Fishmeal / Fish Oil Use in Aquafeeds & The Evolving Nutritional Profile of Farmed Seafood

- PRESENTER DR. GIOVANNI TURCHINI | DEAKIN UNIVERSITY

GLOBAL OUTLOOK FOR AQUACULTURE LEADERSHIP

GUANGZHOU, CHINA | DAY 2

HEALTHY FISH | HEALTHY PEOPLE | HEALTHY PLANET

Global Aquaculture Alliance

GOAL 2016 Guangzhou China

Dr. Giovanni M. Turchini

- Giovanni M. Turchini, PhD, is an associate professor at the School of Life and Environmental Sciences at Deakin University in Geelong, Australia, where he is associate head of school research and leads the marine, freshwater and aquaculture sciences research group and teaching programs.
- Turchini's research interests span from fish to human nutrition, aquaculture, fatty acid metabolism, fishmeal and fish oil replacement, and ethical issues encountered in the fisheries and aquaculture sectors.
- Throughout his career, he has been awarded two ARC Discovery fellowships, developed a series of significant industry collaborations, published extensively, and his work is highly cited and influential.

Global Aquaculture Alliance

GOAL 2016 Guangzhou China

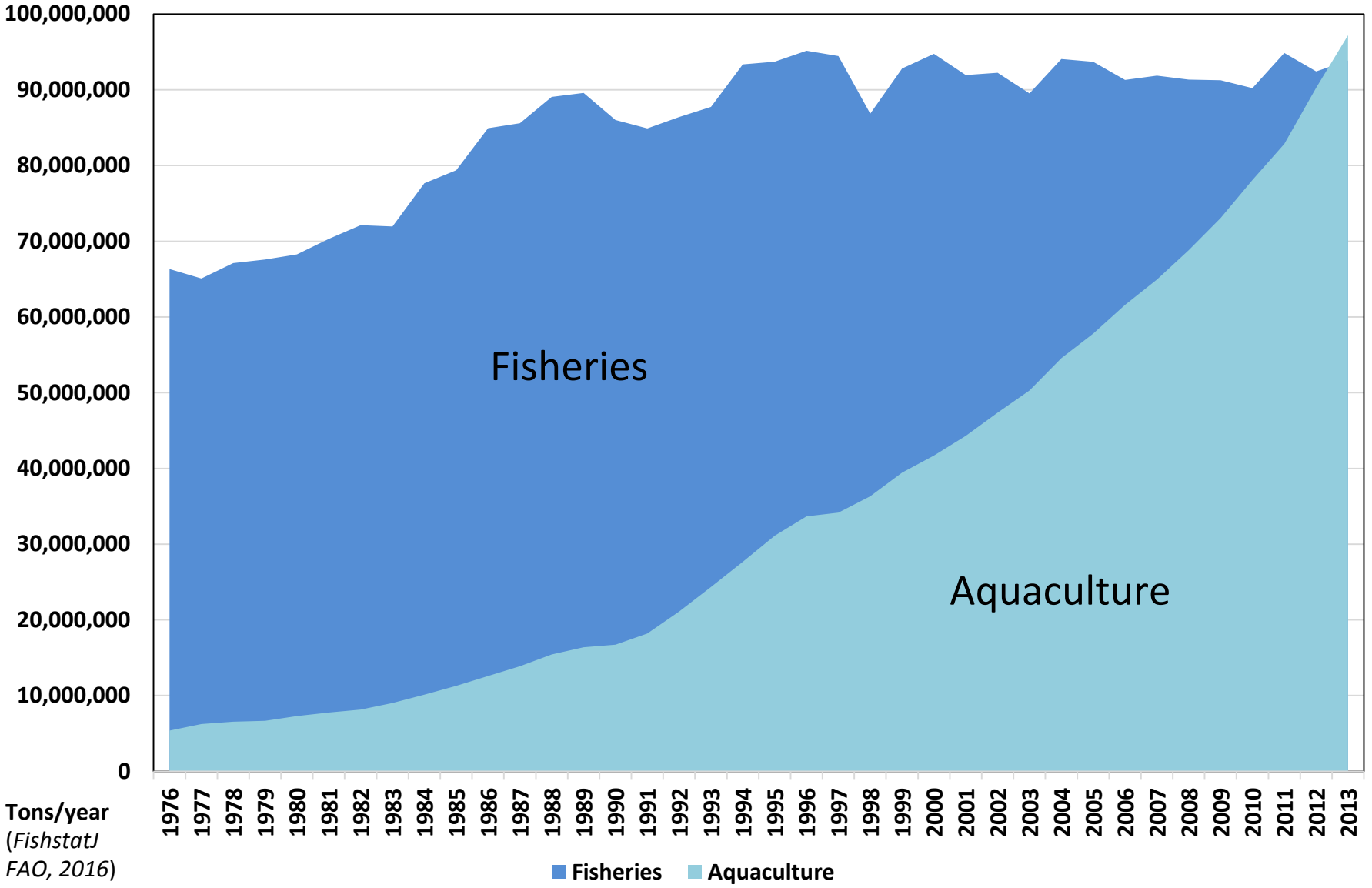
FISHMEAL/FISH OIL USE IN AQUAFEED & THE EVOLVING NUTRITIONAL PROFILE OF FARMED SEAFOOD

A/Prof. Giovani M. Turchini, PhD
Associate Head of School (Research)
School of Life and Environmental Sciences,
Deakin University, Geelong, Australia
giovanni.truchini@deakin.edu.au
@NuSeaLab

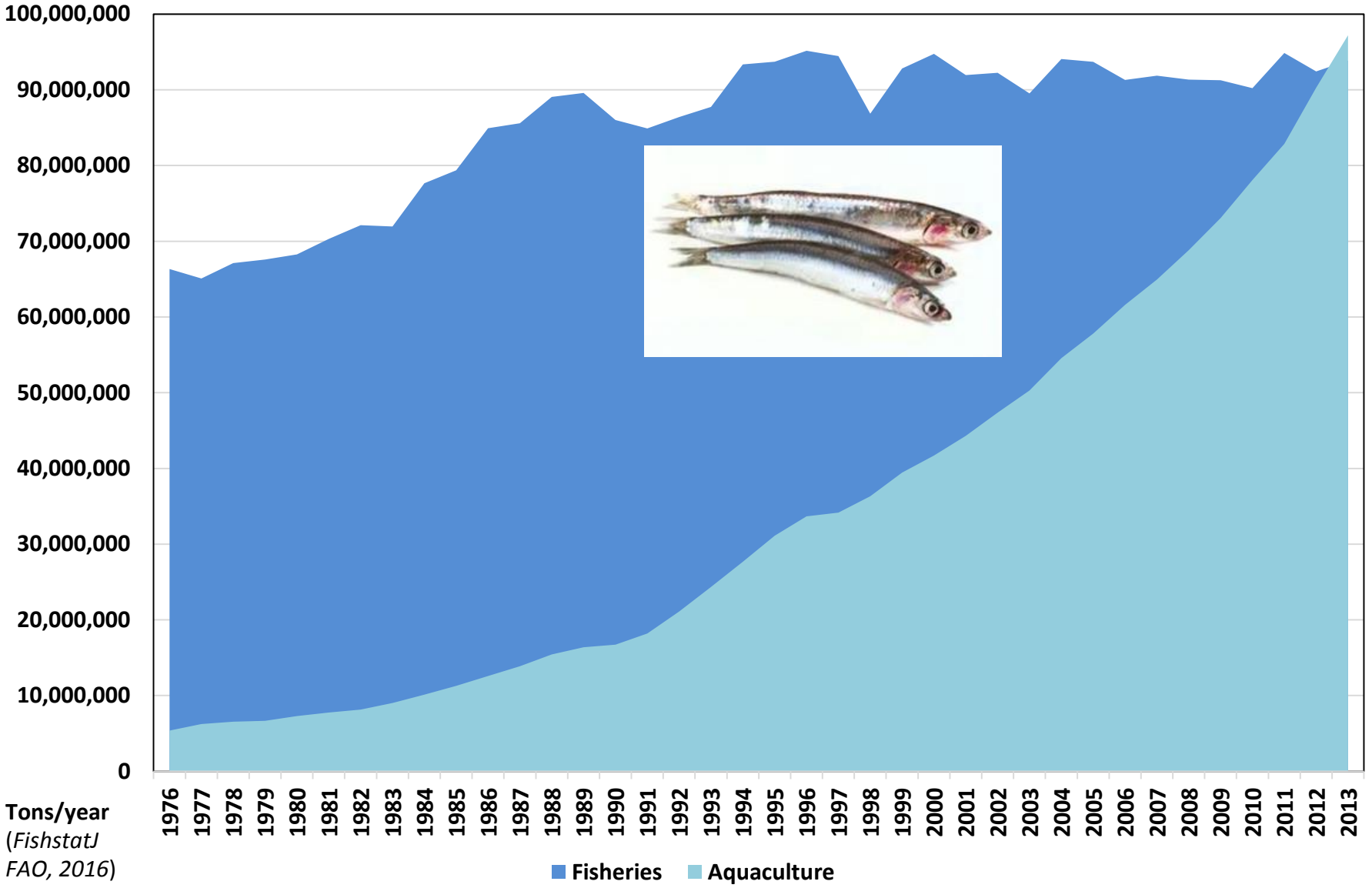
NuSea.Lab
The Nutrition and Seafood Laboratory
Deakin University - Australia

DEAKIN UNIVERSITY

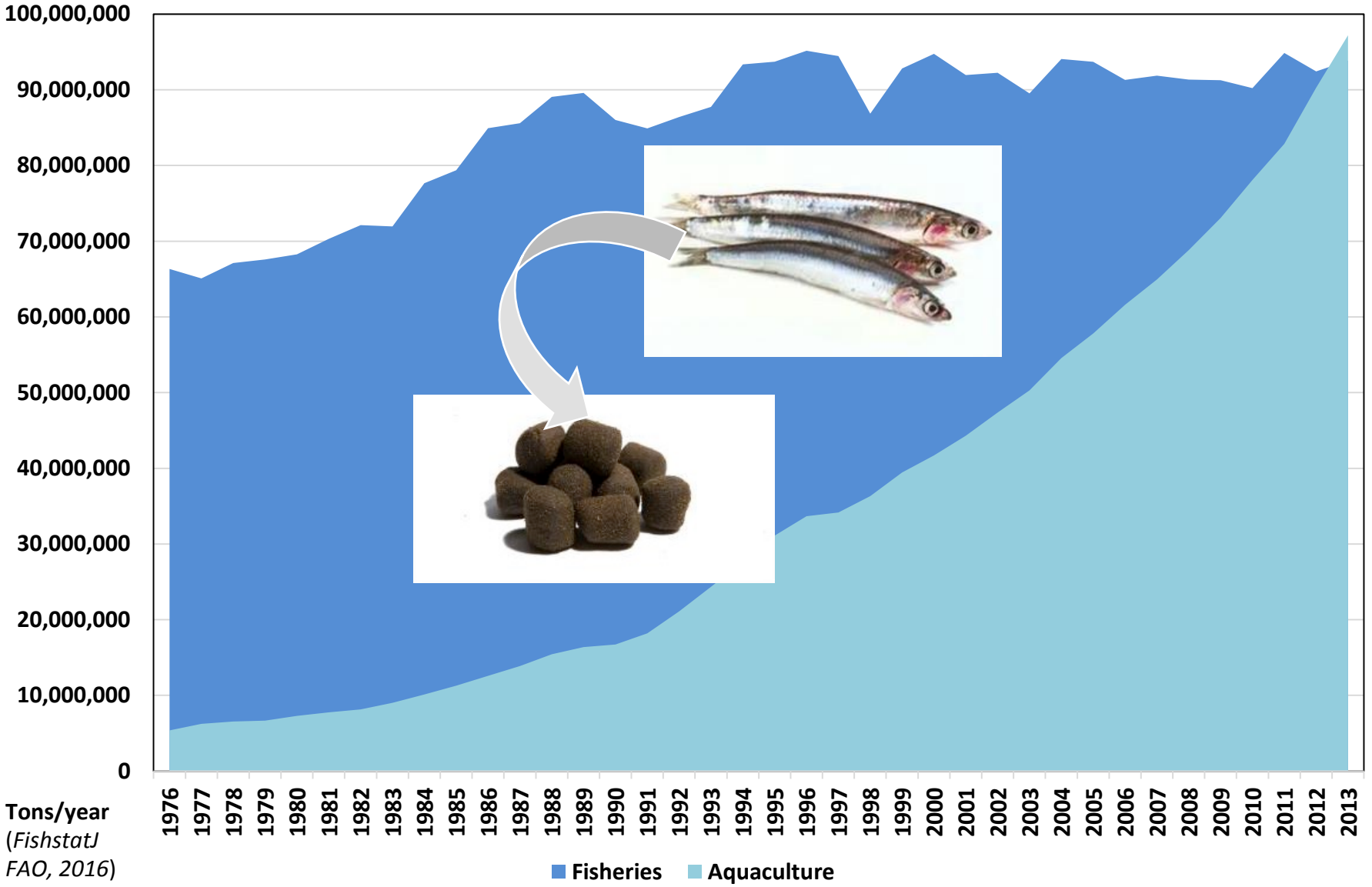
Deakin University CRICOS Provider



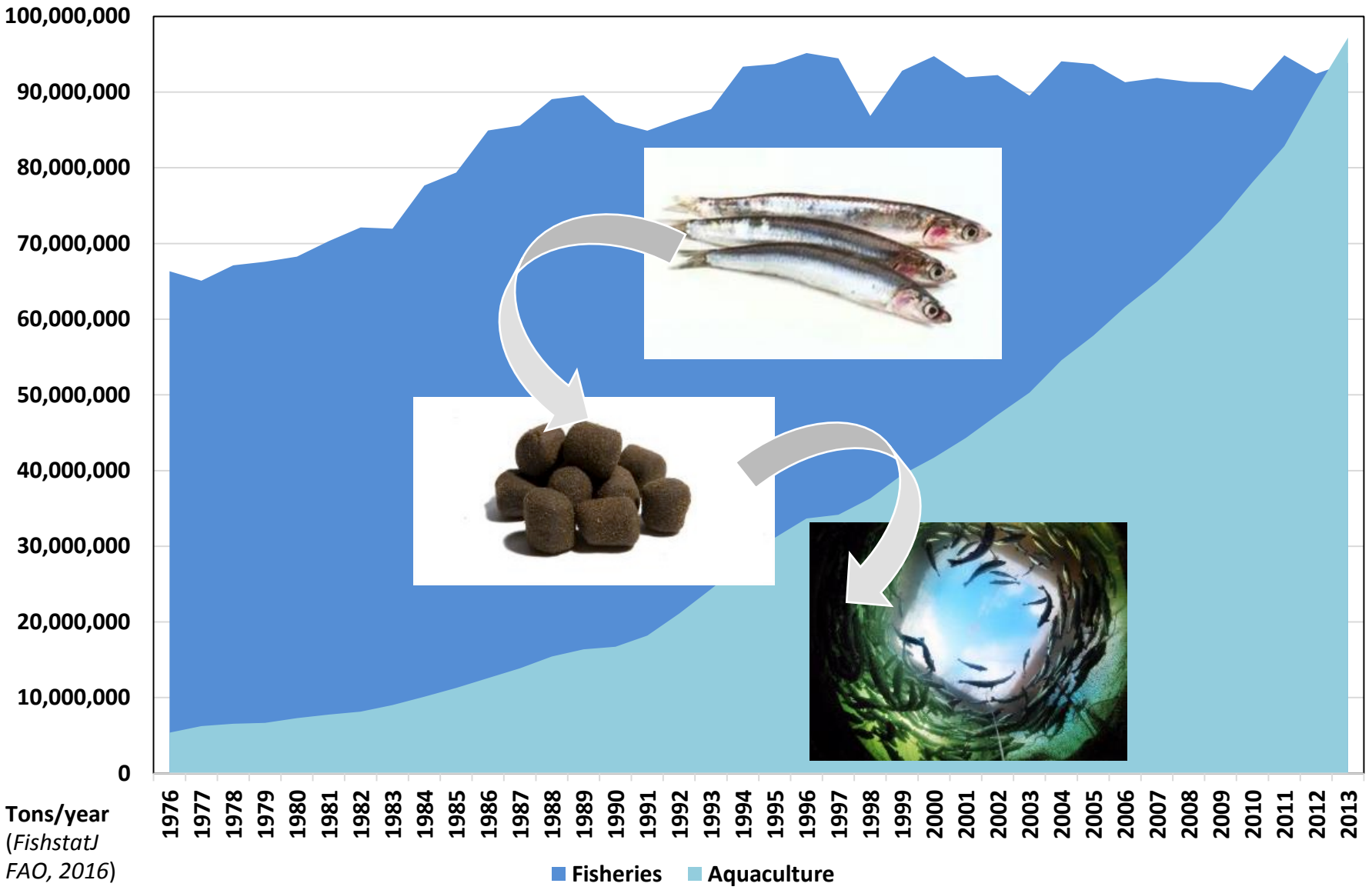
Tons/year
(*FishstatJ*
FAO, 2016)



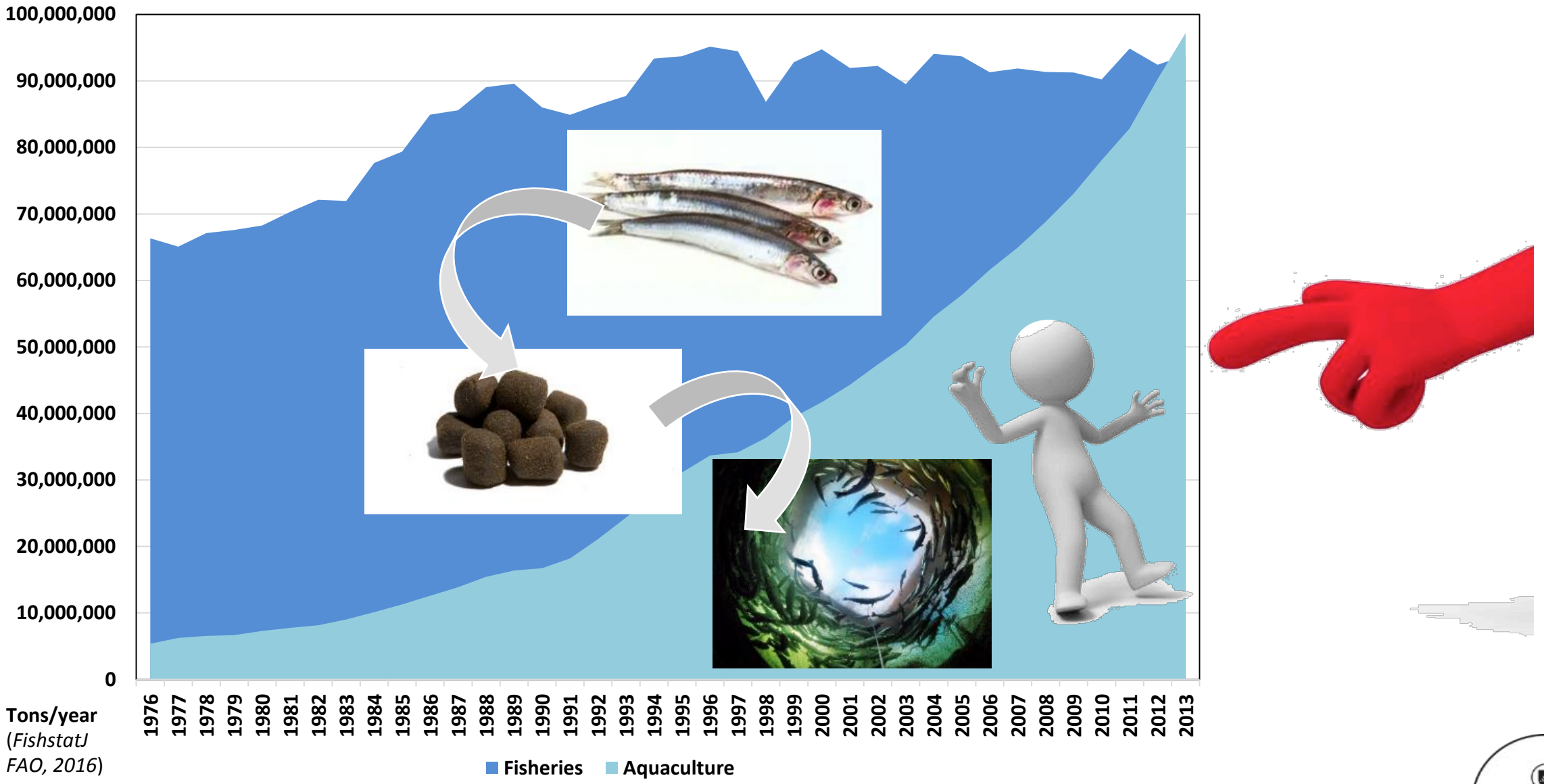
Tons/year
(*FishstatJ*
FAO, 2016)



