Climate change and aquaculture

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Organization

- **Fish food needs**
  - Changes in patterns of production and consumption
  - Role of aquaculture in the supplies
- **Aquaculture production**
  - Climatic/ environmental
  - climatic/ geographical distribution
- **Major climatic change influences on aquaculture**
  - Direct
  - Indirect
  - Adaptive measures
- **Carbon emissions**
  - Comparison with other food production sectors
  - Positive role of aquaculture
Major, global changes taking place in the fishery sector

- Change from a developed country dominated sector to a developing country dominated sector
- This trend is being further consolidated

Data based on Delgado et al. (2003)
Contributions to total fish supplies

- Capture fisheries almost static
- Contribution from aquaculture increasing
Contribution of aquaculture to total, inland and marine fish production

- Aquaculture contributes about 35% to global fish supplies
- The contribution is on the increase

A newly emerged activity in Myanmar: Rohu culture; $84 million exports in 2006
Food fish needs: under different scenarios

- Overall a considerable increase in food fish will be required to meet the increasing demand

| Table 2. Projected global food fish demands (modified after Brugère and Ridler, 2004). |
|---------------------------------|---------------|----------------------------------|
| Forecasts | Needs | Estimated needs from aquaculture \(\times 10^6\) tonnes |
| | Per caput consumption (kg/ yr) | Total demand \(\times 10^8\) t | Fisheries |
| | | | Growing (0.7%) | Stagnating |
| Baseline\(^a\) | 17.1 | 130 | 53.6 (1.8%) | 68.6 (3.5%) |
| Lowest | 14.2 | 108 | 41.2 (0.4%) | 48.6 (1.4%) |
| Highest | 19.0 | 145 | 69.5 (3.2%) | 83.6 (4.6%) |
| 2010\(^b\) | 17.8 | 121 | 51.1 (3.4%) | 59.7 (5.3%) |
| 2050 | 30.4 | 271 | 177.9 (3.2) | 209.5 (3.6%) |
| 1999\(^c\) | 15.6 | 127 | 45.5 (0.6%) | 65.1 (2.0%) |
| 2030 | 22.5 | 183 | 102.0 (3.5%) | 121.6 (4.2%) |

a- Delgado et al. (2003), to 2020; b- Wijkstrom, 2003; c- Ye, 1999
Food fish demands: role of aquaculture

- Approximately an increase of 30 million tonnes needed

<table>
<thead>
<tr>
<th>Continent</th>
<th>Food fish demand-2020 (t)</th>
<th>Aq. Production 2003 (t)(^a)</th>
<th>Aqiculture Demand-2020 (t)(^b)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>9,580,553</td>
<td>520,806</td>
<td>3,035,058</td>
<td>482.8</td>
</tr>
<tr>
<td>Asia</td>
<td>44,130,913</td>
<td>8,686,136</td>
<td>16,304,098</td>
<td>87.8</td>
</tr>
<tr>
<td>China</td>
<td>36,452,838</td>
<td>28,892,005</td>
<td>31,659,237</td>
<td>9.6</td>
</tr>
<tr>
<td>Europe</td>
<td>14,156,188</td>
<td>2,203,747</td>
<td>1,937,833</td>
<td>-12.1</td>
</tr>
<tr>
<td>L. America &amp; Caribbean</td>
<td>5,869,204</td>
<td>1,001,588</td>
<td>1,930,947</td>
<td>92.8</td>
</tr>
<tr>
<td>N. America</td>
<td>6,487,500</td>
<td>874,618</td>
<td>1,642,600</td>
<td>87.8</td>
</tr>
<tr>
<td>Oceania</td>
<td>894,907</td>
<td>125,241</td>
<td>259,860</td>
<td>107.5</td>
</tr>
<tr>
<td>World</td>
<td>123,519,591</td>
<td>42,304,141</td>
<td>60,448,307</td>
<td>42.9</td>
</tr>
</tbody>
</table>

\(^a\) FAO Stats; \(^b\) 2020 fish demand minus estimated current fisheries production
Aquaculture is becoming increasingly important to the GDP

