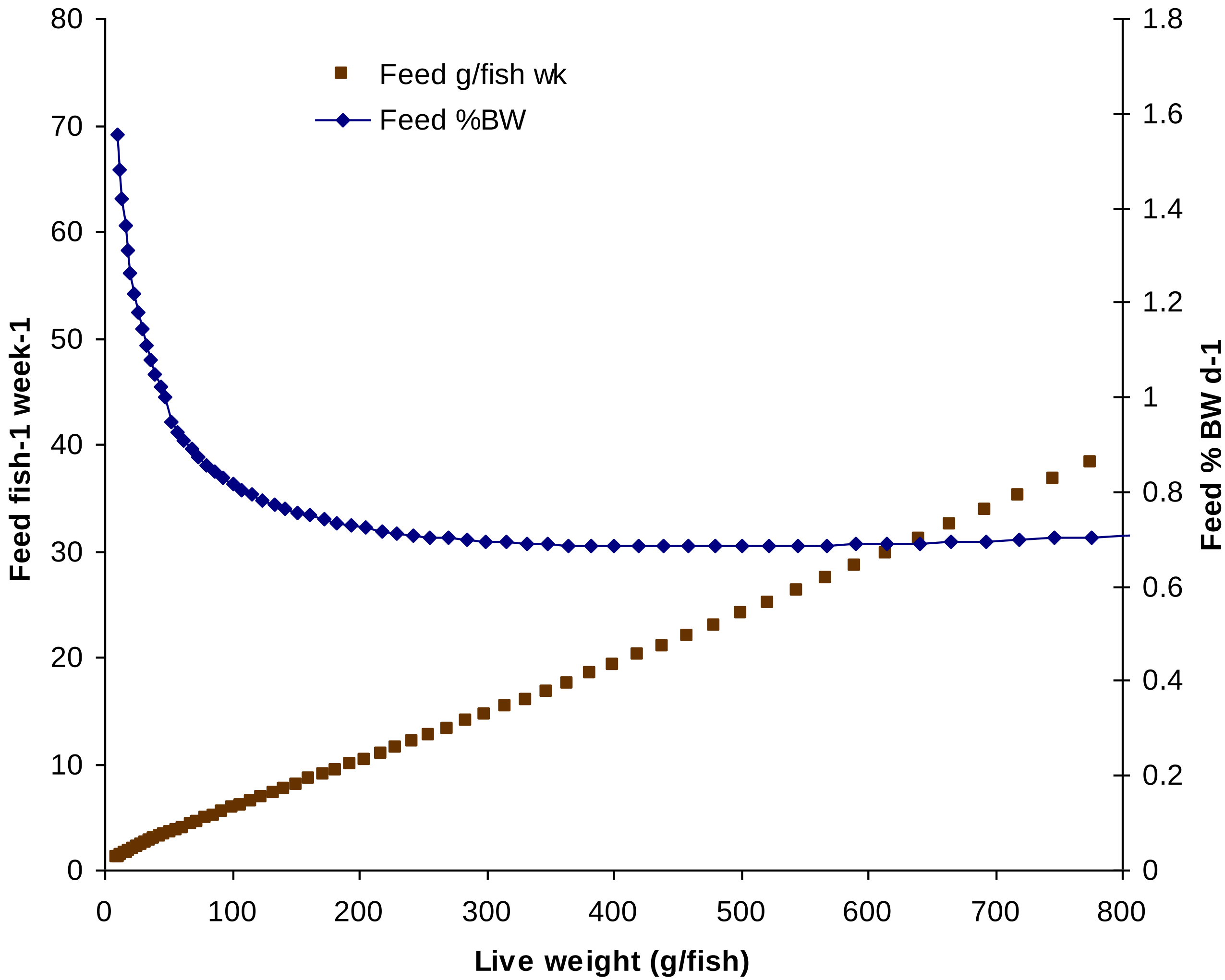
Expected feed intake
(g fish per day)

← How do you get this value?

