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

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Let’s start with a fish...
Southern Chile
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?
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?
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
Global Fish Production and Capture Fisheries Use

Million tonnes

Year


Aquaculture
Reduction fisheries
Non food fish landings
Food fish landings
Total Capture

Source: FAO FishStatJ 2013
Food Commodity Growth 1990-2010

Aquaculture (total): 7.8% pa

Poultry: 4.6% pa

Pork: 2.2% pa

Dairy: 1.4% pa

Grains: 1.4% pa

Beef: 1.0% pa
World Aquaculture Production of Food Fish by Region

Asia: 89%

Source: FAO FishStatJ 2013
World Aquaculture Production of Food Fish by Region

China 62%

Source: FAO FishStatJ 2013
Top 10 Aquaculture Producers Worldwide (2011)

**By Volume**
- China: 62%
- India: 47%
- Viet Nam: 2%
- Indonesia: 20%
- Bangladesh: 16%
- Norway: 10%
- Thailand: 8%
- Egypt: 6%
- Myanmar: 1%
- USA: only 0.6%!

**By Value**
- China: 47%
- India: 20%
- Indonesia: 16%
- Chile: 10%
- Viet Nam: 8%
- Norway: 6%
- Japan: 4%
- Bangladesh: 4%
- Thailand: 4%
- Egypt: 2%
- USA: only 0.8%!

*Source: FAO FishStatJ 2013*
>300 freshwater and marine species farmed around the world
A Norwegian salmon farm: pumping fish live from a pen for delivery to a processor--in January
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.
Boxes of fresh fish, ready to be trucked to the US later that day
GMO Salmon

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

- **Predator Control Program**: Animals targeted to control predation of farmed fish.
- **Fish Meal and Fish Oil**: Made from oily fish, such as anchovies and mackerel.
- **Introduction of Non-Native Species**: For example, Atlantic salmon eggs (seed stock) from Europe.
- **Drugs**: Antibiotics, hormones, anesthetics, pigments, vitamins.
- **Herbicides**: Controls algae growth on netpens.
- **Incubation of Local Diseases**: Caused by a high concentration of fish.
- **New Diseases and Parasites**: Introduced by seed stock.
- **FISH SEWAGE**: Contains uneaten food, waste products, disease, and pathogens.
- **Genetically Modified Organisms (GMOs)**: Compete with native fish for food and habitat.
- **Escape of Non-Native Species**: Spreads into the wild.
- **Mortality**: Impact on local ecosystems.
Risks of disease, parasites, escapes
Dilution as the Solution?

Tuna cages in Croatia
Pollution

6 tidal cycles

Feedlots of the sea?

60 tidal cycles

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

![Graph showing the ratio of wild fish to fed farmed fish for various species and years.](FIFO: A good metric?)
# Stock Status of the Top 10 Forage Fish Species

<table>
<thead>
<tr>
<th>Common Name</th>
<th>State of Exploitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peruvian anchovy</td>
<td>Recovering, Overexploited</td>
</tr>
<tr>
<td>Atlantic herring</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>Chub mackerel</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>Japanese pilchard</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>Japanese anchovy</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>European pilchard (=Sardine)</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>Atlantic mackerel</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>Gulf menhaden</td>
<td>Fully exploited</td>
</tr>
<tr>
<td>South American pilchard</td>
<td>Fully exploited, Overexploited</td>
</tr>
<tr>
<td>Capelin</td>
<td>Fully exploited</td>
</tr>
</tbody>
</table>

*Source: Alder et al. 2008; Review of the state of world marine fishery resources 2011*
Filter Feeders and Plants
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?
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
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
Fishmeal Use in Carp & Tilapia Systems

China’s aquaculture production by species

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.
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
Fishmeal used by aquaculture vs. livestock

FM (unfit for human consumption) use in China

- **2005**: 1.2 million tonnes
- **2008**: 1.2 million tonnes
- **2009**: 0.8 million tonnes
- **2010**: 0.6 million tonnes
- **2011**: 1.1 million tonnes

**Legend:**
- Blue: consumed by aquaculture
- Red: consumed by livestock
## Feed Conversion Ratios (FCRs) of Top Farmed Species

