SUSTAINABLE AQUACULTURE: THE FEED COMPONENT

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OVERVIEW

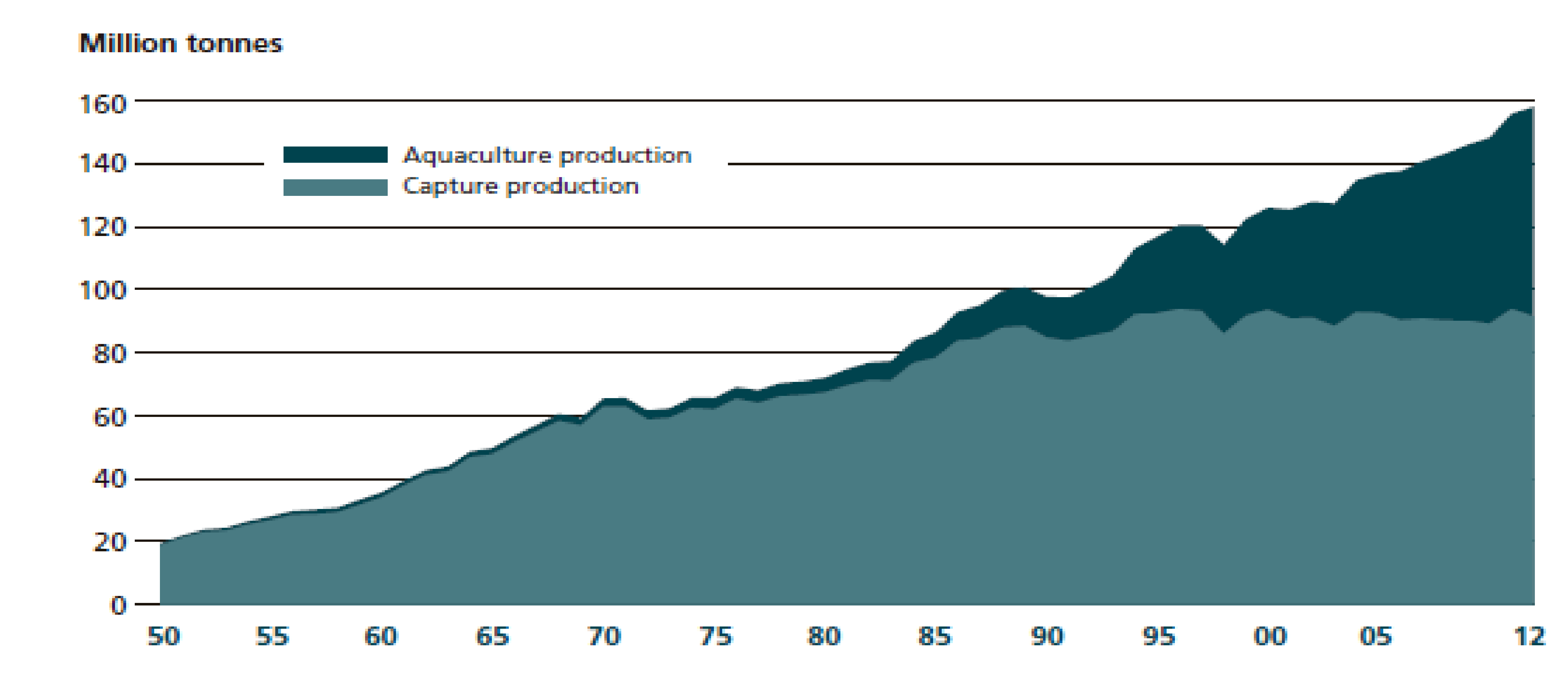
- EARLY AND EVOLVING DEFINITION OF SUSTAINABILITY
- DIETARY RESEARCH HAS BEEN FOLLOWING NEWER DEFINITION OF SUSTAINABILITY
- ADDITIONAL ENVIRONMENTAL CONSIDERATIONS
- COMPLEXITY OF NEW DEFINITION
- RECOMMENDATIONS

- ENCOURAGING

IS THE CONCEPT OF SUSTAINABILITY IMPORTANT?

- STEPHEN HAWKING WARNS WE MUST ESCAPE EARTH WITHIN 100 YEARS IF HUMANS ARE TO SURVIVE (MAY 2017)
- READ MORE: HTTP://WWW.DAILYMAIL.CO.UK/SCIENCETECH/ARTICLE-4468700/STEPHEN-HAWKING-SAYS-LEAVE-EARTH-100-YEARS.HTML#IXZZ56XMMKPCM