Equal

Optimal Dietary Concentration
(%, mg/kg, kcal/kg)

Simulated feed intake of rainbow trout of increasing weight



(TGC= 0.180, Temperature = 9°C)

Bureau et al. (2002)

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journal homepage: www.elsevier.com/locate/aqua-online

Bioenergetics-Based Factorial Model to Determine Feed Requirement and Waste Output of Tilapia Produced under Commercial Conditions

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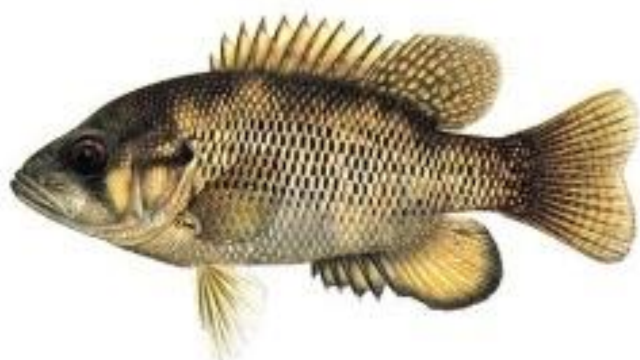
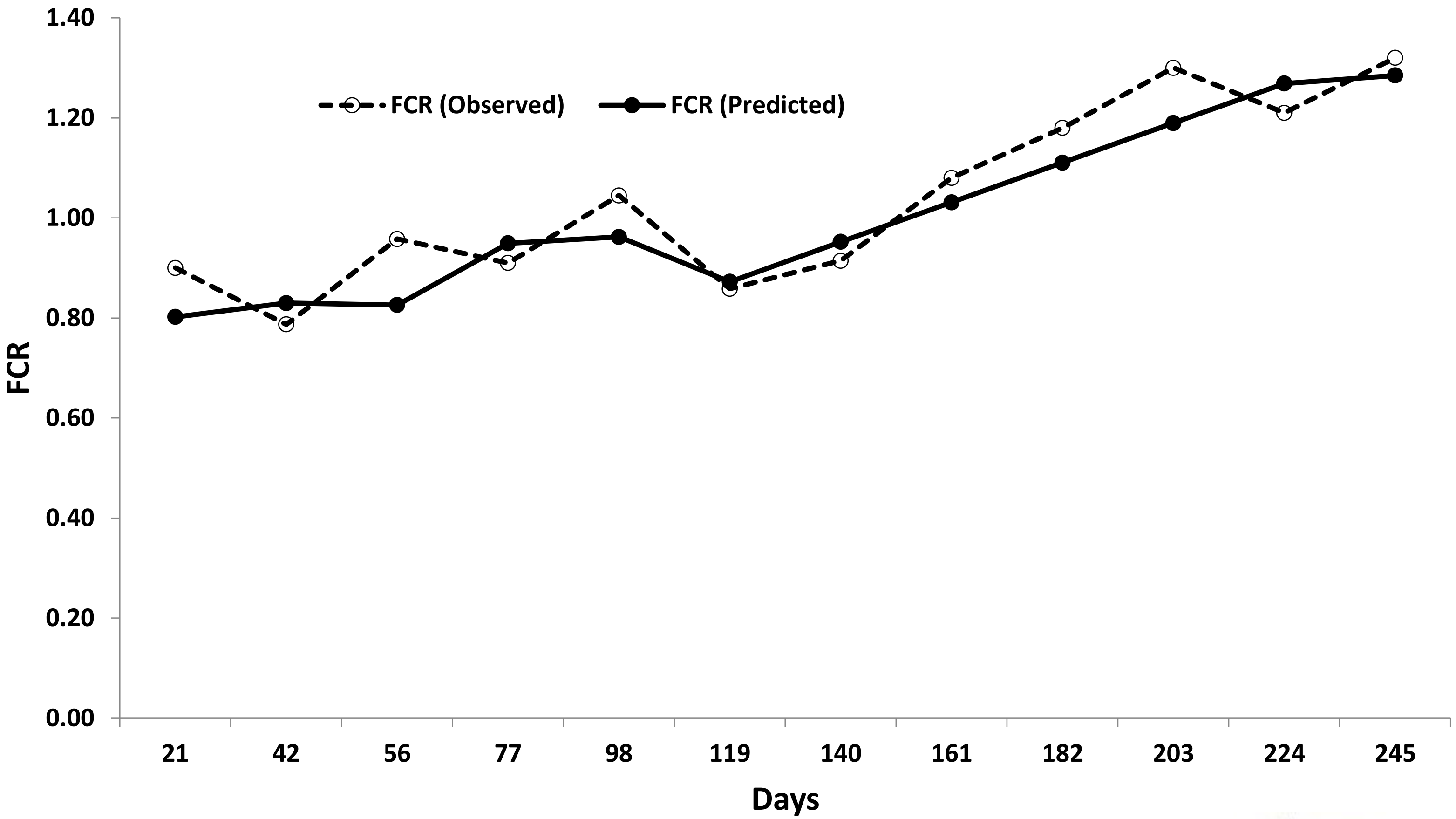
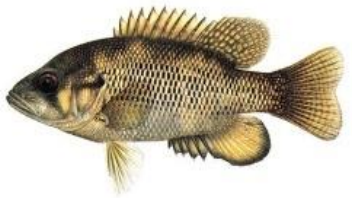
[a] Fish Nutrition Research Laboratory, Dept. of Animal and Poultry Science, University of Guelph, Guelph, Ontario, N1G 2W1, Canada
[b] Dorion Fish Culture Station, Ministry of Natural Resources, Dorion, Ontario, Canada
[c] Faculty of Agriculture and Horticulture, Humboldt-Universität zu Berlin, Invalidenstraße 42, 10115 Berlin, Germany