- In Asia its importance exceeds that from fisheries

<table>
<thead>
<tr>
<th></th>
<th>Capture Fisheries</th>
<th>Aquaculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>1.884</td>
<td>2.688</td>
</tr>
<tr>
<td>PR China</td>
<td>1.132</td>
<td>2.618</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2.350</td>
<td>1.662</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>1.432</td>
<td>5.775</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1.128</td>
<td>0.366</td>
</tr>
<tr>
<td>Philippines</td>
<td>2.184</td>
<td>2.633</td>
</tr>
<tr>
<td>Thailand</td>
<td>2.044</td>
<td>2.071</td>
</tr>
<tr>
<td>Vietnam</td>
<td>3.702</td>
<td>3.497</td>
</tr>
</tbody>
</table>
Summary on food fish needs etc.

- Major changes in the production and consumption over the last three decades
- World will need an extra \( \sim 40-60 \times 10^6 \) t of food fish by 2020
- Aquaculture production has increased \( \sim 33\% \) to total fish supplies
  - Accounts for \( \sim 45\% \) of current global consumption
- Aquaculture expected to meet the future demand for food fish supplies (reaching \( \sim 50-60\% \))
- Aquaculture increasing contribution (by passing that from fisheries) to GDP of some nations; mainly in Asia
Aquaculture production: by climatic regions

- Great bulk of aquaculture occurs in tropical & sub-tropical regions
- With some commodities the contribution from temperate regions have declined; why?
Aquaculture production: by climatic regions/ environment

- For all commodities highest production in tropics & sub tropics and in fw (except seaweeds)
Aquaculture production: by climatic regions/continents

- **Fish**
  - Tropical: 12,000,000
  - Subtropical: 8,000,000
  - Temperate: 2,000,000

- **Molluscs**
  - Tropical: 8,000,000
  - Subtropical: 7,000,000
  - Temperate: 5,000,000

- **Crustaceans**
  - Tropical: 3,000,000
  - Subtropical: 2,500,000
  - Temperate: 1,500,000

- **Seaweeds**
  - Tropical: 8,000,000
  - Subtropical: 7,000,000
  - Temperate: 1,000,000
An example of contribution of different commodities to aquaculture production, 2005

- Fin fish the highest contributor to aquaculture production
- Fin fish culture in fw is still the most dominant
- Crustacean production is relatively low; but high value
Summary on aquaculture production: current status

- Aquaculture production is concentrated in tropical & sub-tropical areas
- Minor contribution from temperate areas- but high valued species
- Amongst former main concentration is Asia
- Predominant commodity: fin fish 40 %
- Fin fish: ~ 90 % in fw
- Many emerging practices
- Mari-culture highest growth potential
Climate change impacts?

• Climate change impacts
  – Direct
  – Indirect

• All cultured aquatic organisms are poikilotherms
  – Hence any temperature change impacts on production
    • More impacts on temperate species
      – Possibility of being higher than the optimal temperature range
    • Tropics: positive; higher growth & production
      – Will need more feed inputs
Climate change impacts? Elements of Direct impact

- **Global warming**
  - Inland waters
    - Eutrophication
    - Increased stratification
- **Sea level rise**
  - Saline water intrusion
  - Increased acidification
- **Overall decline in ocean productivity**
- **Change in monsoonal patterns & extreme weather events**
- **Water stress**
Global warming: temperature rises

• **All cultured aquatic organisms are poikilotherms**
  – Hence any temperature change impacts on production
  • More impacts on temperate species
    – Possibility of being higher than the optimal temperature range
  • Tropics: positive; higher growth & production

• **Inland aquaculture:**
  – Exacerbate
    • Stratification
      – upwelling: deeper deoxygenated water
    • Eutrophication
      – Fish kills in dawn hours
Global warming: temperature rises
Inland aquaculture

- **Mostly cage culture: in static waters**
- **Exacerbate**
  - stratification
  - Eutrophication
- **Fish kills**
- **Adaptive measures:**
  - Practices to conform to carrying capacity
  - Do not localize to small areas:
    - spread activity through the water body
  - Regular monitoring
Sea level rise/ Saline water intrusion

- Major aquaculture activities in deltaic areas of the tropics, mainly Asia
  - Upstream freshwater species
    - E.g. catfish (tra), rohu
  - River mouth & estuaries, shrimp & euryhaline fin fish
Sea level rise/ Saline water intrusion

