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Aquaculture's Role in Fisheries, Food Security and the Environment

Rosamond Naylor
Center on Food Security and the Environment
Stanford University (USA)

Academia Engelberg: Dialogue in Science (October 15, 2014)

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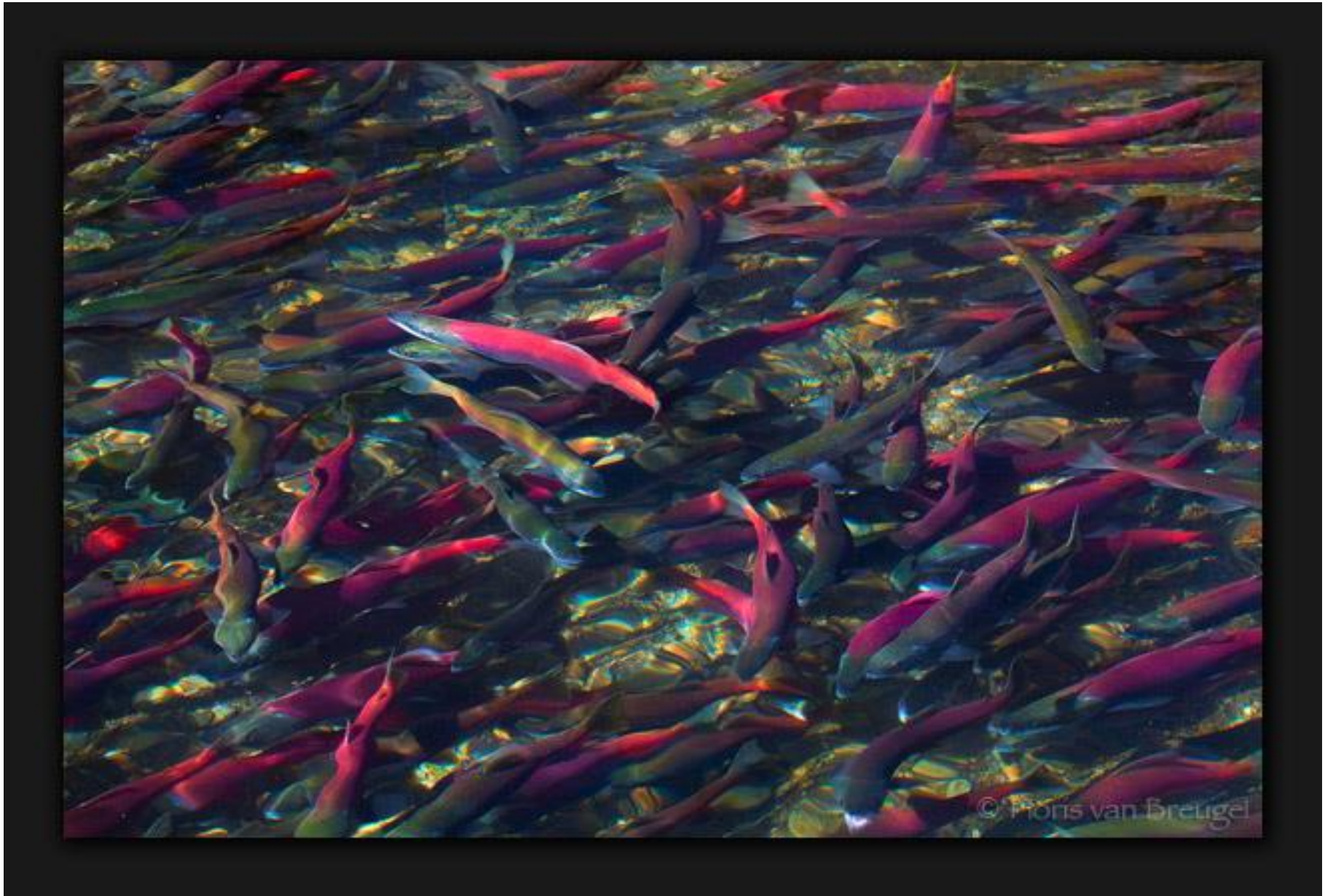
Let’s start with a fish…



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Southern Chile

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Food Security: The Key Questions

1. Can the world produce sufficient amounts of food to meet demand at a reasonable price?

2. Can people get physical and economic access to the food?

3. Can production and access be accomplished without destroying the environment in the process?

4. Can the right nutrition be delivered?

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Today

- Background: aquaculture and the environment
- China: *the* big player in aquaculture and fisheries
- Aquaculture for the poor: a tool for food security
  - Kenya's aquaculture development strategy
- Future trends: can aquaculture enhance resilience in the world food system?

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Increasing Global Demand for Seafood

More people:

1965: 3.3 billion
2013: 7.1 billion

Eating more fish

- 1965 per capita fish consumption: 9.5 kg
- 2013 per capita fish consumption: 19.0 kg

Source: FAOSTAT; OECD

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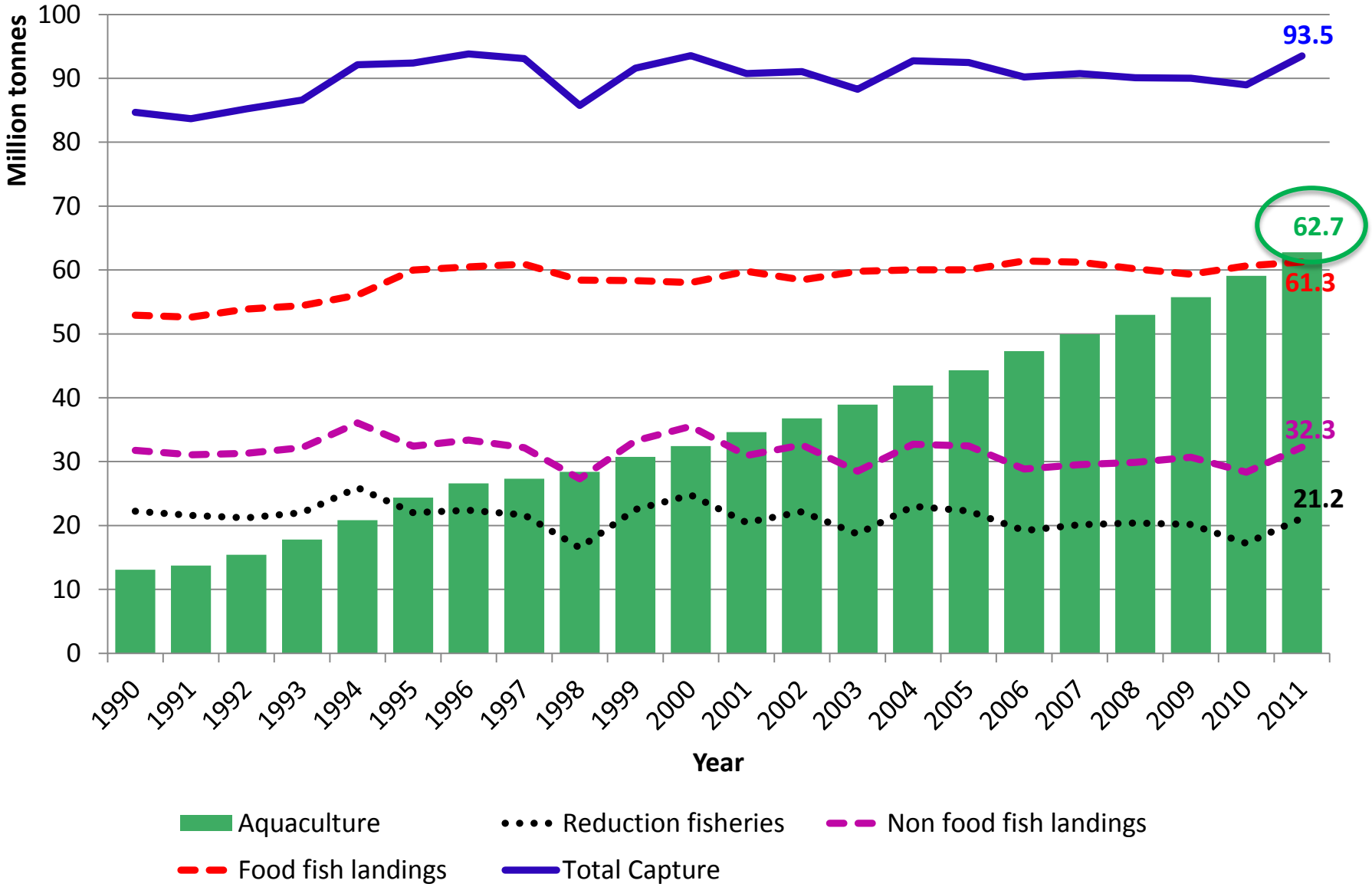
Global Fish Production and Capture Fisheries Use



Source: FAO FishStatJ 2013

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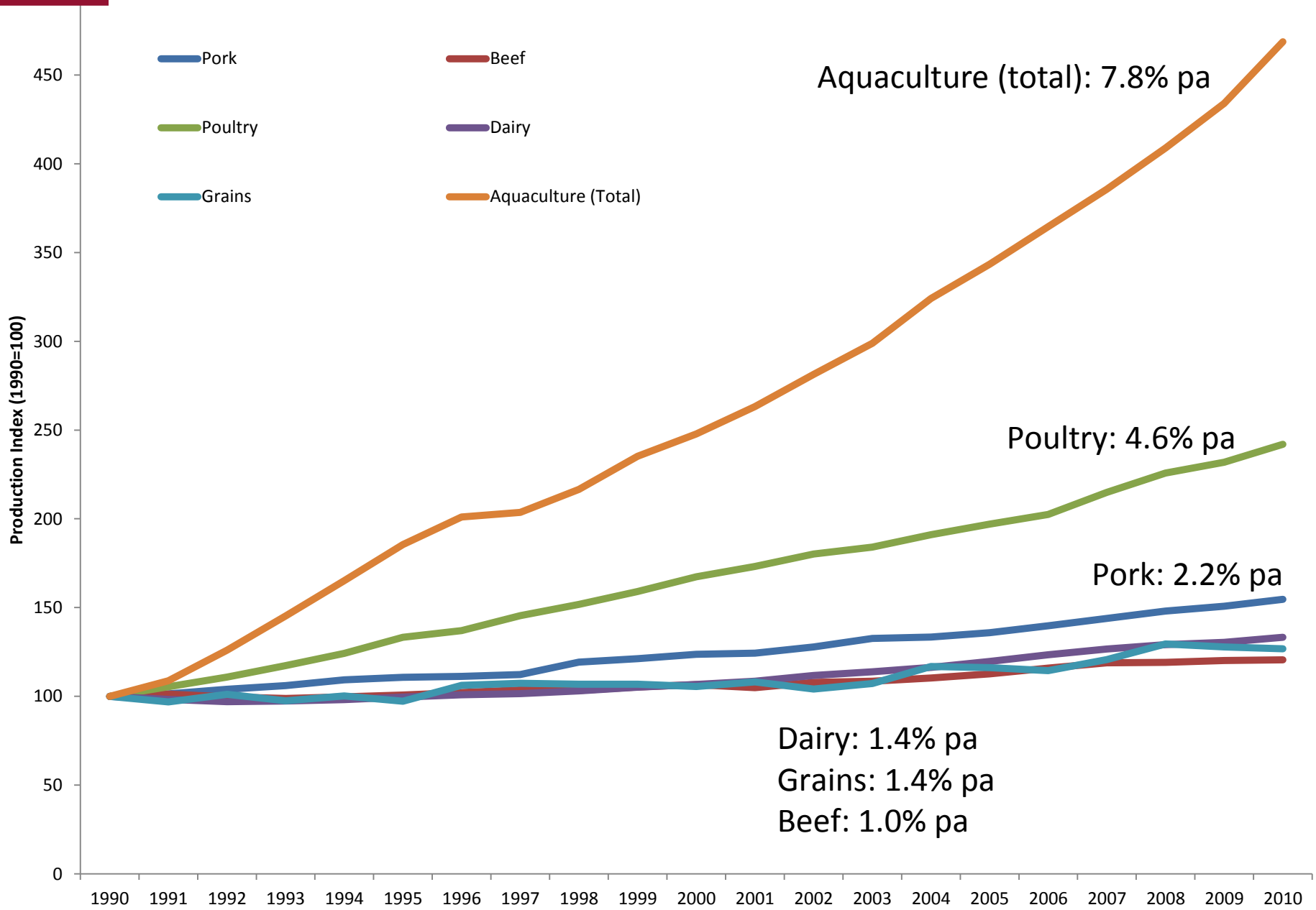
Food Commodity Growth 1990-2010