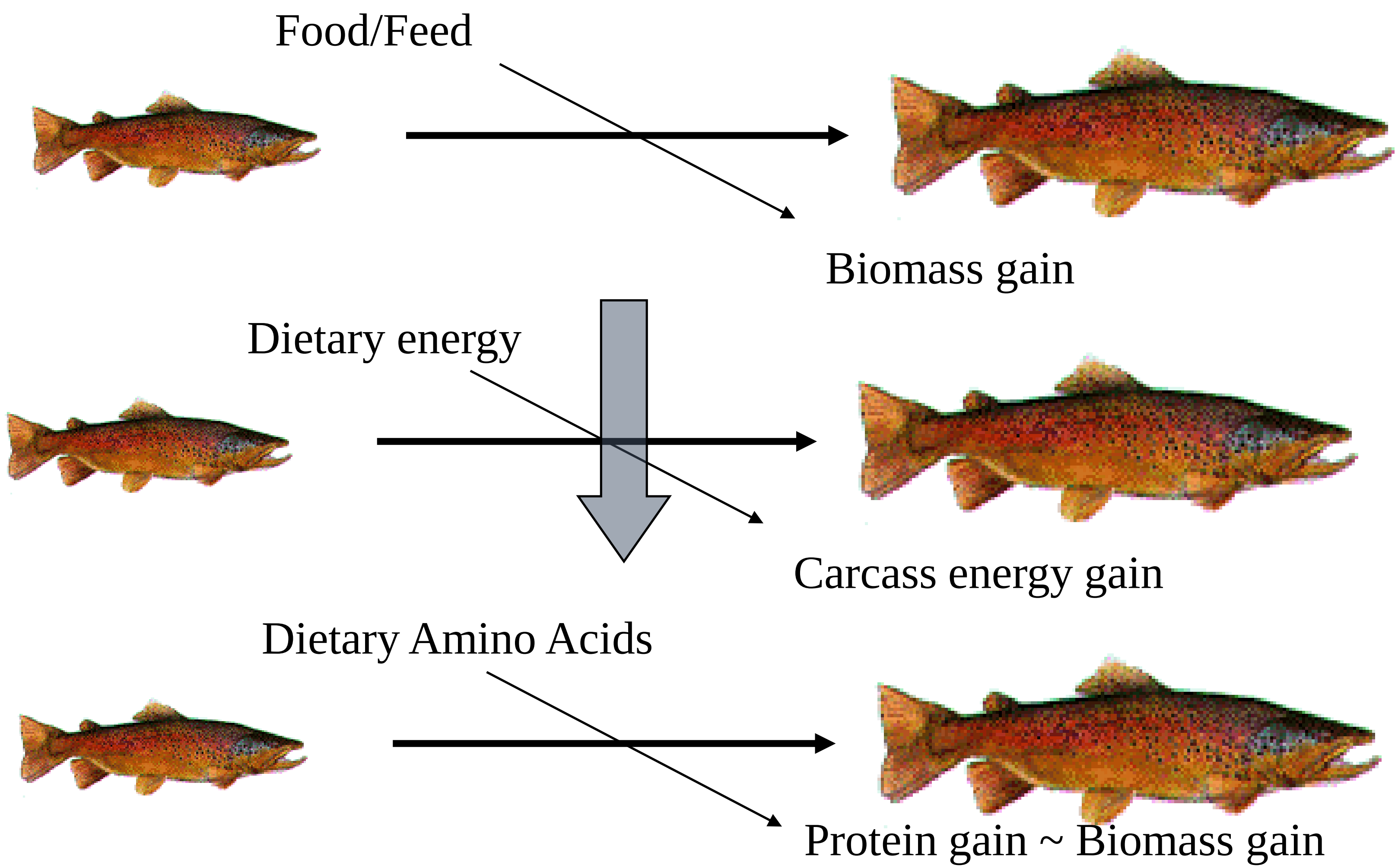


Observed and predicted evolution of feed conversion ratio (feed:gain) of Nile tilapia during a pilot-scale trial