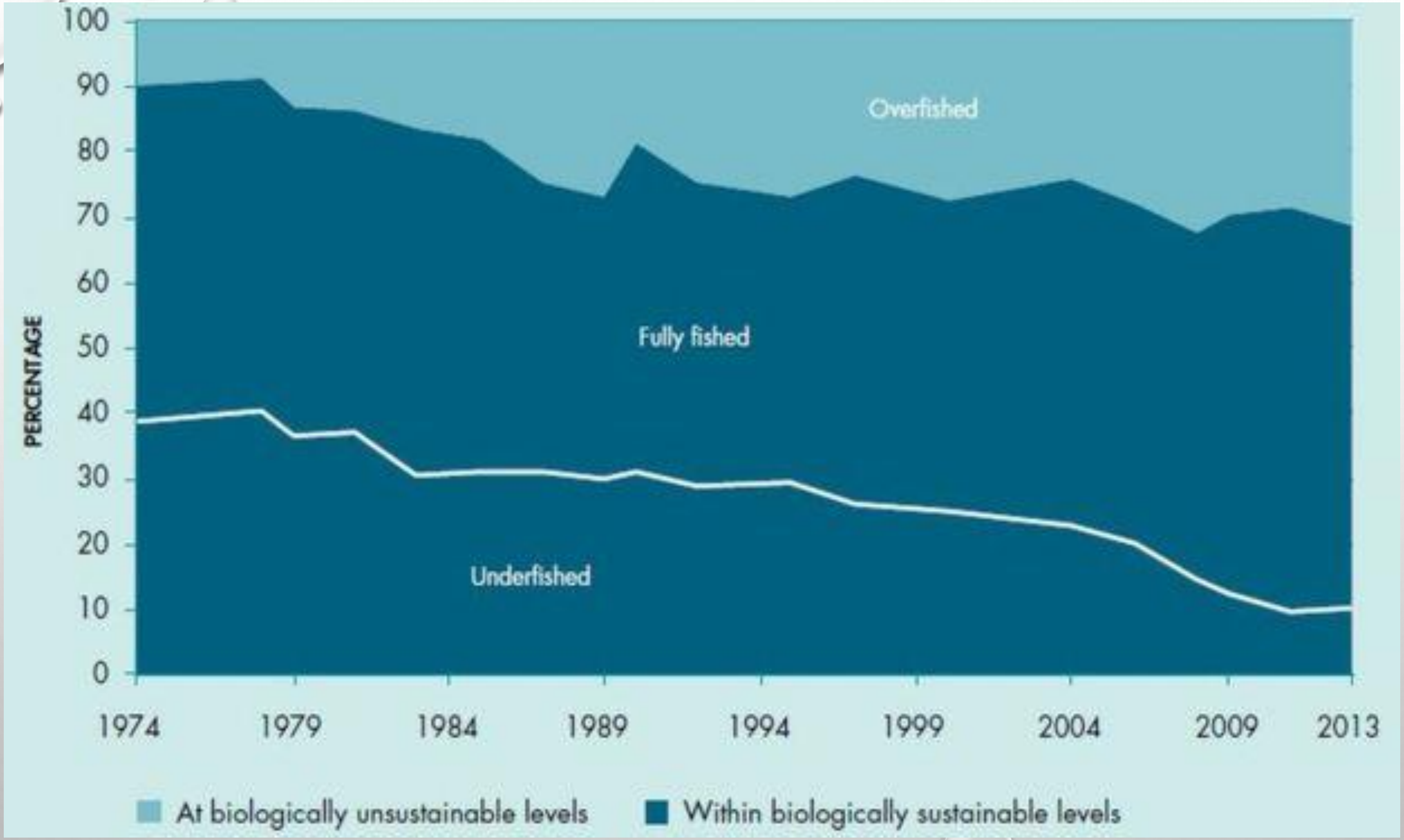
SUSTAINABLE YIELD



INITIAL DEFINITION

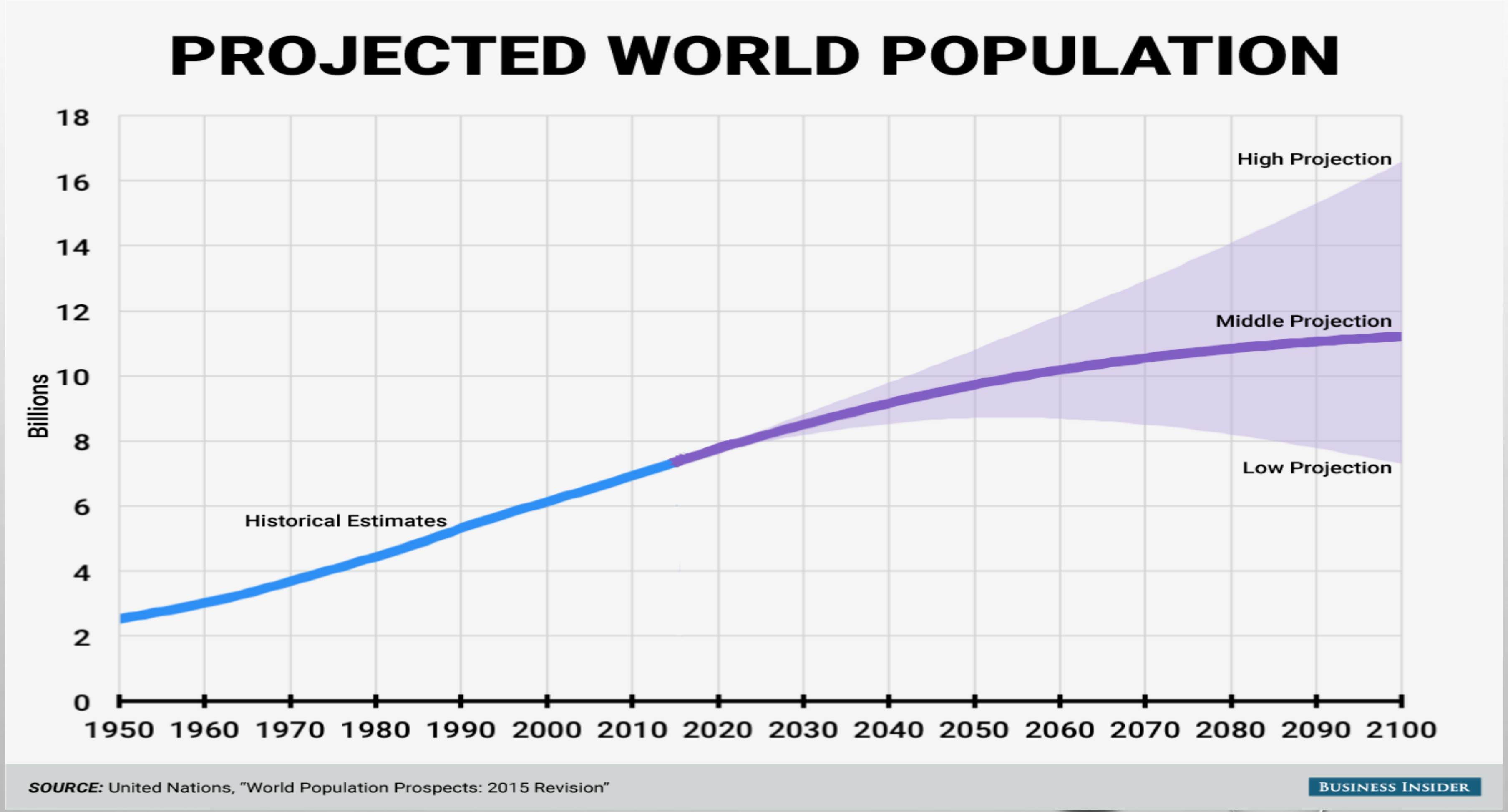
- POPULATION-LEVEL SUSTAINABILITY – ABILITY TO MAINTAIN APPROPRIATE NUMBERS SUCH THAT LOSSES COULD BE REPLACED BY REPRODUCTION AND RECRUITMENT

- IMPACTS ON NON-TARGET ORGANISMS



100
90
80
70
60
50
40
30
20
10
0
PERCENTAGE
Overfished
Fully fished
Underfished
1974
1979
1984
1989
1994
1999
2004
2009
2013
At biologically unsustainable levels
Within biologically sustainable levels