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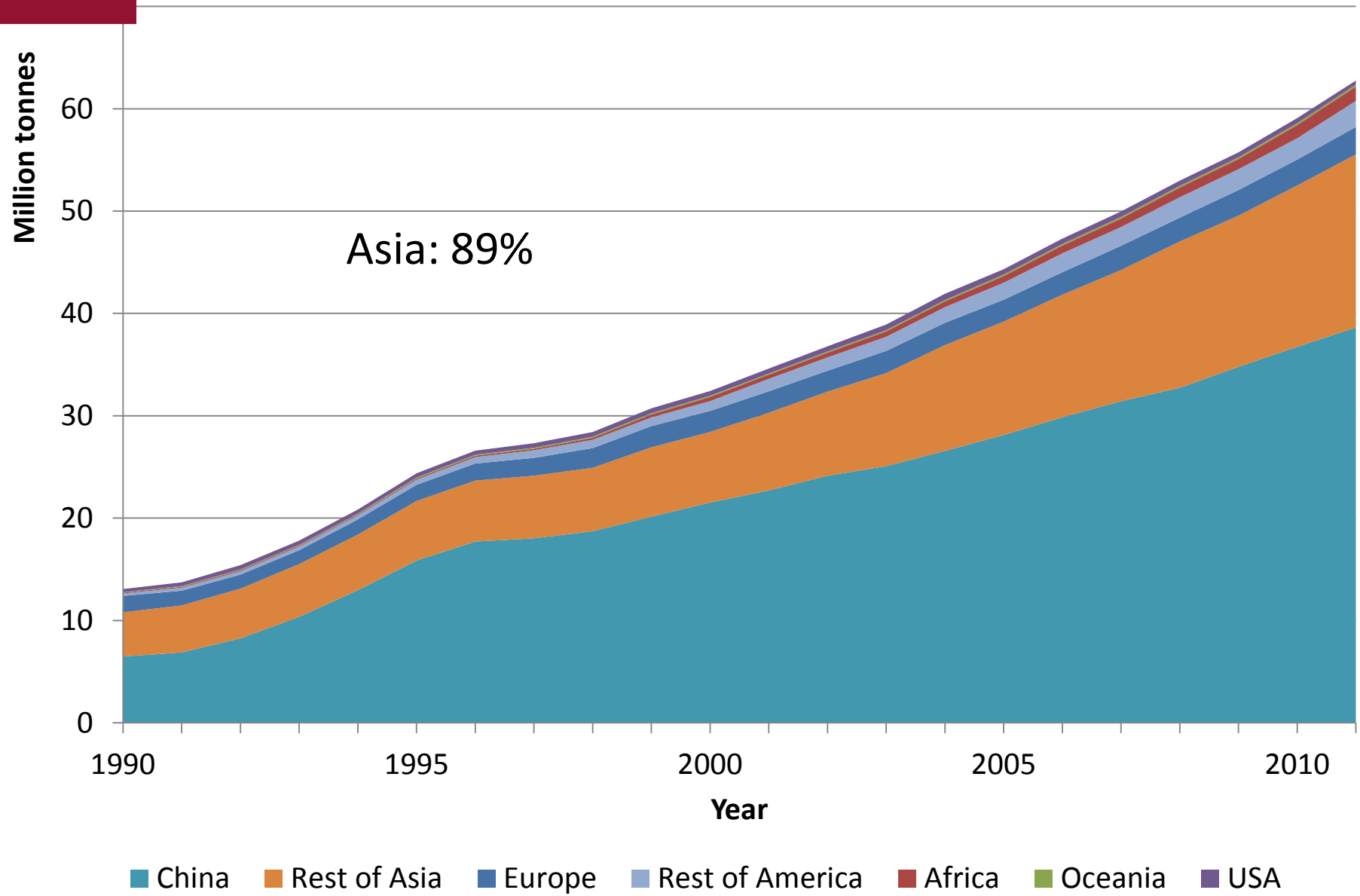
World Aquaculture Production of Food Fish by Region



Source: FAO FishStatJ 2013

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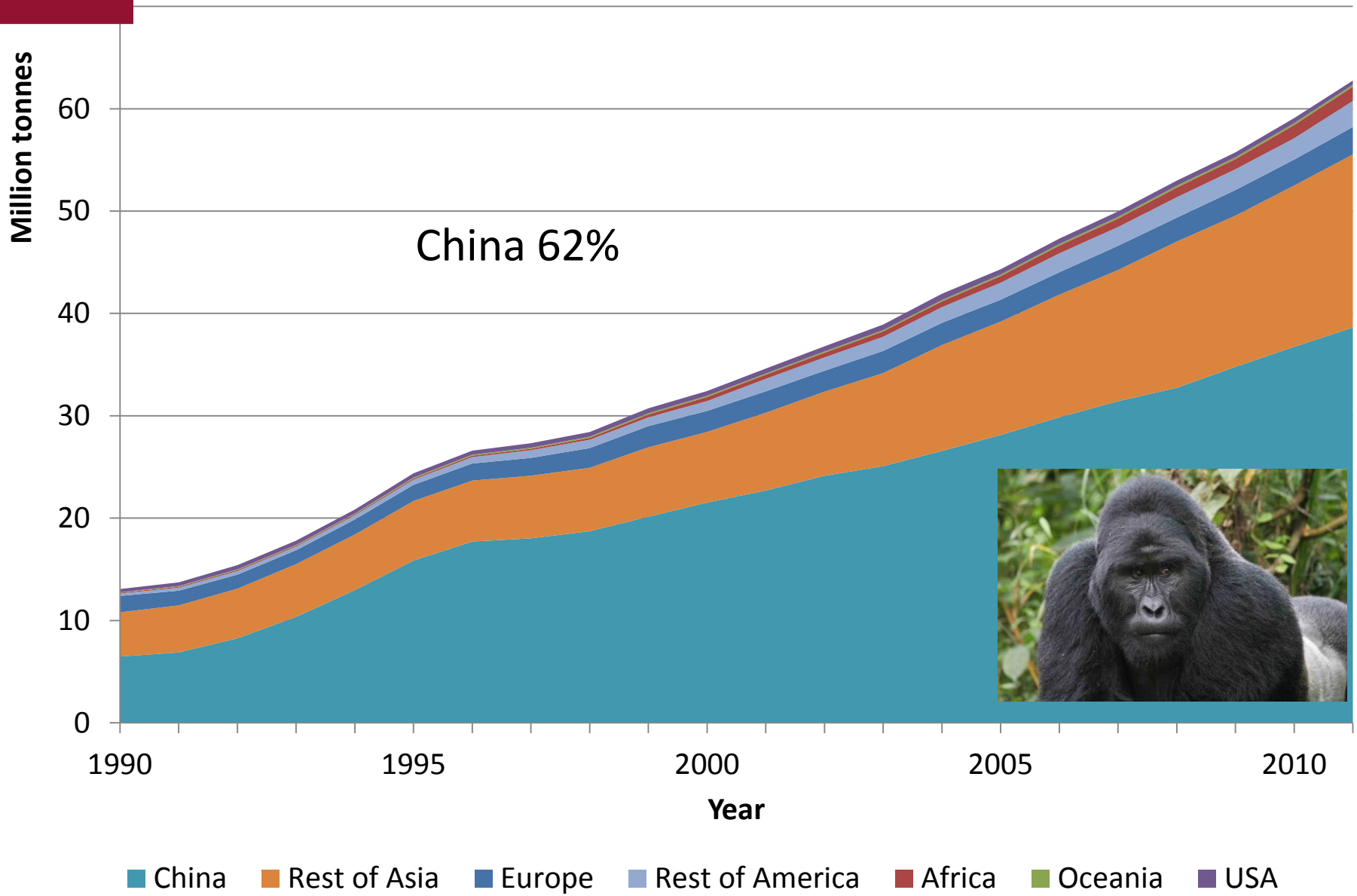
World Aquaculture Production of Food Fish by Region



