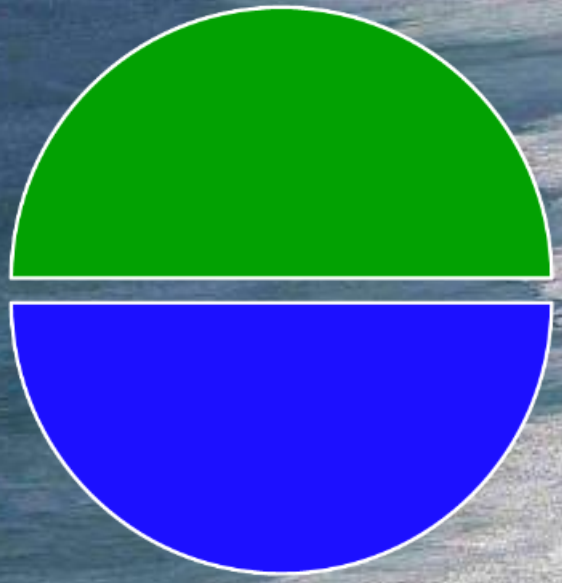
Balanced harvesting in fisheries: the inverted food pyramid

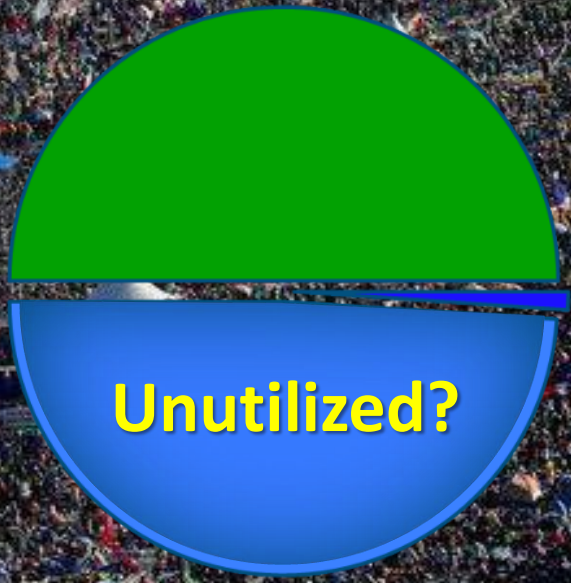
Jeppe Kolding, University of Bergen

Eufishmeal Conference 2015, Iceland 27. August



The oceans contribute 50% of the global biological production

But humans only collect 2% of our food from the oceans.



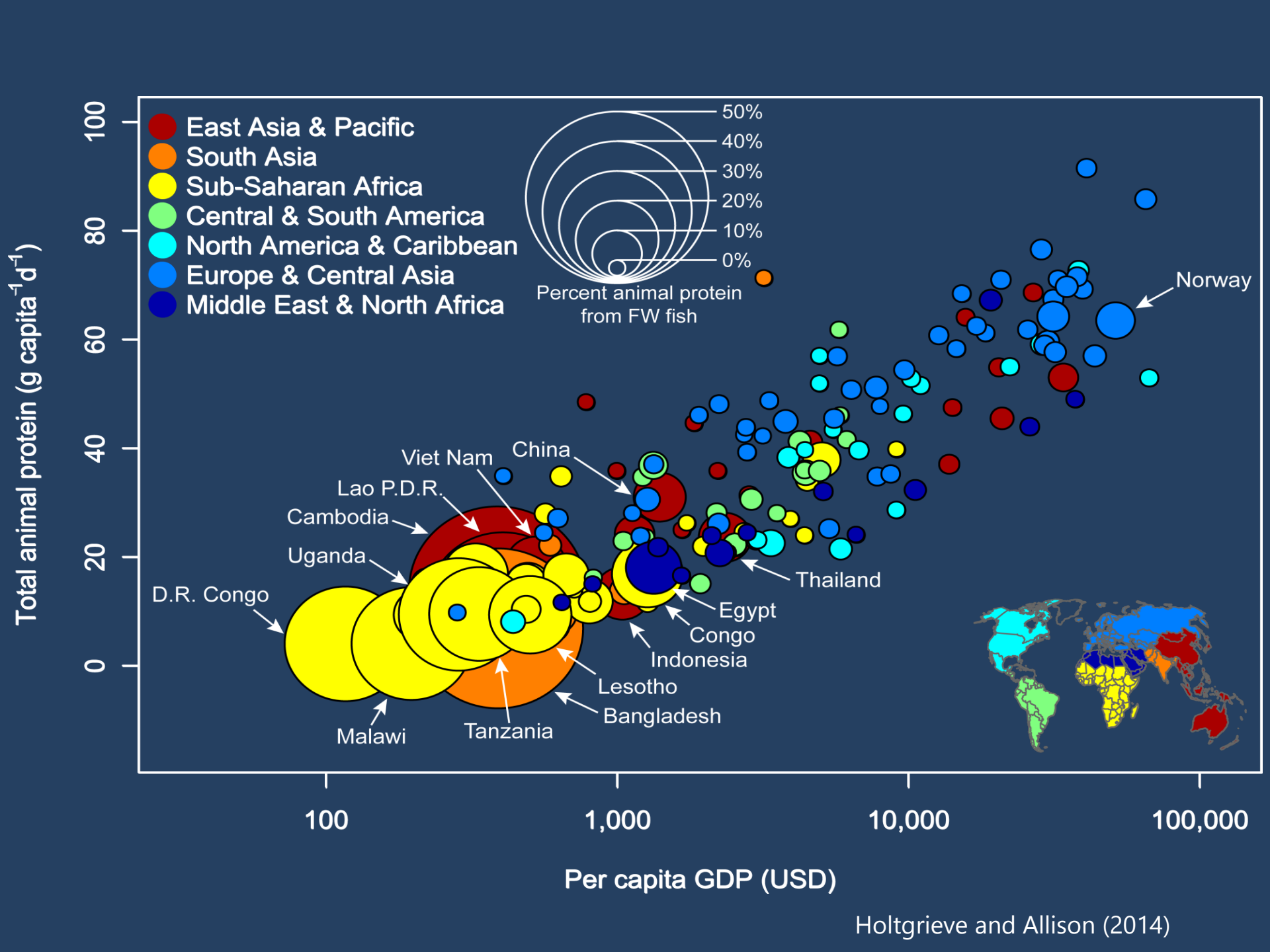
Court

NATIONAL GEOGRAPHIC

http://ocean.nationalgeographic.com/ocean/global-fish-crisis-

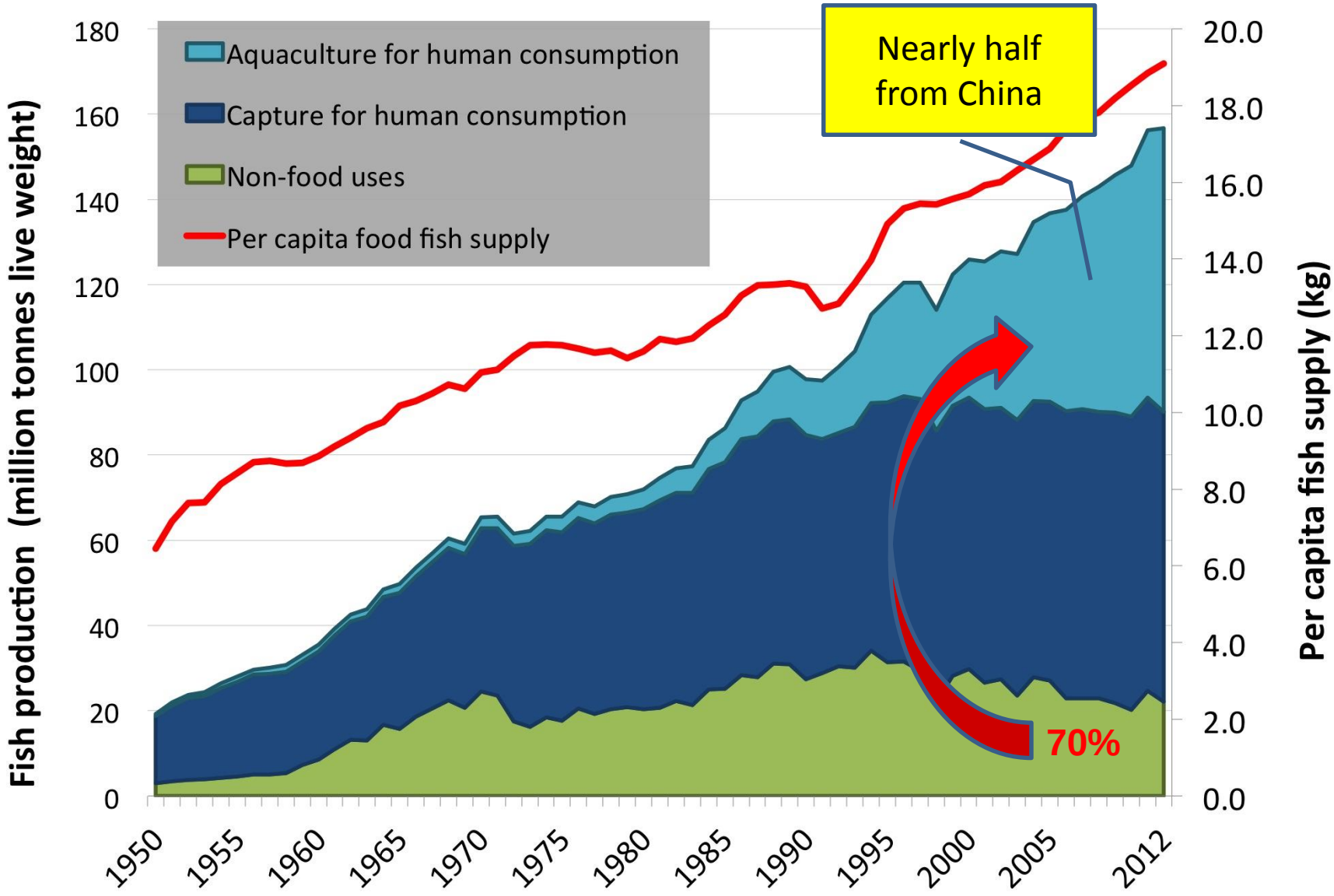
Fish and Human health

Primary sources of vitamin A and zinc



Holtgrieve and Allison (2014)

Global production fisheries & aquaculture



Tacon & Metian 2015 Reviews in Fisheries Science & Aquaculture

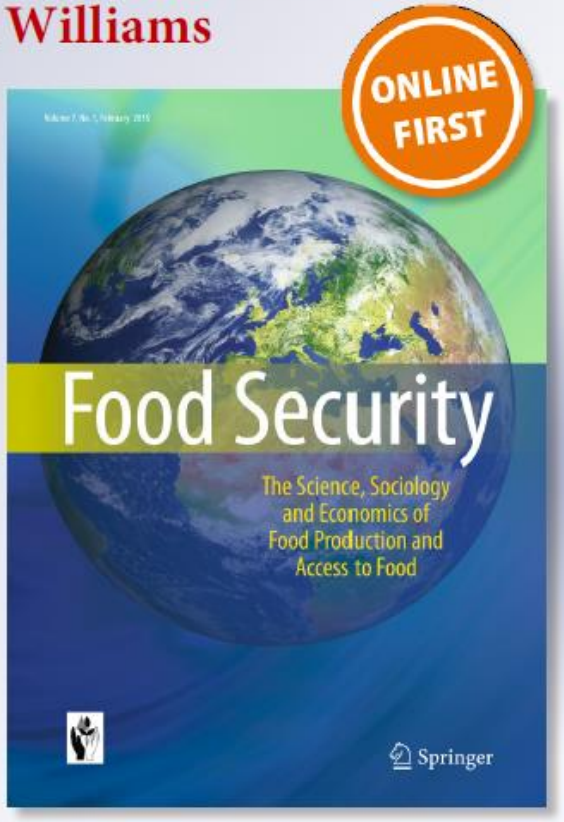
Feeding 9 billion by 2050 – Putting fish back on the menu