DEMAND

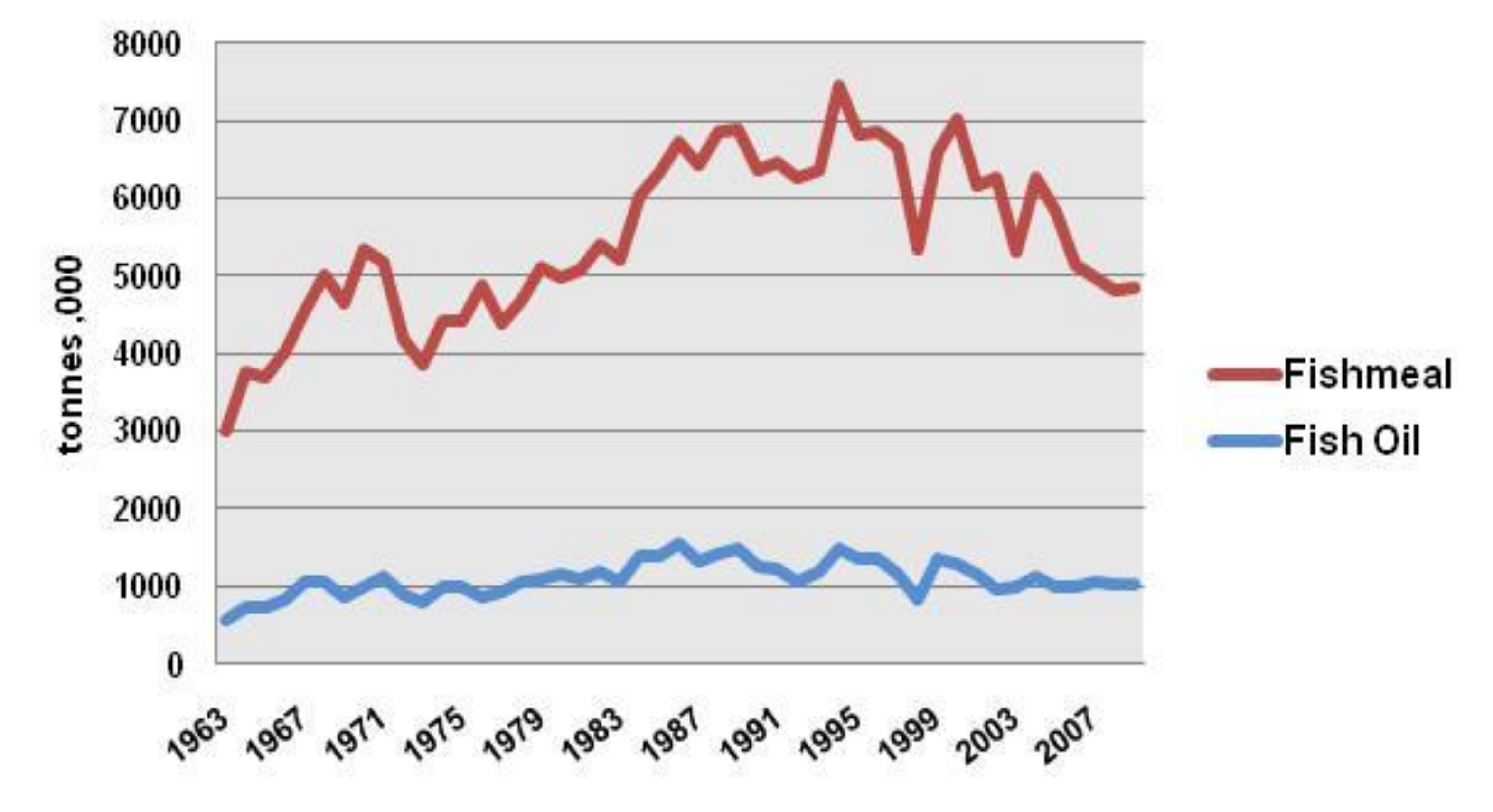

PROJECTED WORLD POPULATION
Billions
18
16
14
12
10
8
6
4
2
0
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
High Projection
Middle Projection
Low Projection
Historical Estimates
SOURCE: United Nations, "World Population Prospects: 2015 Revision"
BUSINESS INSIDER

SUSTAINABLE DIETS

- FEEDS ARE SIGNIFICANT COST IN AQUACULTURE
- FISH MEAL IS AN EXCELLENT INGREDIENT
- FISH MEAL DILEMMA – INITIAL SUSTAINABILITY CONSIDERATION

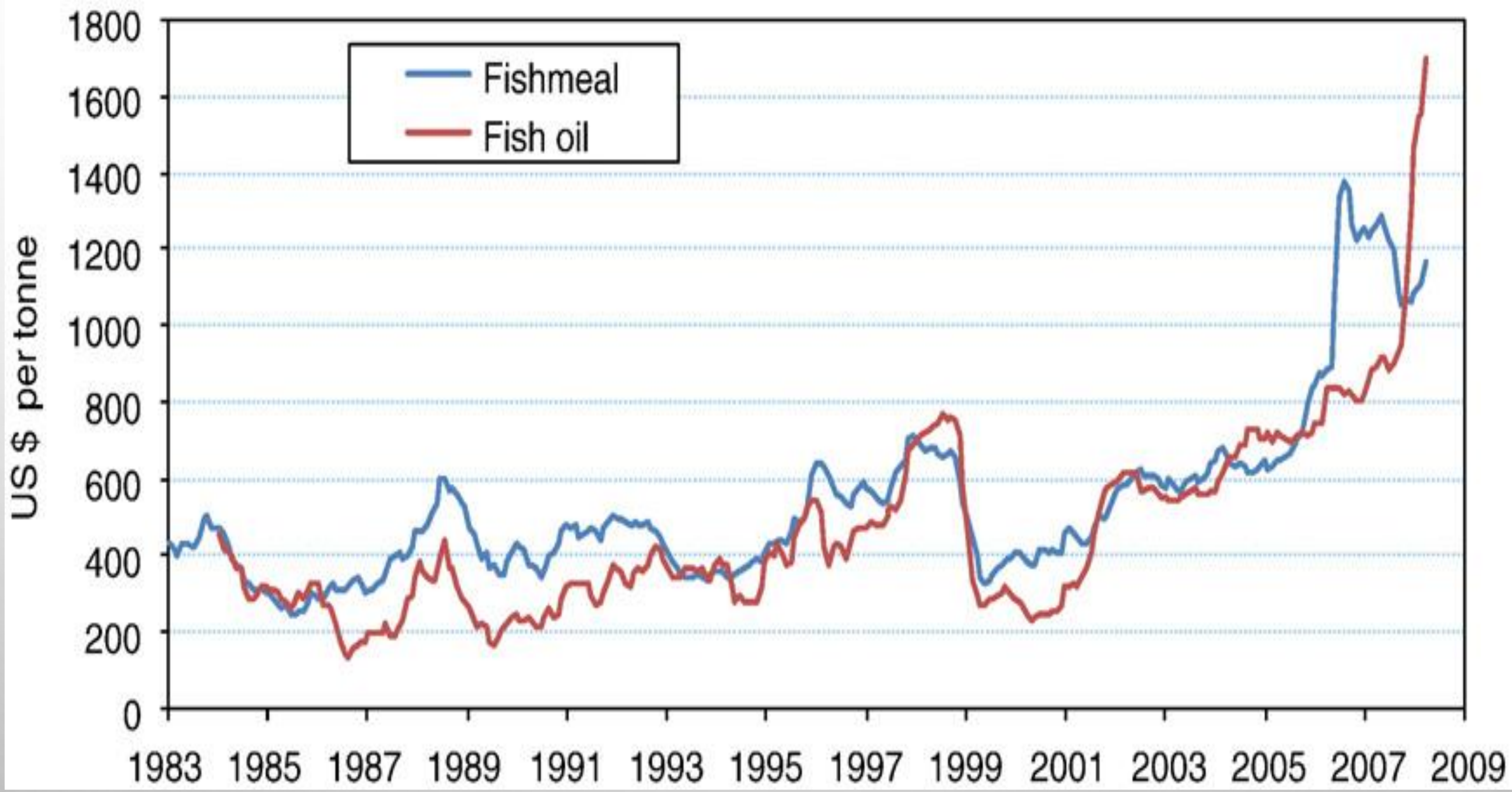
- ALTERNATIVE INGREDIENTS – "SUSTAINABLE"
  - SUPPLY/DEMAND/PRICE CHARACTERISTICS
  - ABILITY TO MEET INCREASING DEMAND DUE TO INCREASED AQUACULTURE PRODUCTION