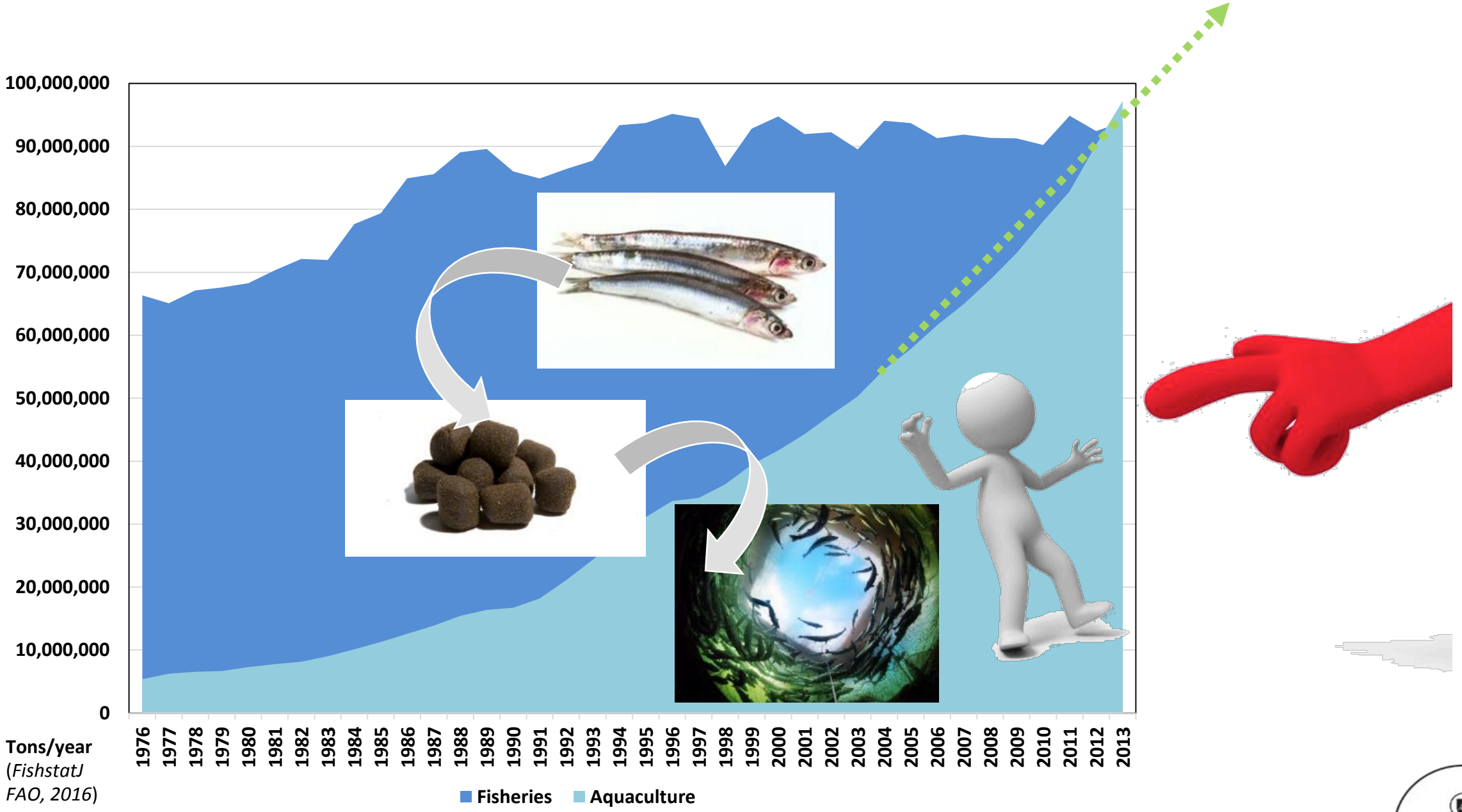
Tons/year
(*FishstatJ FAO, 2016*)



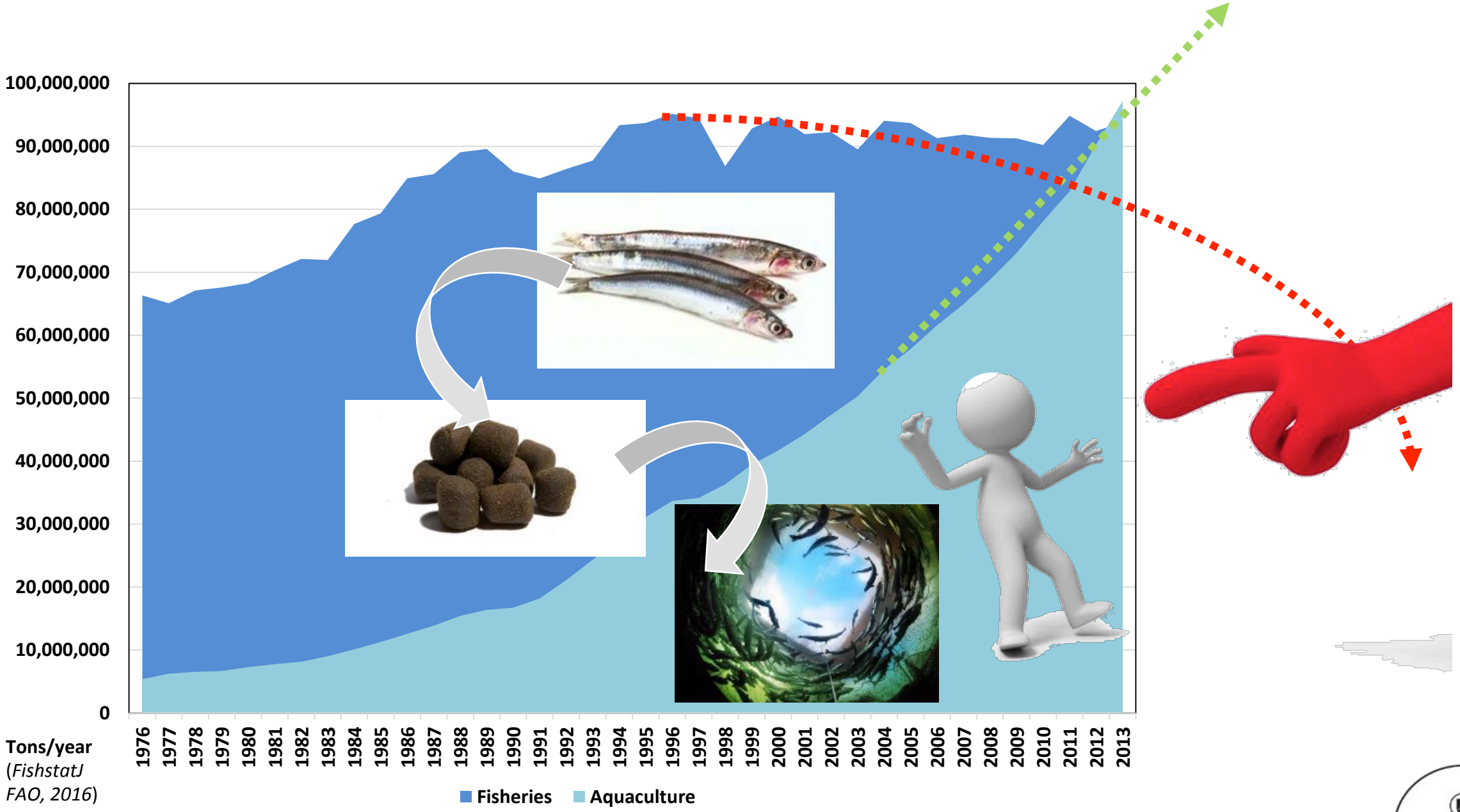
Tons/year
(*FishstatJ FAO, 2016*)

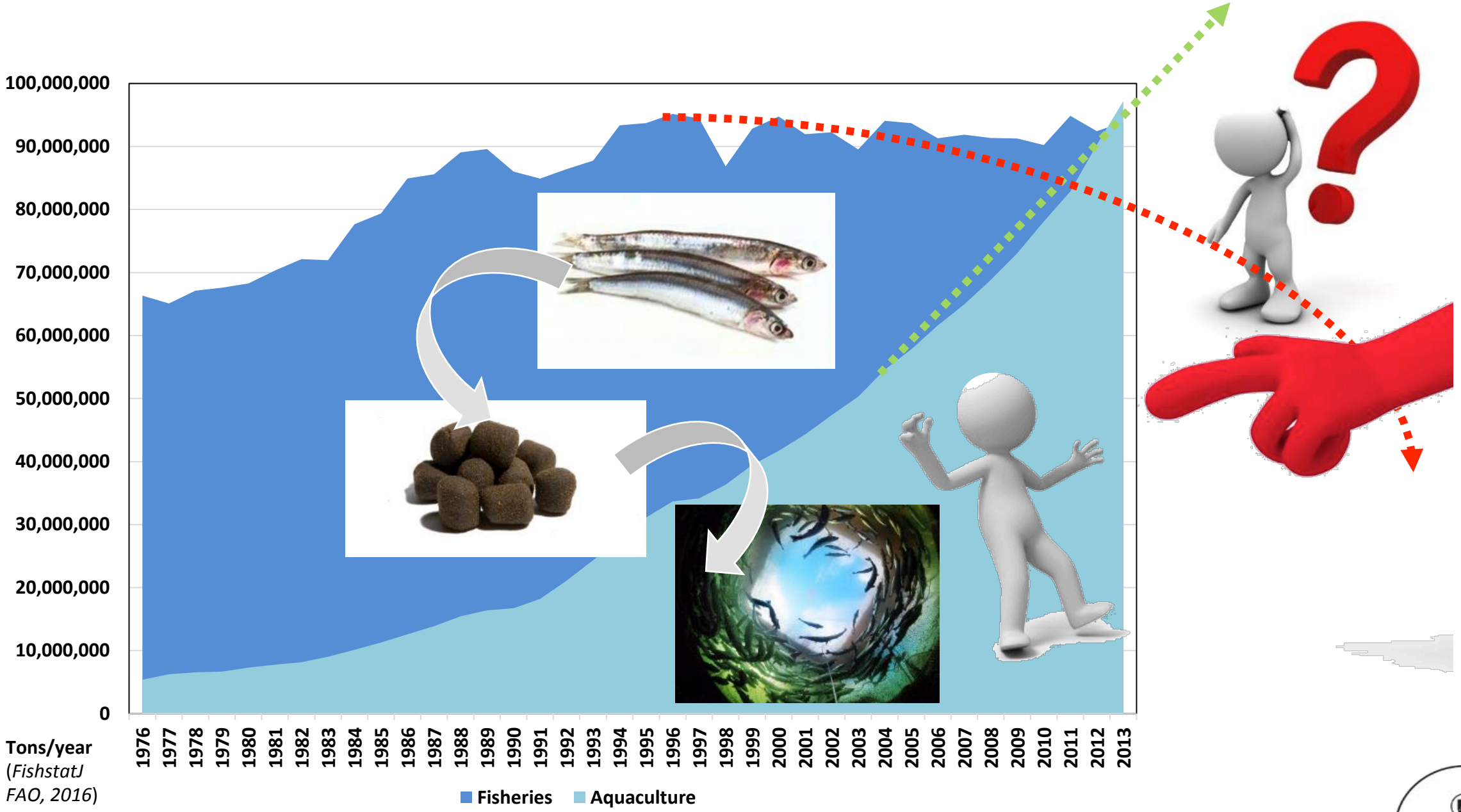


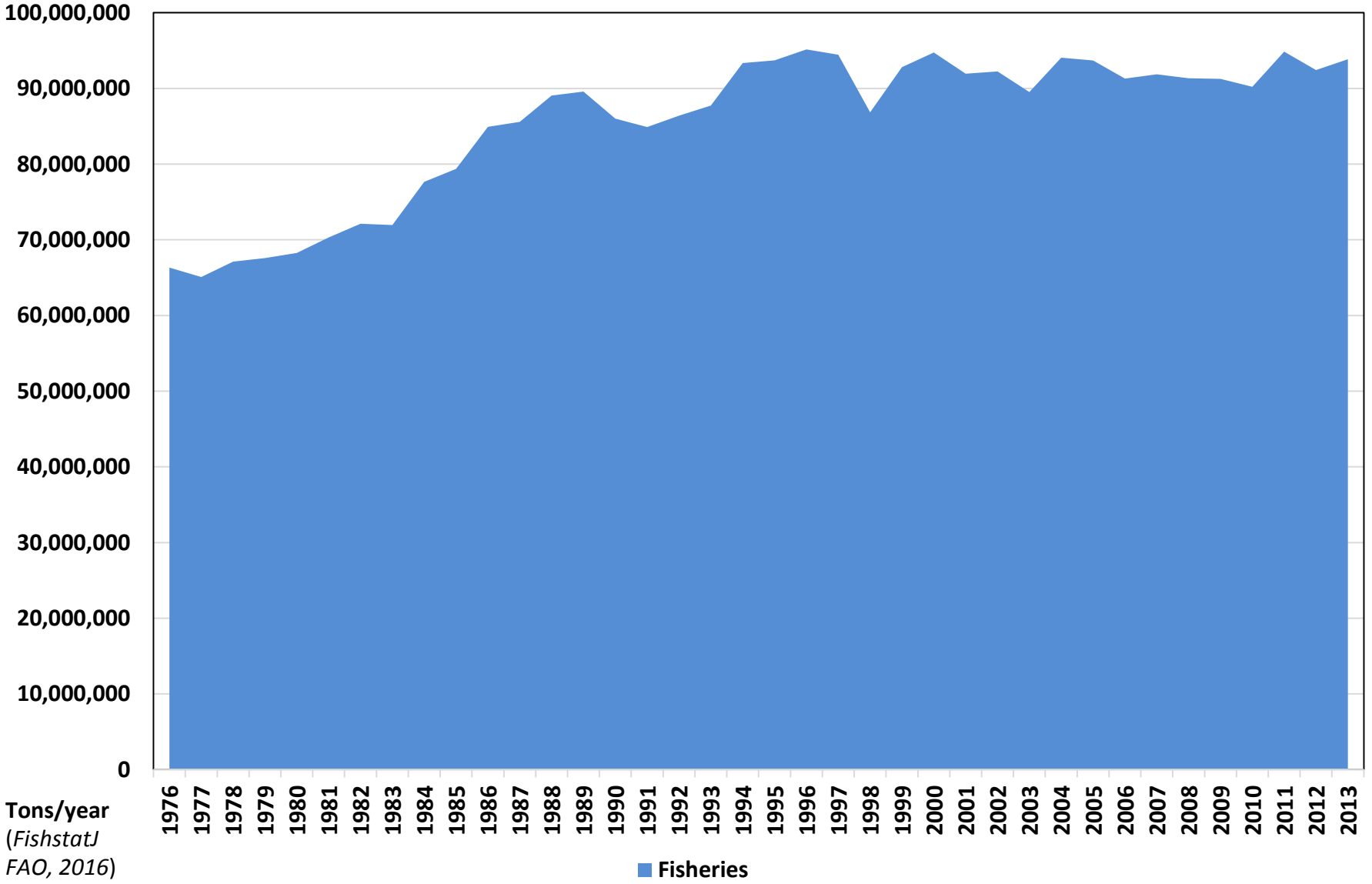
Deakin University CRICOS Provider



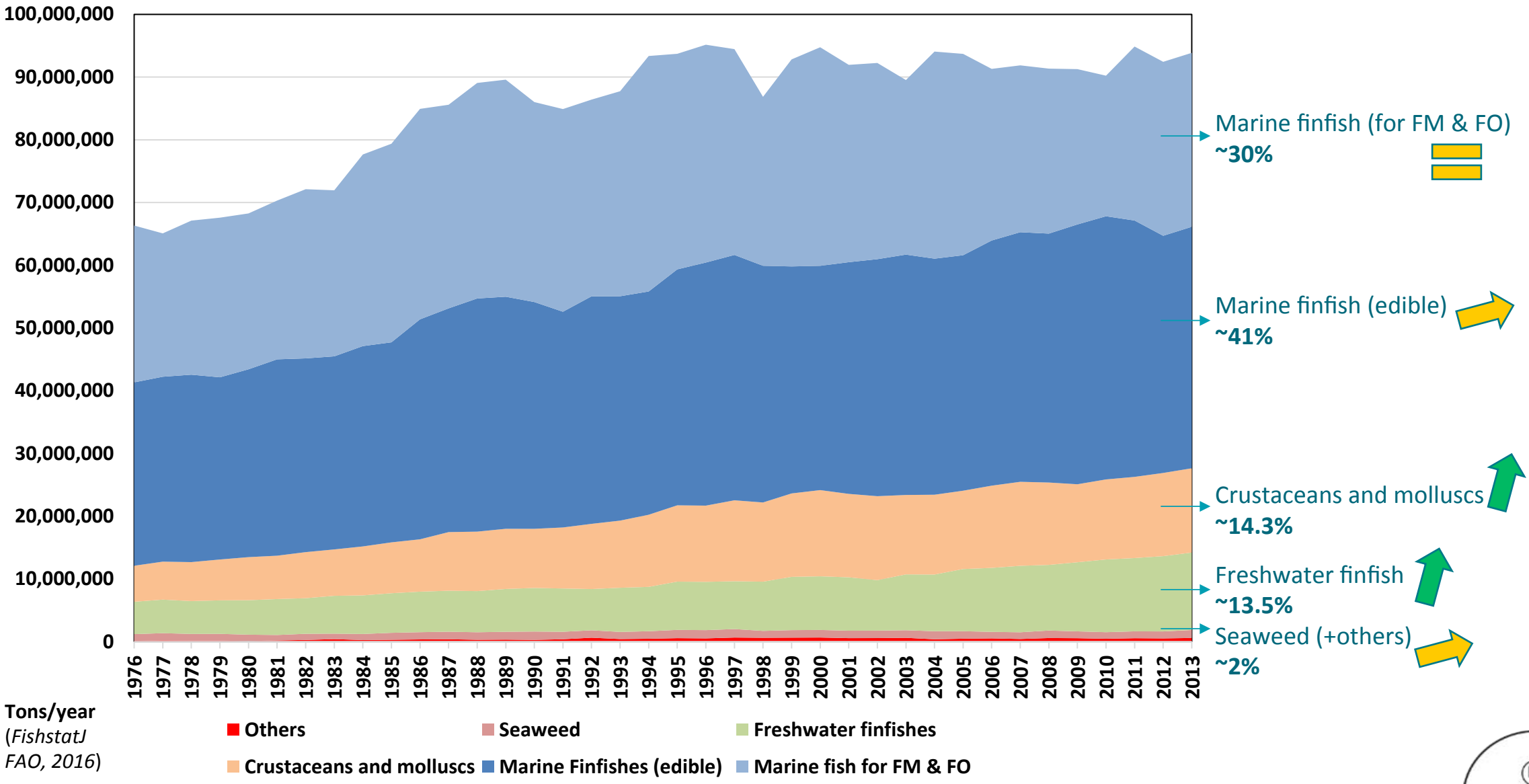
Tons/year
(*FishstatJ FAO, 2016*)