Christophe Béné, Manuel Barange, Rohana Subasinghe, Per Pinstrup-Andersen, Gorka Merino, Gro-Ingunn Hemre & Meryl Williams

Food Security
The Science, Sociology and Economics of Food Production and Access to Food

ISSN 1876-4517

Food Sec.
DOI 10.1007/s12571-015-0427-z



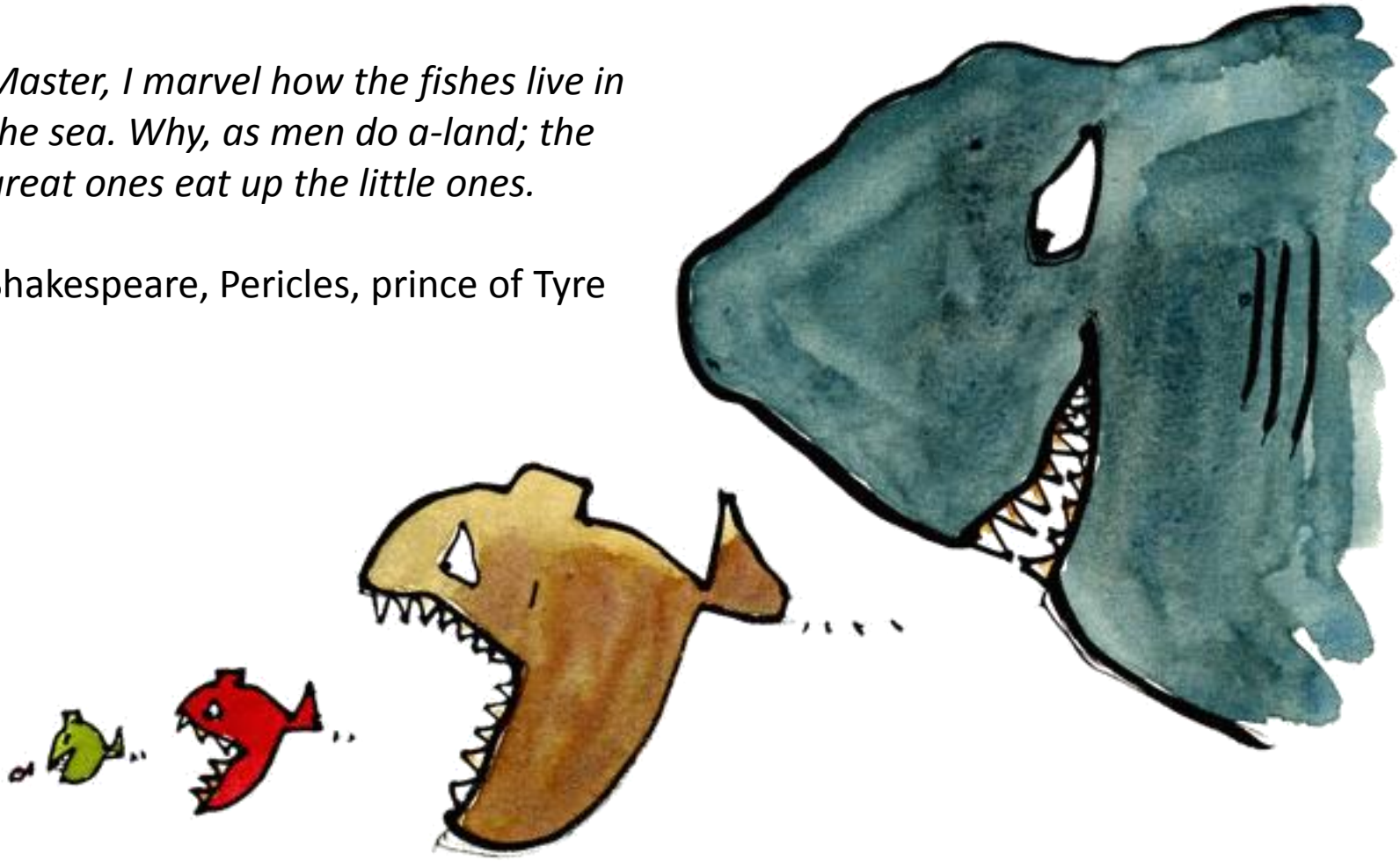
The role of aquaculture?

"..in terms of efficiency, fish in aquaculture systems are very efficient converters of feed into protein – in fact far more efficient than most terrestrial livestock system."

Fish eat fish

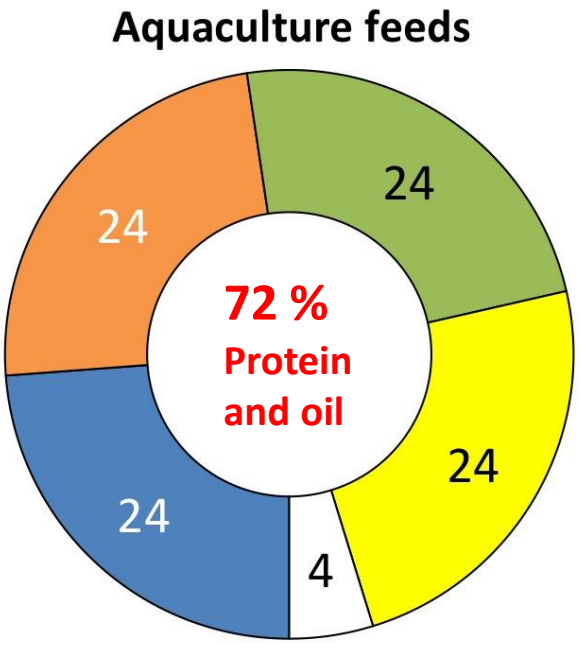
Master, I marvel how the fishes live in the sea. Why, as men do a-land; the great ones eat up the little ones.

Shakespeare, Pericles, prince of Tyre



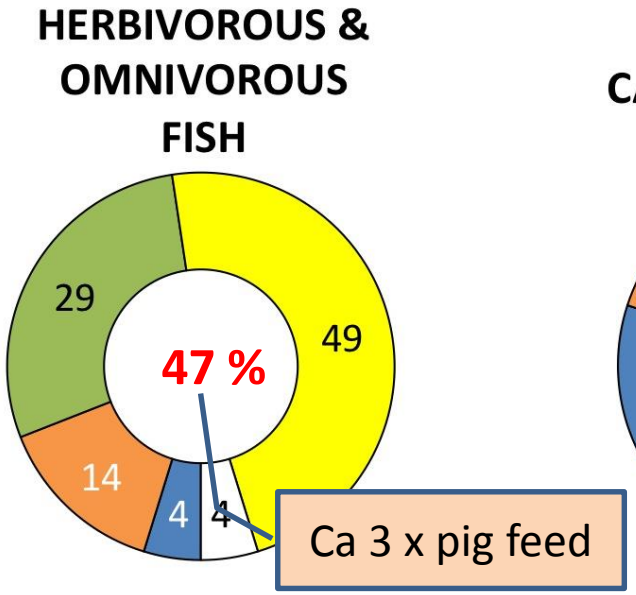
Cartoon by Frits Ahlefelt

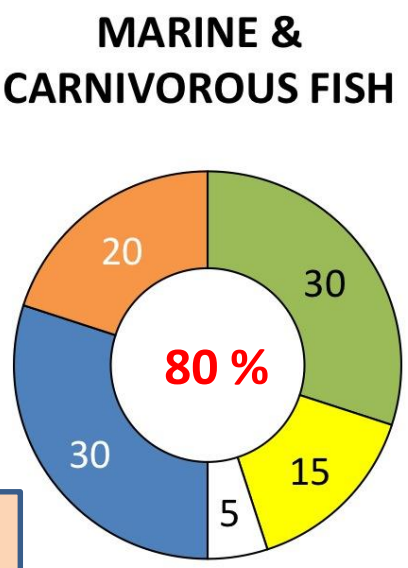
Major categories of feed ingredients in aquaculture feeds

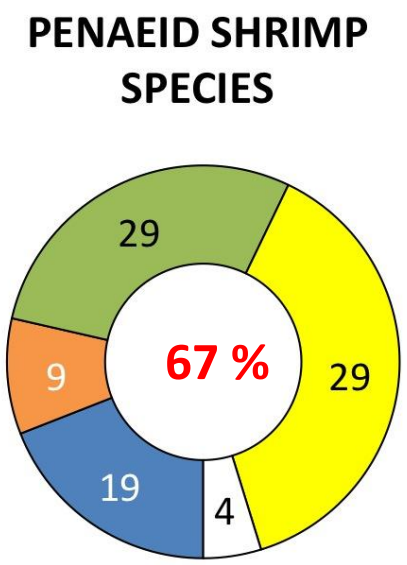


- Aquatic protein meals & oils
- Terrestrial animal proteins & oils
- Terrestrial plant proteins & oils
- Other plant meals & fillers
- Feed additives

% = total combined protein and oil







Tacon & Metian 2015 Reviews in Fisheries Science & Aquaculture

Feed, food and nutrition

	FCR = kg formula feed pr kg meat
Salmon	1.15
Chicken	1.79
Pig	2.63

Source: Torrissen et al. 2013

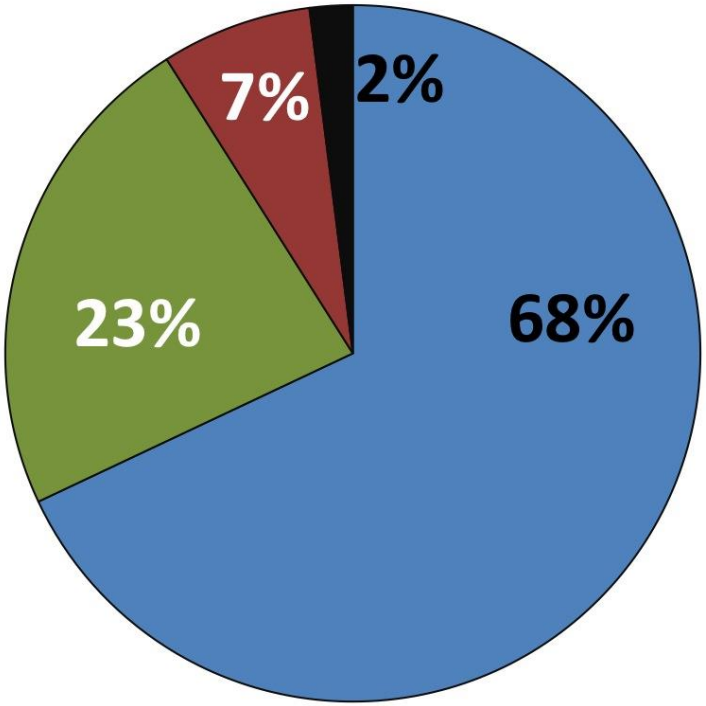
	Metabolizable energy ME (Kcal/g)
Fats	8.5
Protein	4.5
Carbohydrates	1.2-3.2