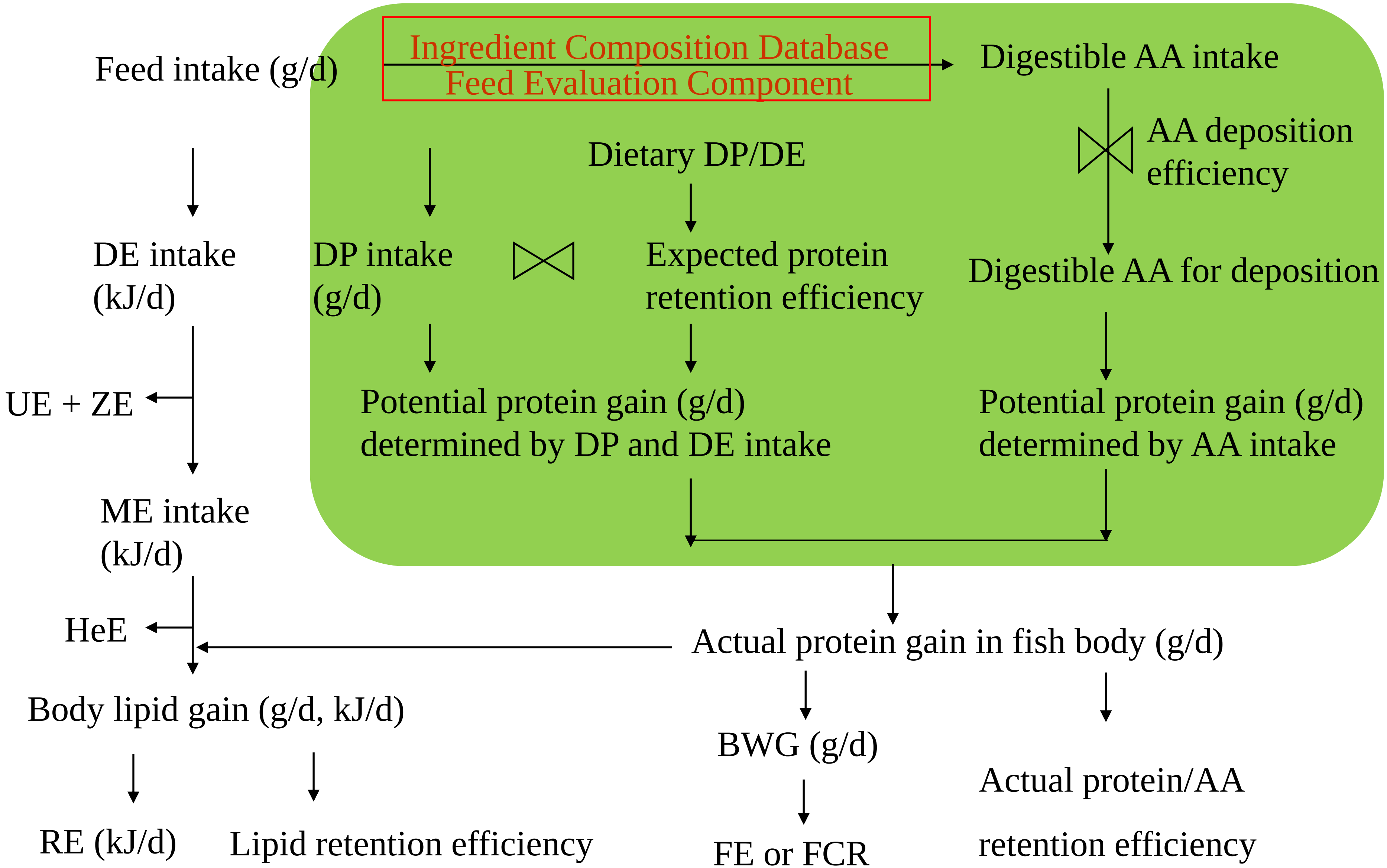




Evolution of Feed Utilization Models

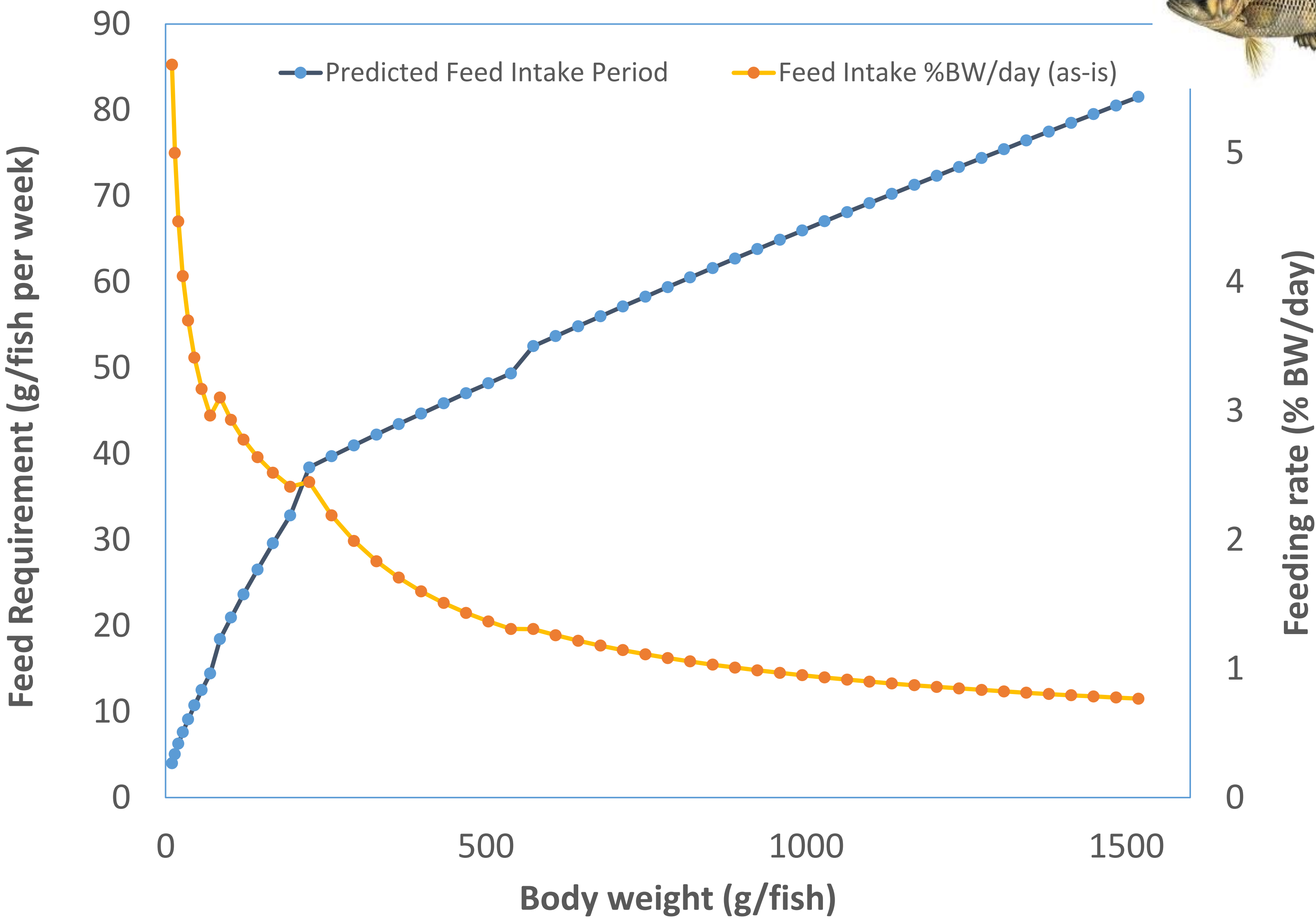


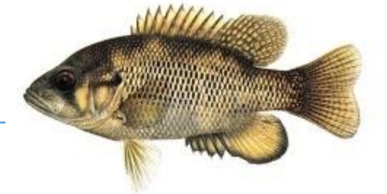
A Factorial Essential Amino Acid - Bioenergetic Hybrid Model