Source: FAO FishStatJ 2013

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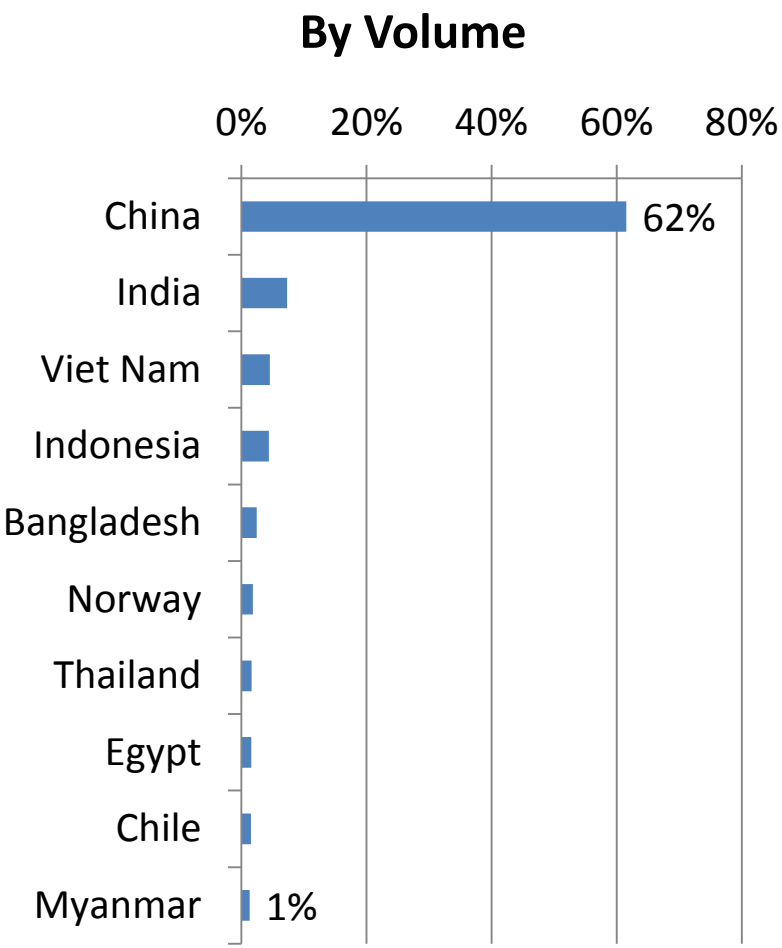
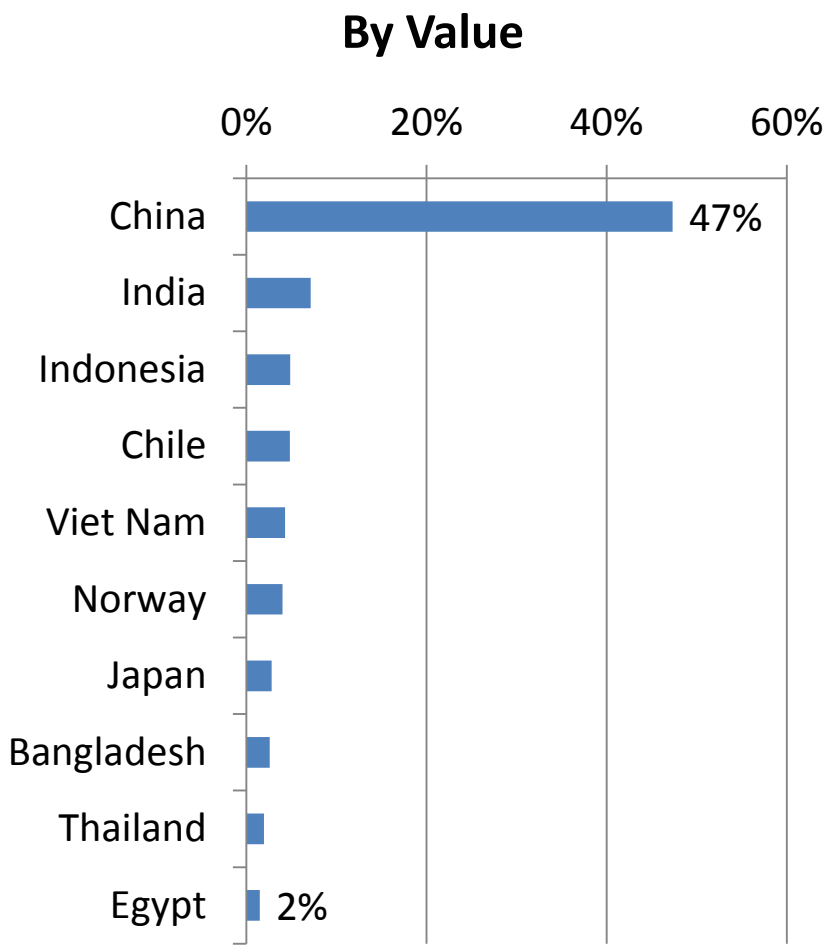
Top 10 Aquaculture Producers Worldwide (2011)



USA: only 0.6%!



USA: only 0.8%!

Source: FAO FishStatJ 2013

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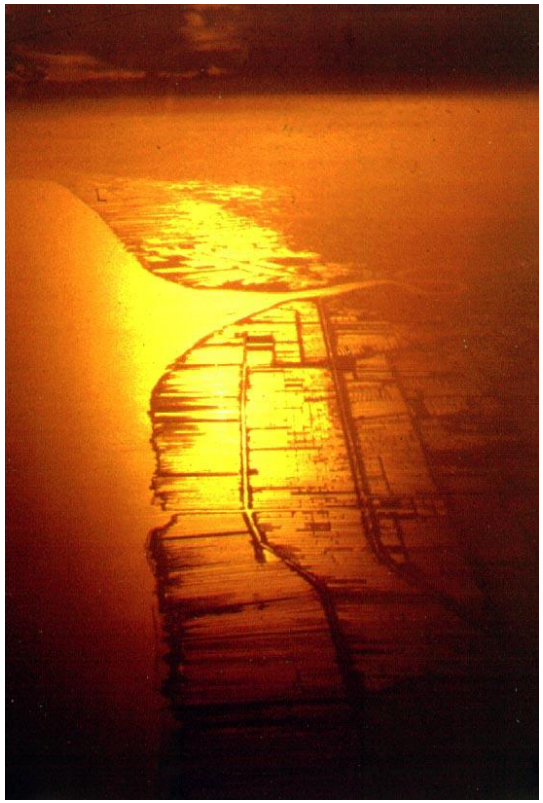

>300 freshwater and marine species farmed around the world

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High-Valued, Marine Finfish Aquaculture

A Norwegian salmon farm: pumping fish live from a pen for delivery to a processor--in January

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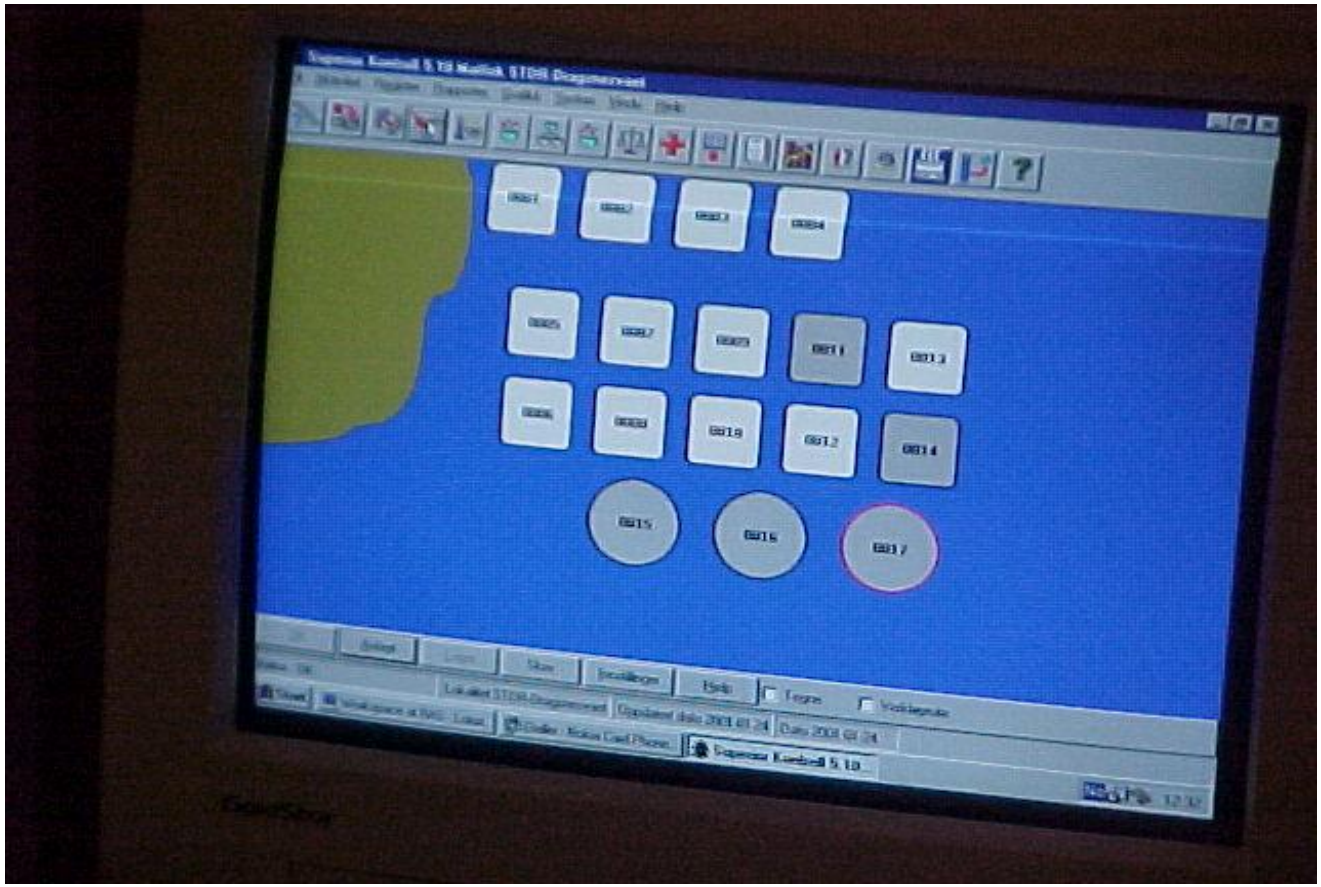
A computer provides detailed information about the fish in each pen--and every other pen of fish in dozens of other fish farms around the world owned by this multinational company.



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Boxes of fresh fish, ready to be trucked to the US later that day


Protect from light!
The SalmoFan™ was developed on the basis of the colour of fresh salmonid flesh pigmented with CAROPHYLL® Pink (astaxanthin). Light conditions can influence visual colour perception.
1997-HMB 50969 (1/0997:25.0) Printed in Switzerland
¡Protéjase de la luz!
El abanico colorimétrico está
en base al color de carne
pigmentados con CAROPHYLL® pink
El tipo de iluminación puede afectar a la percepción visual del color.