Fish are very **efficient** metabolizers of **protein** because of low cost of nitrogen excretion, but they are very **poor** metabolizers of **carbohydrates**, the cheapest and most abundant energy source in Nature

http://www.fao.org/docrep/x5738e/x5738e03.htm#chapter 2. nutritional bioenergetics in fish

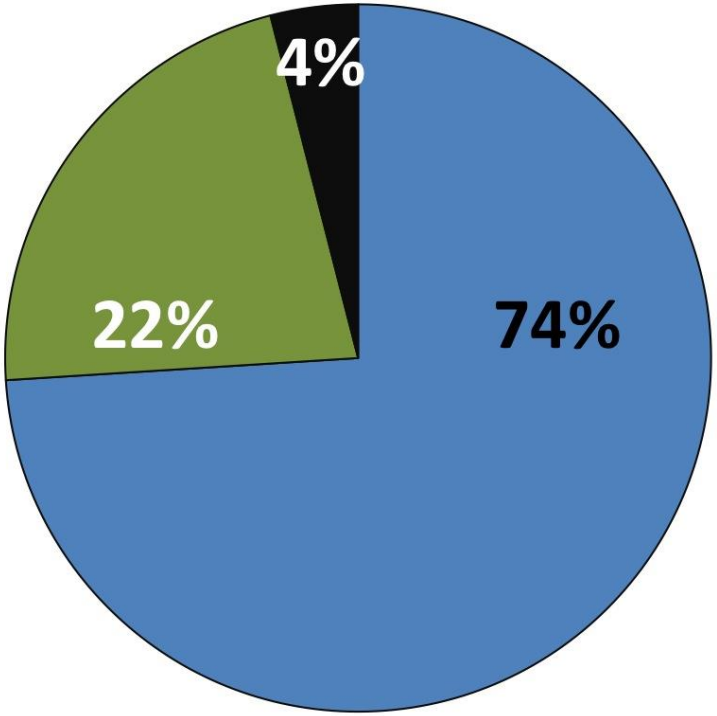
2012

Fishmeal uses*



- Aquaculture
- Pig
- Chicken
- Other

Fish oil uses



- Aquaculture
- Direct Human consumption
- Other uses

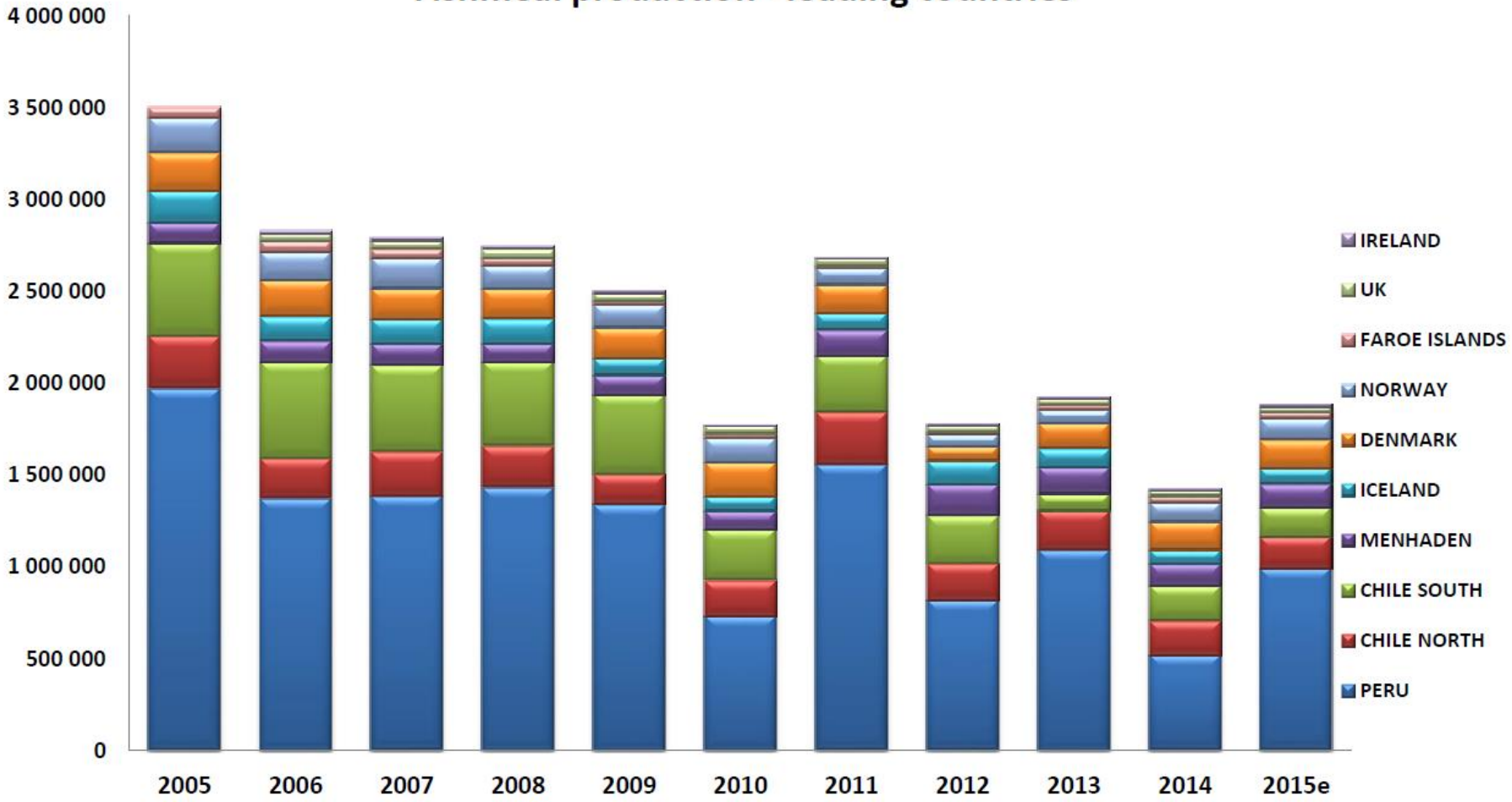
Source: IFFO

Tacon & Metian 2015

**cover 2011 and 2012*

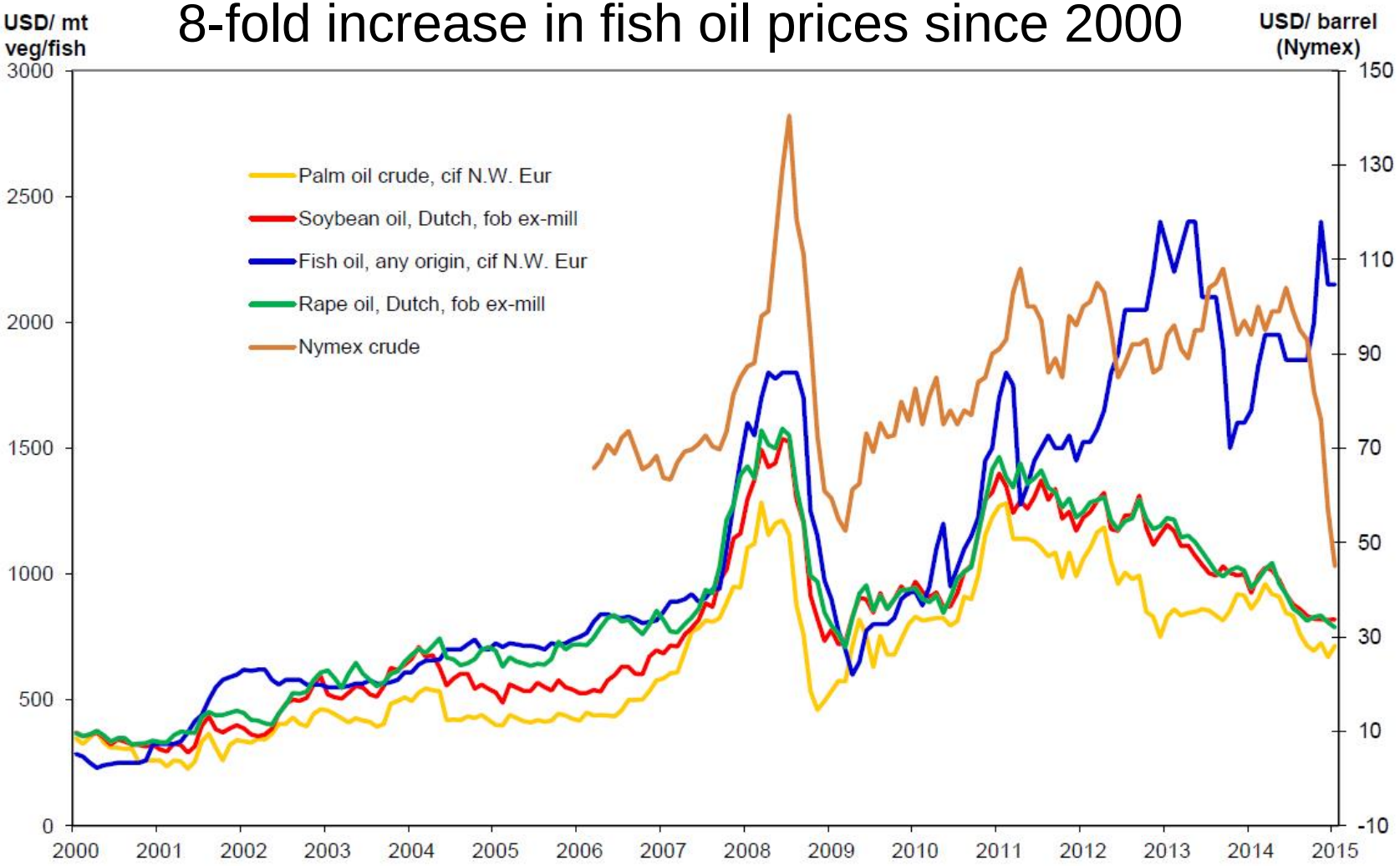
HOLTERMANN
- ESTABLISHED 1916 -

Fishmeal production - leading countries



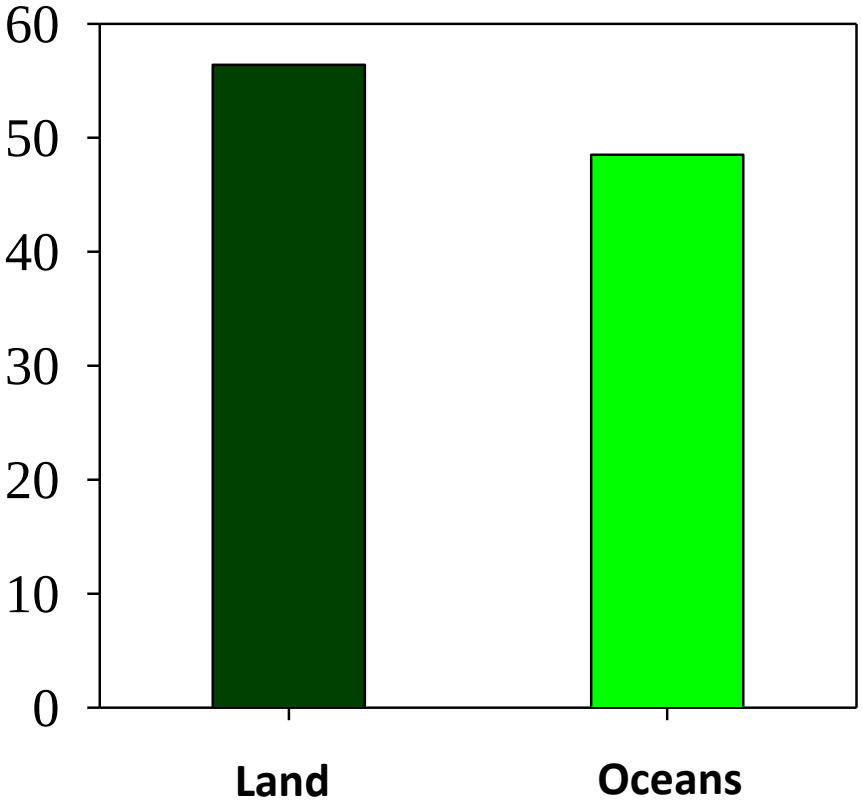
HOLTERMANN
- ESTABLISHED 1916 -

8-fold increase in fish oil prices since 2000

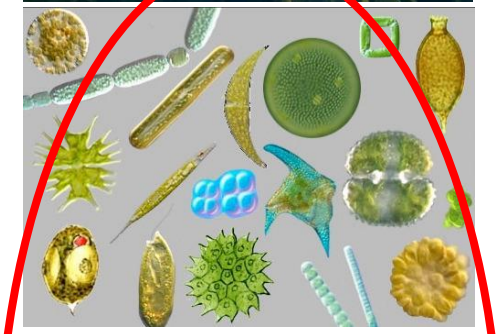