GLOBAL SUPPLY OF FISH MEAL AND OIL

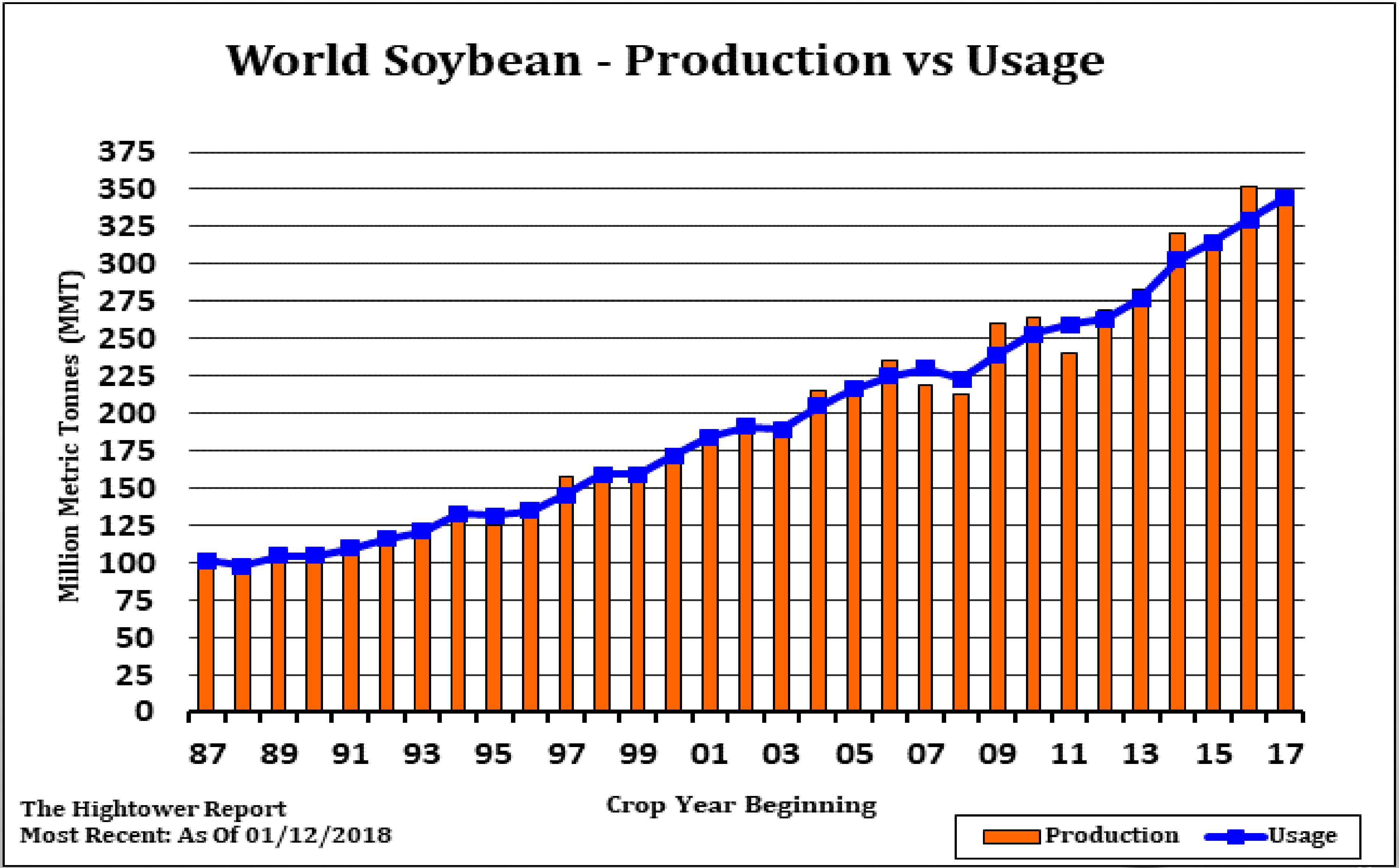


- IFFO - HTTP://WWW.IFFO.NET/DEFAULT.ASP?CONTENTID =718

FISH MEAL AND OIL PRICES

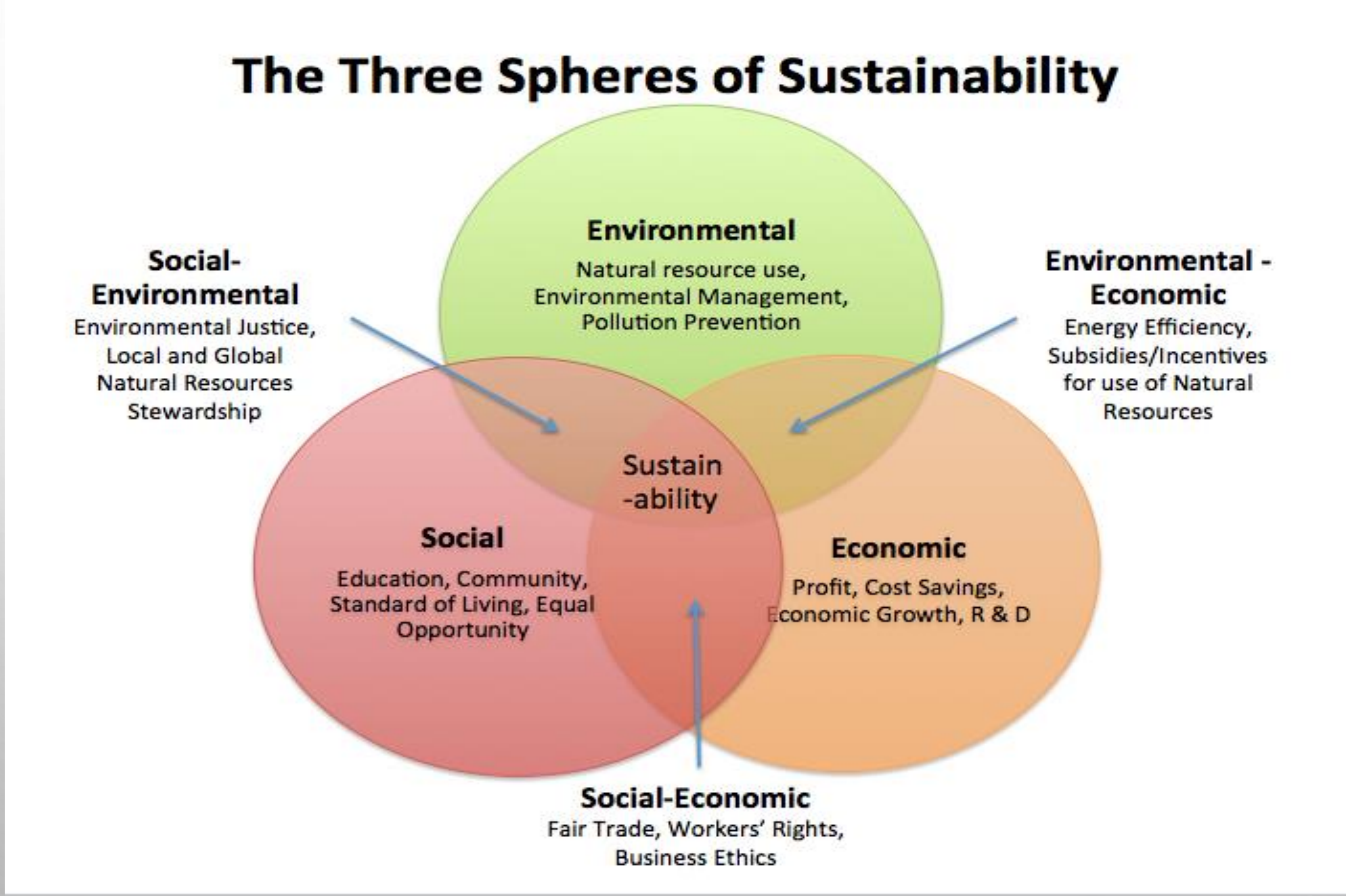


TACON AND METIAN, 2008, AQUACULTURE 285:146-158


World Soybean - Production vs Usage
Million Metric Tonnes (MMT)
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
87
89
91
93
95
97
99
01
03
05
07
09
11
13
15
17
Crop Year Beginning
The Hightower Report
Most Recent: As Of 01/12/2018
Production
Usage

"SUSTAINABLE" LITERATURE CITATIONS

- DATABASE SEARCH – AQUATIC SCIENCES AND FISHERIES ABSTRACTS – AQUACULTURE, JANUARY 2018
- SUSTAINABLE – 11,605
    - SUSTAINABLE DIET – 1,145
    - SUSTAINABLE FEED – 1,833
    - SUSTAINABLE AND DIET – 274
    - SUSTAINABLE AND FEED - 636


The Three Spheres of Sustainability
Environmental
Natural resource use, Environmental Management, Pollution Prevention
Social-Environmental
Environmental Justice, Local and Global Natural Resources Stewardship
Environmental - Economic
Energy Efficiency, Subsidies/Incentives for use of Natural Resources
Sustain -ability
Social
Education, Community, Standard of Living, Equal Opportunity
Economic
Profit, Cost Savings, Economic Growth, R & D
Social-Economic
Fair Trade, Workers' Rights, Business Ethics

- TOTAL WATER FOOTPRINT FOR PRODUCTION OF VARIOUS ANIMAL PRODUCTS (M^3/T).