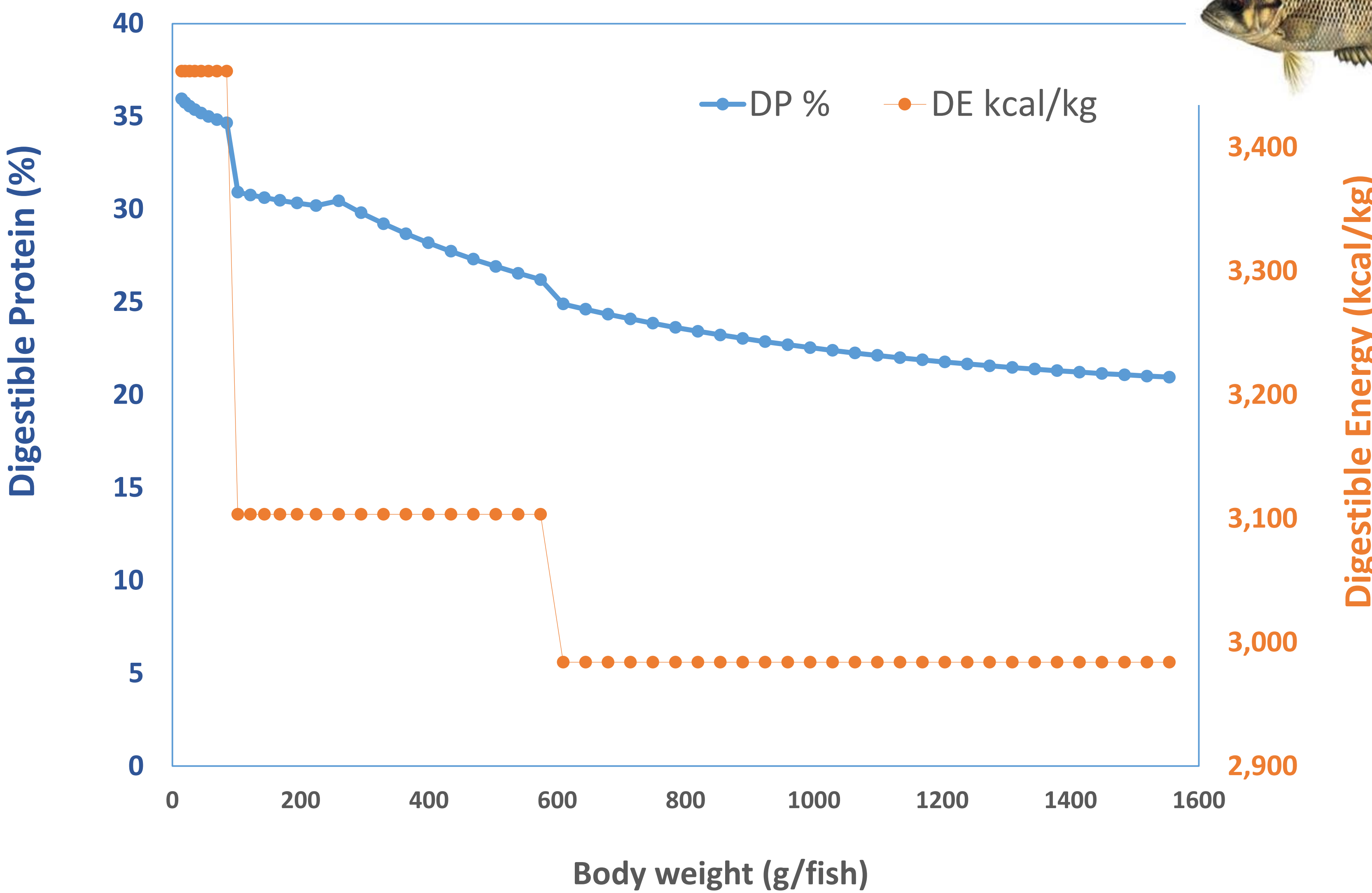
Hua and Bureau (2012)

Simulated feed intake of Nile tilapia of increasing weight





Predicted Optimal Digestible Protein and Digestible Energy Content of Nile Tilapia Feeds



Digestible EAA requirements (% Diet DM) of rainbow trout of different weights Fed Diets with 20 MJ DE. (EAA Requirements estimated using a factorial model)