Can we harvest the waters as land?

Global plant production
Billion ton carbon (Giga t)



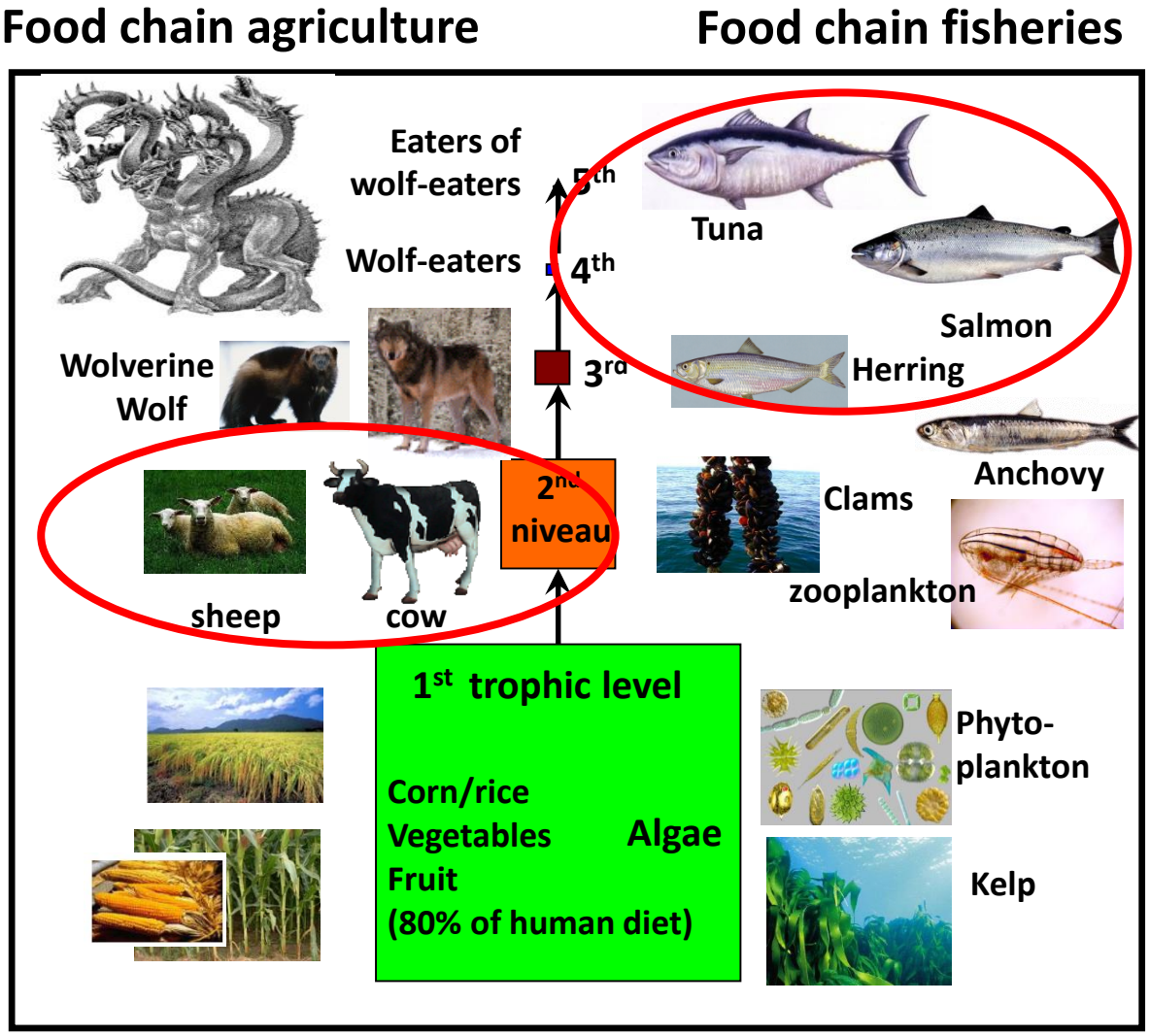
- ✓ **4-5% of the primary production on land is directly consumed by humans**



Courtesy of Yngvar Olsen

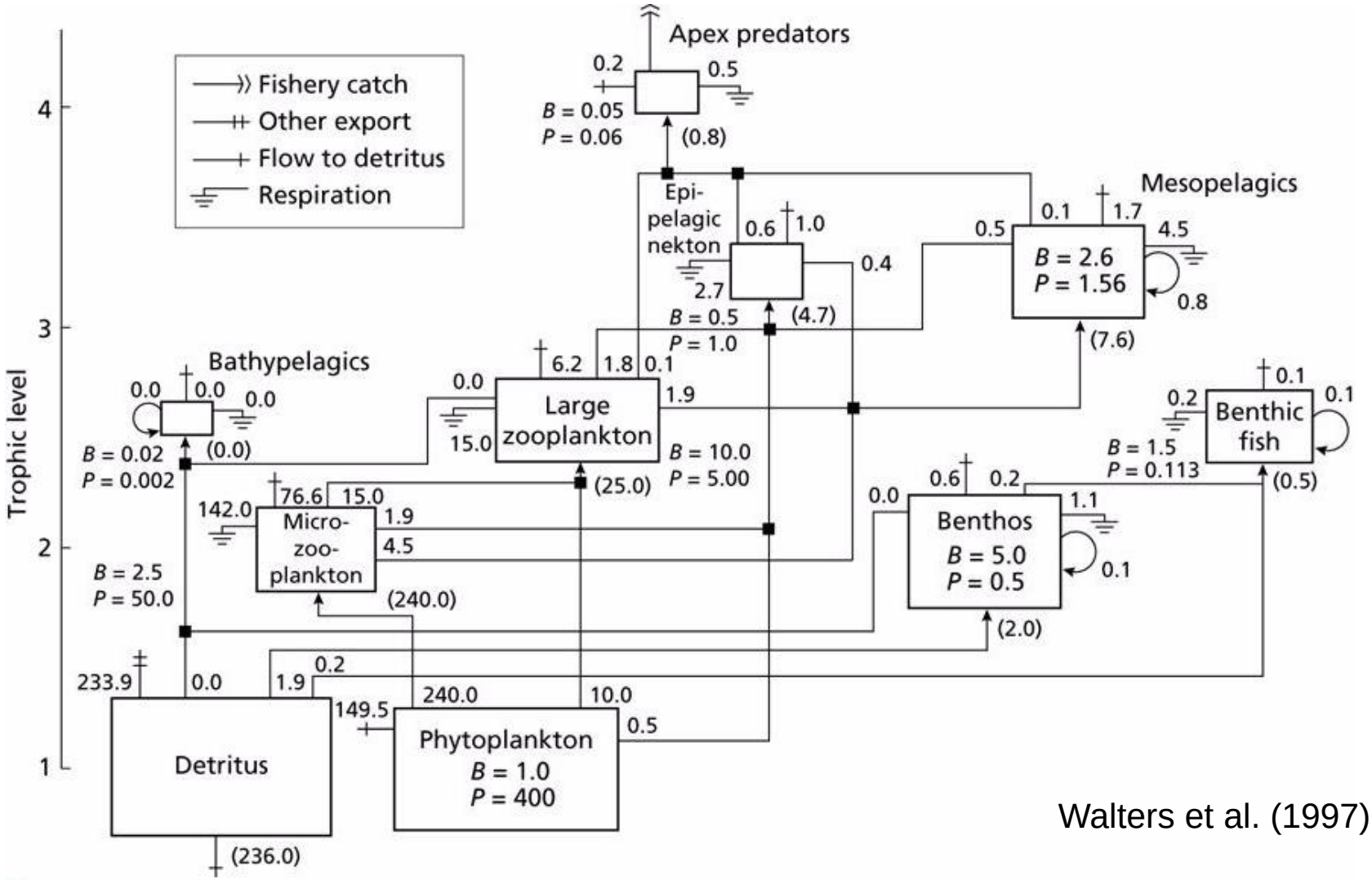
The food chain in fisheries and agriculture

- 4-5% of the primary production (TL 1) on land is directly consumed by humans
- All domesticated animals for food are herbivores (TL 2)
- Humans (TL 2.21) feed 2 trophic levels higher in the oceans than on land
- Very inefficient utilization of the primary productivity



After Duarte et al 2009

The ECOPATH trophic model



Walters et al. (1997)

Flow diagram of the central South China Sea pelagic ecosystem in the 1980s. Arrows indicate flow (t $km^{-2}y^{-1}$) and boxes ($\approx \log_{10}$ of B) the size of biomass (t km^{-2}).