<table>
<thead>
<tr>
<th>Species</th>
<th>% total production</th>
<th>Destined markets</th>
<th>Average FCR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass carp</td>
<td>12%</td>
<td>Domestic</td>
<td>1.7</td>
</tr>
<tr>
<td>Silver carp</td>
<td>9%</td>
<td>Domestic</td>
<td>0 (filter feeders)</td>
</tr>
<tr>
<td>Bighead carp</td>
<td>7%</td>
<td>Domestic</td>
<td>0 (filter feeders)</td>
</tr>
<tr>
<td>Common carp</td>
<td>7%</td>
<td>Domestic</td>
<td>1.7</td>
</tr>
<tr>
<td>Crusian carp</td>
<td>6%</td>
<td>Domestic</td>
<td>1.7</td>
</tr>
<tr>
<td>Bream</td>
<td>2%</td>
<td>Domestic</td>
<td>1.7</td>
</tr>
<tr>
<td>Black carp</td>
<td>1%</td>
<td>Domestic</td>
<td>1.7</td>
</tr>
<tr>
<td>Tilapia</td>
<td>4%</td>
<td>Domestic &amp; Export</td>
<td>1.6</td>
</tr>
<tr>
<td>Penaeid shrimp</td>
<td>4%</td>
<td>Domestic &amp; Export</td>
<td>1.2</td>
</tr>
</tbody>
</table>

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
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
Fishmeal Sourcing: Peru vs. China

Peru: Feeds for high-valued fish
- Resources protection
- Quota reduction
- Fishmeal price increase
- More money
- New vessel, new equipment

China: Feeds for lower-valued fish
- Less fishmeal
- Over-fishing
- Higher prices
- More fake fishmeal
- Poorer quality
- Improved efficiency

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
China’s Multi-Species Fisheries
Alternative inputs for fish feeds

Relative Prices of Proteins in Feeds

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

Prices quoted in Feb 2014

Source: Hammersmith Ltd.

Naylor et al. PNAS 2009
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
Marine Proteins and Oils

- Microalgae
- Bacteria
- Yeasts
- Filamentous algae

- Good source of omega-3s
- Traceable, toxin-free, consistent quality
- Expensive, energy intensive, scale
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?)
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.
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.
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)
Dependence on declining wild stocks

Kenya Total Wild Production

2000 – 2011

36% drop in total yield

7K – 10K tonnes since 1975!
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
Was it the subsidy?

What does it mean for household food security over the LR?
Working well for the entrepreneurial farmers
Disadoption among the poorest farmers
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
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
Does aquaculture add resilience to food systems in the face of climate change?

- Thermal buffering
- Feed conversion
- Disease and pathogen outbreaks

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

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

Index of 100 = Avg. Prices 2002-2004

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

<table>
<thead>
<tr>
<th></th>
<th>Food</th>
<th>Meat</th>
<th>Cereals</th>
<th>Oils</th>
<th>Capture Fish</th>
<th>Aquaculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>1</td>
<td>0.92</td>
<td>0.98</td>
<td>0.95</td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td>Meat</td>
<td>0.92</td>
<td>1</td>
<td>0.88</td>
<td>0.8</td>
<td>0.92</td>
<td>0.94</td>
</tr>
<tr>
<td>Cereals</td>
<td>0.98</td>
<td>0.88</td>
<td>1</td>
<td>0.93</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td>Oils</td>
<td>0.95</td>
<td>0.8</td>
<td>0.93</td>
<td>1</td>
<td>0.87</td>
<td>0.88</td>
</tr>
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<td>Capture Fish</td>
<td>0.95</td>
<td>0.92</td>
<td>0.94</td>
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<td>1</td>
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<td>0.93</td>
<td>0.88</td>
<td>0.97</td>
<td>1</td>
</tr>
</tbody>
</table>

Coefficient Of Variation: 0.33 0.21 0.4 0.43 0.21 0.16
Will Aquaculture Add Resilience?

• Environmental externalities matter

• High dependence on natural resource base

• Future direction: greater concentration of a few species?