• **Fw fish; could be moved further upstream**
  – Pond space/ facilities become available
    • Use for euryhaline species, including shrimp
  – Increased aquaculture production/ income

• **Some areas become unsuitable for terrestrial agriculture**
  – Provide alternative livelihoods through aquaculture
  – Will require
    • Policy changes
    • Capacity building amongst agriculture farmers
    • Infrastructure developments
      – E.g. new hatchery facilities to meet increase demands; markets
Sea level rise/ Saline water intrusion/ acidification

- Could impact on mollusc (15 million t) culture
  - Shell formation
- Reduce its contribution to carbon sequestration
Change in patterns and extreme weather events

- Loss of infrastructure
- Loss of stock
- Recent unusual snow storms in southern China
  - Estimated $0.5 \times 10^6$ loss of stock
  - Large number of escapees
    - Possible impacts on biodiversity?
Change in weather patterns and extreme events

• In Asia, the highest aquaculture activity:
  – small scale farmers
    • Often family owned and family run
    • Clustered together in areas conducive to aquaculture
    • Therefore impacts on many households; livelihoods
Change in weather patterns and extreme events

- **Adaptive measures:**
  - Not many available

- **However:**
  - Encourage cluster insurance
  - Enables a resurrection of the businesses
  - Impacts on production temporary
• **The predicted stress**
  
  – decrease in water availability in major rivers in Central, South, East and South-East Asia (IPCC, 2007)
  
  – areas where there is major aquaculture activities at present
  
  • the deltaic areas of some of the major rivers/ intense aquaculture activity
    
    – E.g., Mekong, the Meghna-Brahmaputra and Ayeyarwaddy,
Water stress:

- water availability in major river systems has to be considered in conjunction with
  - saline water intrusion arising from sea level rise (Hughes et al., 2003)
  - the expected changes in precipitation/monsoon patterns (Goswami et al., 2005).

### Table 7. Specific water demand (m³/t) for different animal food products (data from Zimmer and Renault, 2003) and comparison with needs for aquaculture.

<table>
<thead>
<tr>
<th>Product</th>
<th>Water demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef, mutton, goat meat</td>
<td>13500</td>
</tr>
<tr>
<td>Pig meat</td>
<td>4600</td>
</tr>
<tr>
<td>Poultry</td>
<td>4100</td>
</tr>
<tr>
<td>Milk</td>
<td>790</td>
</tr>
<tr>
<td>Butter + fat</td>
<td>18000</td>
</tr>
<tr>
<td>Common carp (intensive/ponds)</td>
<td>21000</td>
</tr>
<tr>
<td>Tilapia (extensive/ponds)</td>
<td>11500</td>
</tr>
<tr>
<td>Pellet fed ponds a)</td>
<td>30100</td>
</tr>
</tbody>
</table>

a- Muir, 1995; b- Verdegem et al., 2006

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From Nguyen & De Silva, 2006; based on data from Shiklomanov, 1998
Water stress:

Major modelling attempt incorporating the variables for deltaic regions
   e.g. Mekong, Meghna- Brahamputra in Bangladesh and Ayeyarwaddy in Myanmar
   amongst others needed to determine more accurately:
   - The degree of sea water intrusion in the / adjoining wetlands
   - Assessment of agricultural activity likely to be lost
   - The potential impacts on spawning migrations
     • changes in seed availability for subsistence cage farming
   - Overall socio-economic impacts of the resulting events.

• Encourage (=adaptive measures)
  - reduction in water usage in aquaculture (e.g. pond culture)
  - Encourage non-water consumption (direct) aquaculture (apart for feeds)
    • Culture based fisheries
    • Stock enhancement
Climate change: indirect impacts on aquaculture:

- **In 2003, globally:**
  - aquaculture sector consumed 2.94 million tonnes of fish meal (53.2 percent of global fish meal production)
  - equivalent to
    - 14.95 to 18.69 million tonnes of forage fish/trash fish/low valued fish, primarily pelagics
  - production based on pelagics in the sub-tropical and temperate regions

- **Ocean productivity in the North Atlantic will plummet 50 percent and world wide by 20 percent** (Schmittner, 2003).