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GMO Salmon

- “AquaAdvantage”: Genes from Chinook salmon and Ocean Pout
- Matures in 16-18 months (vs. 31-36 months)

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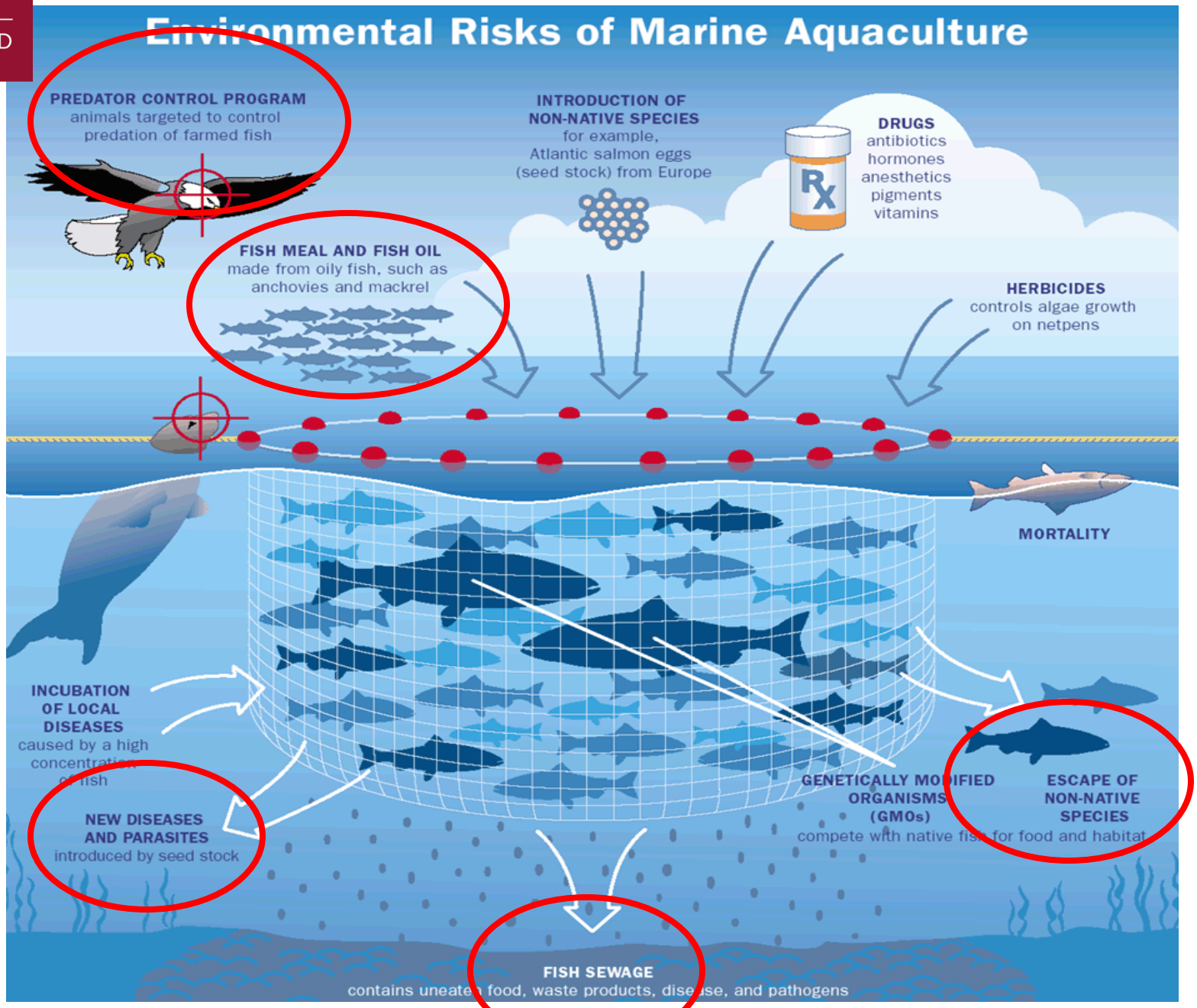

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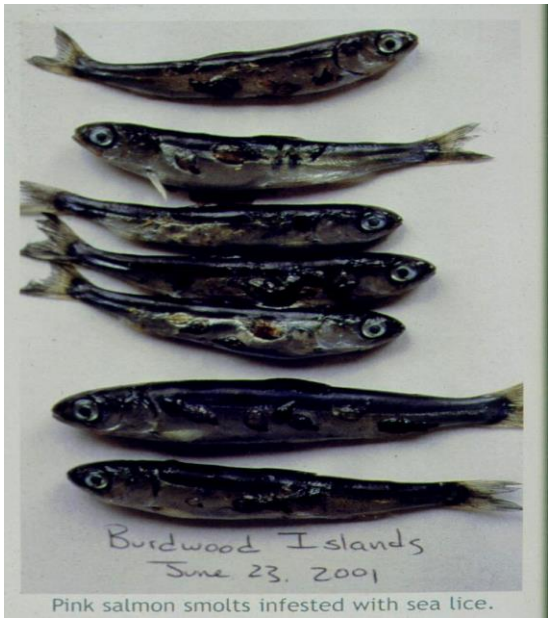
Risks of disease, parasites, escapes



Pink salmon smolts infested with sea lice.

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Dilution as the Solution?

Tuna cages in Croatia

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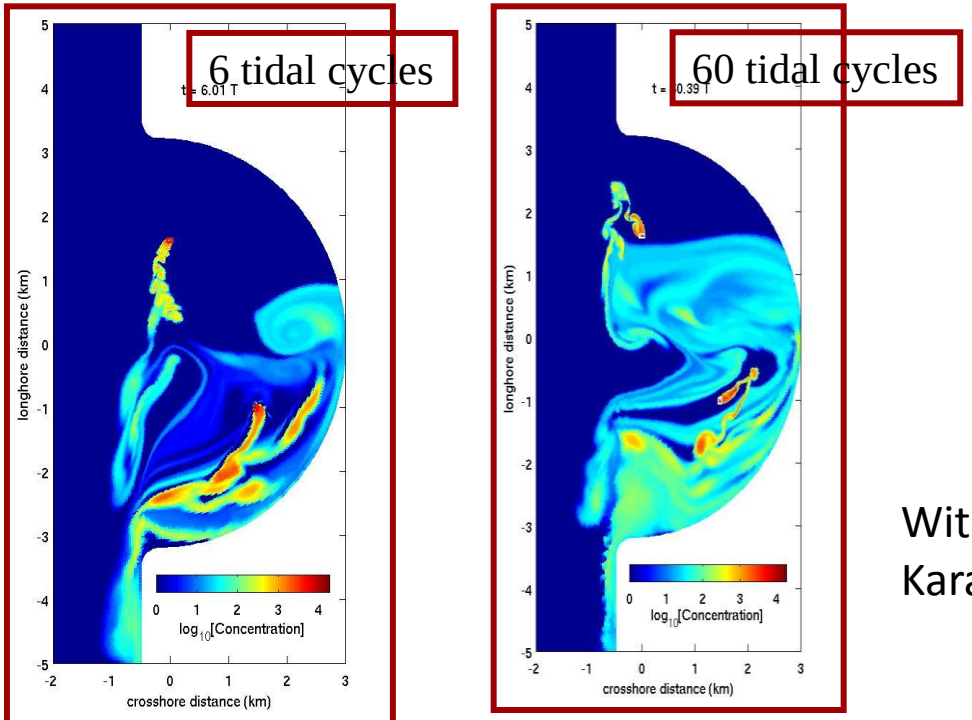
Feedlots of the sea?



With Oliver Fringer, Jeff Koseff, Karan Venayagamoorthy (CEE)

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Marine Aquaculture, Luoyan Bay, Fujian Province, China, 2012.

(Edward Burtynsky)

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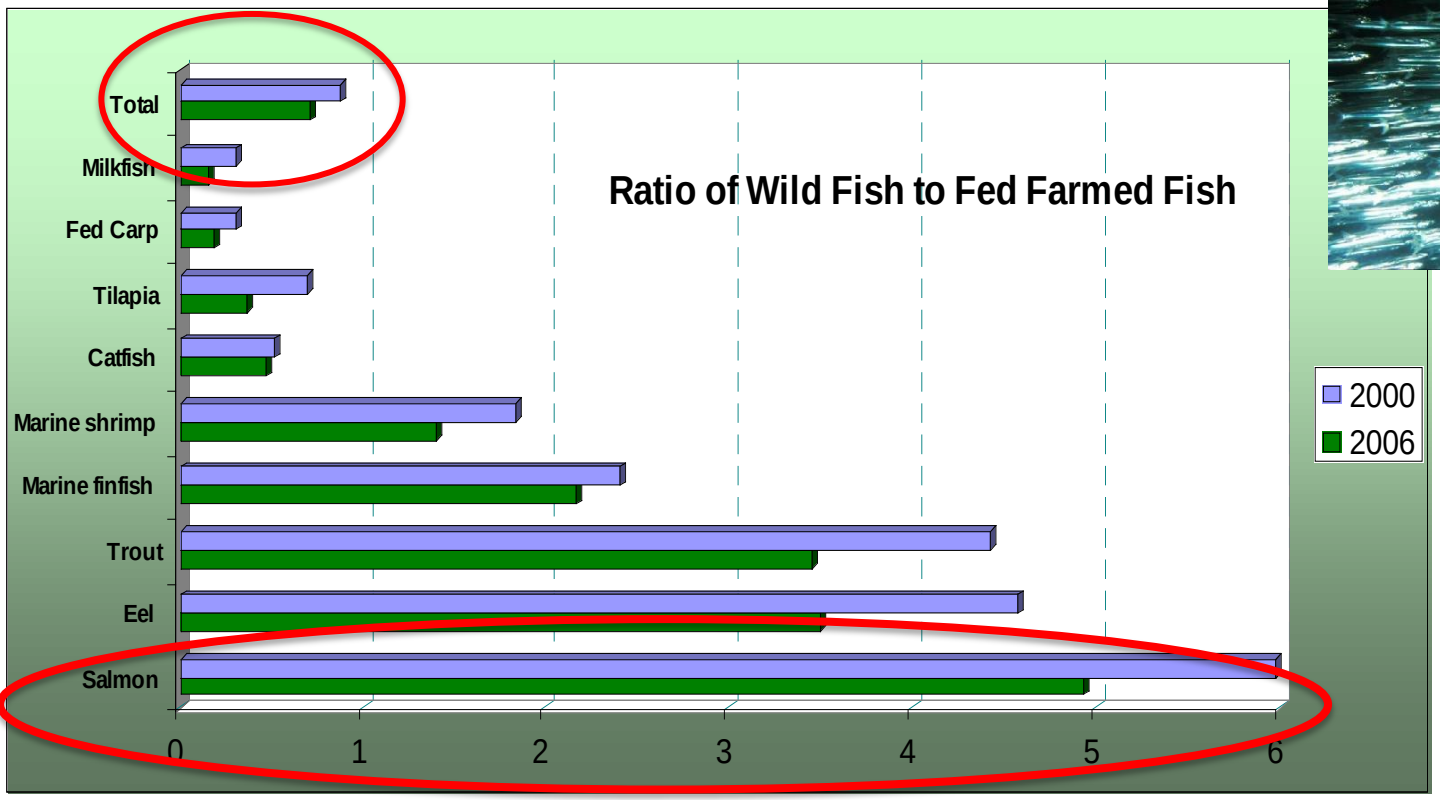
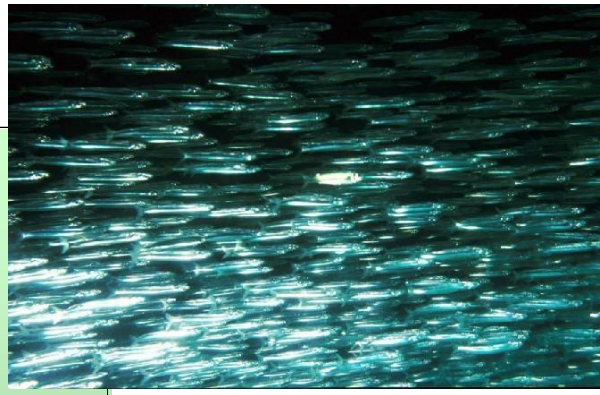
Wild Fish for Feeds

- Fishing down the food web; farming up the food web
- Net positive balance of total farmed fish to wild fish used in feed
- Why is it important?