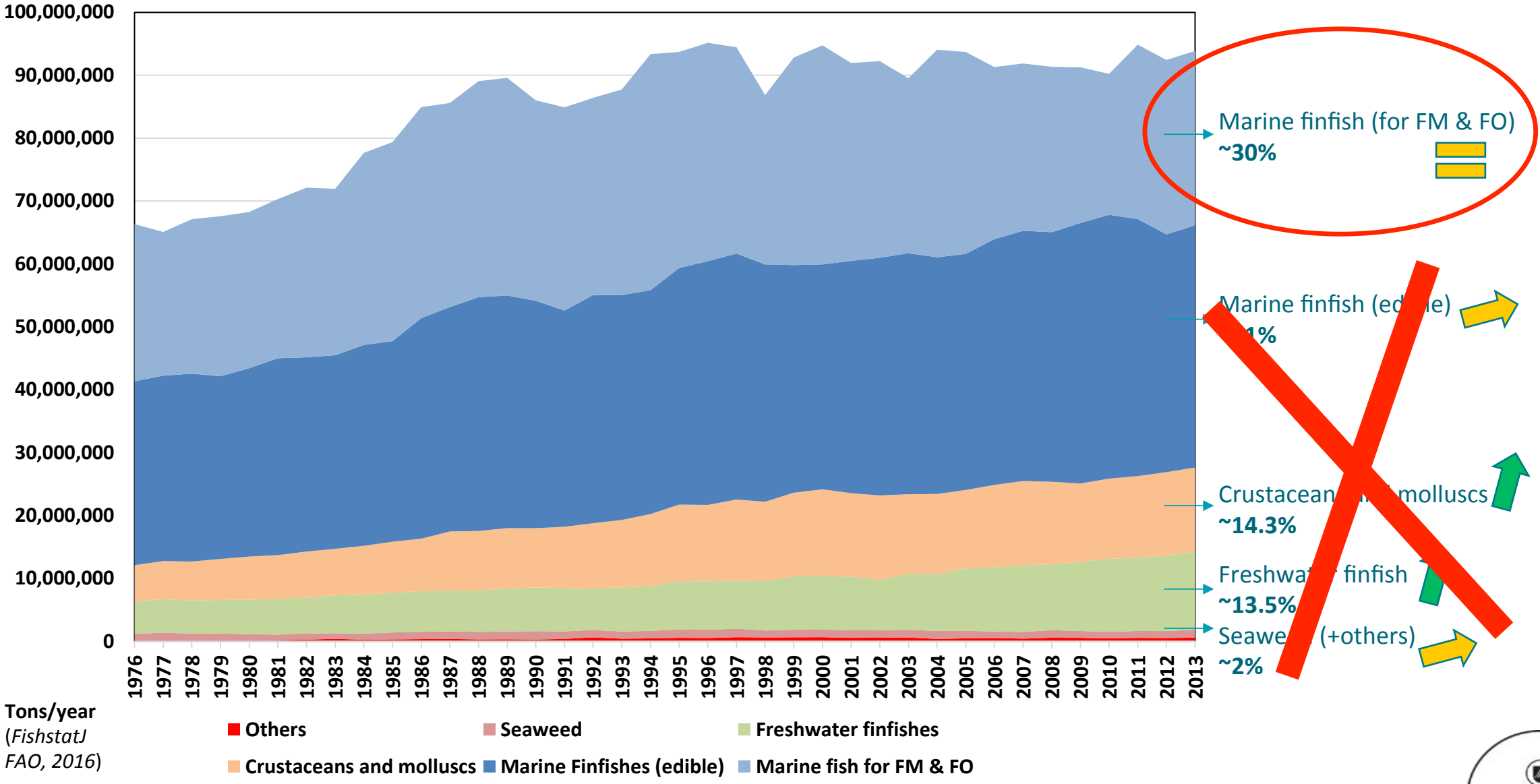

100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Tons/year
(FishstatJ
FAO, 2016)
Fisheries
Aquaculture

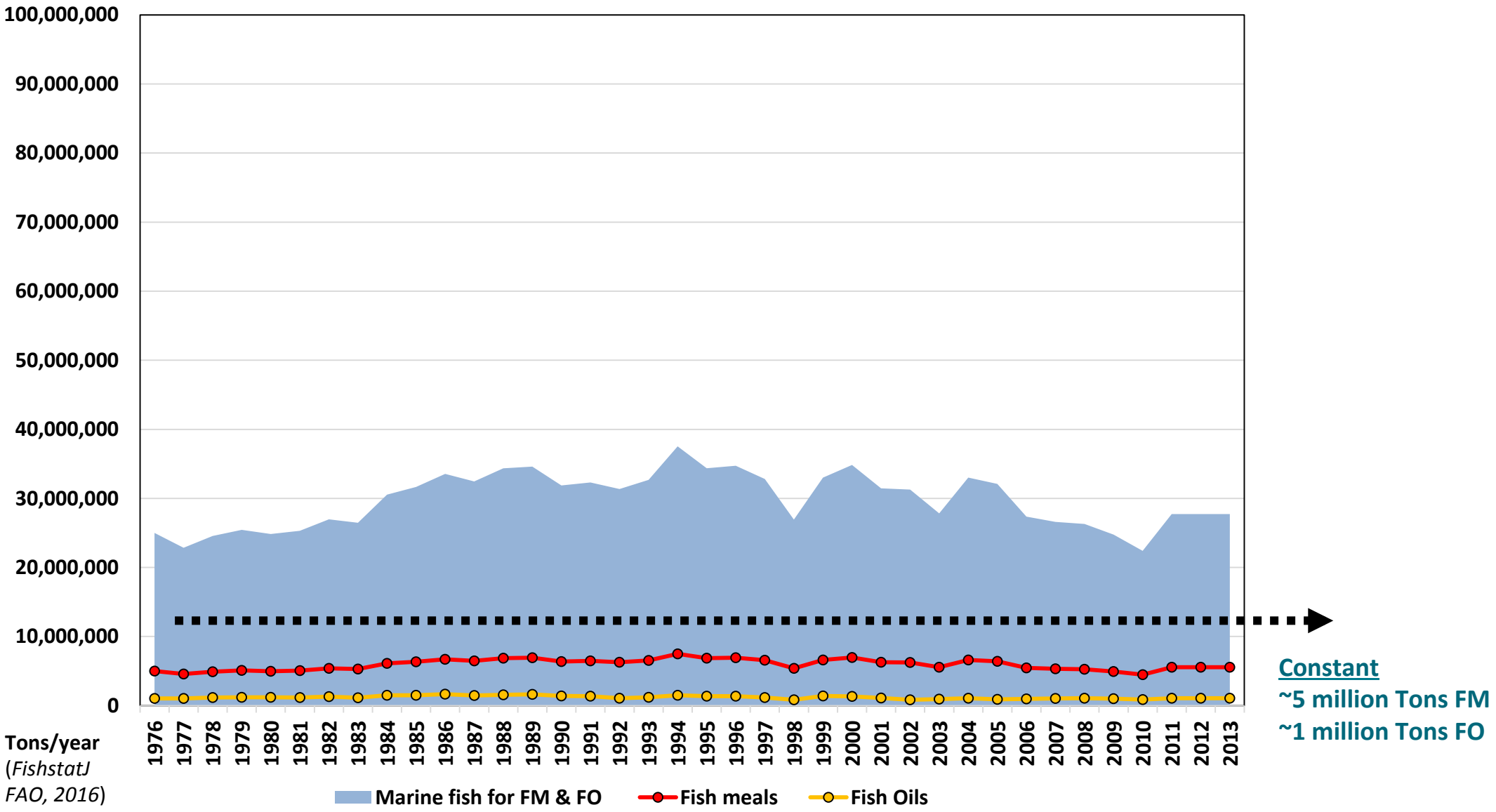

100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Tons/year
(FishstatJ
FAO, 2016)
Fisheries
Aquaculture



Tons/year
(*FishstatJ*
FAO, 2016)

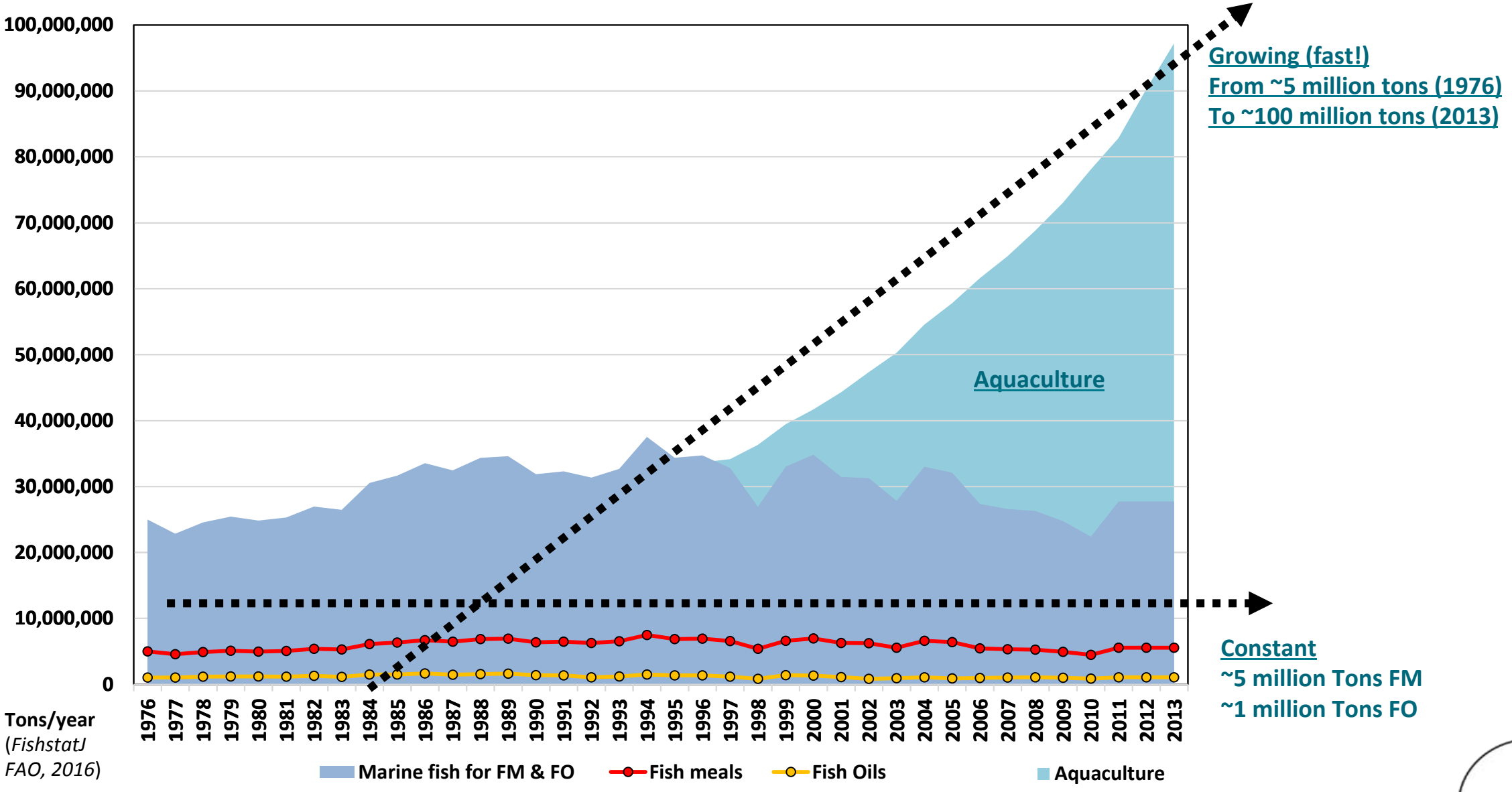

100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Tons/year
(FishstatJ
FAO, 2016)
Others
Seaweed
Freshwater finfishes
Crustaceans and molluscs
Marine Finfishes (edible)
Marine fish for FM & FO
Marine finfish (for FM & FO)
~30%
Marine finfish (edible)
~41%
Crustaceans and molluscs
~14.3%
Freshwater finfish
~13.5%
Seaweed (+others)
~2%

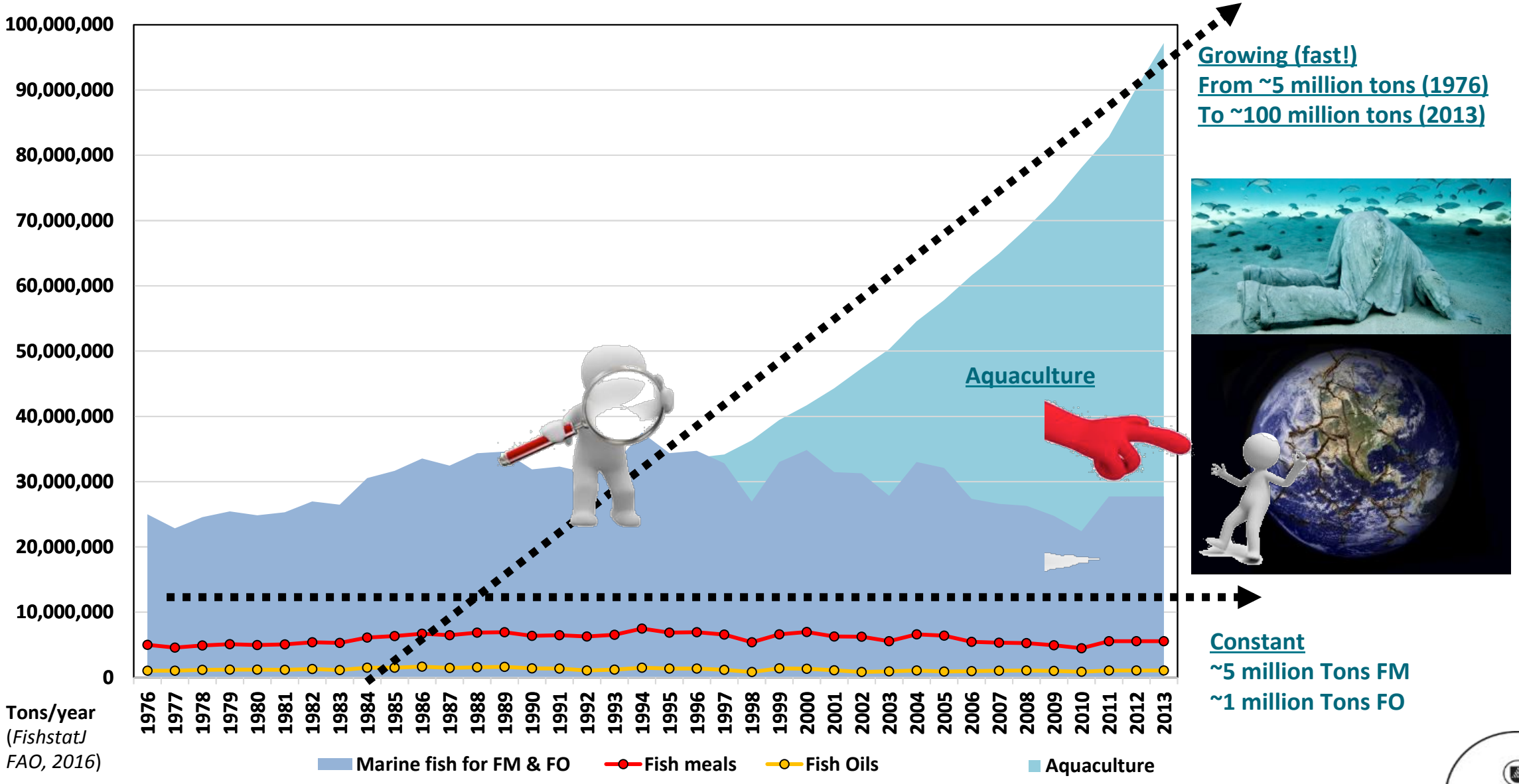

100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Tons/year
(FishstatJ
FAO, 2016)
Others
Seaweed
Freshwater finfishes
Crustaceans and molluscs
Marine Finfishes (edible)
Marine fish for FM & FO
Marine finfish (for FM & FO)
~30%
Marine finfish (ed ie)
1%
Crustacean molluscs
~14.3%
Freshwa finfish
~13.5%
Seawe (+others)
~2%