PRODUCT	
BEEF	15,415
SHEEP	10,412
GOAT	5,521
PIG	5,988
CHICKEN	4,325
EGG	3,265

- FROM MEKONNEN AND HOEKSTRA (2012).

- WATER FOOTPRINTS FOR AQUACULTURE FEEDS (M^3/T).
- SPECIES
- GRASS CARP 2,200
- COMMON CARP 2,350
- INDIAN MAJOR CARPS 1,700
- NILE TILAPIA 2,300
- CHANNEL CATFISH 2,000
- MANDARIN FISH 88
- ATLANTIC SALMON 1,850
- RAINBOW TROUT 1,500
- MILKFISH 2,450
- BARRAMUNDI 1,100
- ATLANTIC COD 650
- GILTHEAD SEABREAM 500
- RED DRUM 2,150
- WHITELEG SHRIMP 1,700

- FROM PAHLOW ET AL. (2015)

- TOTAL WATER FOOTPRINT OF SELECTED FEED INGREDIENTS (GLOBAL AVERAGE, M^3/T).

INGREDIENT	
BARELY	1,423
CANOLA MEAL	2,270
CASSAVA MEAL	1,878
CORN	1,222
CORN GLUTEN MEAL	12,534
COTTONSEED MEAL	860
GROUNDNUT MEAL	3,272
LUPIN KERNEL MEAL	2,607
RICE BRAN	754
SOYBEAN MEAL	2,524
SOY PROTEIN CONCENTRATE	1,779
SUNFLOWER MEAL	3,960
WHEAT	1,826
WHEAT BRAN	855

- FROM PAHLOW ET AL. (2015).

LIFE CYCLE ANALYSIS (LCA)

- EXAMINING ALTERNATIVE PROTEIN SOURCES IN DIETS
- WHOLE FARM LCA – PONDS, INDOOR RECIRCULATING SYSTEMS AND HETEROTROPHIC MARINE SHRIMP SYSTEMS
- LCA OF SUPPLYING N-3 FATTY ACIDS INTO HUMAN POPULATION

GLOBAL WARMING POTENTIAL, GWP (KG CO_2/TONNE)

Blood Meal	68
Feather Meal	68
Fish Meal, Menhaden	3500
Meat and Bone Meal	68
Poultry Meal Rendered	68

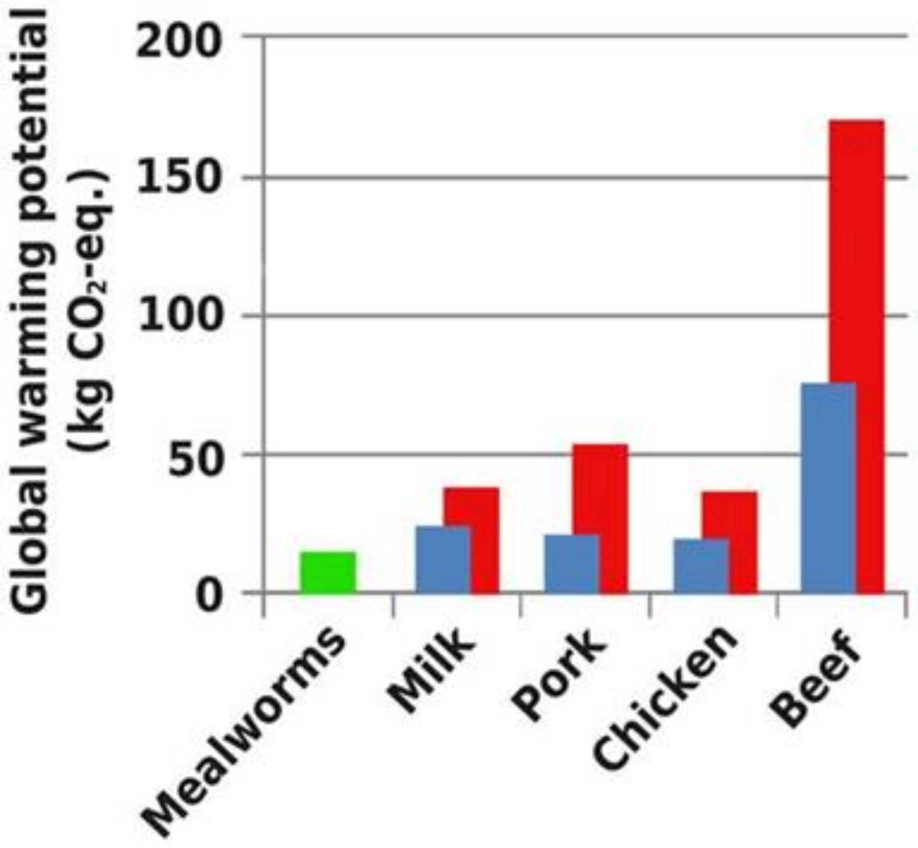
Brewers Grain	480
Canola Meal, Solvent Extracted	1740
Cassava Meal	266
Corn DDG	940
Corn Gluten Meal	1190
Cottonseed Meal	412
Faba Bean	1040
Flaxseed Meal	360
Millet	480
Peanut Meal, Extracted	305
Rice	1750
Safflower Meal, Dehulled	412
Soy Products	108-437
Soybean Lecithin	879
Sunflower Meal, Solvent Extracted	376
Wheat DDGS	943
Wheat Products	402- 658
Yeast, Brewers	3200
Yeast, Single Cell Protein	3200

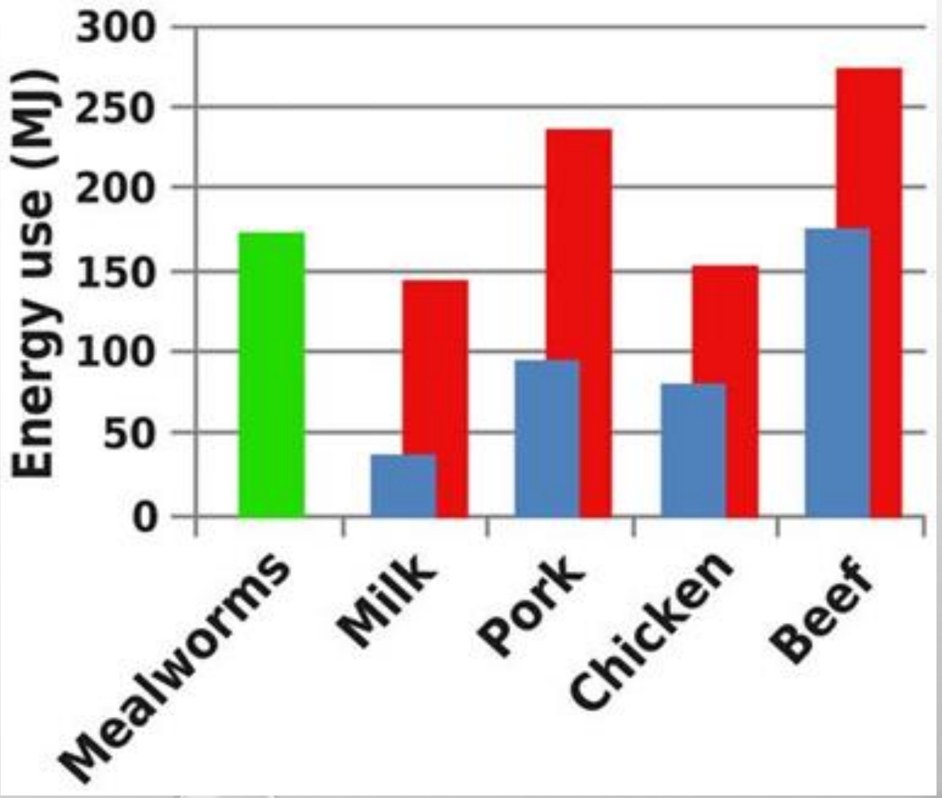
GWP – LIPID SOURCES

Canola Oil	2690
Corn Oil	2290
Flaxseed Oil	365
Herring Oil	2390
Menhaden Oil	2390
Palm Kernel Oil	3730
Peanut Oil	260
Safflower Oil	1060
Salmon Oil	5312
Sesame Oil	444
Soybean Oil	879
Sunflower Oil	1060