FIFO: A good metric?

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Stock Status of the Top 10 Forage Fish Species

Common Name	State of Exploitation
Peruvian anchovy	Recovering, Overexploited
Atlantic herring	Fully exploited
Chub mackerel	Fully exploited
Japanese pilchard	Fully exploited
Japanese anchovy	Fully exploited
European pilchard (=Sardine)	Fully exploited
Atlantic mackerel	Fully exploited
Gulf menhaden	Fully exploited
South American pilchard	Fully exploited, Overexploited
Capelin	Fully exploited

Source: Alder et al. 2008; Review of the state of world marine fishery resources 2011

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Filter Feeders and Plants

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China
Aquaculture, Fisheries, and Food Security

- World's largest aquaculture producer
- World's largest fish producer overall
  - 3x growth since 1990
  - 70% aquaculture
- World's largest fish exporter
- World's largest fish processor
  - Export, domestic use, re-export
- World's fastest growing economy
- Changing consumer tastes, rising fish demand

- Future: World's largest fish consumer?

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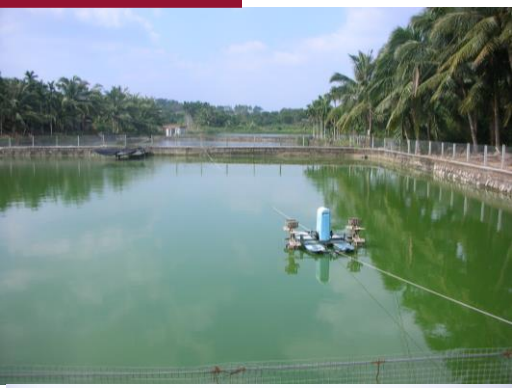
Focus on China's Fisheries and Aquaculture



Field Survey

•410 rural households, 770 urban households

•350 fish farmers in 3 carp/tilapia provinces

•15 feed and fishmeal plants

• Validation: scientific studies and secondary data (*J. Aquaculture* 2013)

Symposium at SPKU (May 2014)

• 35 scientists from within and outside of China

• International collaboration

• Policy orientation

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Field Study Results

Official statistics underestimate current seafood consumption by 20-35%

Annual per capita fish consumption (est):

- 30 kg today
- 50 kg in 2030

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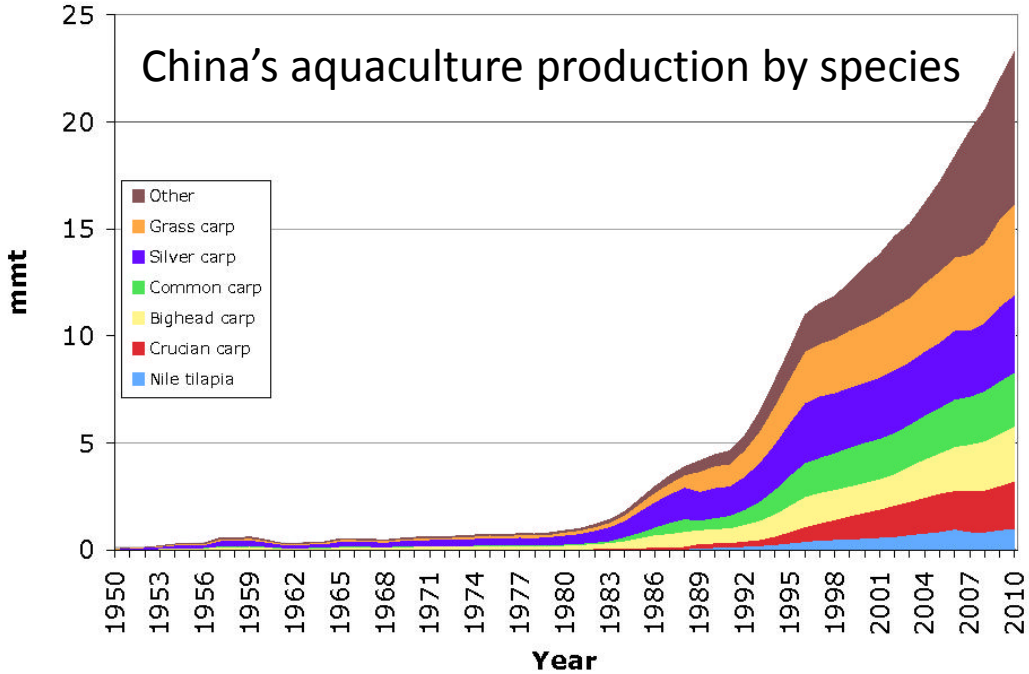
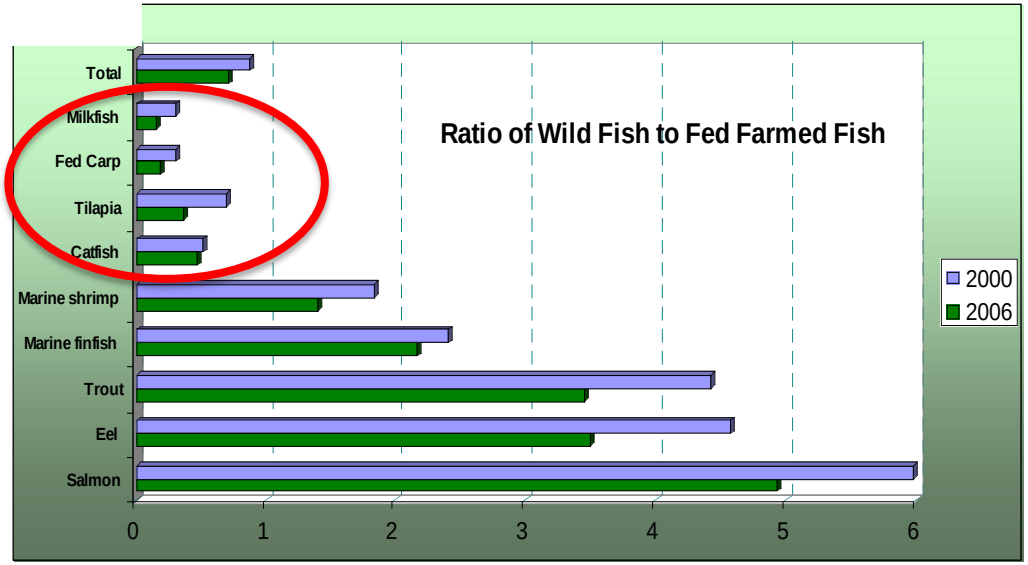
Fishmeal Use in Carp & Tilapia Systems



How much fishmeal is used in carp/tilapia systems?

Are FCR's close to 1?

Even small inclusion rates of FM can add up to a big number given the scale of production



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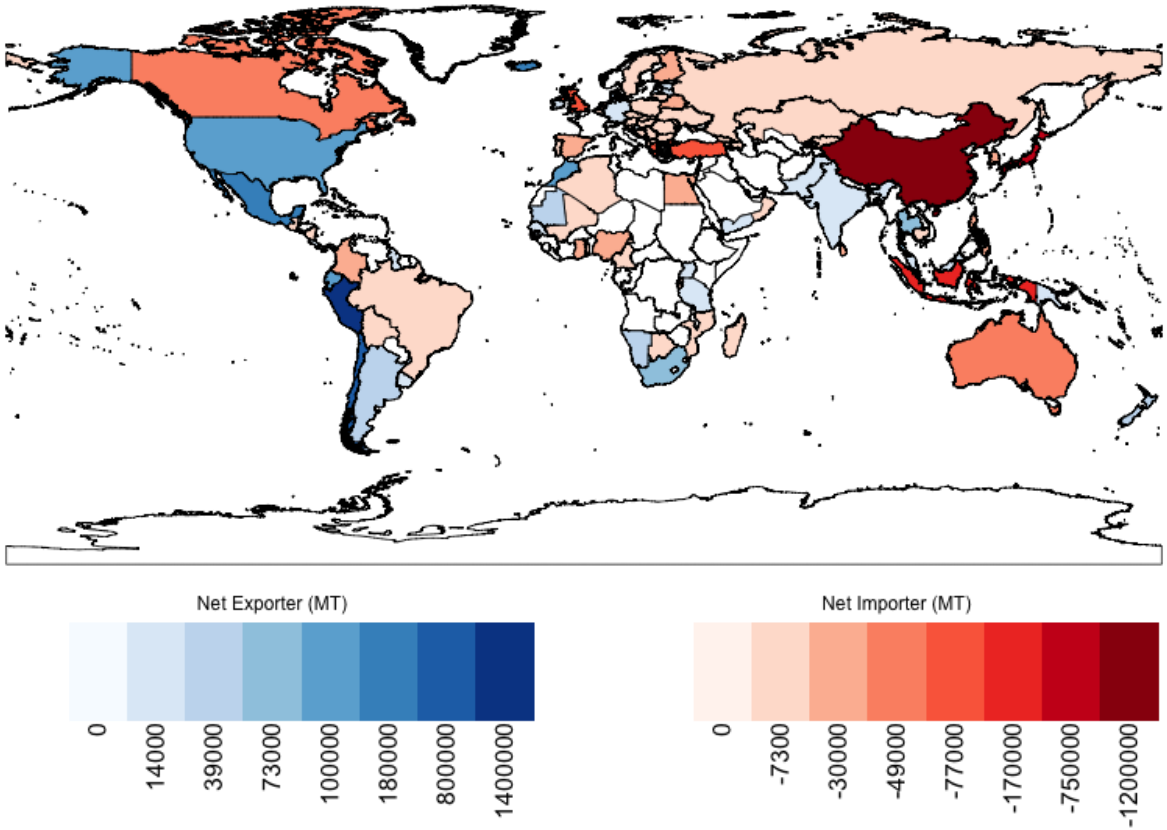
Fishmeal trade

- China is the leading fishmeal importer in the world, steady demand 1.2 MMT/yr
- Top 3 fishmeal suppliers for China: Peru, USA and Chile