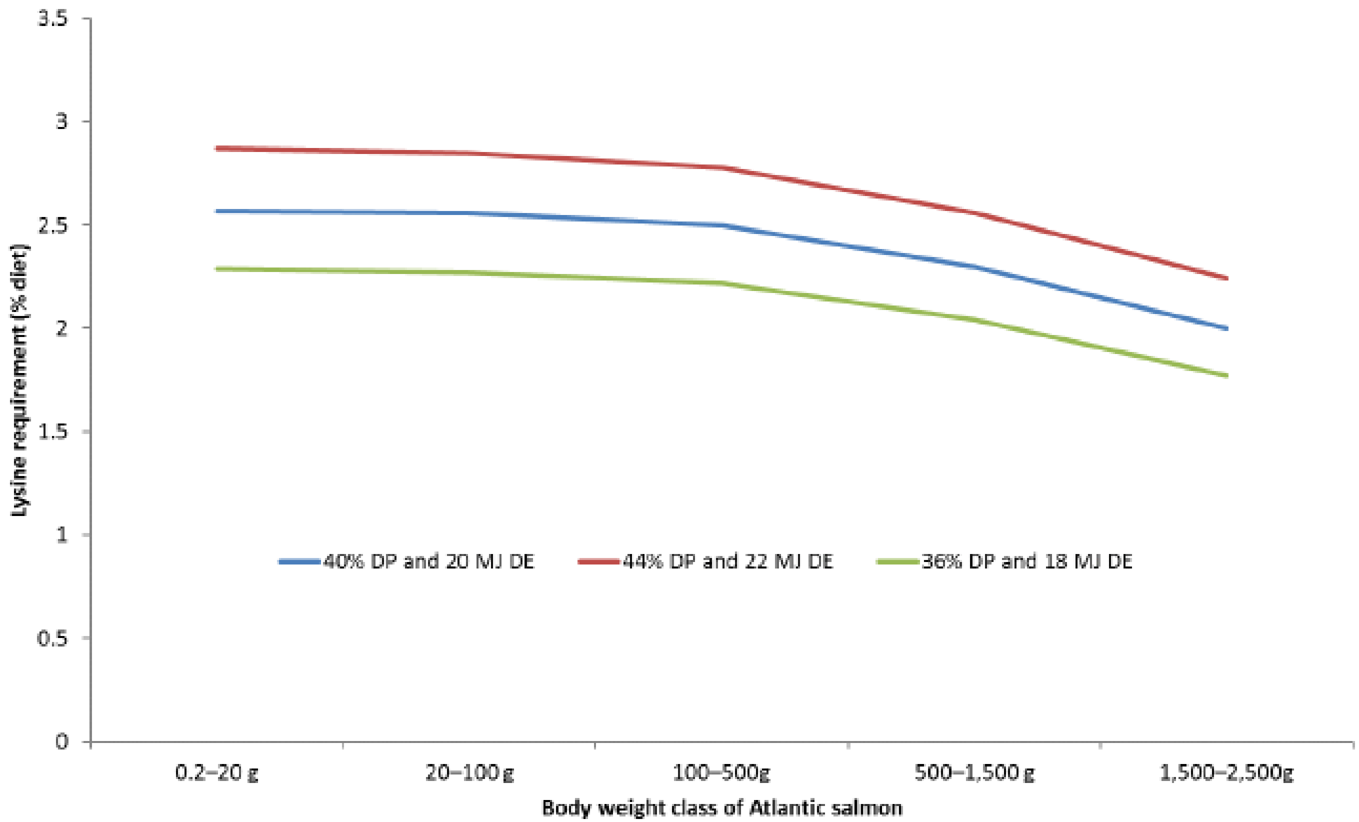
	Weight Class		
Essential Amino Acids	0.2–20 g	20–500 g	500–1,500 g
	% diet DM		
Arg	1.91	1.77	1.62
His	0.83	0.77	0.69
Ile	1.27	1.19	0.98
Leu	2.26	2.11	1.78
Lys	2.47	2.31	1.92
Met + Cys	1.32	1.23	1.10
Phe + Tyr	2.49	2.33	1.82
Thr	1.77	1.63	1.60
Trp	0.43	0.40	0.42
Val	1.90	1.76	1.64

Source: NRC (2011)

Digestible EAA requirements (% diet DM) estimated for Atlantic salmon of different weights fed diets

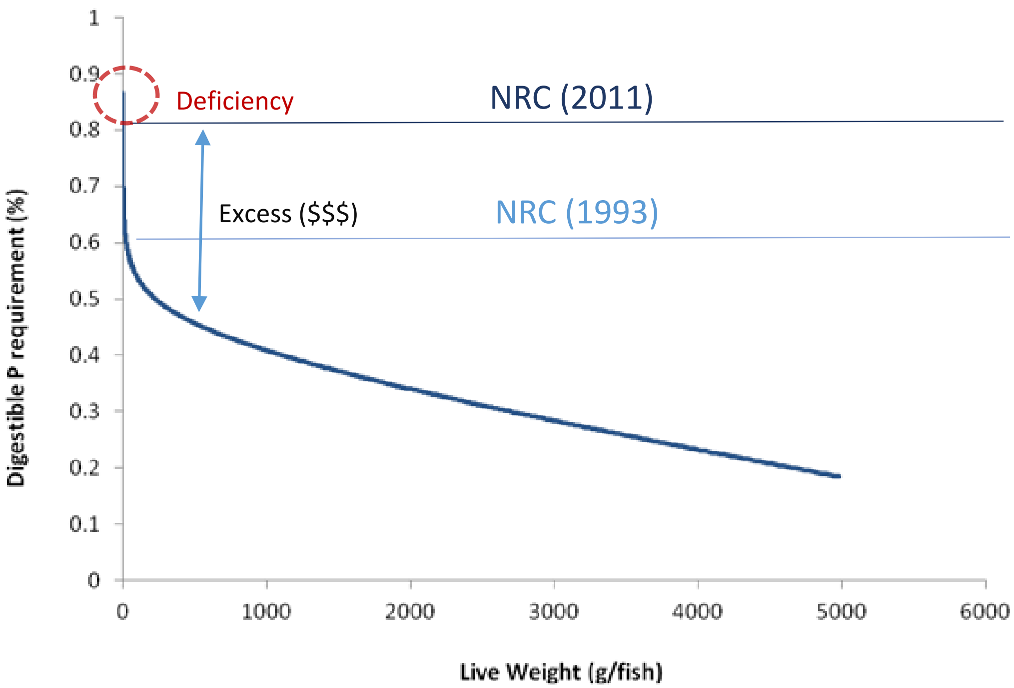
Diets with 40% DP and 20 MJ DE (Diet 40/20), 44% DP and 22 MJ DE (Diet 44/22), 36% DP and 18 MJ DE (Diet 36/18).