The global picture: 150 Ecopath models from all over the world

Vol. 512: 155–166, 2014
doi: 10.3354/meps10946

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published October 9

Contribution to the Theme Section 'Trophodynamics in marine ecology'

FREE ACCESS

A century of fish biomass decline in the ocean

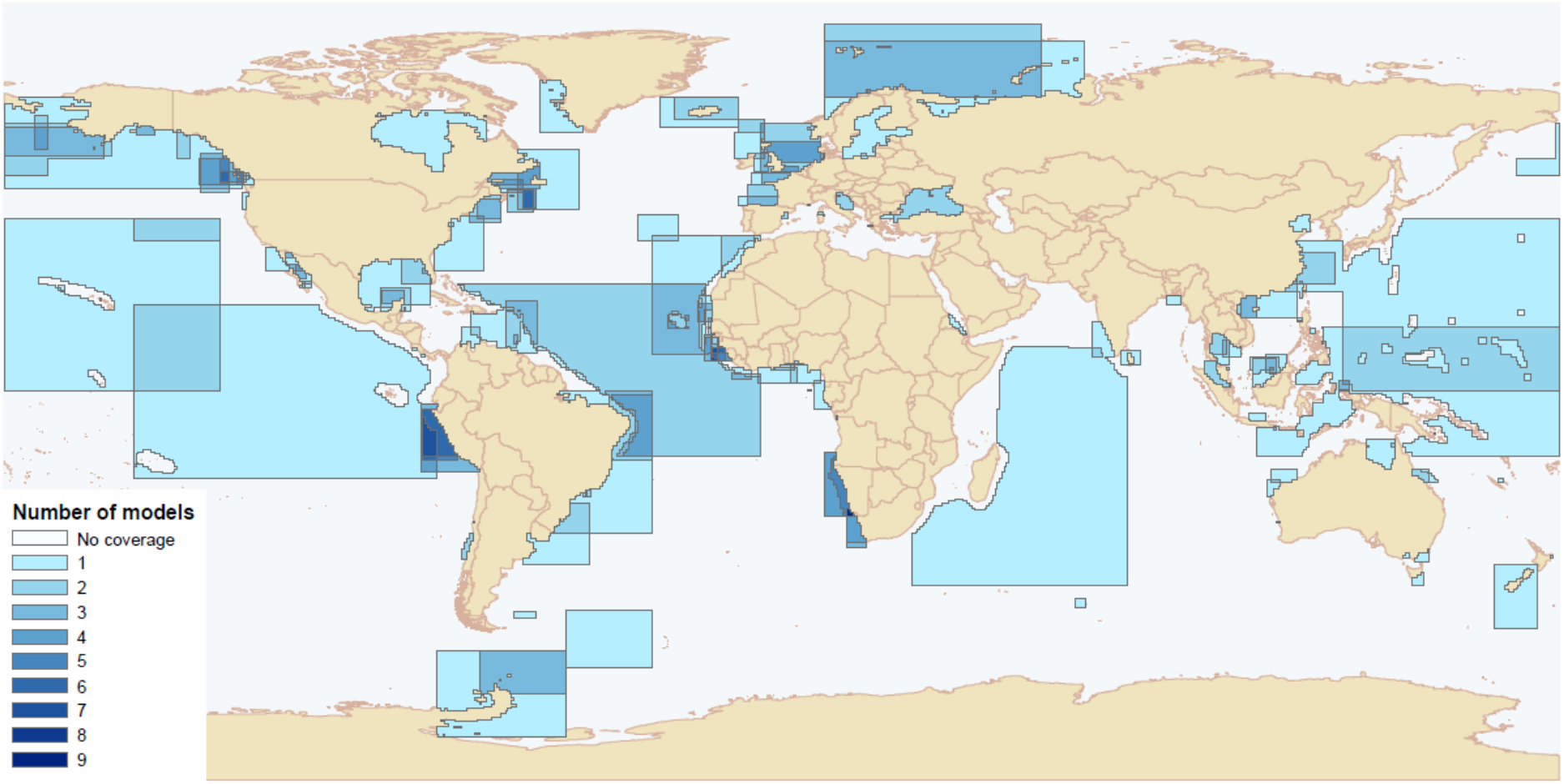
Villy Christensen[1,*], Marta Coll[2,3], Chiara Piroddi[4], Jeroen Steenbeek[3], Joe Buszowski[3], Daniel Pauly[1]

[1]Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC V6T 1Z4, Canada

[2]Institut de Recherche pour le Développement, UMR EME 212, Centre de Recherche Halieutique Méditerranéenne et Tropicale, Avenue Jean Monnet, BP 171, 34203 Sète Cedex, France, and Institute of Marine Science, ICM-CSIC, Passeig Marótim de la Barceloneta, 37-49, Barcelona 08003, Spain

[3]Ecopath International Initiative Research Association, Barcelona, Spain

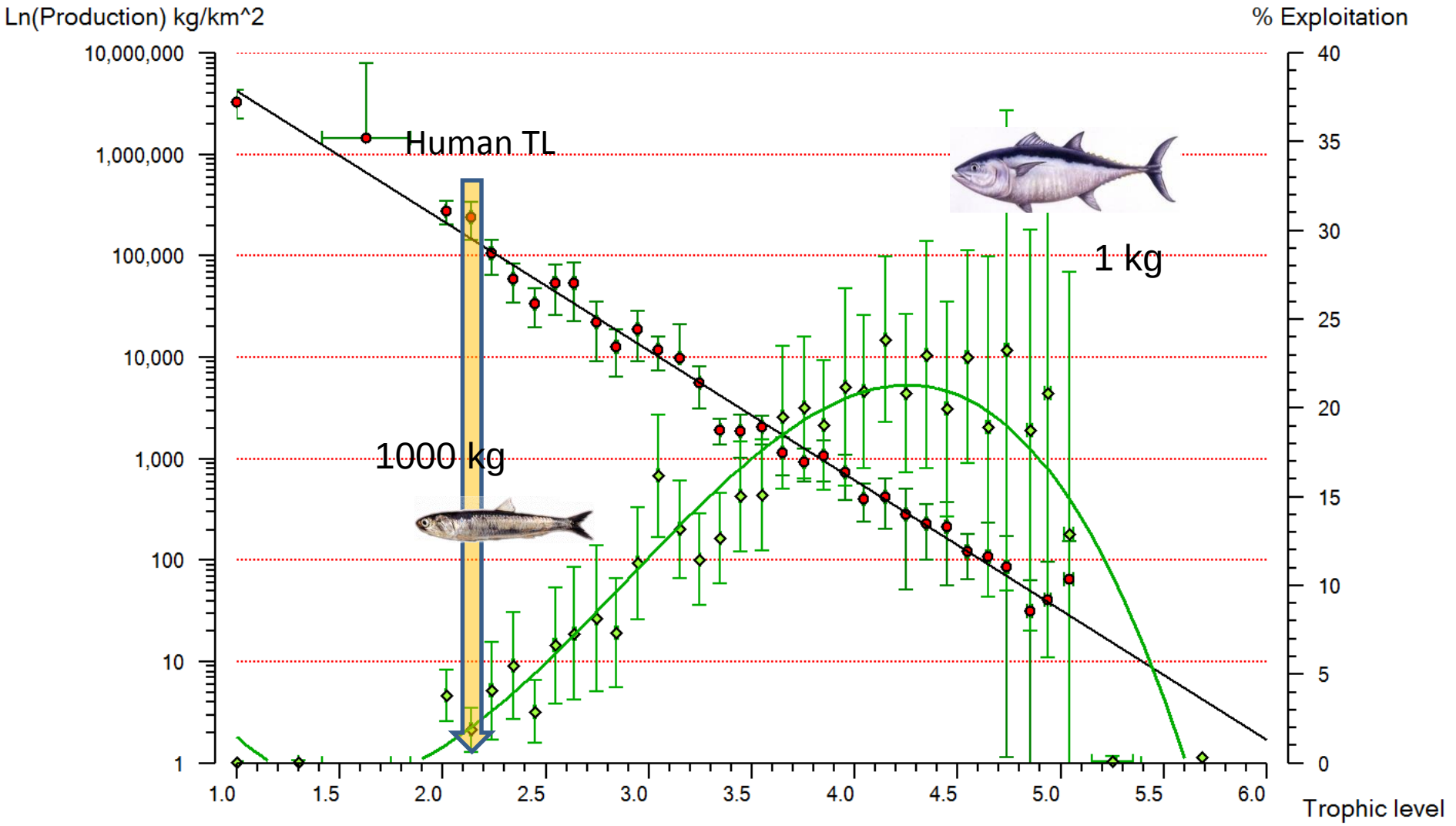
[4]European Commission - DG JRC, Institute for Environment and Sustainability, Water Resources Unit, Via E. Fermi, 2749 - TP 272, 21027 Ispra, VA, Italy



150 Ecopath models ≈ 40% of oceans

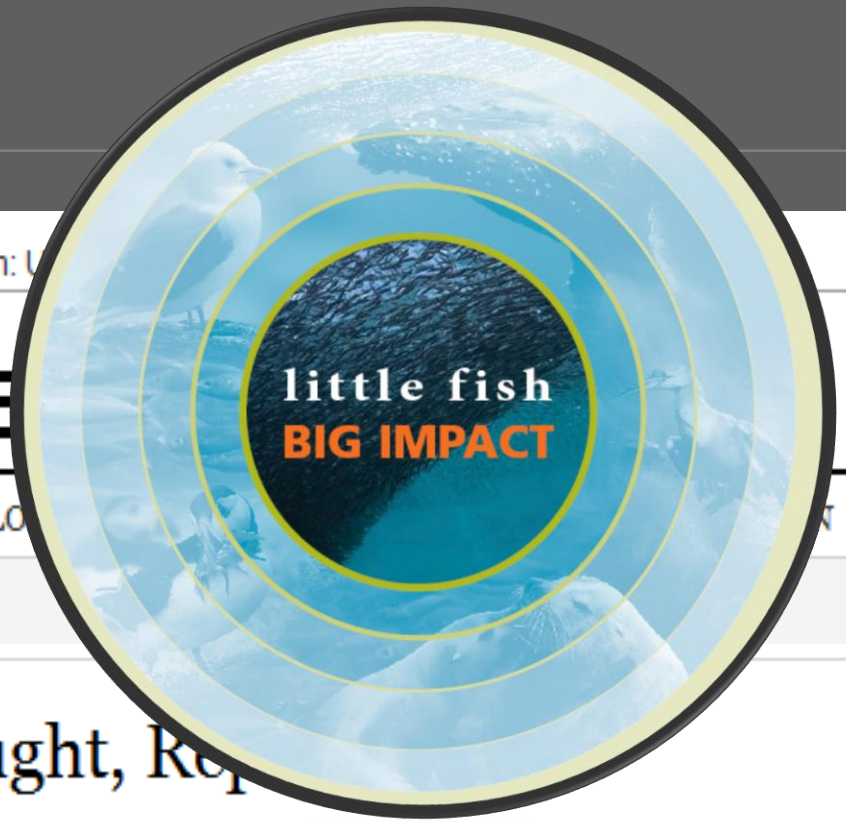
Christensen et al. 2014

Global mean exploitation rate vs trophic level
Our highly selective fishing pattern is very unbalanced and very inefficient in terms of healthy food