- **El Niño influences on the Peruvian sardine and anchovy landings**
  - consequently on global fish meal and fish oil supplies and prices (Pike and Barlow, 2002).

- **Changes in the North Atlantic Oscillation winter index** (Schmittner, 2003),
  - higher winter temperatures
  - could influence sandeel (*Ammodytes* spp.) recruitment.
Climate change: indirect impacts on aquaculture: Fish meal & oil usage in aquaculture
Climate change: indirect impacts on aquaculture: Fish meal & oil usage in aquaculture

- The return for unit use of the resources is much higher in culturing fish feeding lower in the food chain
- Adaptive measures
  - encourage a shift
  - Alternative ingredients
  - Better feed management

![Graph showing production per tonne of fish meal usage and fish oil usage for different fish species]
Trash fish/ low valued fish/ forage fish supplies
A potential problem in mariculture in the tropics

• In the Asia-Pacific region:
  – uses 1,603,000 to 2,770,000 tonnes of trash fish/ low valued fish as a feed source directly.
  – The low and high predictions for year 2010 are 2,166,280- 3,862,490 tonnes

• Indian Ocean
  – most rapidly warming ocean; Could bring about major changes
    • land primary productivity
    • changes in current patterns (Gianni et al., 2003).
    • further exacerbated by extreme climatic events such as changes in monsoonal rain patterns (Goswami et al., 2006)
  – Most supplies from subsistence fishers/ fishing
  – small scale artisanal
    • subsistence and other small-scale fishers
      – lack mobility and alternatives
      – often the most dependent on specific fisheries
      – will suffer disproportionately from changes and occurrence of such changes have been rated at Medium Confidence by the IPCC (2007).

  – influence inshore fish productivity
    • overall impact on the supplies of trash fish/ low valued fish.
Climate change: indirect impacts on aquaculture
Impacts on diseases

• On human health and the associated risks well documented (e.g. Epstein et al., 1998; McMichael, 2003; Epstein, 2005)
  – general consensus
    • incidence of terrestrial vector borne and diarrhoeal diseases will increase.
  – the potential trends on climatic change on aquatic organisms less well documented
    • primarily concentrated on coral bleaching and associated changes

• climatic change may influence selection of different life-history traits
  – affecting parasite transmission and
  – potentially, virulence (Marcogliese, 2001).

• increase in the rate of eutrophication in some oceans
  – filter feeding molluscs- shell fish poisoning
  – harmful effects on cage culture operations of salmon for example
Climate change: indirect impacts on aquaculture
Impacts on diseases

• **Possibility enabling competitive species to spread to new areas**
  – the Pacific oyster (*Crassostrea gigas*) and associated pathogenic species (Diederich *et al.*, 2005).

• **Comparable evidence of the spread of two protozoan parasites (*Perkinsus marinus* and *Haplosporidium nelsoni*) northwards from the Gulf of Mexico to Delaware Bay (Hofmann *et al.*, 2001)
  – has resulted in mass mortalities in Eastern oyster (*Crassostrea virginica*).
  – suggested that this spread is brought about by higher winter temperatures
  – the pathogens otherwise were kept in check by temperatures $<3^\circ$C.
  – With the predicted pole ward increase in temperatures
    • witness the emergence of pathogens that were kept in check by lower winter temperatures
    • impact on cultured organisms such as mollusc
Impacts on biodiversity

• the greatest impacts biodiversity
  – predicted to occur in terrestrial habitats
  – less so in aquatic habitats
  – apart from those brought about through coral bleaching
    • subsequent loss of coral habitats, one of the most diverse habitats.
• To date only the extinction of one species is clearly related to climatic change
  – golden toad (*Bufo periglenes*) from Costa Rica (Crump, 1998)
• Aquaculture:
  – heavy dependence on alien species, in all climatic regimes, continents and regions
    (Gajardo and Laikre, 2003; De Silva *et al.*, 2005)
  – Alien species:
    • Adversely affect biodiversity (?)
• climate change induced changes will not overly bring about impacts on biodiversity through aquaculture *per se*
• any new introductions for aquaculture purposes will have to take into consideration such factors in the initial risk assessments undertaken for purposes of decision making.
Impacts on biodiversity: coral reefs

• The decline of coral reefs
  – from bleaching
  – weakening of coral skeletons
  – reduced accretion of reefs,
  – estimated to be as high as 60 percent by year 2030 (Hughes et al., 2003).