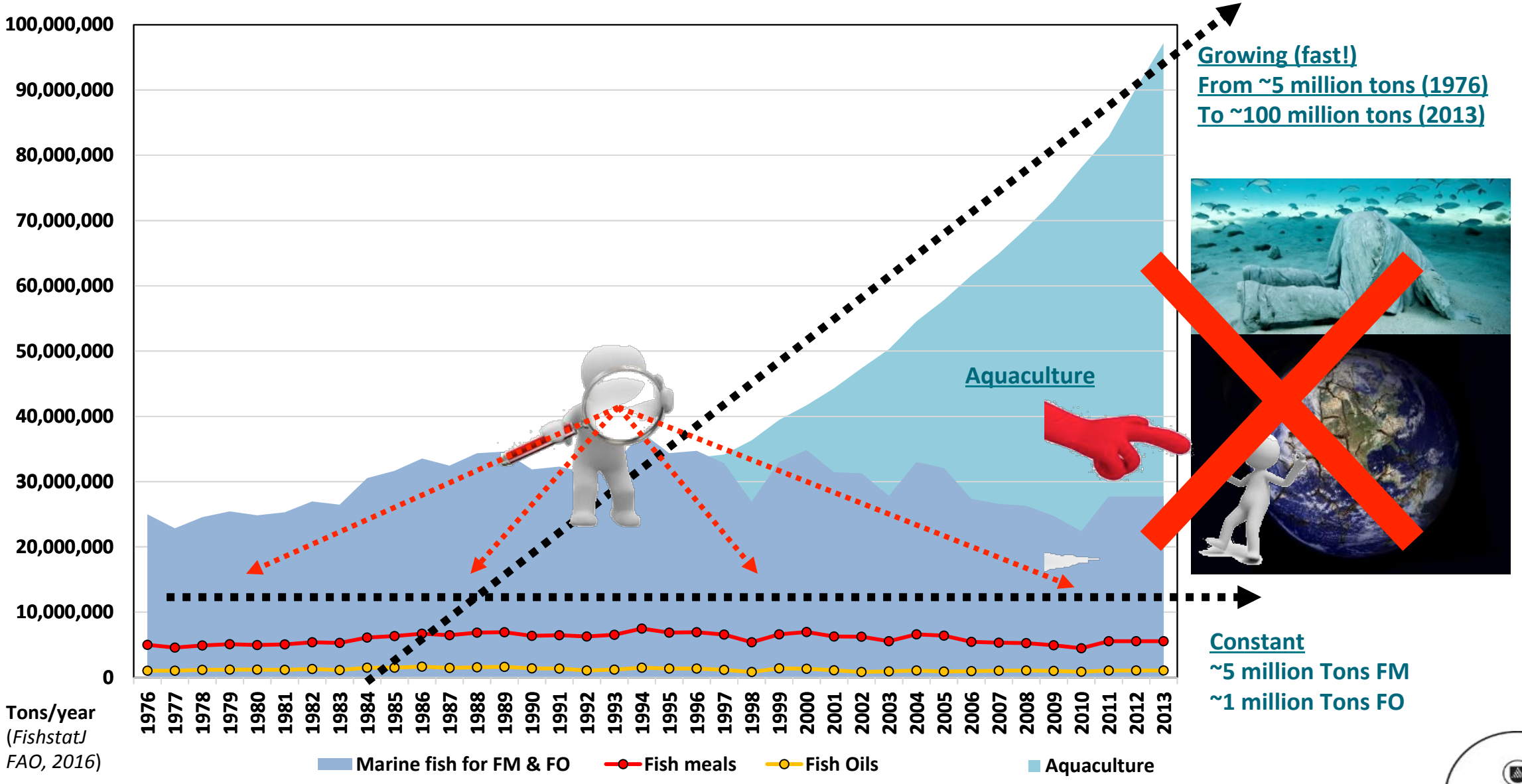


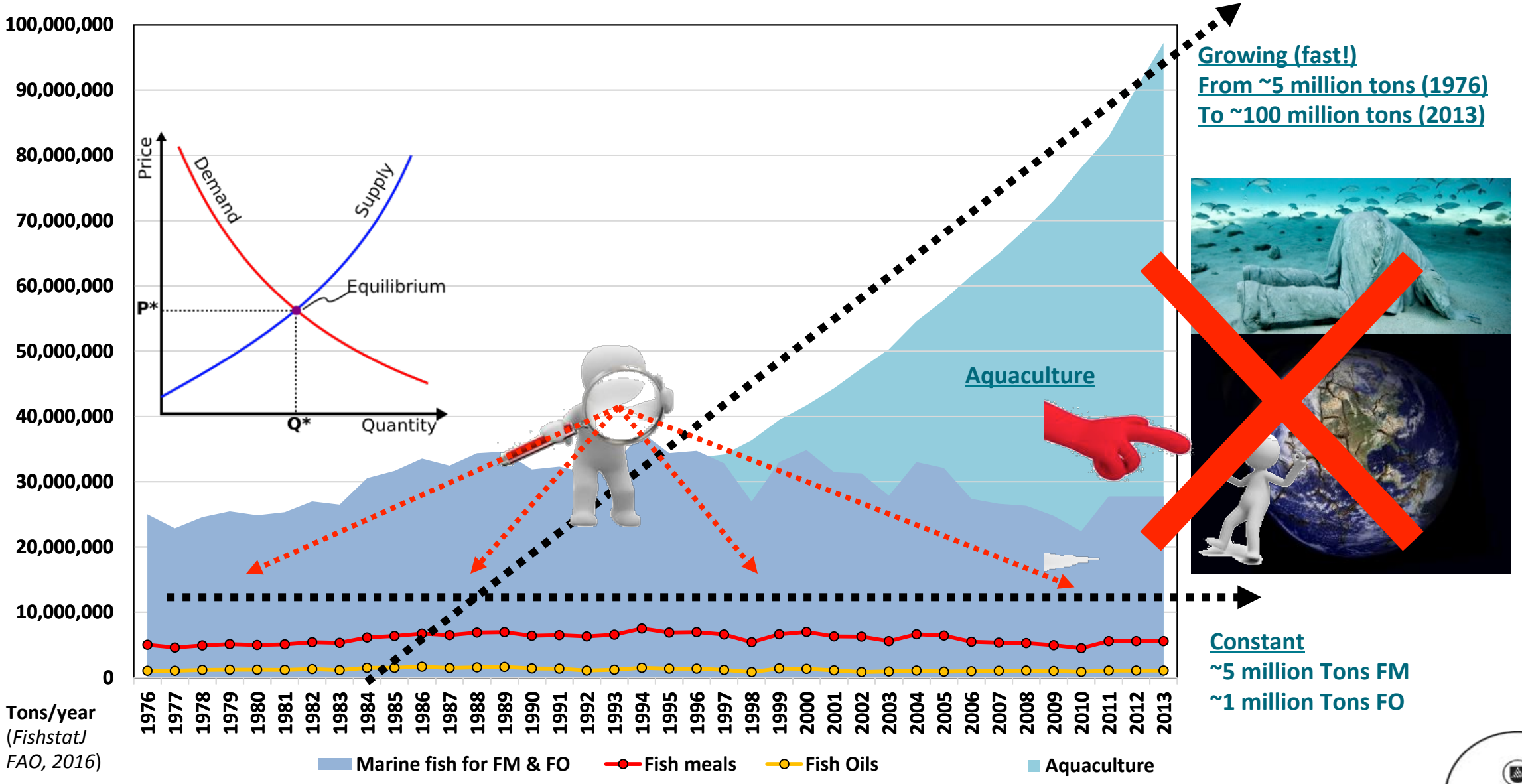
Tons/year
(*FishstatJ FAO, 2016*)

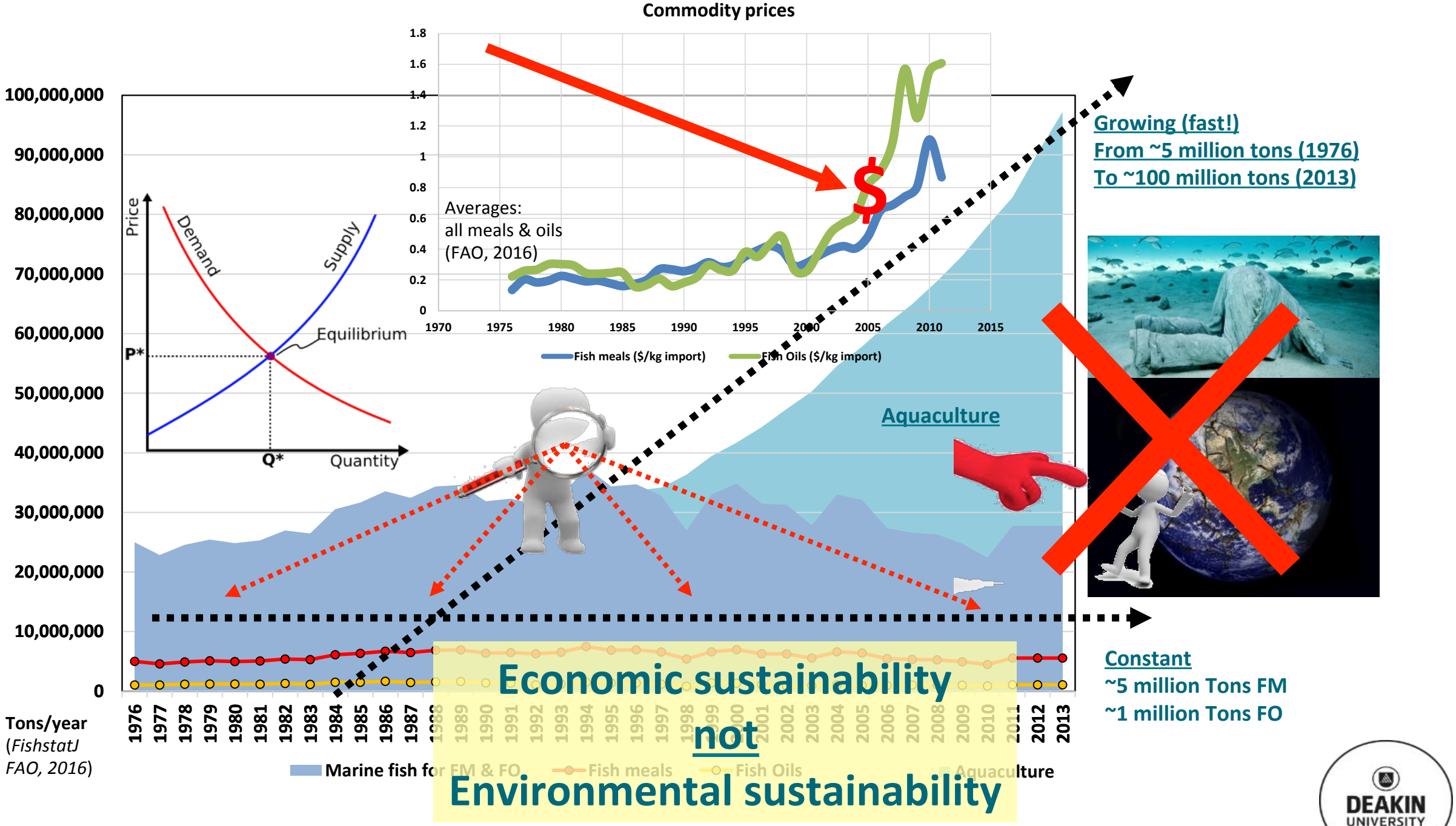
Constant
~5 million Tons FM
~1 million Tons FO

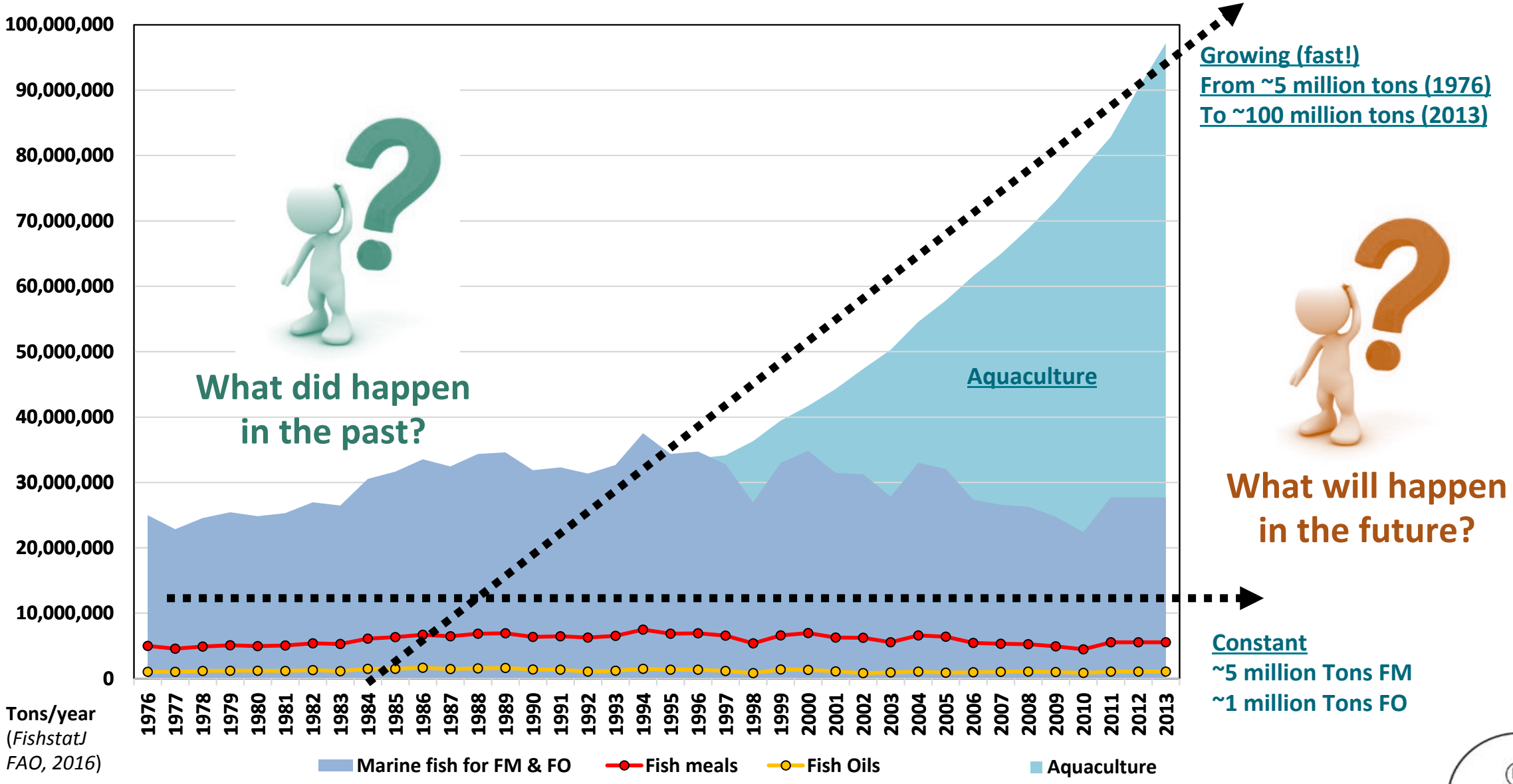

100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Tons/year
(FishstatJ
FAO, 2016)
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Marine fish for FM & FO
Fish meals
Fish Oils
Aquaculture
Aquaculture
Growing (fast!)
From ~5 million tons (1976)
To ~100 million tons (2013)
Constant
~5 million Tons FM
~1 million Tons FO


100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Tons/year
(FishstatJ
FAO, 2016)
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Marine fish for FM & FO
Fish meals
Fish Oils
Aquaculture
Aquaculture
Growing (fast!)
From ~5 million tons (1976)
To ~100 million tons (2013)
Constant
~5 million Tons FM
~1 million Tons FO


100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Tons/year
(FishstatJ
FAO, 2016)
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Marine fish for FM & FO
Fish meals
Fish Oils
Aquaculture
Aquaculture
Growing (fast!)
From ~5 million tons (1976)
To ~100 million tons (2013)
Constant
~5 million Tons FM
~1 million Tons FO


100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Price
Demand
Supply
Equilibrium
P*
Q*
Quantity
Aquaculture
Growing (fast!)
From ~5 million tons (1976)
To ~100 million tons (2013)
Constant
~5 million Tons FM
~1 million Tons FO
Tons/year
(FishstatJ
FAO, 2016)
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Marine fish for FM & FO
Fish meals
Fish Oils
Aquaculture


Commodity prices
Averages:
all meals & oils
(FAO, 2016)
Fish meals ($/kg import)
Fish Oils ($/kg import)
Price
Demand
Supply
Equilibrium
P*
Q*
Quantity
Aquaculture
Growing (fast!)
From ~5 million tons (1976)
To ~100 million tons (2013)
Constant
~5 million Tons FM
~1 million Tons FO
Tons/year
(FishstatJ
FAO, 2016)
Marine fish for FM & FO
Fish meals
Fish Oils
Aquaculture
Economic sustainability
not
Environmental sustainability


100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Tons/year
(FishstatJ
FAO, 2016)
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Marine fish for FM & FO
Fish meals
Fish Oils
Aquaculture
What did happen
in the past?
Aquaculture
Growing (fast!)
From ~5 million tons (1976)
To ~100 million tons (2013)
What will happen
in the future?
Constant
~5 million Tons FM
~1 million Tons FO

Fishmeal

History of Fishmeal Uses

1950

1970

1990

2010

2030

DEAKIN UNIVERSITY

Fishmeal

1950

2030

DEAKIN UNIVERSITY

Fishmeal

1950

2030

1970

DEAKIN UNIVERSITY

Fishmeal

1950

2030

1990

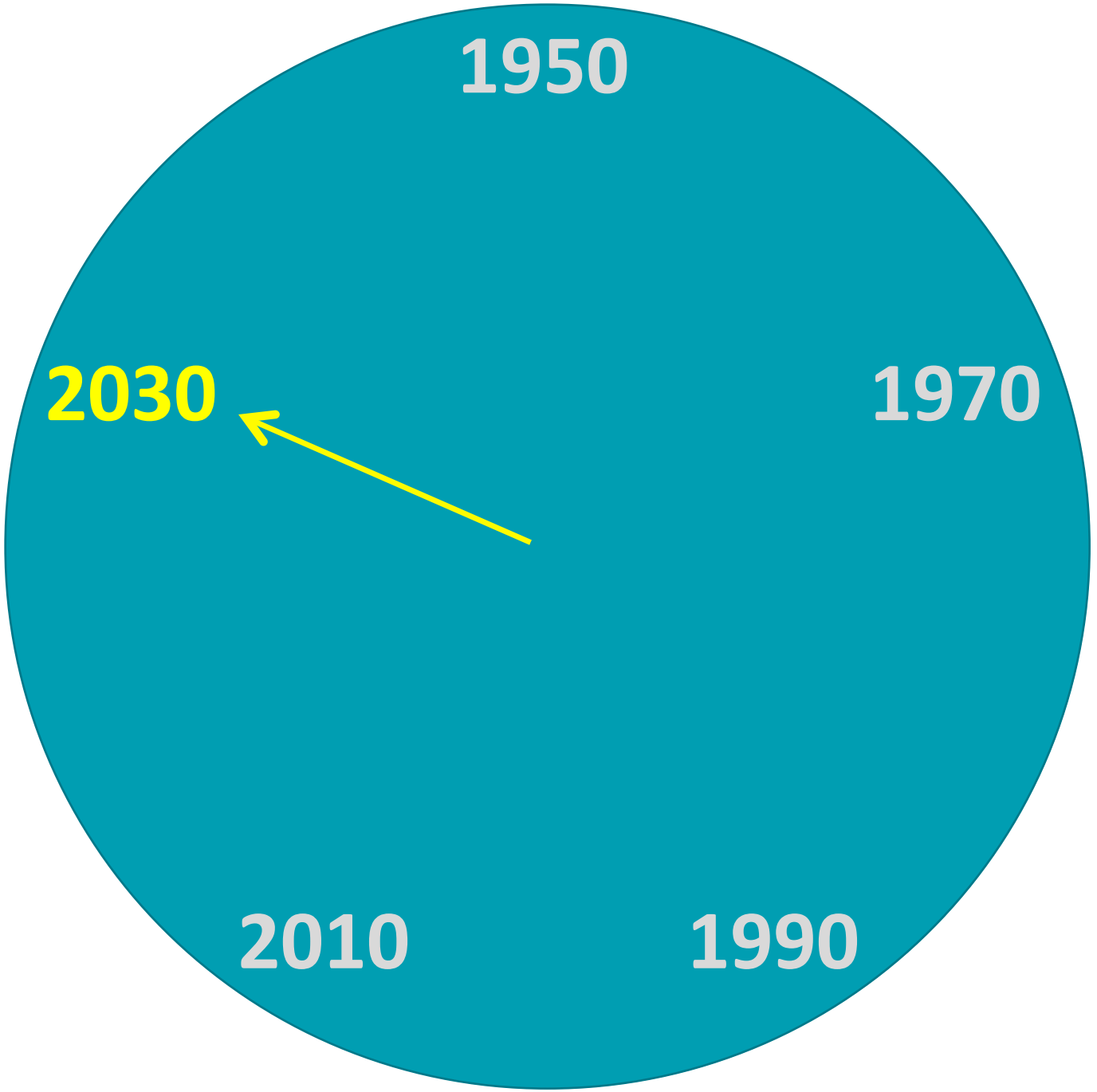
DEAKIN UNIVERSITY

Fishmeal

2010

DEAKIN UNIVERSITY

Fishmeal



DEAKIN UNIVERSITY

Fishmeal

1950

1970

2030

"No longer the primary protein source in aquafeeds…
…a specialty ingredient added to enhance palatability, balance dietary amino acids, supply other essential nutrients and biologically active compounds or enhance product quality."
(Hardy, 2010. Aqua Res 41,770-776)