Kolding et al. submitted

NYT 2. April 2012



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The New York Times

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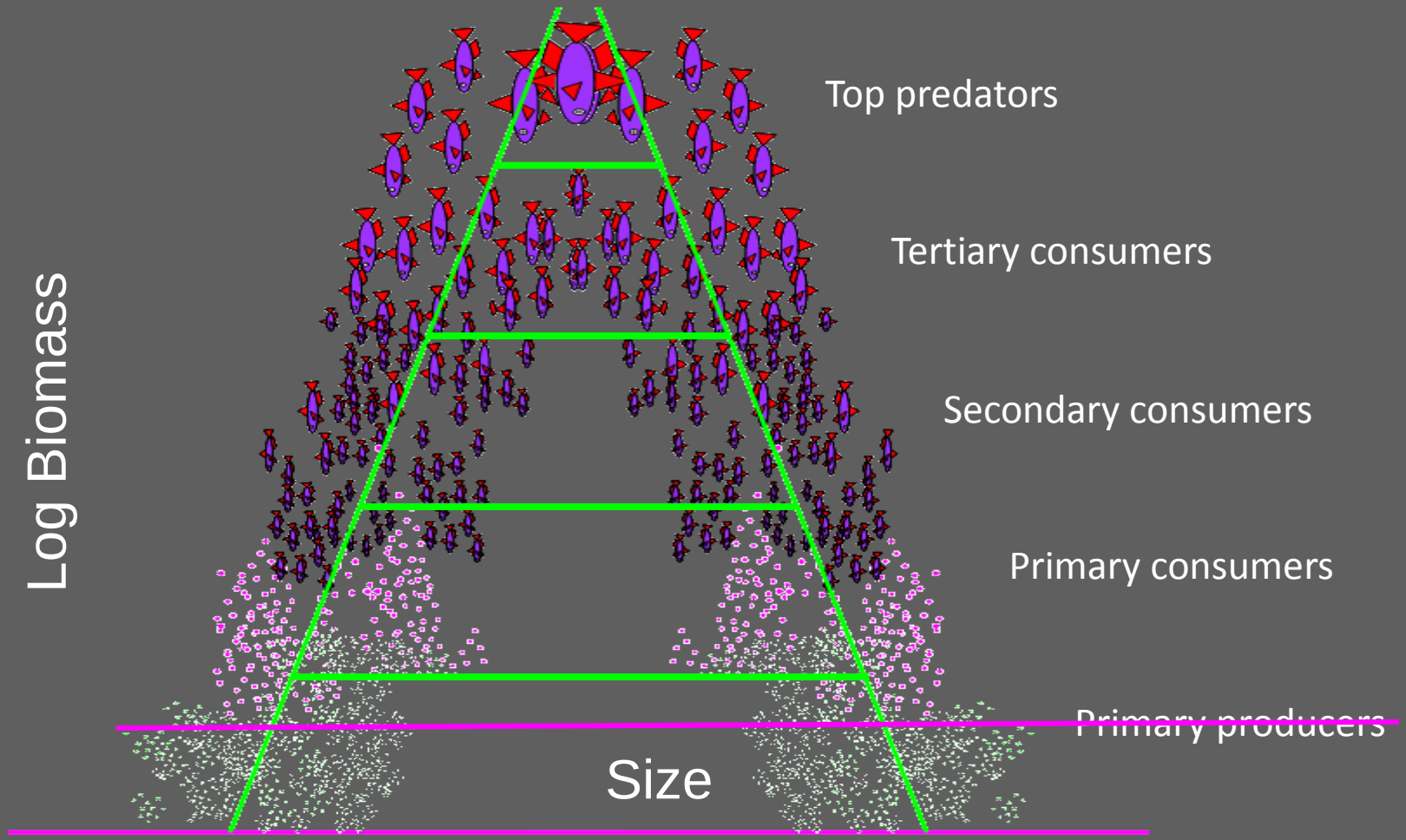
Too Many Small Fish Are Caught, Re

By HENRY FOUNTAIN
Published: April 2, 2012

An international group of marine scientists is calling for cuts in commercial fishing for sardines, herring and other so-called forage fish whose use as food for fish farms is soaring. The catch should be cut in half for some fisheries, the scientists say, to protect populations of both the fish and the natural predators that depend on them.

RECOMMEND
TWITTER
LINKEDIN
E-MAIL
PRINT

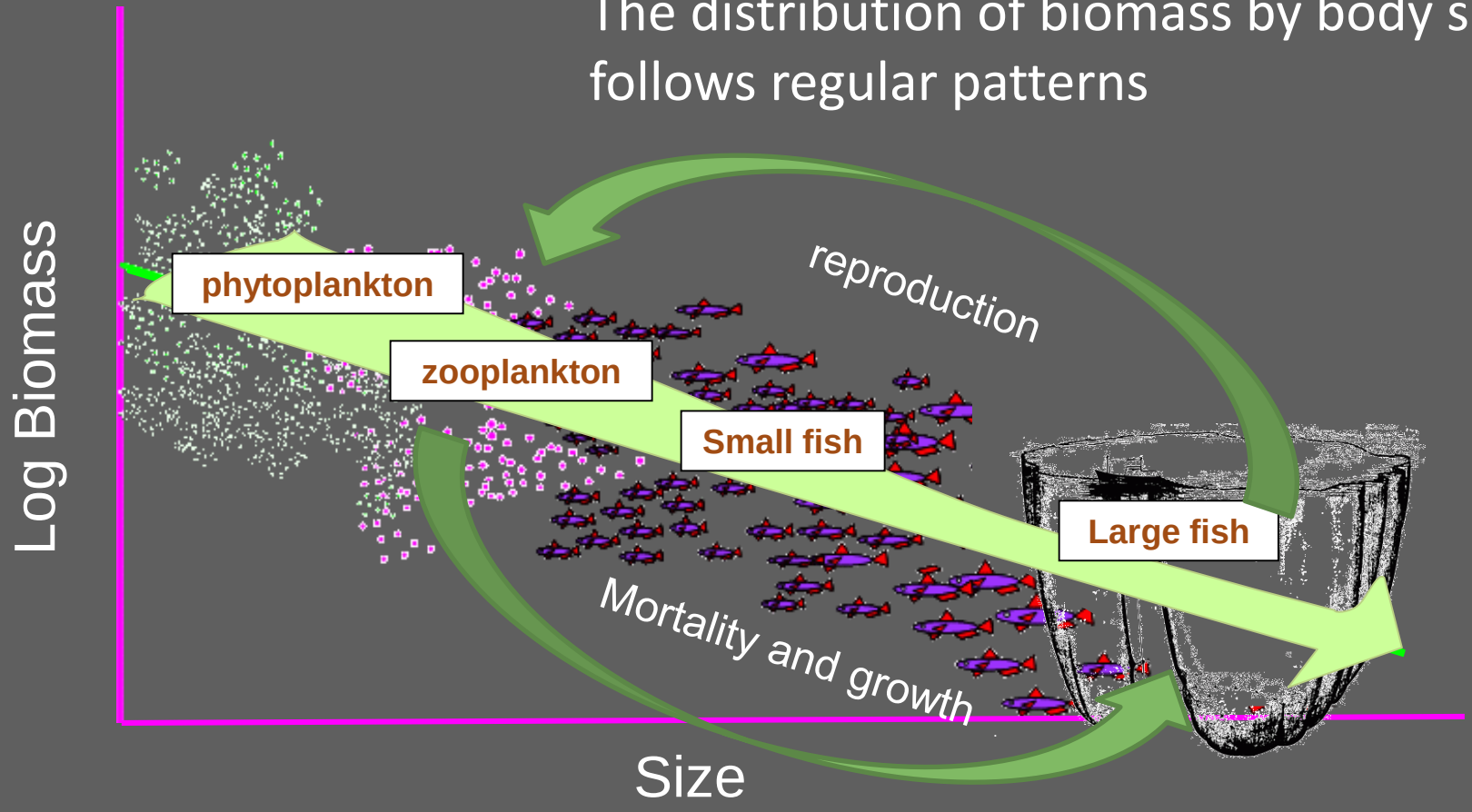
The aquatic food web is size structured…



..abundance is inversely correlated with size

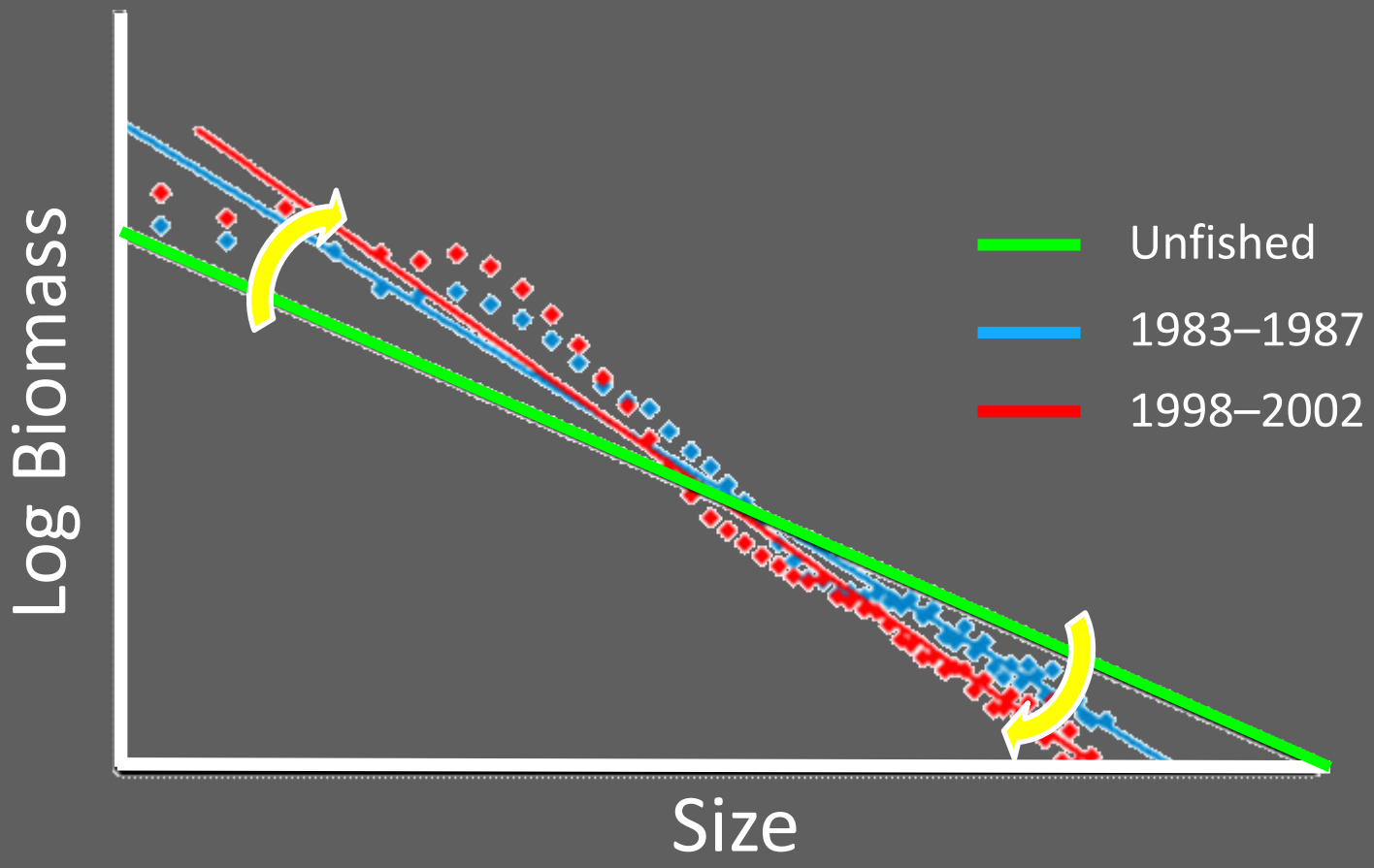
Community size spectrum

The distribution of biomass by body size follows regular patterns



Under conventional selective fishing slope and intercept will change

Changes in the North Sea



Garcia et al. 2012

How do we reconcile global objectives?