- 2012 World top 5 net importers: China, Japan, Indonesia, Greece, Turkey
- 2012 World top 5 net exporters: Peru, Chile, Iceland, Mexico, USA



Chris Fedor:
Fish Map

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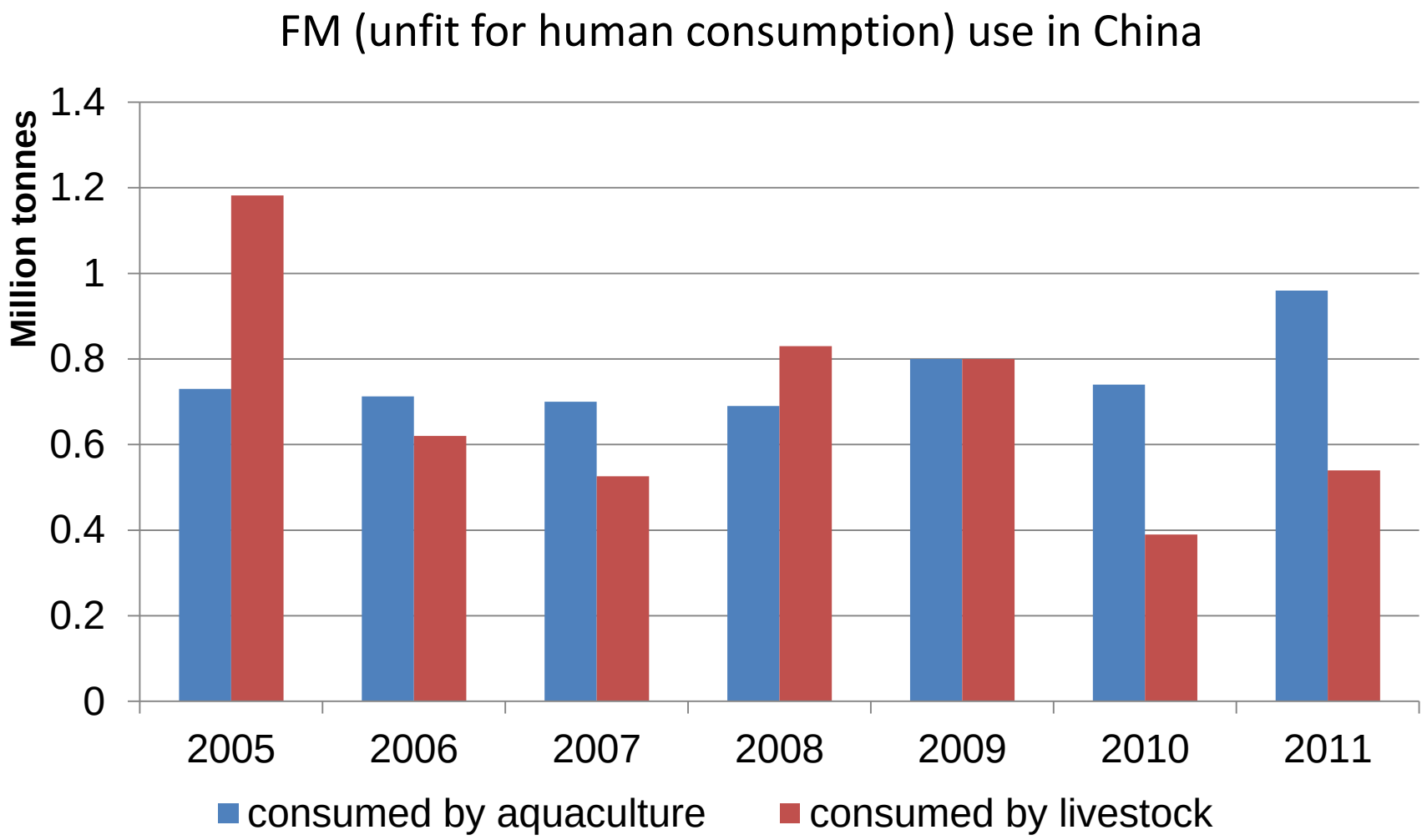
Fishmeal used by aquaculture vs. livestock



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Feed Conversion Ratios (FCRs) of Top Farmed Species

Species	% total production	Destined markets	Average FCR*
Grass carp	12%	Domestic	1.7
Silver carp	9%	Domestic	0 (filter feeders)
Bighead carp	7%	Domestic	0 (filter feeders)
Common carp	7%	Domestic	1.7
Crusian carp	6%	Domestic	1.7
Bream	2%	Domestic	1.7
Black carp	1%	Domestic	1.7
Tilapia	4%	Domestic & Export	1.6
Penaeid shrimp	4%	Domestic & Export	1.2

Why such high FCRs? Why so much FM in carp and tilapia feeds?

* FCR: Economic FCR, the amount of feed supplied to a farm/amount of fish delivered to market

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Growing scarcity of land and water

Is there any meaning to a "carp FCR"?

- Diversification into higher valued species
- Intensification of systems
- Polyculture with inefficient feed targeting
- In the study's carp and tilapia systems, 31 different species raised

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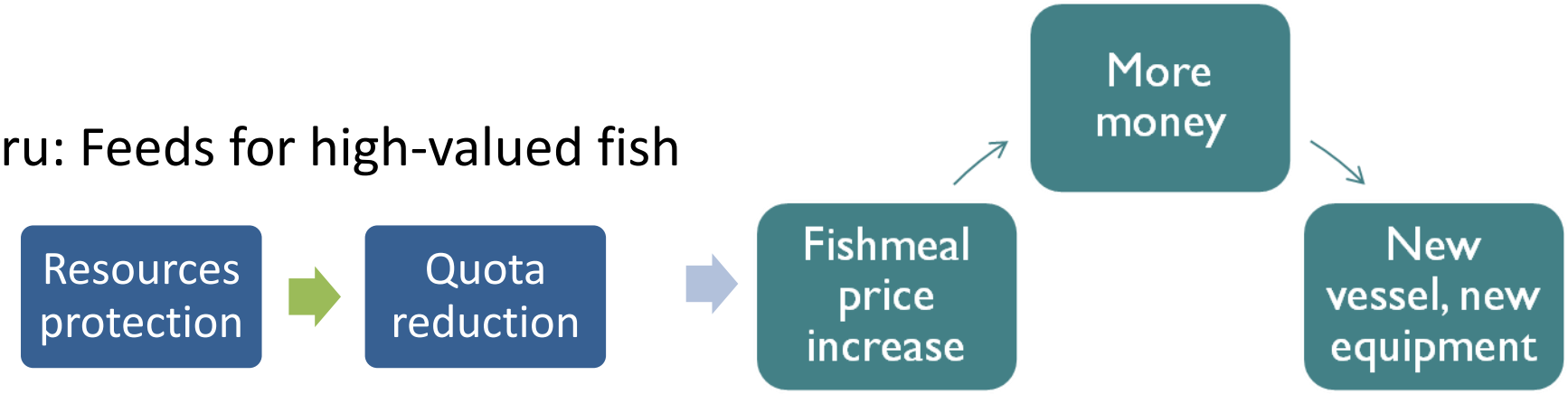
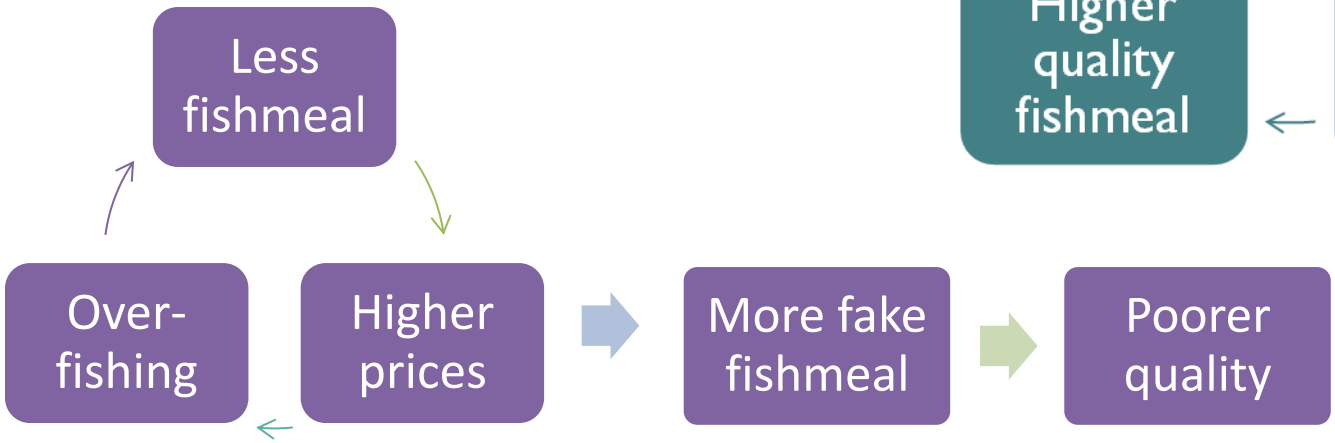
Fishmeal Sourcing: Peru vs. China

Peru: Feeds for high-valued fish



China: Feeds for lower-valued fish



- Src: Wenpu Jin, IFFO/CBBC, May 8, 2007

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What else is in the feeds?

Use of by-catch: "Trash Fish"

-Mainly juveniles of commercial important fish species (32%-50%), small pelagic fish, crustaceans, and cephalopods

-A total of 56 trash fish species have been identified to be used by aquaculture in China

-Some of them already overexploited; stock status of most species remains unknown

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China's Multi-Species Fisheries

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Alternative inputs for fish feeds

Relative Prices of Proteins in Feeds

Ingredient	Crude protein (kg/mt)	Cost ($/mt)	($/kg protein)
Feather meal	800	$780	0.98
DDGS	350	$300	0.86
Poultry meal	570	$570	1.00
Meat and bone meal	500	$590	1.18
Soybean meal	480	$567	1.18
Corn gluten meal	600	$770	1.28
Anchovy meal	650	$1380	2.12

Prices quoted in Feb 2014

Source: Hammersmith Ltd.

Naylor et al. PNAS 2009

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China's Green Economy

Recycle Fish Processing Wastes as Feed

- China is the world's largest fish processor, re-exporter of wild-caught fish
- Its large aquaculture sector is expanding, producing more fish processing wastes

- Converting all fish processing wastes to feed could account for one-half (up to two-thirds) of its current fishmeal imports

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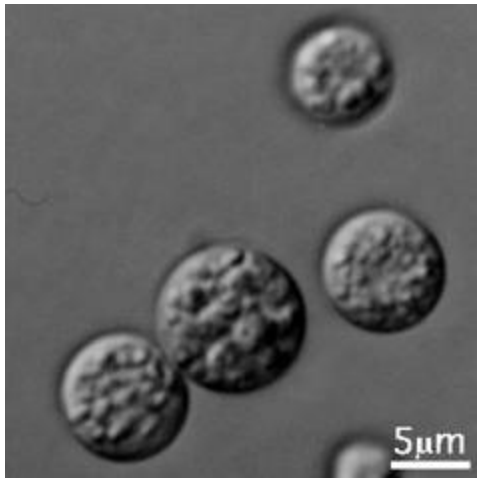
Marine Proteins and Oils

- Microalgae
- Bacteria
- Yeasts
- Filamentous algae



- Good source of omega-3s
- Traceable, toxin-free, consistent quality
- Expensive, energy intensive, scale

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Marine Proteins

- Farmed Polychaete Worms
  - High protein content
  - High levels of long-chain omega-3s
  - Palatable
  - Digestible
  - Can be used as starter feed

  - Fairly new industry (scale, economics?)