DEAKIN UNIVERSITY

Fish oil

History of fish oil uses

1950

1970

1990

2010

2030

DEAKIN UNIVERSITY

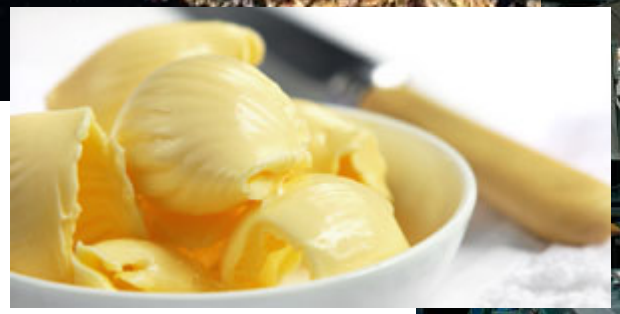
Fish oil

1950

1970

1990

2030



DEAKIN UNIVERSITY

Fish oil

Fish oil

1950

1990

Fish oil

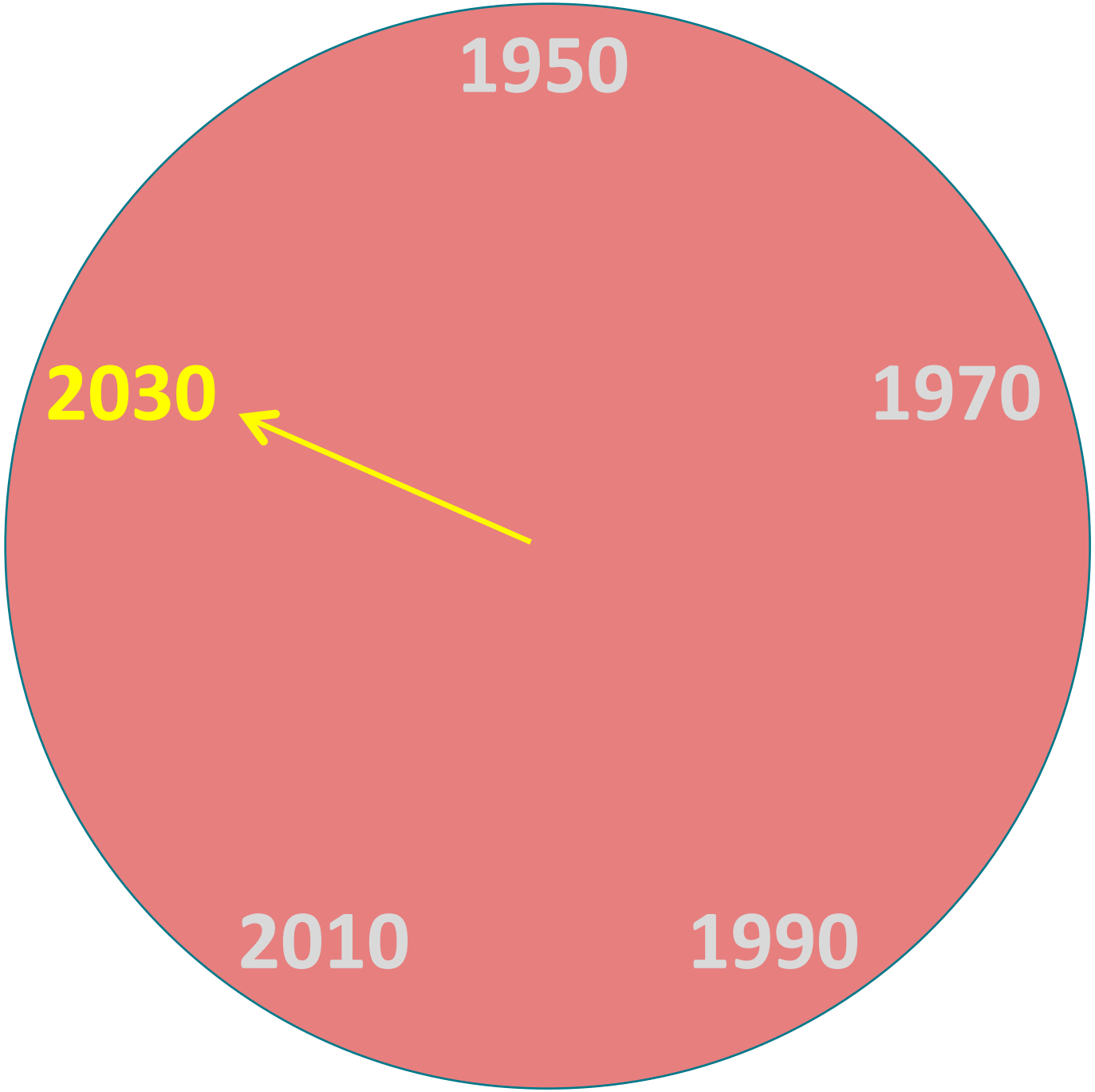
2030

2010

1990

DEAKIN UNIVERSITY

Fish oil



DEAKIN UNIVERSITY

Fish oil

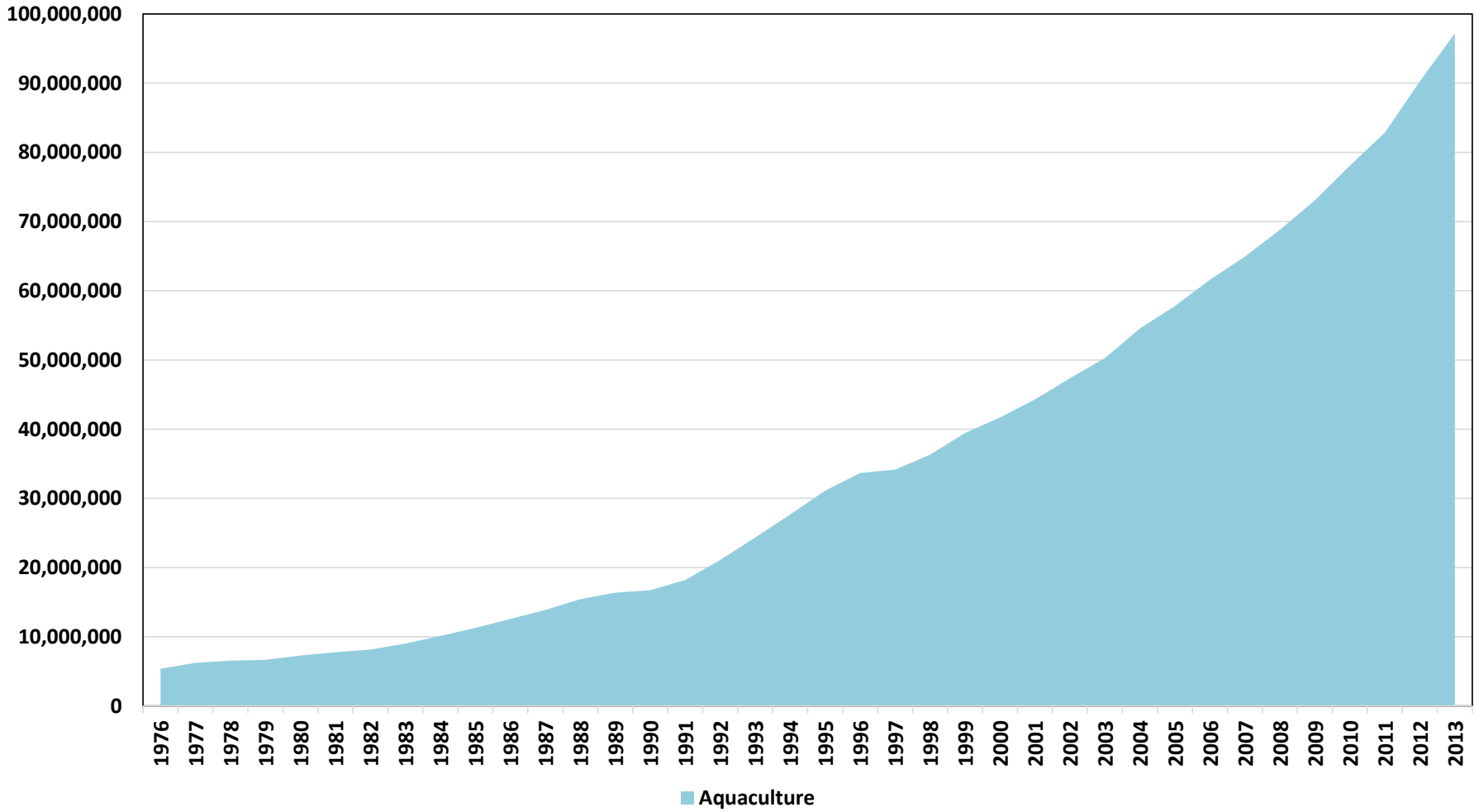
1950

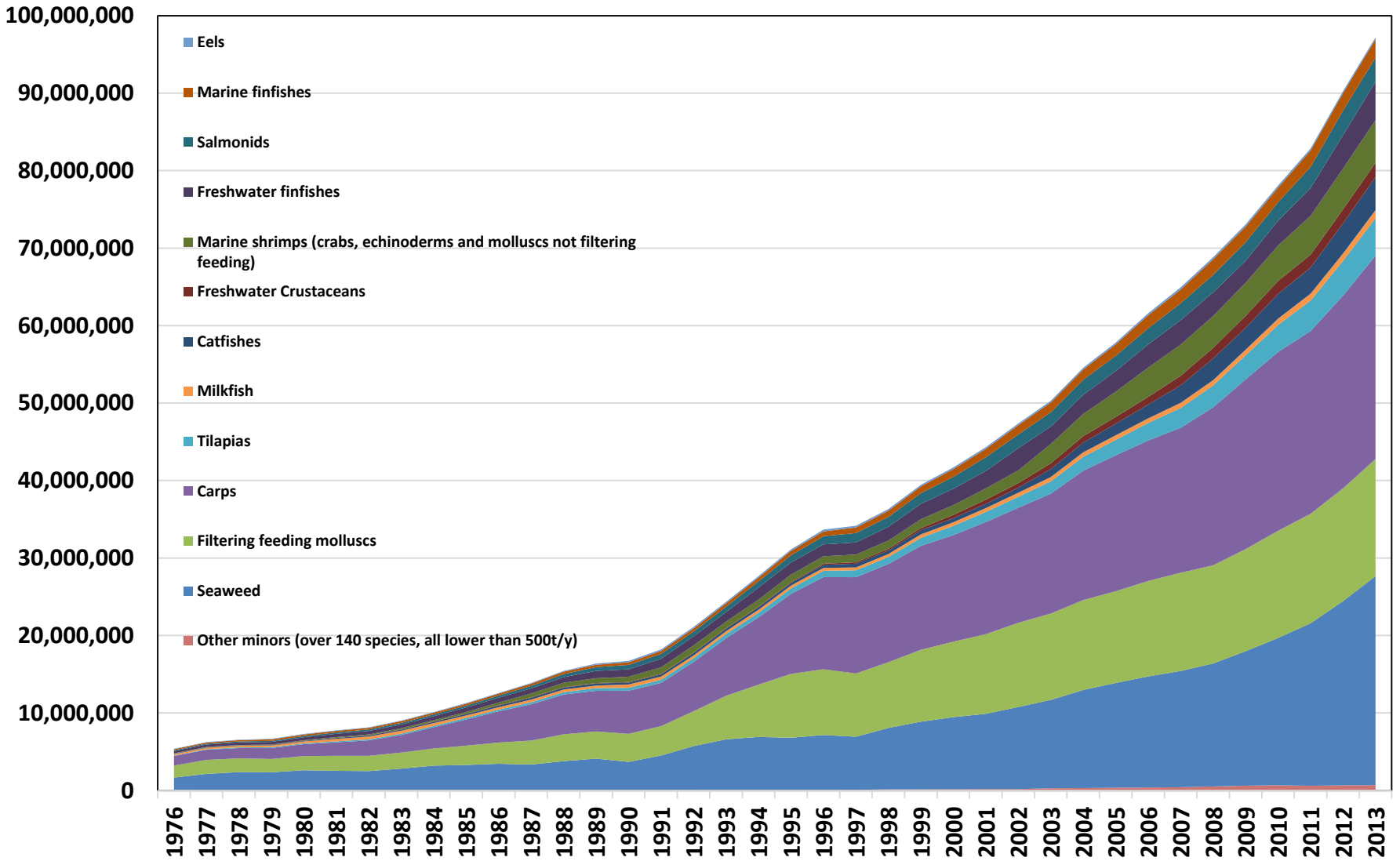
2030

"That market would be the nutraceutical market, not aquaculture!"

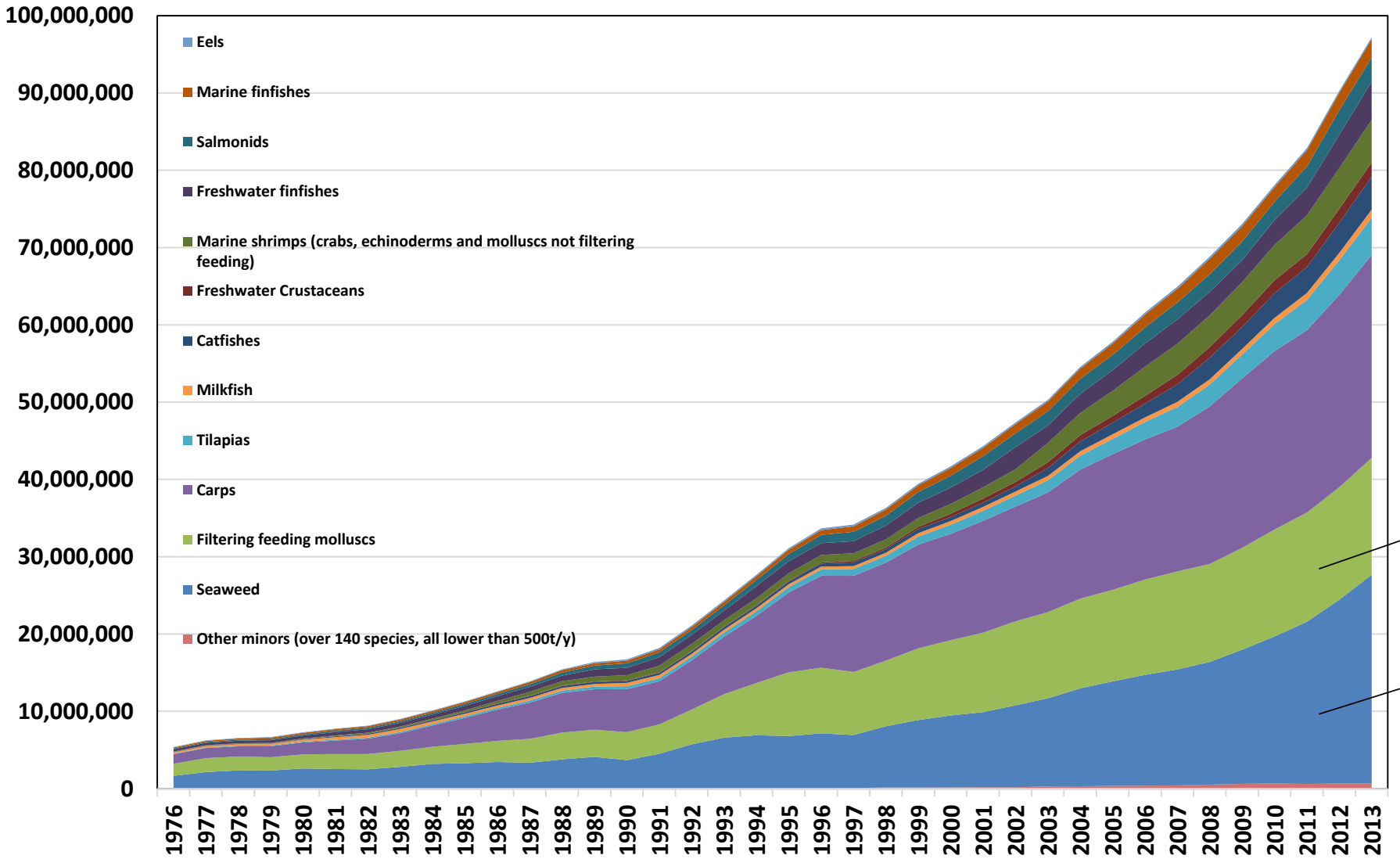
Anthony P. Bimbo (2009) *99th AOCS Annual Meeting & Expo in Seattle, Washington, USA, May 19, 2008*