UNCLOS 1982; Johannesburg 2002 Declaration § 31 (a):

«Stocks should be kept at biomass levels that can produce maximum sustainable yields (MSY).»

CBD Malawi principles for Ecosystem Approach:

«A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning»

CONSERVATION

Reconsidering the Cons of Selective Fisheries

Balanced fishing across a range of species, stocks, and sizes could mitigate adverse effects and address food security better than increased selectivity.

S. M. Garcia,[1*] J. Kolding,[1,2*] J. Rice,[1,3*] M.-J. Rochet,[4*†] S. Zho
L. Borges,[8] A. Bundy,[9] D. Dunn,[10] E. A. Fulton,[11] M. Hall,[12] M. Hein
A. D. Rijnsdorp,[17] F. Simard,[18] A. D. M. Smith[11]

Concern about the impact of fishing on ecosystems and fisheries production is increasing (*1*, *2*). Strategies to reduce these impacts while addressing the growing need for food security (*3*) include increasing selectivity (*1*, *2*): capturing species, sexes, and sizes in proportions that differ from their occurrence in the ecosystem. Increasing evidence suggests that more selective fishing neither maximizes production nor minimizes impacts (*4*–*7*). Balanced harvesting would more effectively mitigate adverse ecological effects of fishing while supporting sustainable fisheries. This strategy, which challenges present management paradigms, distributes a moderate mortality from fishing across the widest possible range of species, stocks, and sizes in an ecosystem, in proportion to their natural productivity (*8*), so that the relative size and species composition is maintained.

which are not going to be used," i.e., by-catch (*13*). Fisheries worldwide have used species and size limits (*9*, *14*), gear technology (*5*, *15*), and spatial and temporal fishing restrictions (*16*) to reduce fishing impacts while pursuing human benefits.

But selective removals will inevitably alter the composition of a population or community and, consequently, ecosystem structure and biodiversity. Old individuals contribute the most to reproduction (*17*). Even moderate fishing reduces the proportion of large and old fish in a population. Selectively

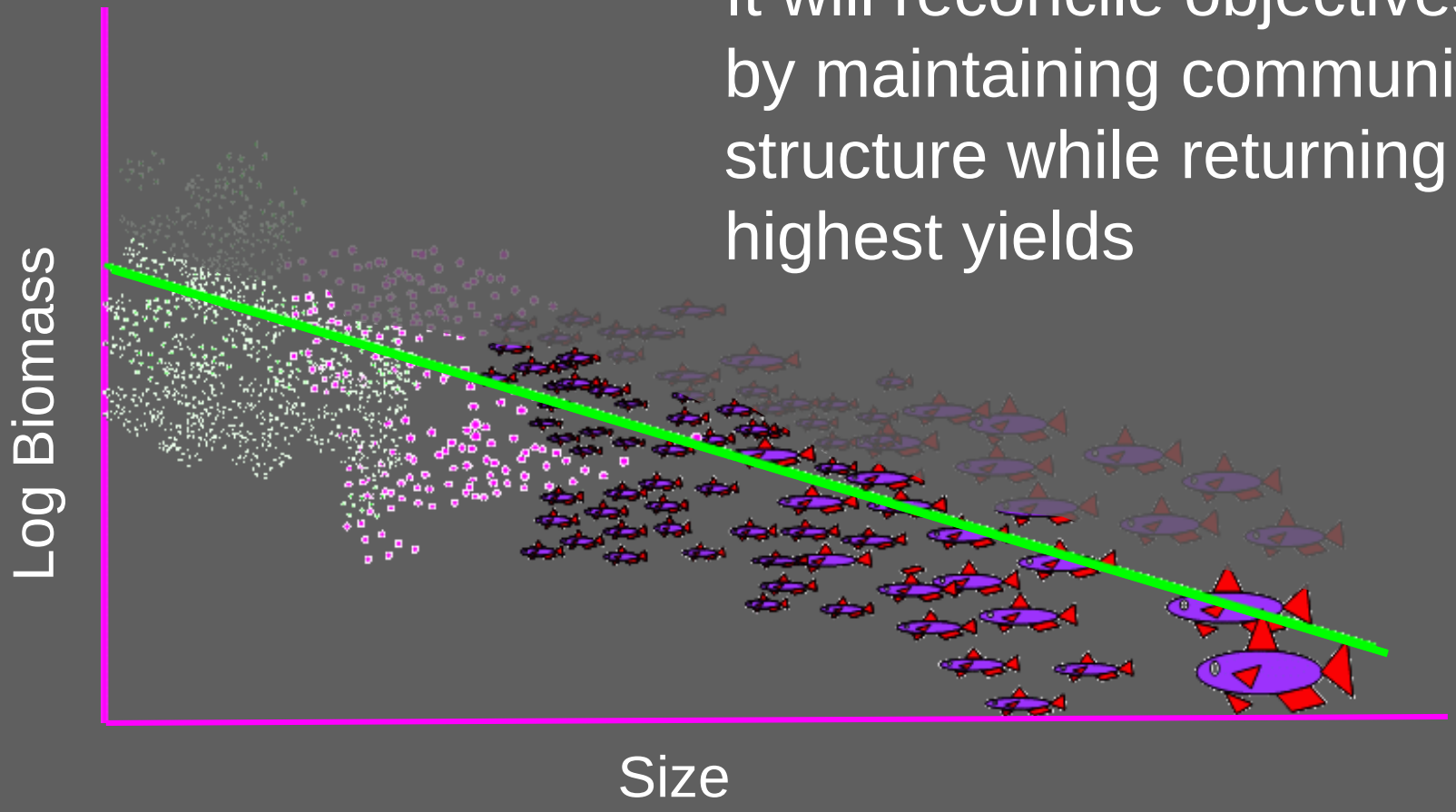
species and individuals in the North Sea (*22*) (fig. S1). By contrast, in several African small-scale inland fisheries, the fish size spectrum (*23*) has been maintained under intense and diverse fishing activities that cause high mortality with low selectivity (*5*, *24*) (fig. S1).

Results from models suggest that moderating fishing mortality across a wide range of species and sizes maximizes overall catch summed across species while better conserving biodiversity. Multispecies fishery models show that increased mesh sizes may reduce

Balanced harvesting … distributes a moderate mortality from fishing across the widest possible range of species, stocks, and sizes in an ecosystem.

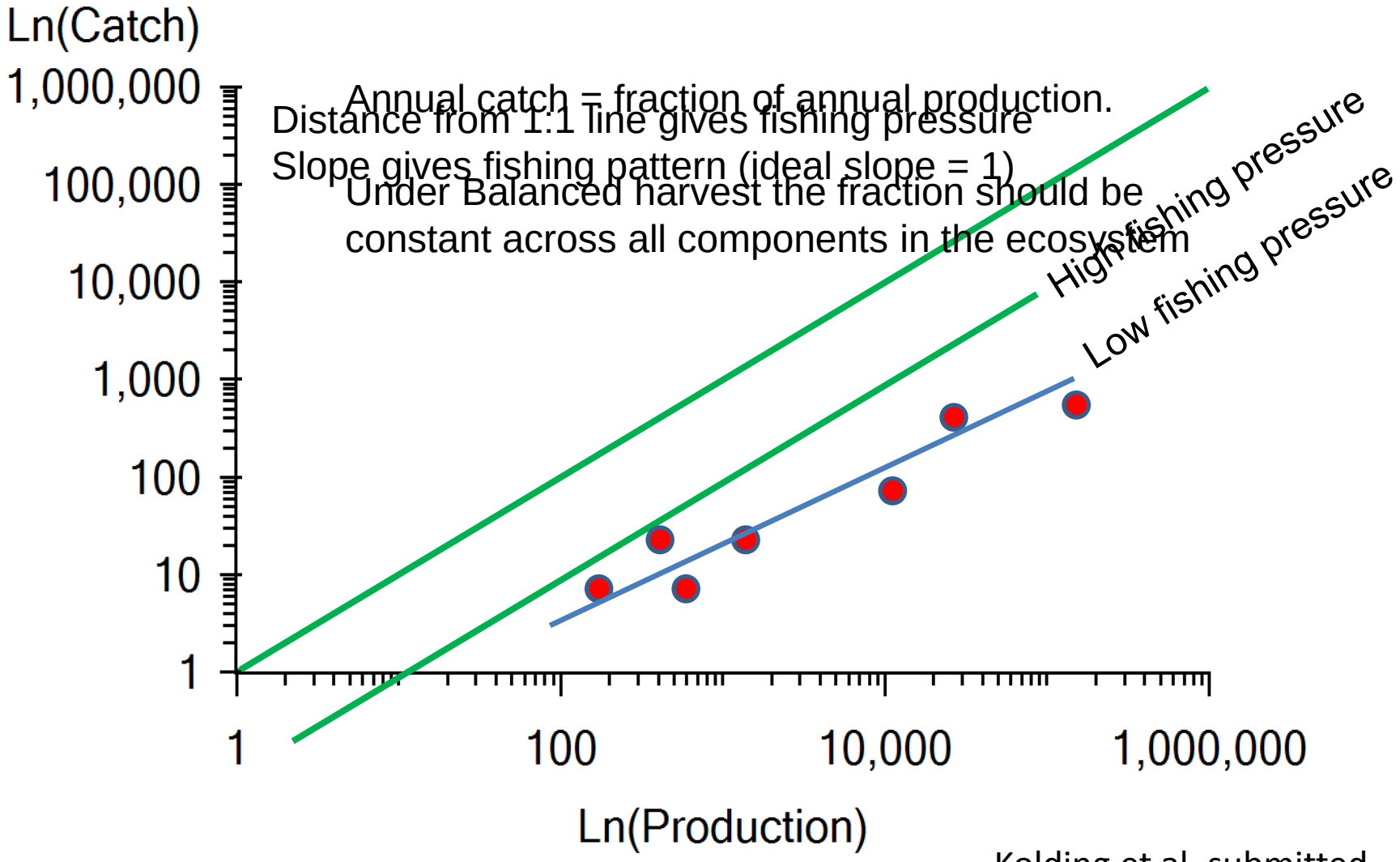
Balanced harvesting… (Garcia et al 2012)

It will reconcile objectives by maintaining community structure while returning highest yields