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Trade-offs and Constraints

- High fiber content of plant proteins (pollution)
- Amino acid and mineral content of plant proteins
- Palatability of feeds to farmed fish
- Omega-3 content of plant oils
  - Soy, corn, palm rel high in omega 6 (low N3:N6 ratio)
  - GM oilseeds (long-chain omega 3s)
- Consumer distaste for animal by-products in fish (disease risks, concept)
- Consumer acceptance of GMO-based feed input
- Food safety and scale issues of seafood processing wastes
- Economic constraints on algae, worms etc.

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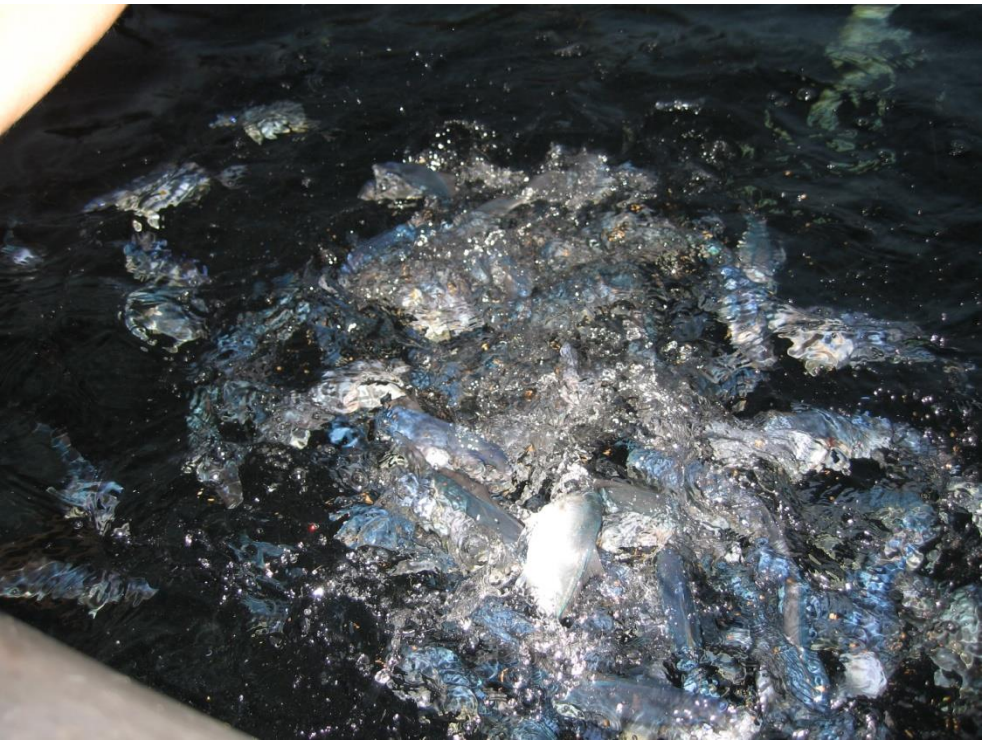

Fishmeal

Soy pellets

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Reducing the use of wild fish for aqua feeds

- Farm at lower trophic levels
- Source from sustainably managed fisheries
- Use alternative feeds (not forage fish) to max extent possible
  - Fish processing wastes
  - Other plant and animal by-products

Science can help determine most sustainable feed sources, but economics is also important.

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Freshwater Aquaculture Development in Kenya

~ 98% fish from capture (ocean, Lake Victoria)

Rural economies need further growth

Poverty alleviation, food security

Research: Katrina Ole-Moiyoi (E-IPER)

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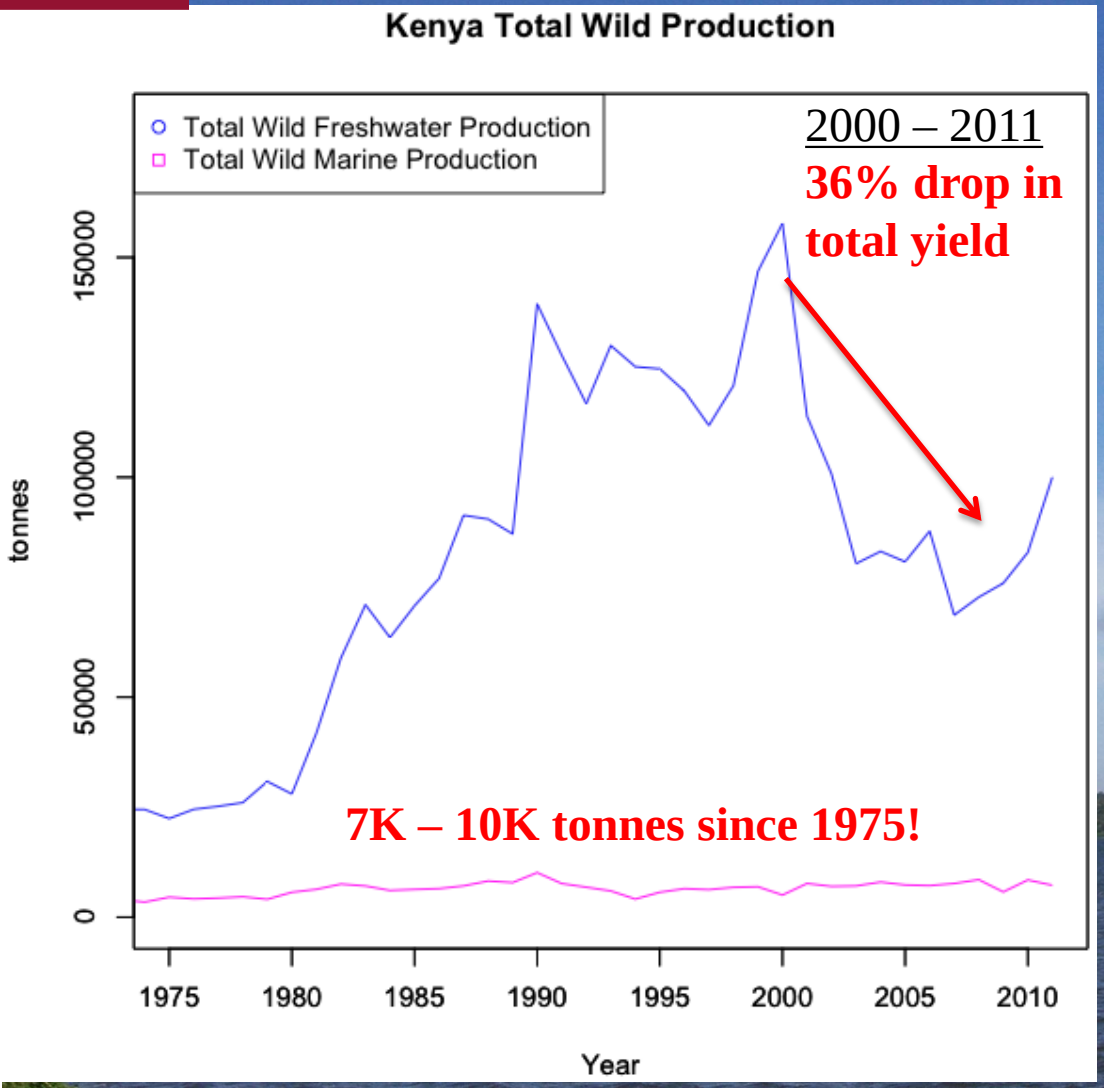
Dependence on declining wild stocks



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Policy Initiatives

Dr. Micheni Ntiba
Permanent Secretary
Ministry of Fisheries Development

Dr. Charles Ngugi
Fisheries Secretary
Ministry of Fisheries Development

2009 ESP Subsidy Program

- Economic Stimulus for Kenya

- $240 million for all sectors
  - $12 million in aquaculture
- Goal: "To enhance contribution of the sector to food security, the economy and increase income to the communities"
- Subsidy package components
  - Pond construction
  - Fingerlings
  - Feed

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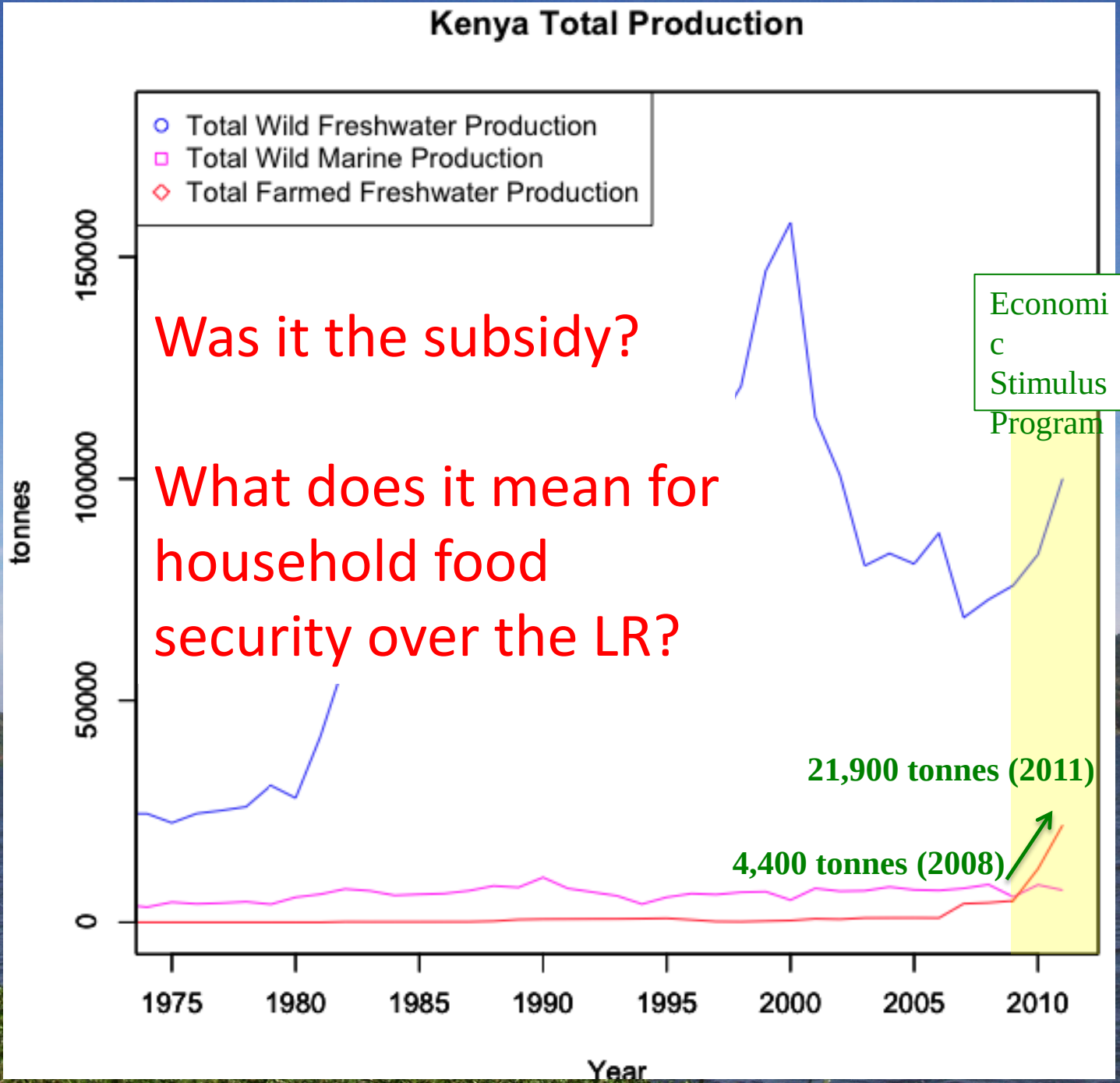