DEAKIN UNIVERSITY


100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Aquaculture



~100 million tons

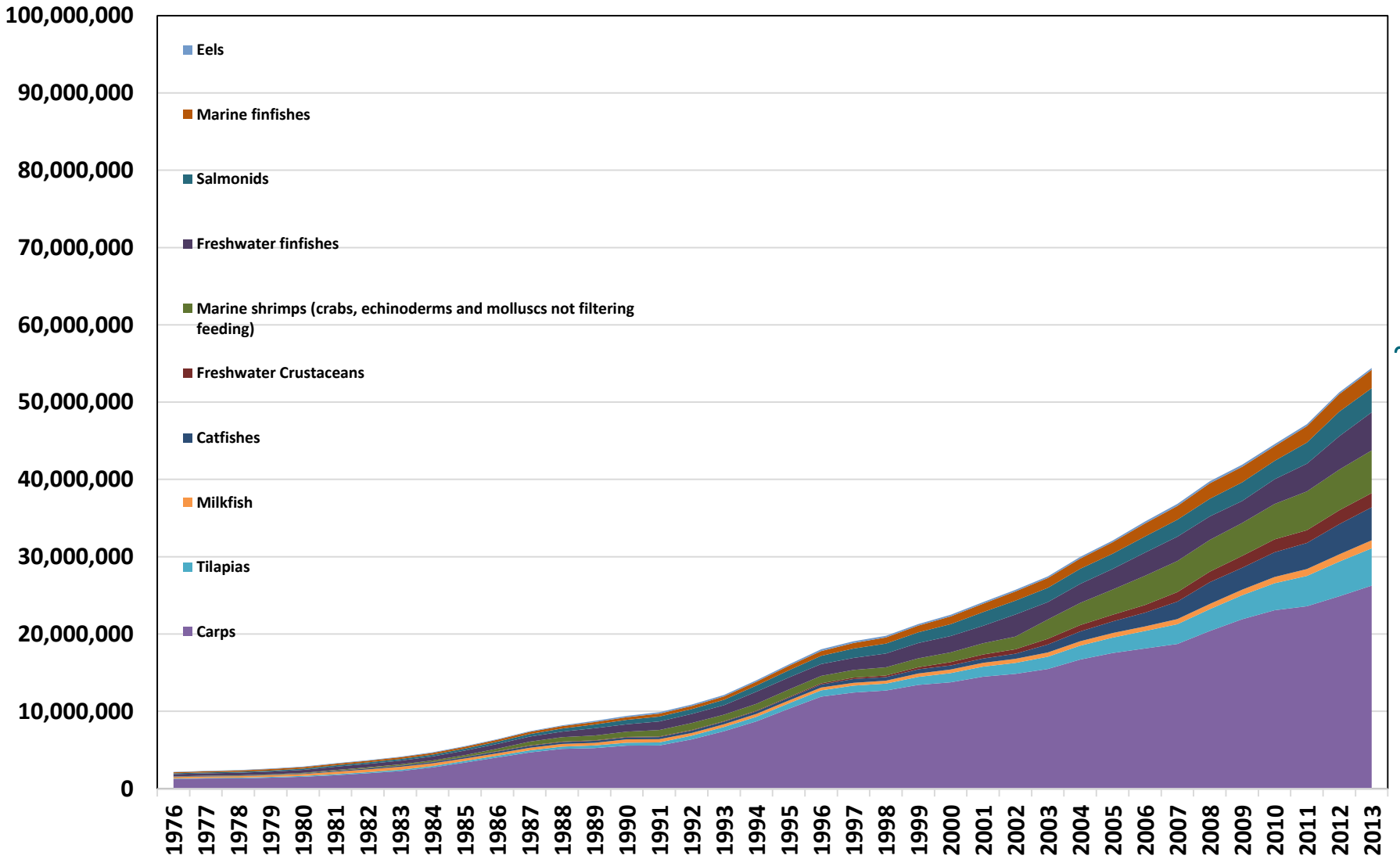


~100 million tons

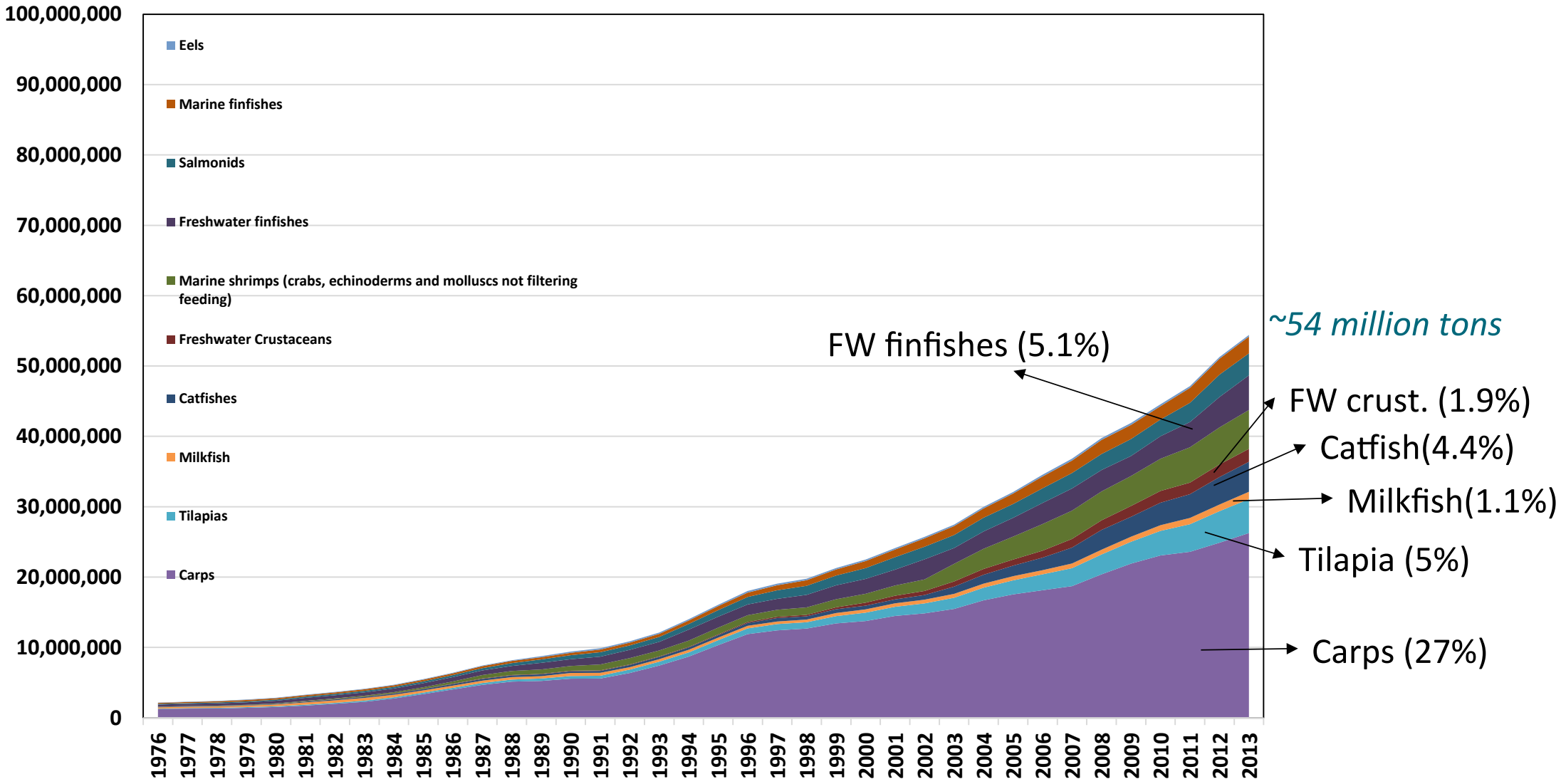
Not fed!

Filtering feeding Molluscs (15.5%)

Seaweed (27.8%)

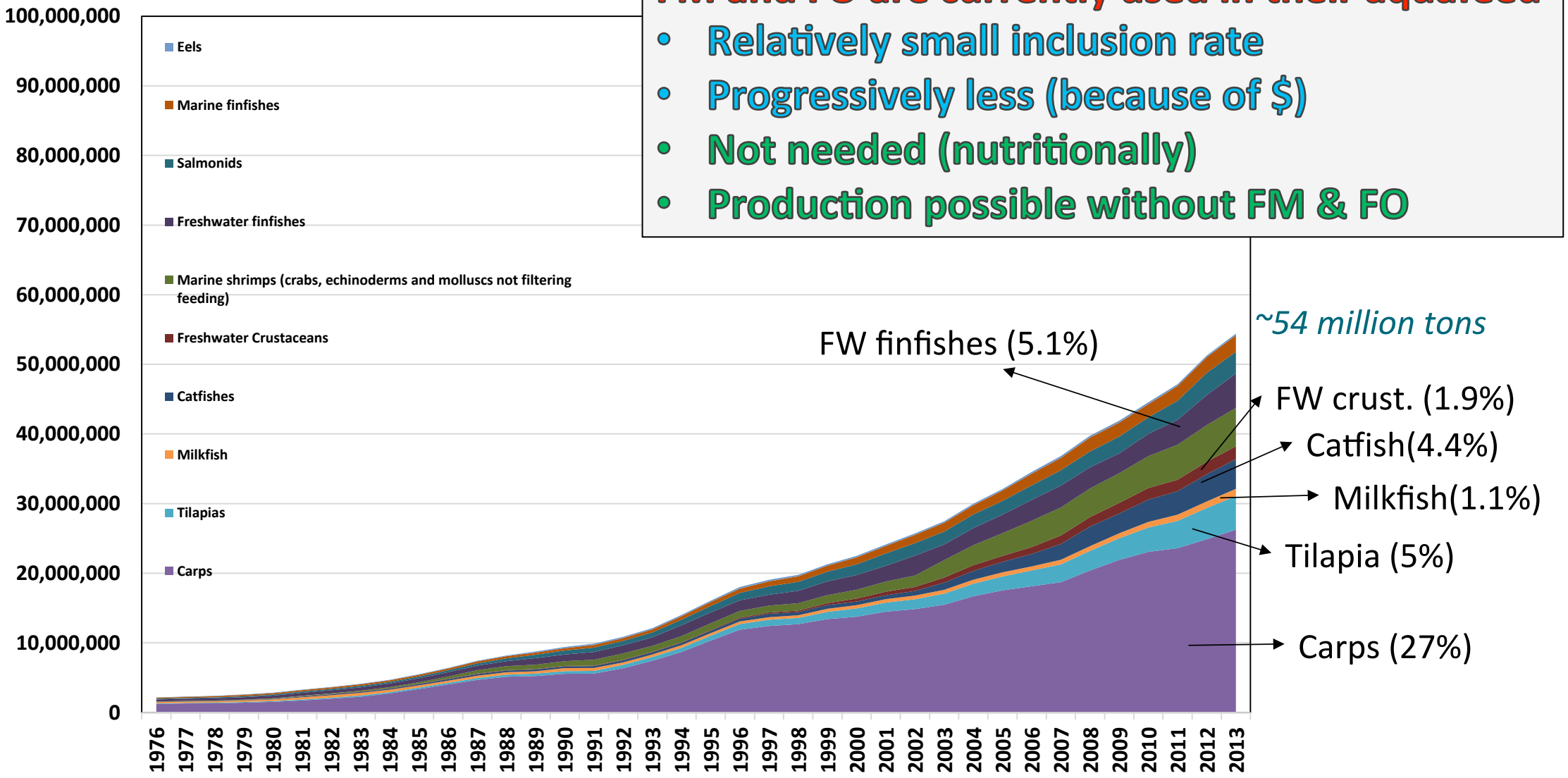


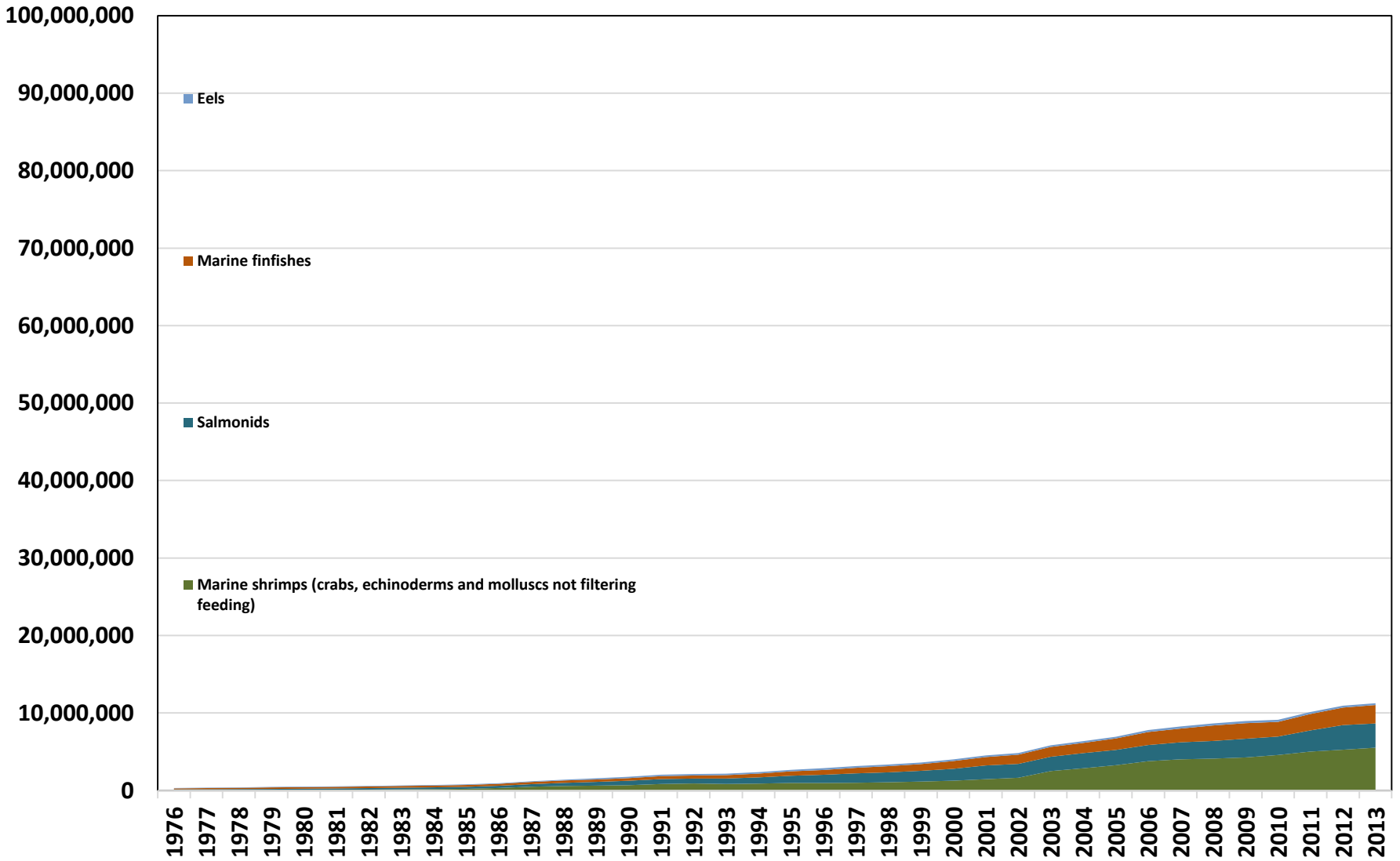
~54 million tons


100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Eels
Marine finfishes
Salmonids
Freshwater finfishes
Marine shrimps (crabs, echinoderms and molluscs not filtering feeding)
Freshwater Crustaceans
Catfishes
Milkfish
Tilapias
Carps
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
~54 million tons
FW finfishes (5.1%)
FW crust. (1.9%)
Catfish(4.4%)
Milkfish(1.1%)
Tilapia (5%)
Carps (27%)

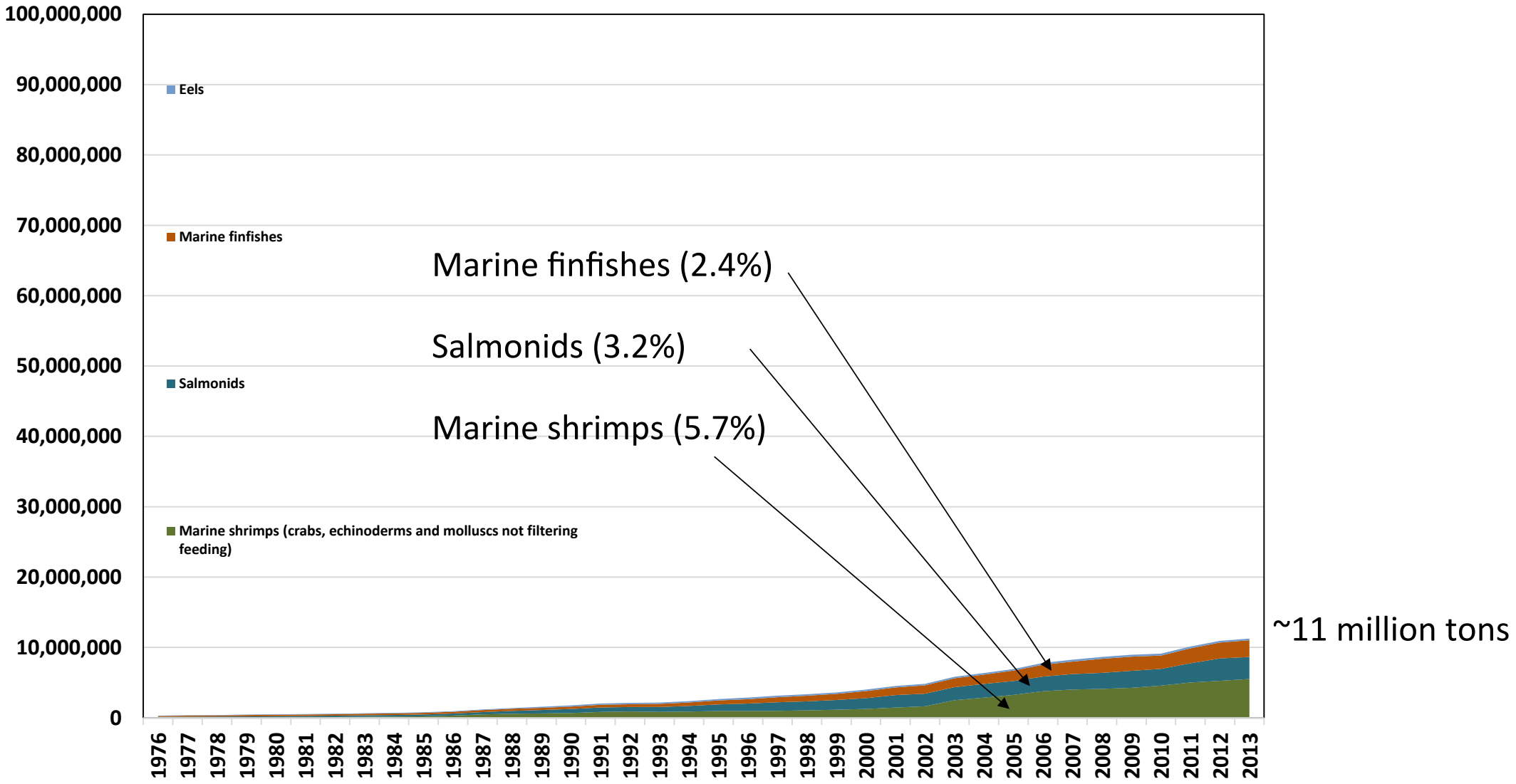
FM and FO are currently used in their aquafeed

- Relatively small inclusion rate
- Progressively less (because of $)
- Not needed (nutritionally)
- Production possible without FM & FO