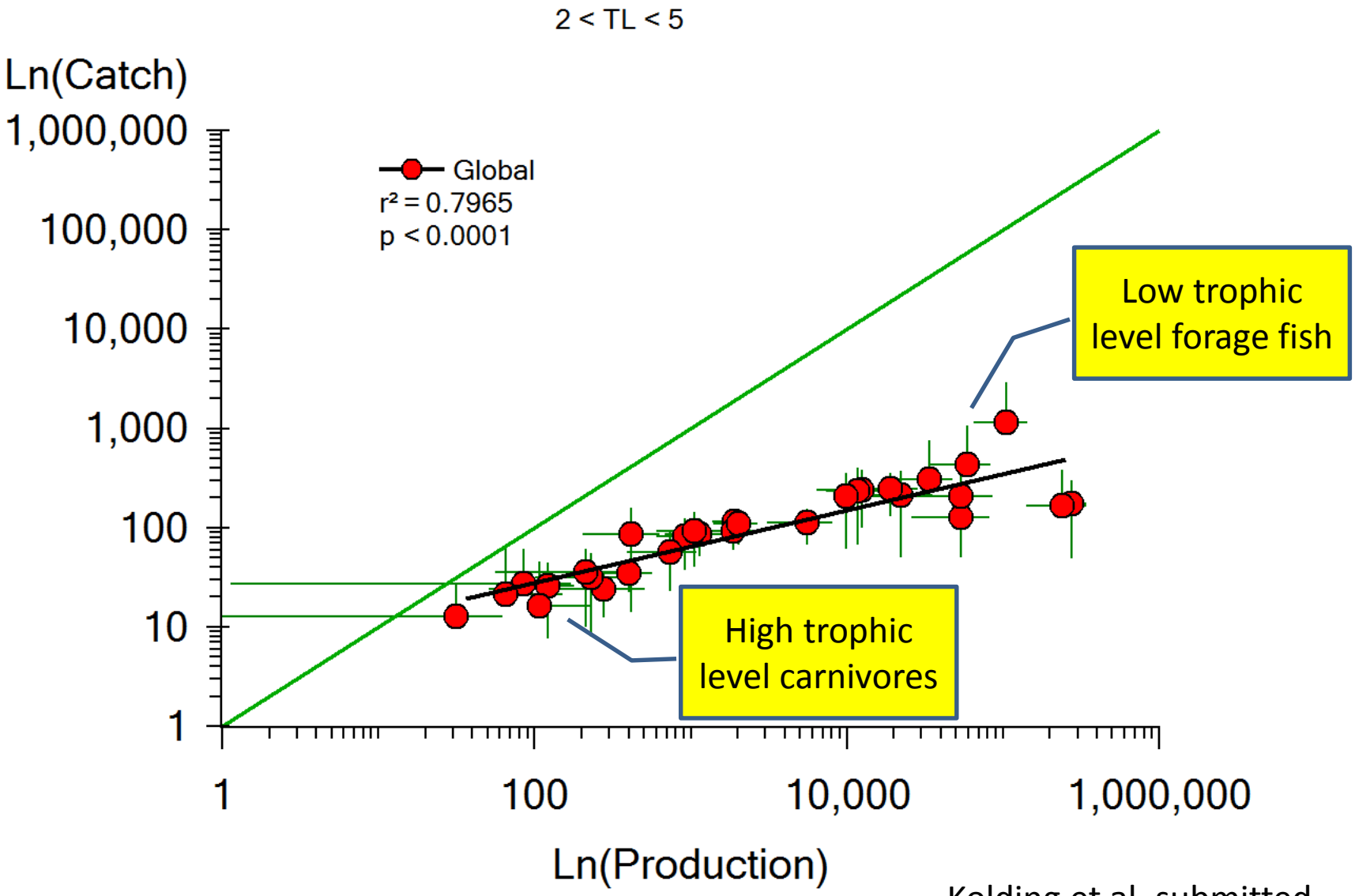
.. is fishing as many sizes and species as possible in proportion to natural productivity

How to measure the balance?



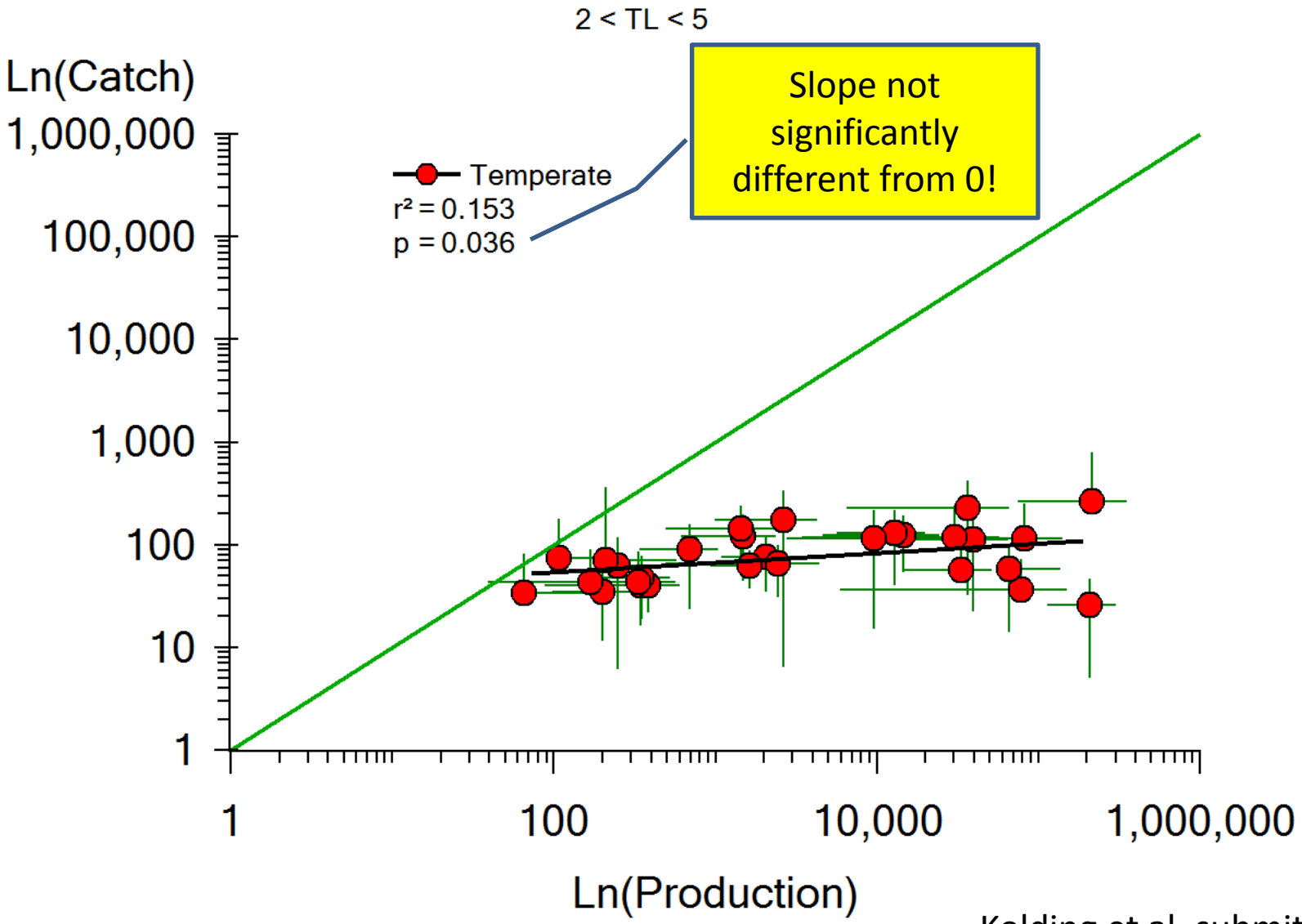
Kolding et al. submitted

Global fishing pattern (151 ecosystems)



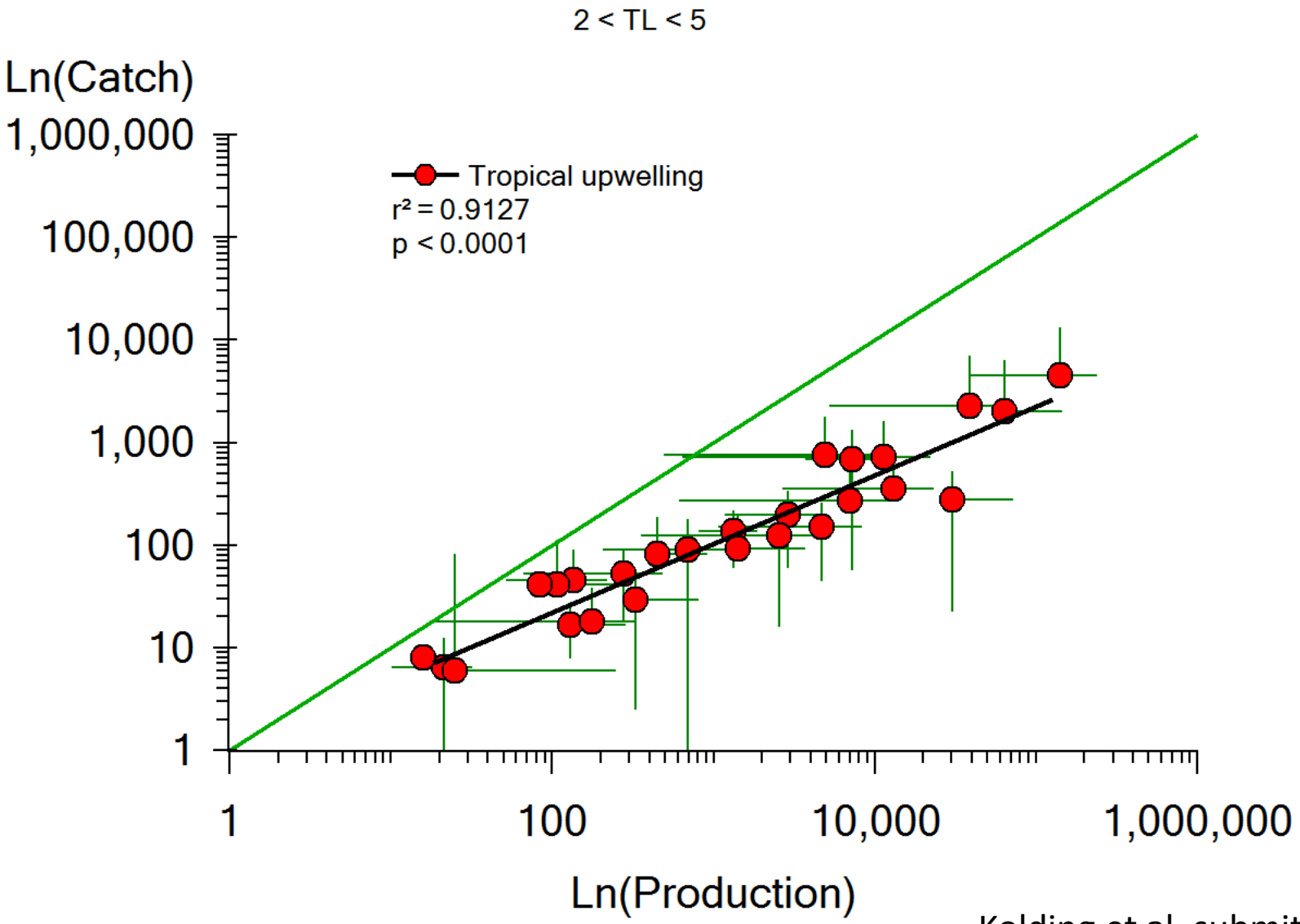
Kolding et al. submitted

Temperate fisheries (ICES, North Pacific)



Kolding et al. submitted

Tropical upwelling



Kolding et al. submitted

Balanced harvest will reconcile objectives

Johannesburg 2002 Declaration § 31 (a) (MSY):

We can sustainably increase the amount of food harvested (by fishing lower in the food chain)

CBD Malawi principles for Ecosystem Approach:

While keeping the ecosystem structure and functioning

Thank you