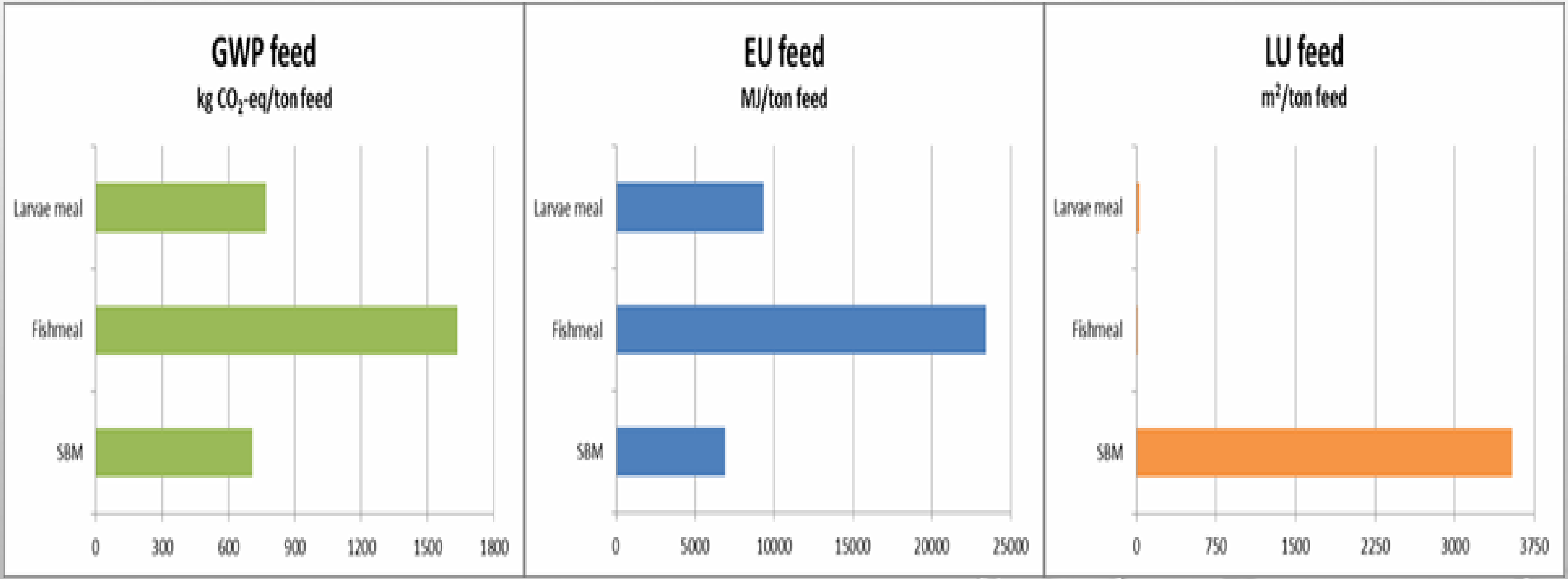
Choline Chloride 60%	828
Dicalcium Phosphate	1260
DL-Methionine	4680
Grow-Finish Vitamin Premix	436
L-Lysine-HCl	7060
L-Threonine	7060
L-Tryptophan	7060
Phyzyme 1200	1900
Phyzyme 600	1900
Trace Mineral Premix (NB-8534)	440
Trace Mineral Premix, NSNG	436
Vitamin E (20000)	3980
Vitamin Premix (NB -6508)	440
Zinc Sulfate, Monohydrate	1740

INSECT MEALS – MEAL WORMS





HOUSE FLY MEAL



ADDITIONAL METRICS

- ABIOTIC DEPLETION – KG Sb (antimony), fossil fuel use
- ACIDIFICATION POTENTIAL – PO_4^-
- EUTROPHICATION POTENTIAL - PO_4^-
- HUMAN TOXICITY POTENTIAL – 1,4-DICHLOROBENZENE
- MARINE TOXICITY POTENTIAL - 1,4-DICHLOROBENZENE
- CUMULATIVE ENERGY POTENTIAL - MJ

- TABLE 3. TOTAL ENVIRONMENTAL IMPACTS OF THE FUNCTIONAL UNIT FED CONV. FEED

IMPACT CATEGORY	HATCHERY	FEED PRODUCTION	FISH FARMING	TRANSPORT	TOTAL
ADP (KG SB EQ)	0,0001	0,0087	0,0001	0,0012	0,0101
ACD (KG SO2 EQ)	0,0001	0,0137	0,0001	0,0021	0,0159
EUT (KG PO4 EQ)	0,0025	0,0044	0,0159	0,0003	0,0230
GWP (KG CO2 EQ)	0,1480	1,7600	0,1350	0,1740	2,2200
HTP (KG 1,4-DB EQ)	0,0023	0,4320	0,0021	0,0065	0,4430
MAE (KG 1,4-DB EQ)	0,2930	267,0000	0,2670	2,0400	269,0000
CED (MJ)	43,8	33,7	39,8	2,38	120

- ADP - ABIOTIC DEPLETION, ACD - ACIDIFICATION POTENTIAL, EUT - EUTROPHICATION POTENTIAL, GWP - GLOBAL WARMING POTENTIAL, HTP – HUMAN TOXICITY POTENTIAL, MAE - MARINE AQUATIC ECOTOXICITY POTENTIAL, CED - CUMULATIVE ENERGY DEMAND

Table 3 Impact categories used in the assessment of environmental impacts associated with the five papers in this literature review

Impact categories	(Oonincx and de Boer 2012)[1]	(van Zanten et al. 2015)	(Roffeis et al. 2015)	(Smetana et al. 2015)	(Salomone et al. 2016)	(Smetana et al. 2016)
Climate change (expressed in GWP)	X	X			X	
Climate change—ecosystems				X		X
Climate change—human health				X		X
Ozone depletion				X	X	X
Human toxicity				X	X	X
Photochemical oxidant formation				X	X	X
Particulate matter formation				X		X
Ionizing radiation				X		X
Terrestrial acidification				X	X	X
Freshwater eutrophication				X	X	X
Terrestrial ecotoxicity				X	X	X
Freshwater ecotoxicity				X	X	X
Marine ecotoxicity				X	X	X
Agricultural land occupation			X	X		X
Urban land occupation				X		X
Natural land transformation				X		X
Metal depletion				X		X
Fossil depletion			X	X		X
Abiotic depletion					X	
Energy use	X	X				
Land use	X	X				
Water depletion potential			X			