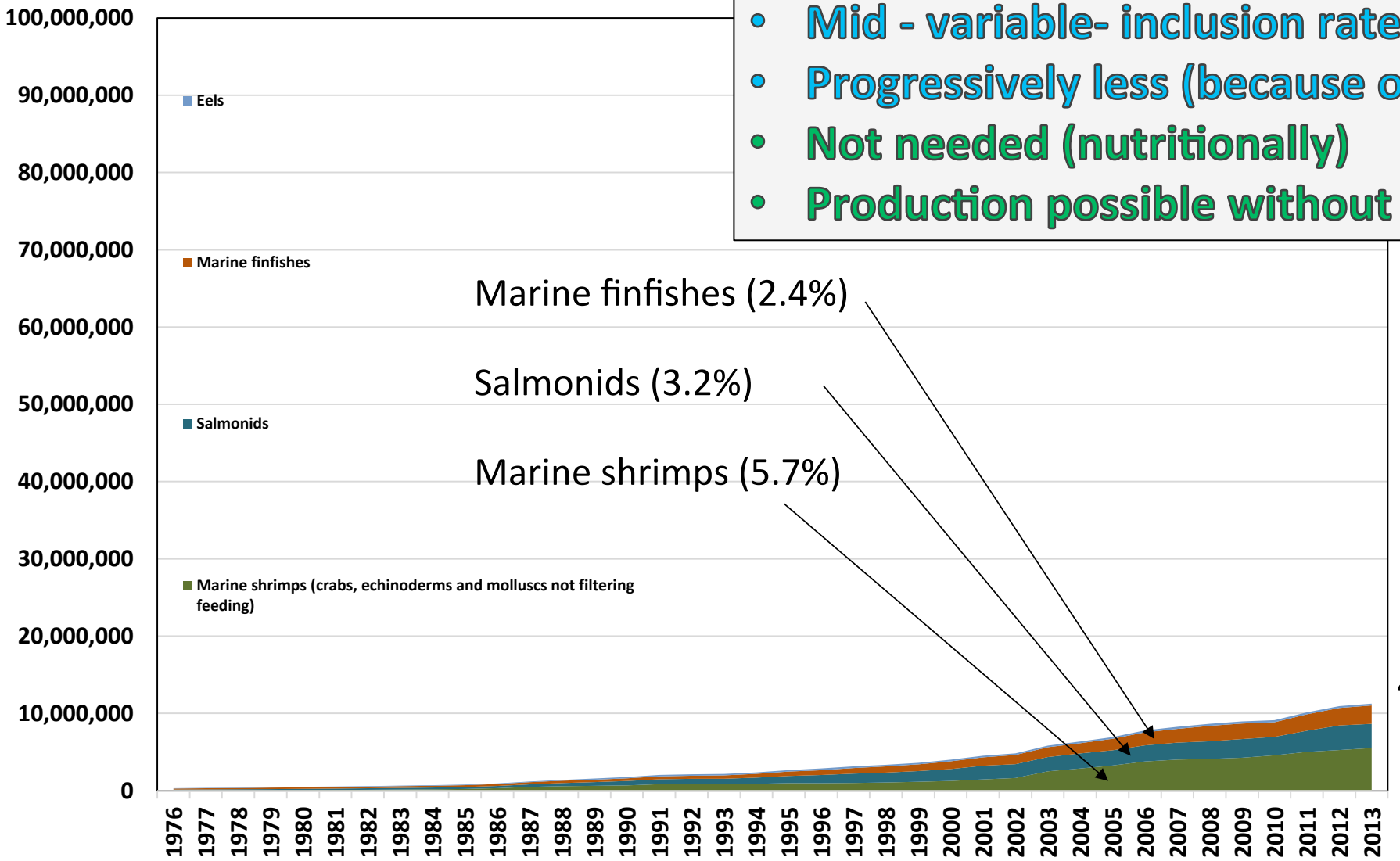
~11 million tons



~11 million tons

FM and FO are currently used in their aquafeed

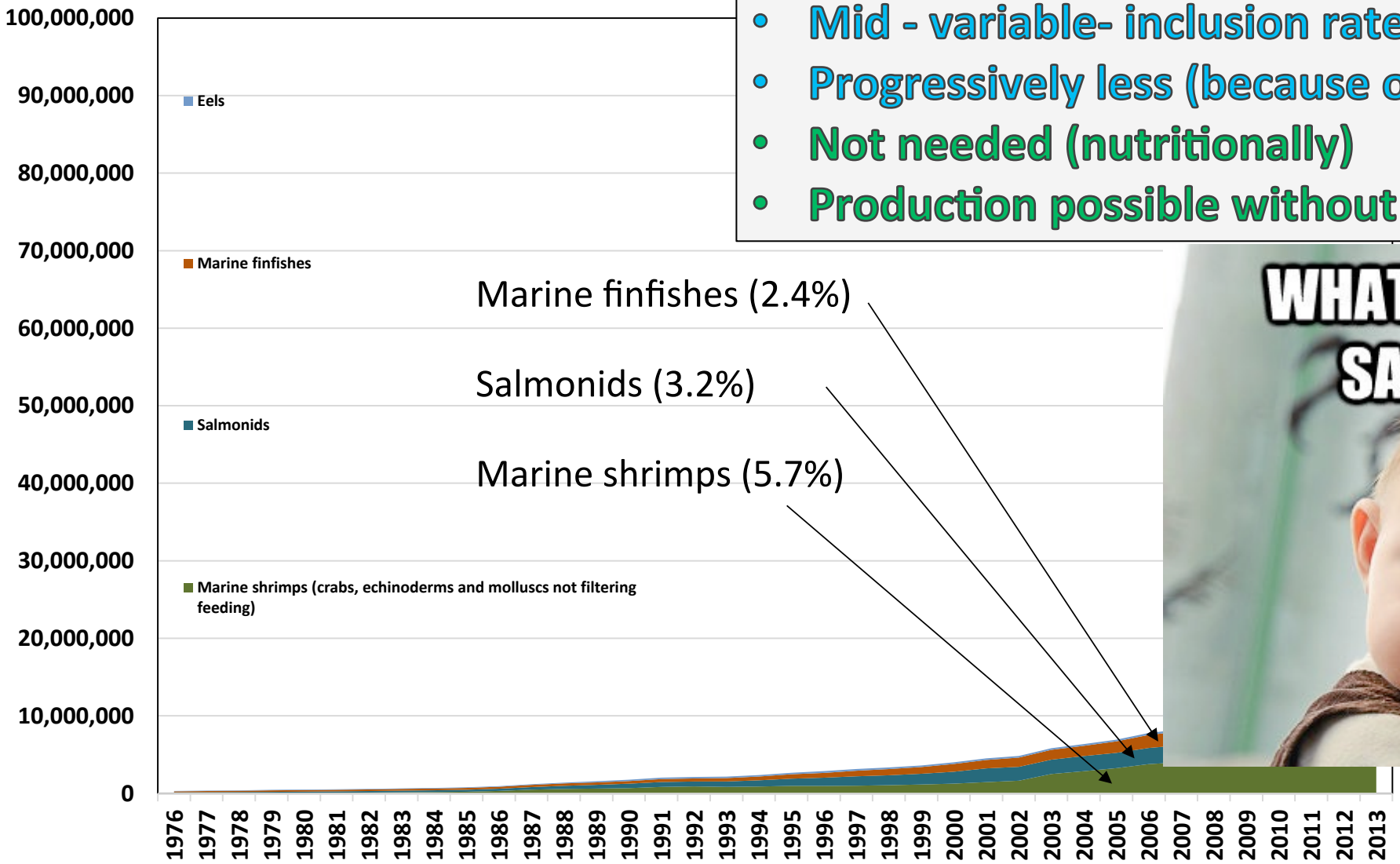
- Mid - variable- inclusion rate
- Progressively less (because of $)
- Not needed (nutritionally)
- Production possible without FM & FO



~11 million tons

FM and FO are currently used in their aquafeed

- Mid - variable- inclusion rate
- Progressively less (because of $)
- Not needed (nutritionally)
- Production possible without FM & FO



Fishmeal

No fish, nor shrimp, needs any fishmeal

- They need:
  - Essential amino acids
  - Correct protein/energy ratio

FM is just an excellent source of highly digestible, highly palatable, dietary protein, with an excellent AA composition (essential and not, + taurine) and no anti-nutritional factors.

- FM can be replaced! …. but it will cost $.
- We need coordinated and adequately supported R&D investments to reduce costs of FM replacement.

Gatlin et al. 2007 *Aquaculture Research,* 38**,** 551-579
Hardy 2010 *Aquaculture Research,* 41**,** 770-776

Fish oil

No fish, nor shrimp, needs any fish oil

They need:

- Highly digestible energy sources
- Essential fatty acids (and in particular omega-3)
- Shrimp: also need phospholipids and cholesterol

Plenty of options of alternative oils providing highly digestible energy, phospholipids and cholesterol.

The only real bottleneck is omega-3 (long-chain) (aka n-3 LC-PUFA)

- EPA (20:5n-3; *eicosapentaenoic acid*)
- DHA (22:6n-3; *docosahexaenoic acid*)

Turchini et al. 2009 *Reviews in Aquaculture, 1, 10-57*
Turchini, Ng, Tocher 2011. *Fish Oil replacement and Alternative Lipid Sources in Aquaculture Feeds*. CRC Press, Taylor & Francis Group

EFA REQUIREMENTS OF FISH

1. Physiological EFA Requirement. To prevent EFA deficiency/nutritional pathology.

Low: Some species C_{18} PUFA can satisfy, even in species requiring LC-PUFA, only ~ 0.2 to 0.8% of diet.

Not too big a problem.

2. EFA Requirement for Optimal Growth/Health.

Higher: but unknown & variable. Probably related to dietary lipid, endogenous metabolism, and other factors

Problem only for some species ($ for EPA/DHA)

3. Nutritional quality expectations

Very High: To satisfy human "requirements" for n-3LC-PUFA, i.e. for fish to remain as the major providers of EPA and DHA

That is the big problem!

it is impacting the sector and it will shape it

Tocher 2015. *Aquaculture* 449:94–107

DEAKIN UNIVERSITY

EVOLVING AQUAFEED

FM & FO inclusion in aquafeed is constantly and rapidly declining

Fishmeal

Fish oil

Agriculture (land based) products & by-products

EVOLVING AQUAFEED

FM & FO inclusion in aquafeed is constantly and rapidly declining

Fishmeal

Fish oil

Agriculture (land based) products & by-products

Why aquafeed companies do so?

DEAKIN UNIVERSITY

EVOLVING AQUAFEED

FM & FO inclusion in aquafeed is constantly and rapidly declining

Because: (part 1)

1) Consumers' perception of "sustainability" and impact of aquaculture
2) Retailers' perception of consumers' expectations
3) Farmers' perception of retailers' expectations

I. Farmers asking for low FM & low FO inclusion
II. Marketing tool for feed companies

DEAKIN UNIVERSITY

EVOLVING AQUAFEED

FM & FO inclusion in aquafeed is constantly and rapidly declining

Because: (part 2)

1) Increasing prices of FM & FO

   → Reducing margin

2) Uncertain availability (quantity and quality) of FM and FO

   → Constant re-formulation (technologically challenging and expensive)

DEAKIN UNIVERSITY

Fishmeal

Replacing Fish Meal

- **No effects on final product quality**

Possible effects are on:

- Fish performance
- Fish health

A “quantitative” issue!

Fish oil

Replacing Fish Oil

- **Minor/no effects on performance and health**
- **Major effects on final product quality**
  - Final fatty acid composition
  - Reduction (dilution) of long chain omega-3 Fatty acids (EPA & DHA)

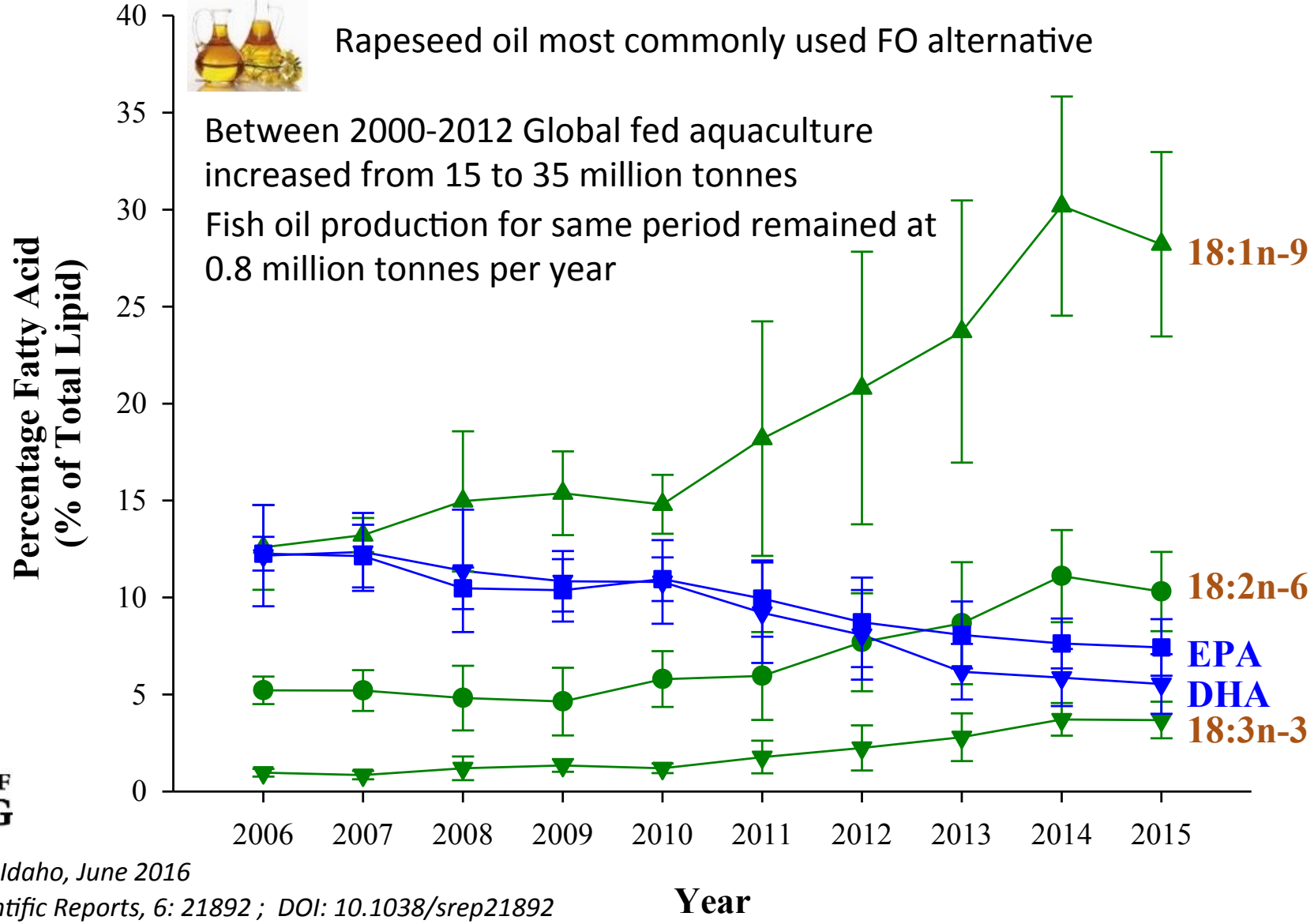
A “qualitative” issue!

Changing aquafeed and effects on nutritional composition

Rapeseed oil most commonly used FO alternative

Between 2000-2012 Global fed aquaculture increased from 15 to 35 million tonnes

Fish oil production for same period remained at 0.8 million tonnes per year



UNIVERSITY OF STIRLING

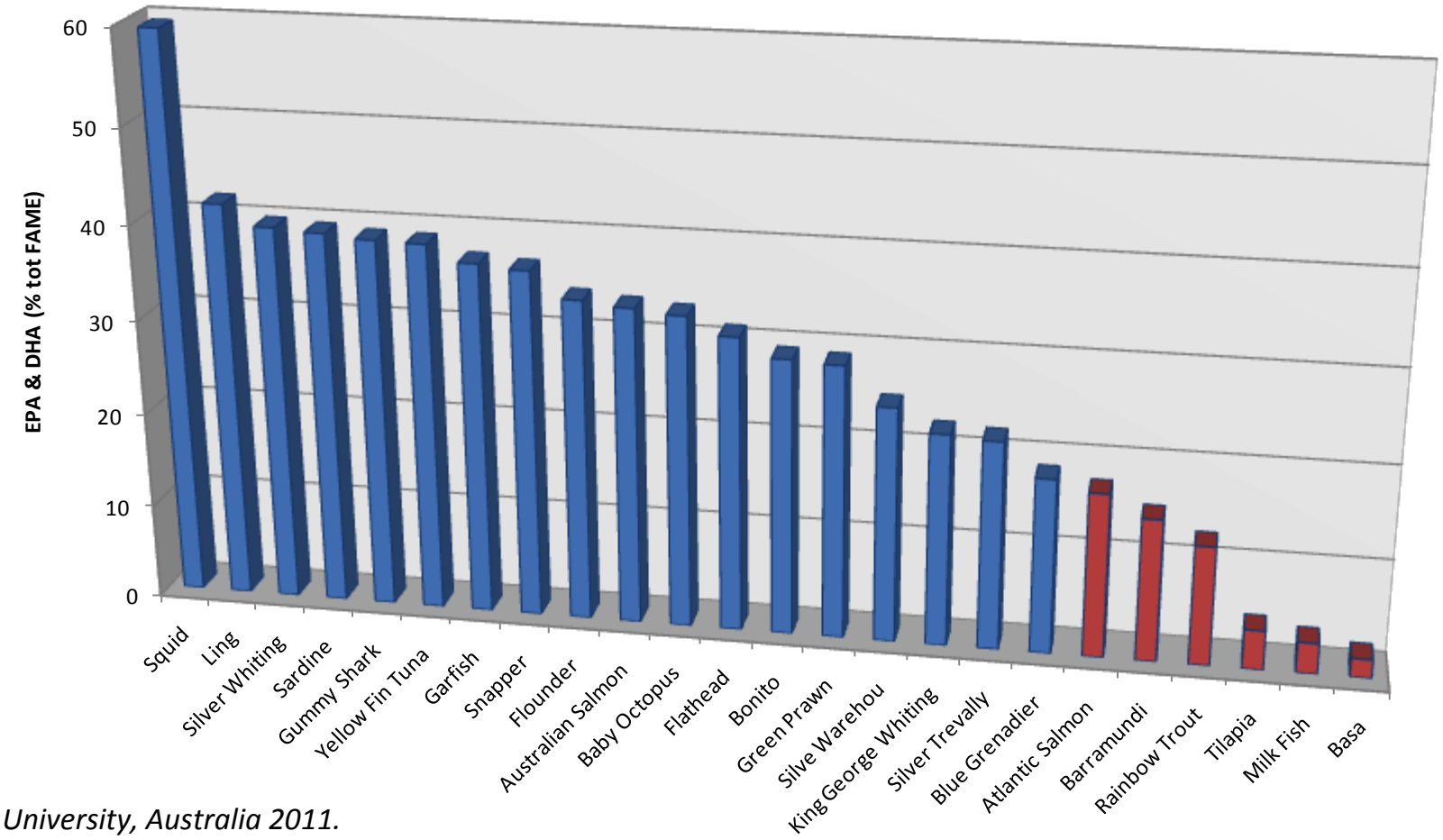
Sprague et al. XVI ISFNF. Idaho, June 2016

Sprague et al. 2016. Scientific Reports, 6: 21892 ; DOI: 10.1038/srep21892

DEAKIN UNIVERSITY

Changing aquafeed and effects on nutritional composition

Farmed fish (RED) are the worst for LC Omega-3 (**when expressed as %**).

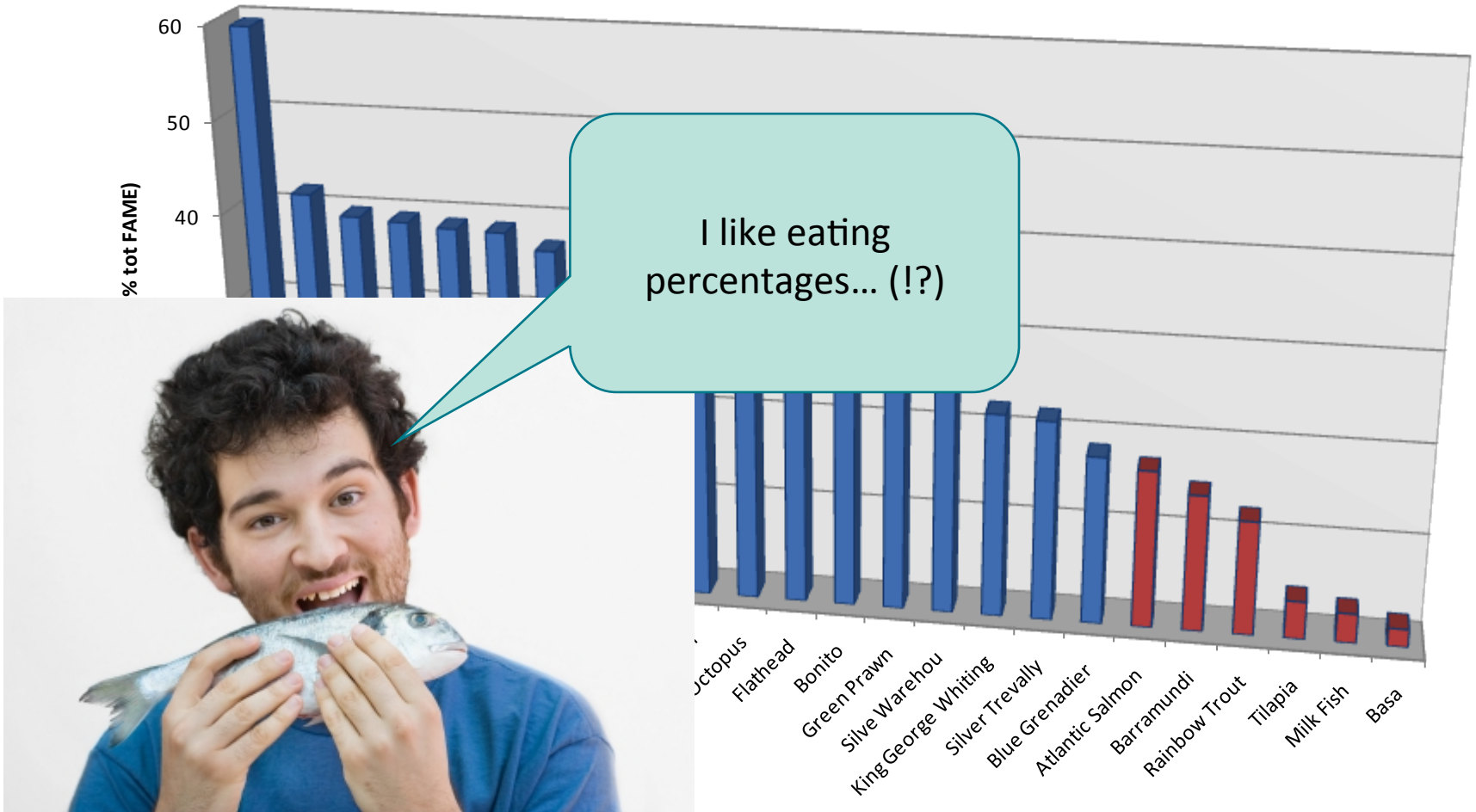


Unpublished data:
Francis et al. Deakin University, Australia 2011.