	Weight Class														
	0.2–20 g			20–100 g			100–500g			500–1,500 g			1,500–2,500g		
Diet	40/20	44/22	36/18	40/20	44/22	36/18	40/20	44/22	36/18	40/20	44/22	36/18	40/20	44/22	36/18
Arg	1.72	1.92	1.53	1.71	1.91	1.52	1.67	1.86	1.48	1.53	1.71	1.36	1.34	1.50	1.18
His	1.07	1.19	0.95	1.06	1.18	0.94	1.03	1.15	0.92	0.95	1.06	0.84	0.83	0.93	0.73
Ile	1.40	1.56	1.24	1.39	1.55	1.23	1.35	1.51	1.20	1.25	1.39	1.11	1.09	1.21	0.96
Leu	2.52	2.81	2.24	2.51	2.80	2.23	2.45	2.73	2.17	2.25	2.51	2.00	1.96	2.19	1.73
Lys	2.57	2.87	2.29	2.56	2.85	2.27	2.50	2.78	2.22	2.30	2.56	2.04	2.00	2.24	1.77
Met	1.03	1.14	0.91	1.02	1.14	0.91	1.00	1.11	0.88	0.92	1.02	0.81	0.80	0.89	0.71
Phe	1.60	1.78	1.42	1.59	1.77	1.41	1.55	1.73	1.38	1.43	1.59	1.26	1.24	1.39	1.10
Thr	1.40	1.56	1.25	1.39	1.55	1.24	1.36	1.52	1.21	1.25	1.40	1.11	1.09	1.22	0.96
Trp	0.30	0.33	0.26	0.30	0.33	0.26	0.29	0.32	0.26	0.26	0.30	0.23	0.23	0.26	0.20
Val	1.78	1.99	1.58	1.77	1.98	1.58	1.73	1.93	1.54	1.59	1.78	1.41	1.39	1.55	1.23



3.5
3
2.5
2
1.5
1
0.5
0
Lysine requirement (% diet)
40% DP and 20 MJ DE
44% DP and 22 MJ DE
36% DP and 18 MJ DE
0.2–20 g
20–100 g
100–500g
500–1,500 g
1,500–2,500g
Body weight class of Atlantic salmon

Theoretical Digestible P Requirement of Atlantic salmon of Increasing Weights



Theoretical estimate of digestible P requirement of Atlantic salmon of increasing weights

	Weight Class g/fish				
	0.2 – 20	20 - 500	500 - 1500	1500 - 3000	3000 - 5000
Expected FCR, feed:gain*	0.7	0.8	1.0	1.2	1.6
Dig. P Requirement, Mean, %	0.74	0.55	0.44	0.35	0.25
Dig. P Requirement, Range, % **	0.91-0.64	0.64-0.48	0.48-0.39	0.39-0.30	0.30-0.20

Estimates derived from a factorial modeling exercise (Feed with 20 MJ DE) based on the model described by Hua and Bureau (2012) and used in modeling exercises developed for the NRC (2011).

Type of Information Required?

- Simple growth curve (weight vs. time) under practical conditions
- Realistic estimates of Feed Conversion Ratio (feed:gain) vs. live weight
- Whole body composition
  - Proximate : Dry matter, protein, lipids, ash, gross energy
  - amino acids, phosphorus, fatty acid profile of phospholipids
- Reliable budgets for energy, nitrogen and other nutrients
- Results from essential nutrient requirement trials
  - Effect of live weight / life stages
  - Effect of diet composition
- Testing / Feedback / Criticisms !!!