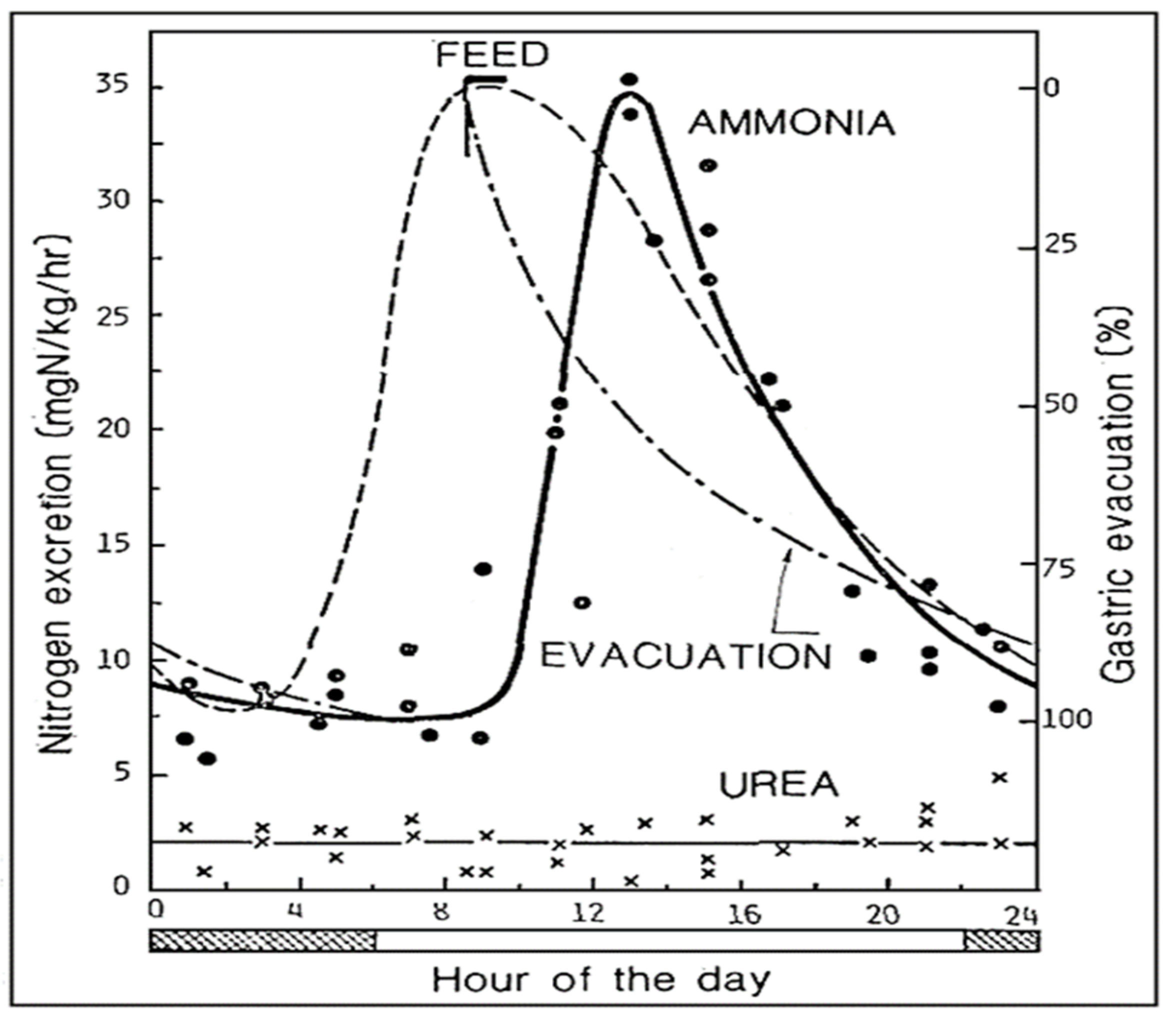
[1] The water depletion potential (water footprint) of mealworm production was calculated by Miglietta et al. 2015 using data from Oonincx and de Boer 2012

ENERGY DILEMMA

- CONTINUED INTENSIFICATION OF FOOD PRODUCTION DEMANDS MORE ENERGY (AQUACULTURE, AQUAPONICS)
  - HYDROPONIC LETTUCE PRODUICTION COMPARED TO FIELD PRODUCTION
  - 8-10% OF WATER DEMAND, 80-100% INCREASED PRODUCTION, 80-100% INCREASED ENERGY DEMAND
- SIMILAR EARLY RESULTS FOR AQUACULTURE, SUSPECT SIMILAR RESULTS FOR AQUAPONICS

ENERGY MODELLING

- PULSED USE
- NON-PEAK USE
- INTEGRATED GRIDS
- RENEWABLES



FATE OF AQUACULTURE IN THE 21ST CENTURY

- FITS WELL WITH EVOLVING DEFINITION OF SUSTAINABLE
- FITS WELL WITH HUMAN HEALTH NEEDS IN URBAN AND RURAL AREAS
- OPPORTUNITIES FOR OUR STUDENTS, LEADERSHIP

- REQUIRES ADDITIONAL EXPERTISE FROM OTHER DISCIPLINES, PARTICULARY ENGINEERING
- ENERGY DEMAND

FATE OF SUSTAINABLE AQUACULTURE IN THE 21ST CENTURY

- DEFINITION BECOMING OVERLY COMPLEX
- WE MUST CONTRIBUTE TO DISCUSSION AND EDUCATE CONSUMERS
- WHICH SUSTAINABLE METRICS ARE NECESSARY?
- WHICH SUSTAINABLE METRICS CAN BE UNDERSTOOD BY CONSUMERS?
- WHICH METRICS MIGHT STIMULATE AQUACULTURE DEVELOPMENT?

CAN WE PROVE PROFESSOR HAWKING WRONG?

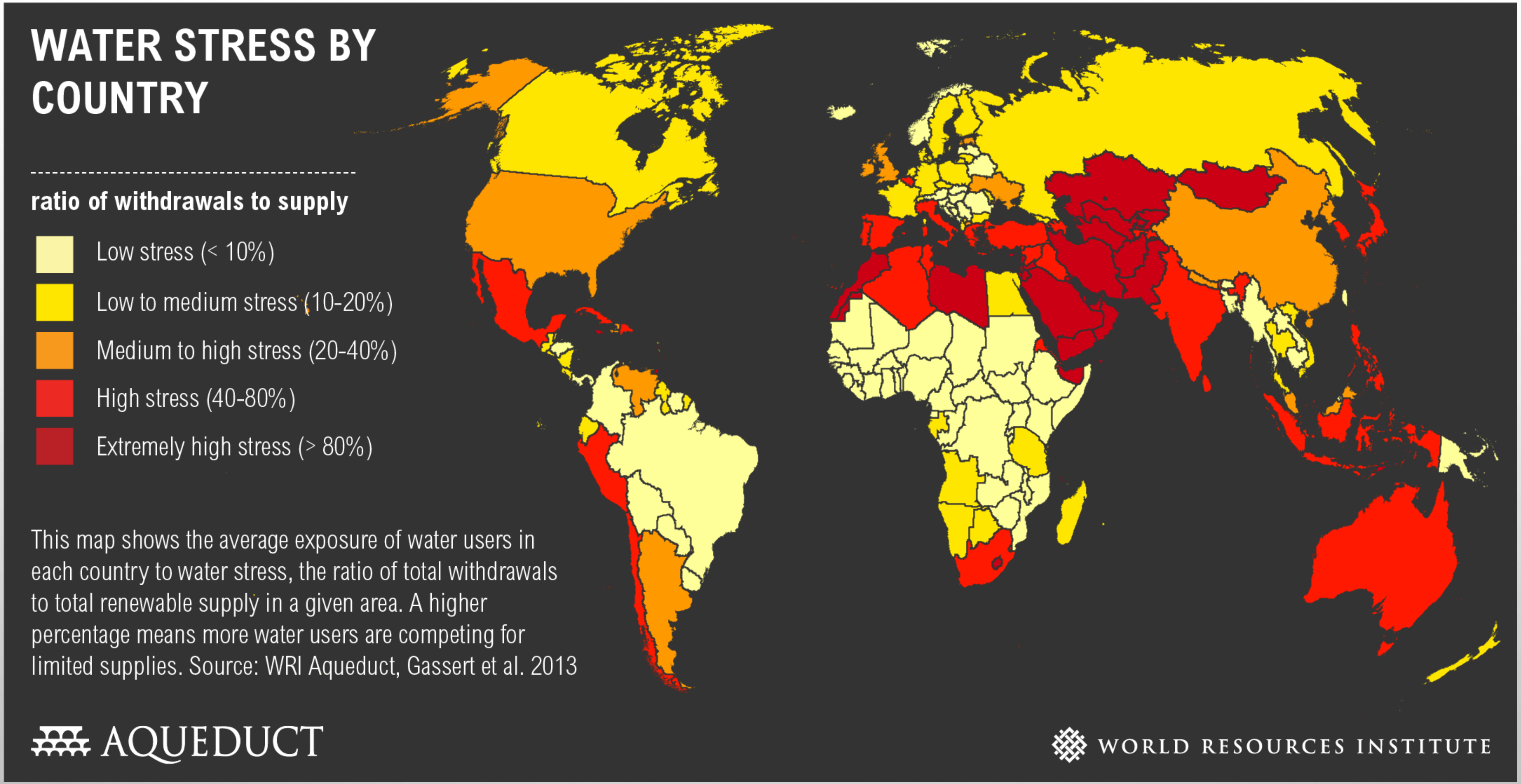
WHERE ARE WE?