DEAKIN UNIVERSITY

Changing aquafeed and effects on nutritional composition

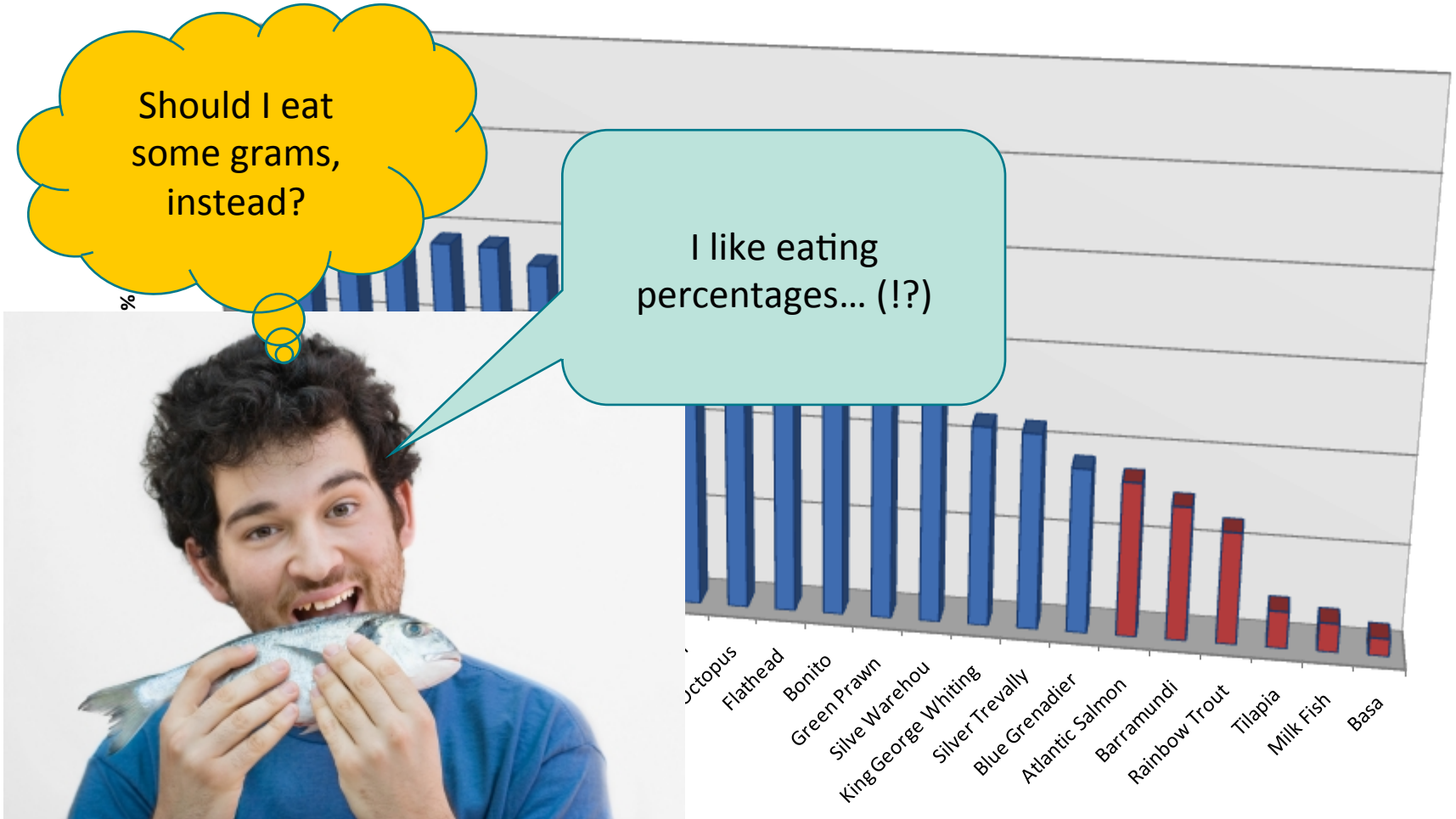
Farmed fish (RED) are the worst for LC Omega-3 (**when expressed as %**).



DEAKIN UNIVERSITY

Changing aquafeed and effects on nutritional composition

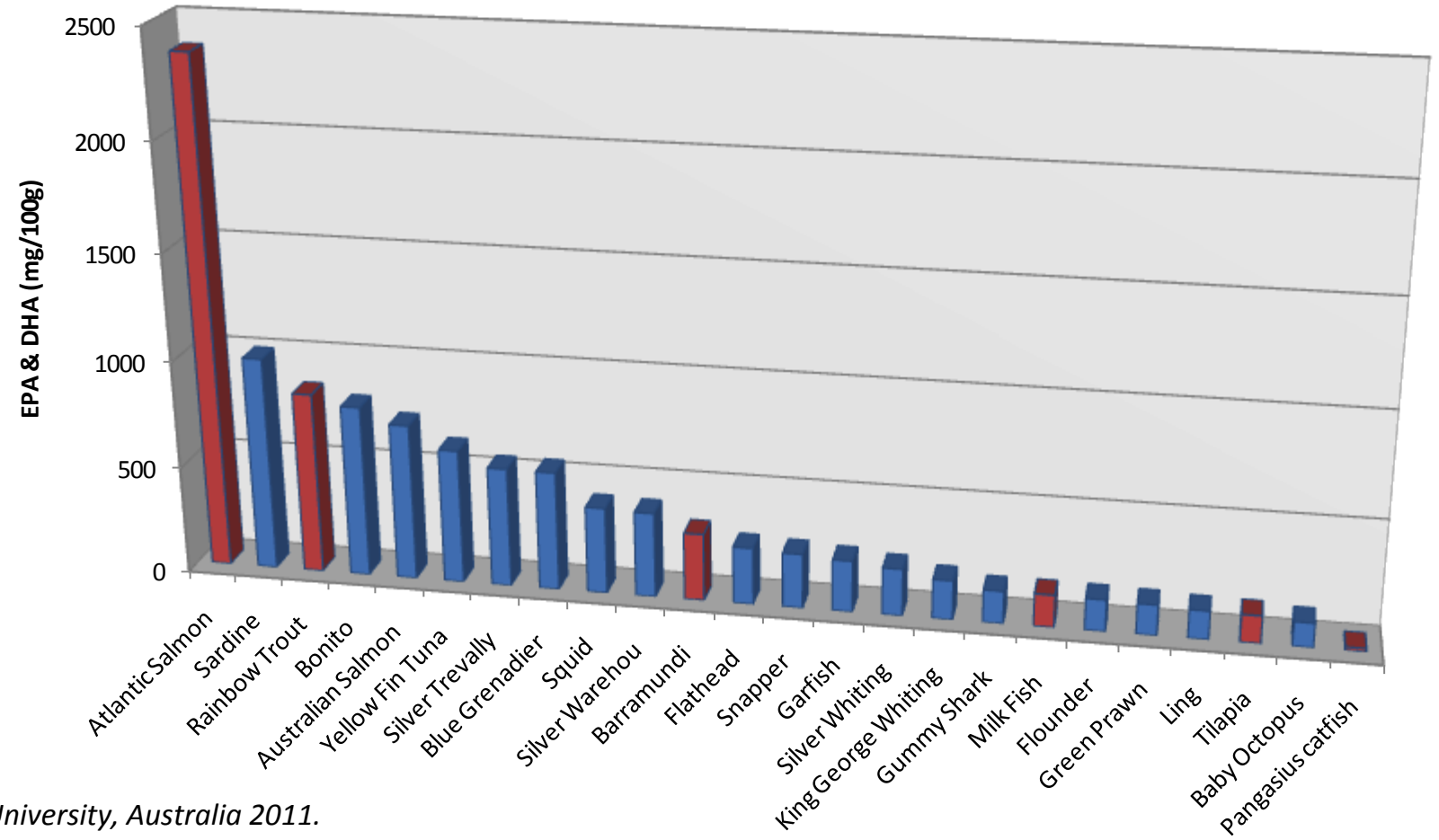
Farmed fish (RED) are the worst for LC Omega-3 (**when expressed as %**).



DEAKIN UNIVERSITY

Changing aquafeed and effects on nutritional composition

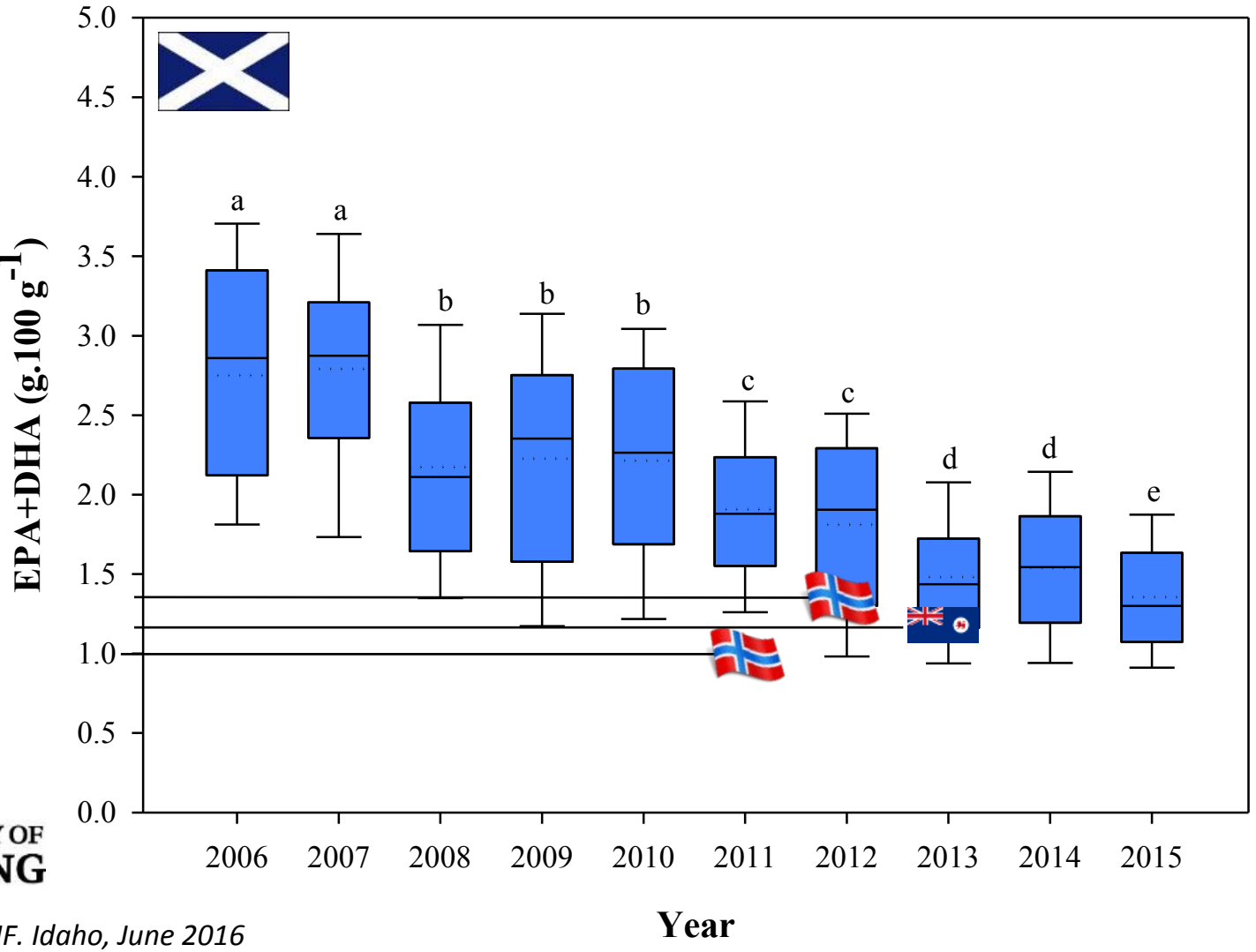
Farmed fish (RED) are amongst the best for LC Omega-3 (as **mg/100g**).



Unpublished data:
Francis et al. Deakin University, Australia 2011.

DEAKIN UNIVERSITY

EPA+DHA LEVELS IN SCOTTISH FARMED SALMON



Jensen et al. (2012). *Nutr. Bull.*, 37, 25-29

Ytrestøyl et al. (2015). *Aquaculture*, 448, 365-374

Nichols et al. (2014). *Nutrients*, 6, 1063-1079

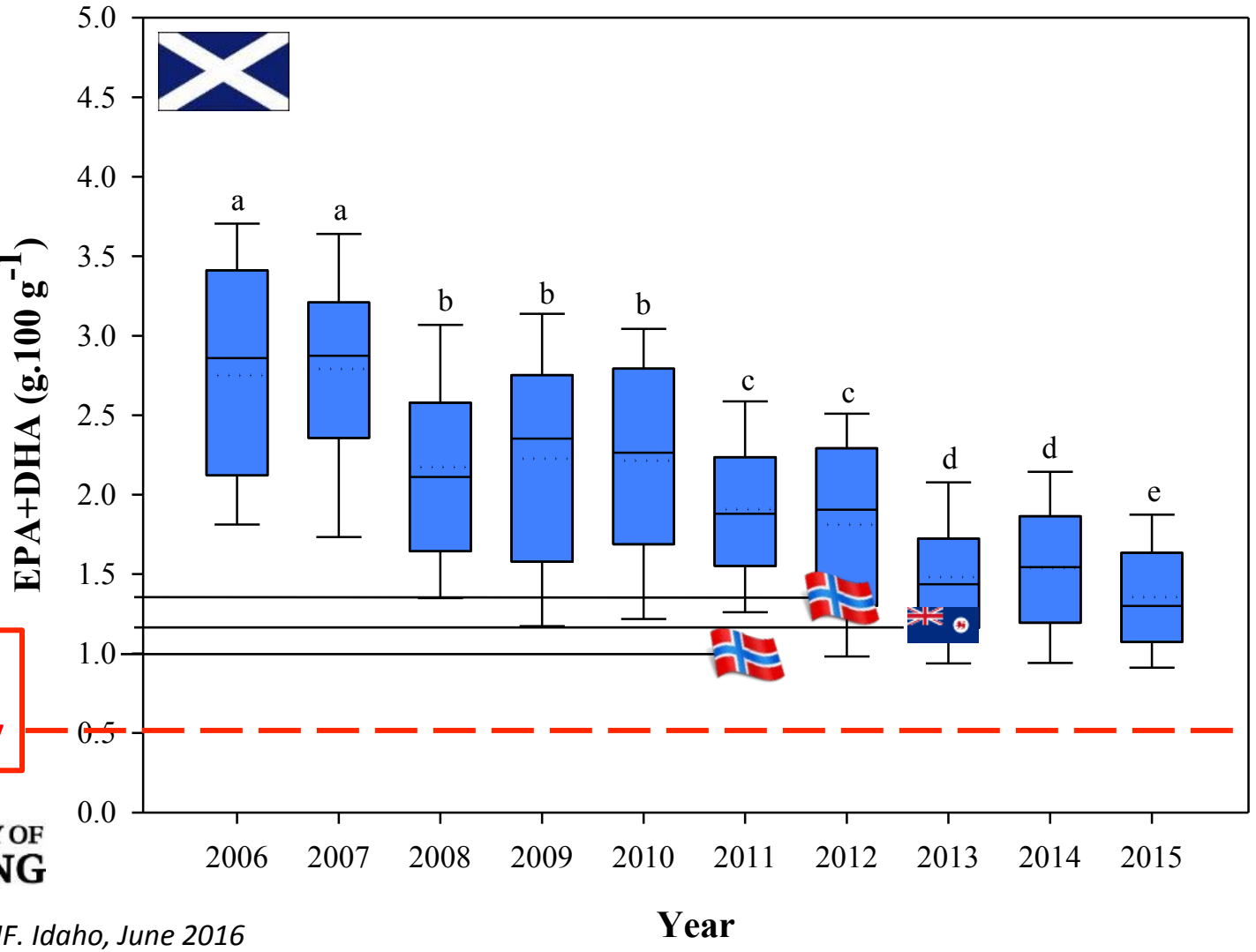
UNIVERSITY OF STIRLING

DEAKIN UNIVERSITY

Sprague et al. XVI ISFNF. Idaho, June 2016

Sprague et al. 2016. Scientific Reports, 6: 21892 ; DOI: 10.1038/srep21892

EPA+DHA LEVELS IN SCOTTISH FARMED SALMON



RDI
500 mg/day

Jensen et al. (2012). *Nutr. Bull.*, 37, 25-29

Ytrestøyl et al. (2015). *Aquaculture*, 448, 365-374

Nichols et al. (2014). *Nutrients*, 6, 1063-1079

UNIVERSITY OF STIRLING

DEAKIN UNIVERSITY

Sprague et al. XVI ISFNF. Idaho, June 2016

Sprague et al. 2016. Scientific Reports, 6: 21892 ; DOI: 10.1038/srep21892

The future

Fish meal:

- Almost all global production available for aquafeed
- No longer a protein source, but a specialty ingredient
- Less per unit of feed, but better used!

Fishmeal

Fish oil:

- Small (nil) fraction of global production available for aquafeed
- Alternative sources of n-3 LC-PUFA needed
  - not edible (or low edible qualities)
    - By-products oil
    - GM crops
    - single cell/algae oils

Fish oil

The future

Fish meal:

- Almost all global production available for aquafeed
- No longer a protein source, but a specialty ingredient
- Less per unit of feed, but better used!

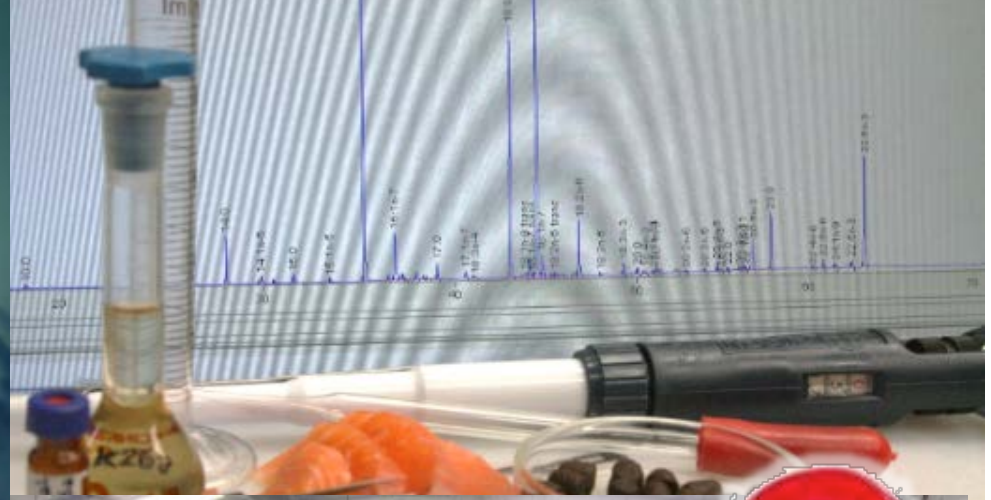
Fishmeal

Fish oil:

- Small (nil) fraction of global production available for aquafeed
- Alternative sources of n-3 LC-PUFA needed
  - not edible (or low edible qualities)
    - By-products oil
    - GM crops
    - single cell/algae oils

Fish oil

Industry: we need to define minimal level of omega-3 acceptable in final products (species specific, and likely relative to RDI and marketing objectives).



Thank you!

A/Prof. Giovanni M. Turchini
School of Life and Environmental Sciences,
Deakin University, Geelong, Australia
giovanni.turchini@deakin.edu.au
http://lab.org.au/
@NuSeaLab

NuSea.Lab
The Nutrition and Seafood Laboratory
Deakin University - Australia

DEAKIN UNIVERSITY