Was it the subsidy?

What does it mean for household food security over the LR?

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Working well for the entrepreneurial farmers

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Disadoption among the poorest farmers

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Integrating Framework

Can a growing aquaculture sector add resilience to the global food system? In face of:

-- climate change and variability?

-- market fluctuations?

Portfolio theory: correlation between outcomes, risk management

-- e.g., stocks and bonds

Troell, Naylor et al., *PNAS* 2014

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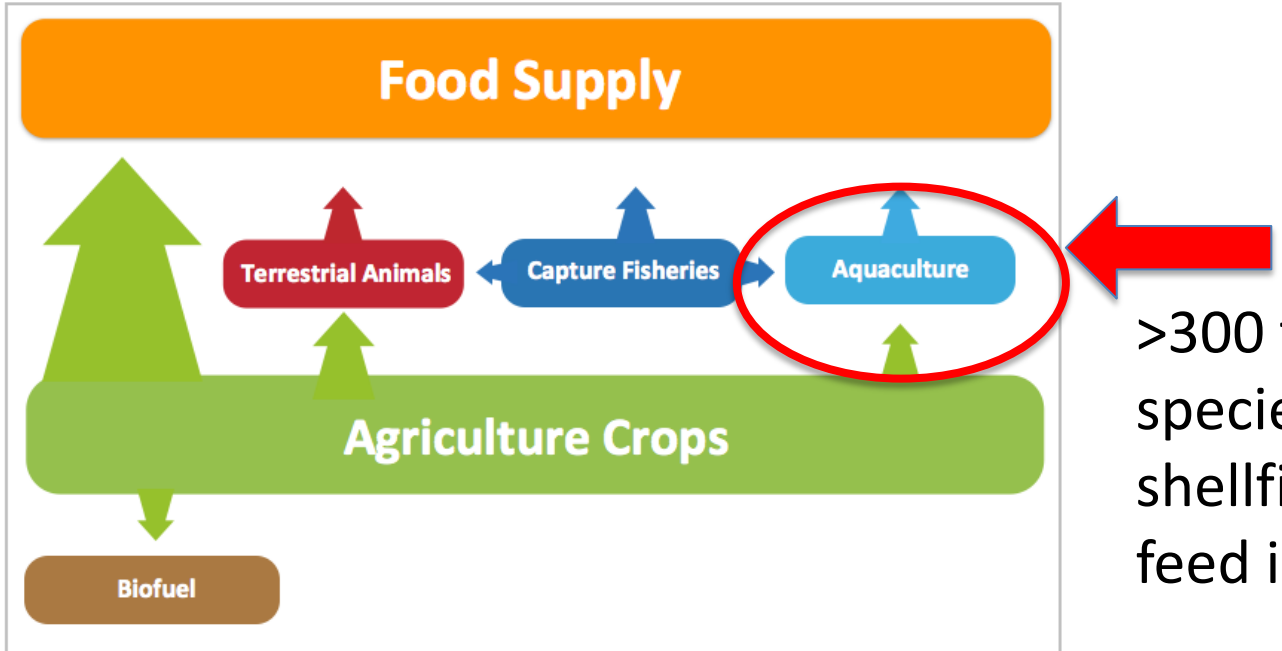
Integrating Framework: Resilience

- Diversity of outputs/inputs influences resilience
- Substitution in production (outputs) and consumption (feed inputs)
  - Model with own- and cross-price elasticities of demand/supply



>300 farmed species of fish & shellfish; many feed inputs

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Does aquaculture add resilience to food systems in the face of climate change?

- Thermal buffering
- Feed conversion
- Disease and pathogen outbreaks

Journal of Applied Ecology

Journal of Applied Ecology 2012 doi: 10.1111/1365-2644.12017

More rapid and severe disease outbreaks for aquaculture at the tropics: implications for food security

Tommy L. F. Leung[1]* and Amanda E. Bates[2,3]

[1]*Centre for Behavioural and Physiological Ecology, Zoology, University of New England, Armidale, NSW, 2351, Australia ;* [2]*Institute of Marine and Antarctic Studies, University of Tasmania, PO Box 49, Taroona, TAS, 7001, Australia ; and* [3]*School of Life and Environmental Sciences, Deakin University, PO Box 432, Warrambool, Vic., 3280, Australia*

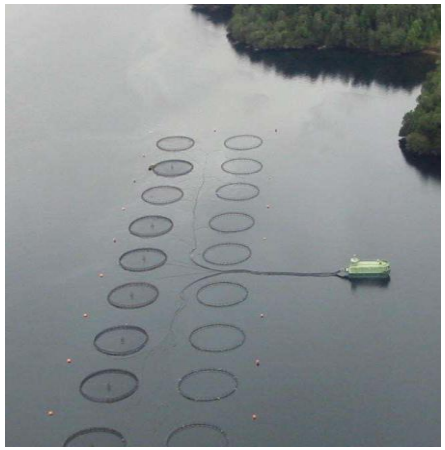

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Figure 2A: Trend in Food Prices by Sector, 1990-2013

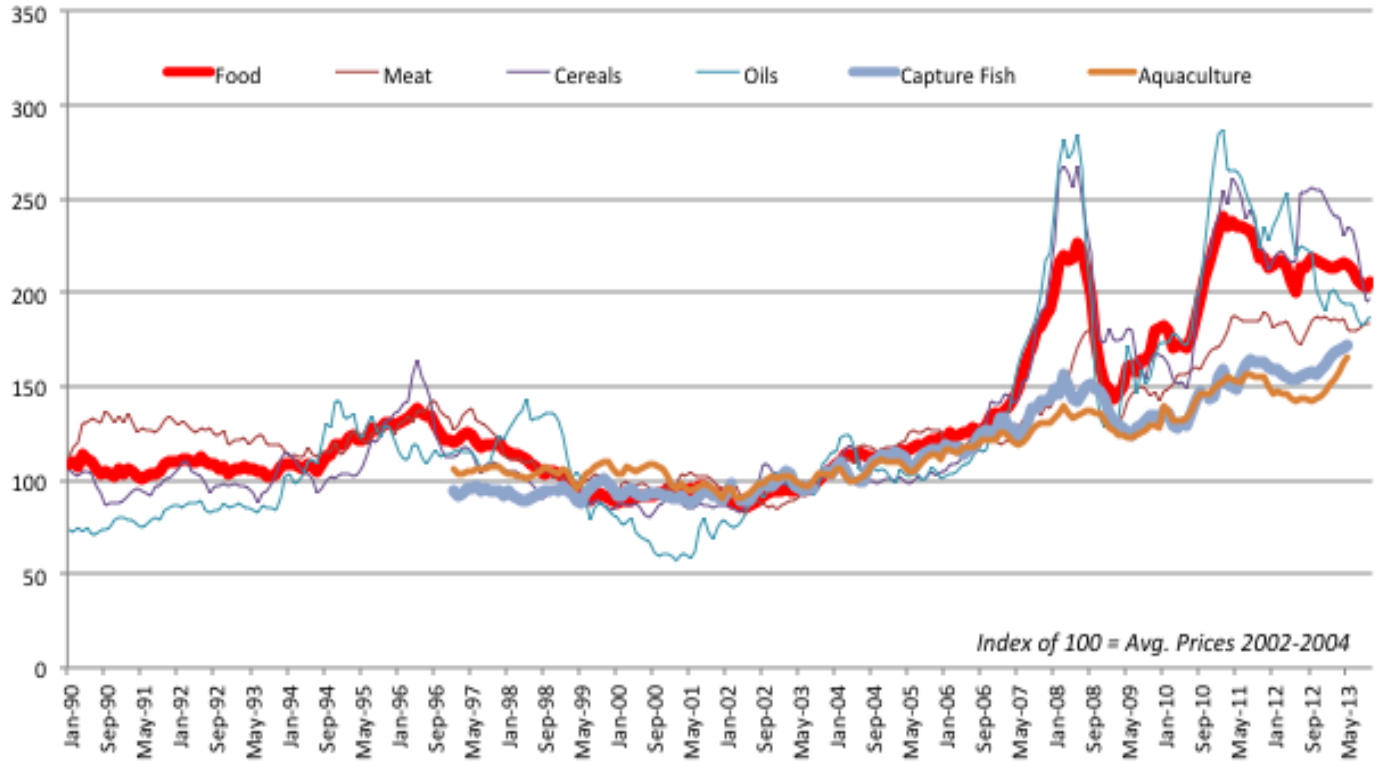

Figure 2B : Price Correlation Between Sectors, 1990-2013

	Food	Meat	Cereals	Oils	Capture Fish	Aquaculture
Food	1	0.92	0.98	0.95	0.95	0.96
Meat	0.92	1	0.88	0.8	0.92	0.94
Cereals	0.98	0.88	1	0.93	0.94	0.93
Oils	0.95	0.8	0.93	1	0.87	0.88
Capture Fish	0.95	0.92	0.94	0.87	1	0.97
Aquaculture	0.96	0.94	0.93	0.88	0.97	1
Coefficent Of Variation	0.33	0.21	0.4	0.43	0.21	0.16

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Will Aquaculture Add Resilience?

- Environmental externalities matter
- High dependence on natural resource base
- Future direction: greater concentration of a few species?


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