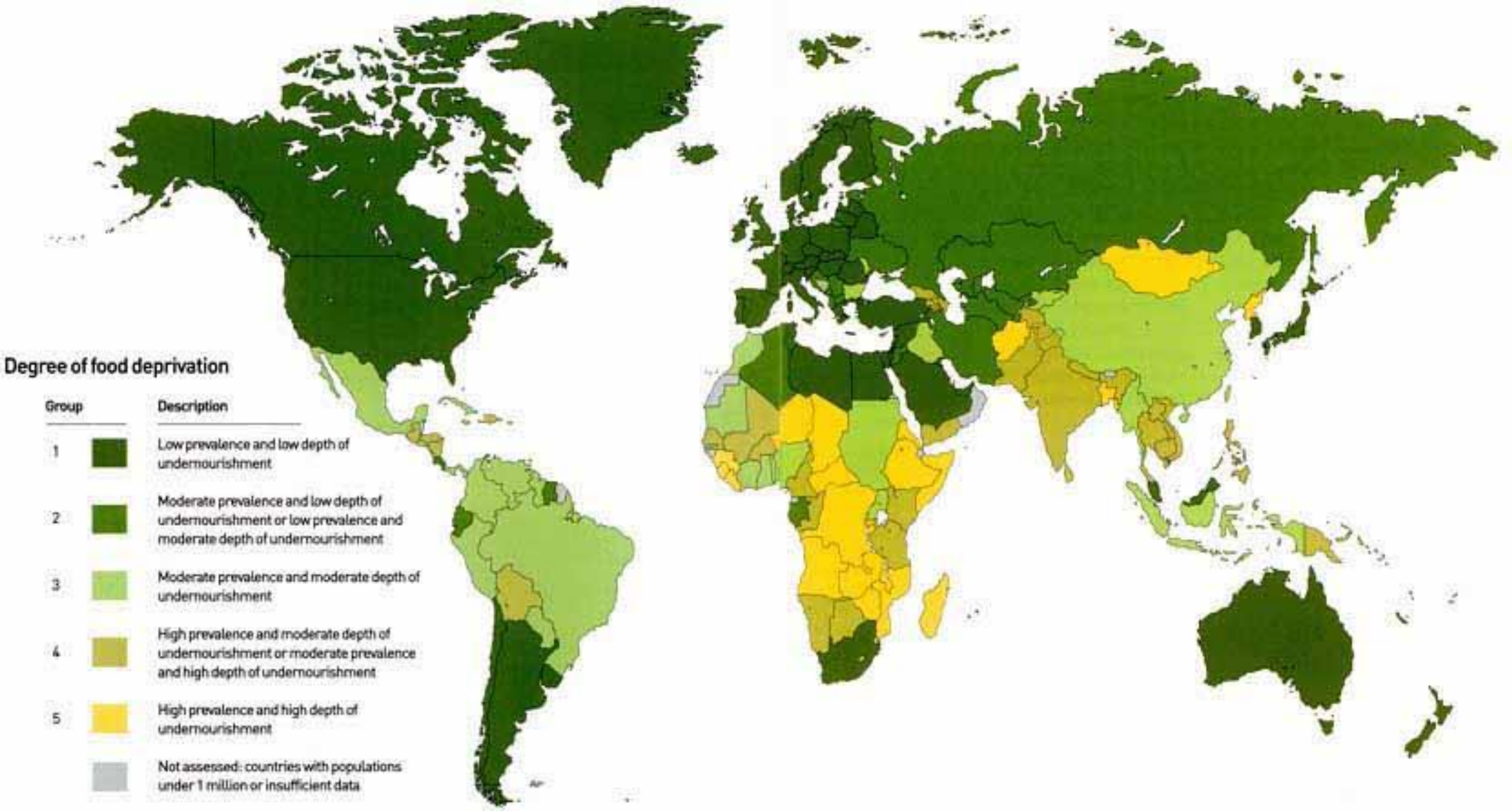
- ENVIRONMENTAL
  - SUPPLY/DEMAND
- ECONOMIC
  - FISH MEAL AND COST OF PRODUCTION
  - COMPETING SUPPLIES – WILD VS CULTURED
- TRENDS DRIVING FOOD DEMAND
  - LOCAVORE DEMAND, FRESH, ORGANIC, URBANIZATION
- “WESTERN” DIET
- FOOD DEPRIVED POPULATIONS

WHERE ARE WE…………?

- FOOD PRODUCTION MUST INCREASE BY 70-100% BY 2050
- CURRENT FOOD PRODUCTION SYSTEMS DEMAND 70% OF THE GLOBAL SUPPLY OF FRESH WATER
- CONTINUED DEFORESTATION FOR AGRICULTURAL LANDS
- LOSS OF BIODIVERSITY
- SOCIETAL CONCERNS

- CONTINUING INTENSIFICATION OF FOOD PRODUCTION
  - LESS LAND, LESS WATER, BUT INCREASED ENERGY DEMAND


WATER STRESS BY COUNTRY
ratio of withdrawals to supply
Low stress (< 10%)
Low to medium stress (10-20%)
Medium to high stress (20-40%)
High stress (40-80%)
Extremely high stress (> 80%)
This map shows the average exposure of water users in each country to water stress, the ratio of total withdrawals to total renewable supply in a given area. A higher percentage means more water users are competing for limited supplies. Source: WRI Aqueduct, Gassert et al. 2013
AQUEDUCT
WORLD RESOURCES INSTITUTE


Degree of food deprivation
Group
Description
1
Low prevalence and low depth of undernourishment
2
Moderate prevalence and low depth of undernourishment or low prevalence and moderate depth of undernourishment
3
Moderate prevalence and moderate depth of undernourishment
4
High prevalence and moderate depth of undernourishment or moderate prevalence and high depth of undernourishment
5
High prevalence and high depth of undernourishment
Not assessed: countries with populations under 1 million or insufficient data

AQUACULTURE IN THE 21ST CENTURY

- SEAFOOD REMAINS A HEALTHY FOOD ITEM FOR HUMAN CONSUMPTION
  - N-3 FATTY ACIDS
  - MINERALS
  - VITAMINS
- BEST CONVERSION OF FEED TO GAIN (FCR)
- LOW WATER DEMAND
- HIGH PRODUCTION PER UNIT AREA

ATLANTIC COD