• the drivers of coral reef destruction is different from the past
  – these are predominantly climate change associated drivers

• direct relevance of loss of coral reefs and biodiversity thereof to aquaculture is not immediately apparent
Impacts on biodiversity: coral reefs

- One of the coral reef destruction drivers is
  - destructive fishing methods (McManus et al., 1997; Mous et al., 2000)
  - supply the luxurious “live fish” restaurant trade (Pawiro, 2005; Scales et al., 2007) is on the decline.
    - Primarily
      - the required fish supplies being met through aquaculture, mainly the grouper species
    - possibility that the coral reef supply chain of fishes, could be almost totally replaced through aquaculture
    - removes a coral reef destruction driver,
  - contribute to conserving these critical habitats
  - hence biodiversity.
Aquaculture impacts on climate change

- **On a global scale, and in comparison to animal husbandry**
  - significant contributor to the human food basket only relatively recently
  - sector has witnessed a very strong growth rate over the last two decades
  - fastest growing primary production industry (FAO, 2007).

- **Sector blossomed during the period**
  - the world as a whole was becoming increasingly conscious and concerned about
    - sustainability
    - Prudent use of primary resources
    - environmental degradation issues
  - when sustainability, biodiversity and conservation became an integral part of all development efforts

- **Global awareness and public “policing”**
  - the sector has been targeted in many fronts
    - the use of fish meal and fish oil,
    - raw material supposedly suitable for direct human consumption, and considered to be ethically correct to do so (Naylor et al., 1998; 2000; Aldhous, 2004),
    - mangrove clearing for during the shrimp farming boom (Primavera, 1998; 2005),
Aquaculture impacts on climate change:
Comparison of carbon emissions/ contributions to green house gases from animal husbandry and aquaculture

• **US EPA recognised 14 major sources responsible for methane emission**
  − enteric fermentation and manure management from animal husbandry as the third and fifth highest emitters, respectively
  − these two animal food production sources were 117.9 and 114.8, and 31.2 and 39.8 TgCO₂ Equivalents for years 1990 and 2002

• **World’s livestock**
  − account for 18 percent of the greenhouse gases emitted,
  − more than all transport modes put together
  − of which 1.5 billion cattle contributes most (Lean, 2006)

• **The livestock sector is estimated:**
  − to account for 37 percent of all human-induced methane emissions
  − global warming potential (GWP) of methane is estimated to be 23 times that of carbon dioxide

• **Aquaculture:**
  − Data scanty; but no where near the above
Aquaculture impacts on climate change:
*Comparison of carbon emissions/ contributions to green house gases from animal husbandry and aquaculture*

- **The developing world**
  - the per capita meat consumption arose from 15 kg in 1982 to 28 kg in 2002
  - expected to reach 37 kg by 2030 (FAO, 2003).

- **Any analysis has to revolve around the human food needs and the proportionate contribution of each food producing sector to green house gas emissions.**
Aquaculture impacts on climate change

Comparison of carbon emissions/ contributions to greenhouse gases from animal husbandry and aquaculture

- Many methods available for assessing environmental cost
  - life cycle assessment
- Need for standardization
- Current data needs to be extended

Table 9. Energy used in different farming systems. Data from Bunting and Pretty, 2007; Munkung and Gheewala, 2007; Troell et al., 2004. Please refer to these authors for the original references.

<table>
<thead>
<tr>
<th>System</th>
<th>Direct energy</th>
<th>Indirect energy</th>
<th>Total</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-intensive shrimp f.</td>
<td>58</td>
<td>114</td>
<td>169</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Thai shrimp</td>
<td>na</td>
<td>na</td>
<td>45.6</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Marine shrimp</td>
<td>54.2</td>
<td>102.6</td>
<td>156.8</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Salmon f.</td>
<td>9</td>
<td>99</td>
<td>105</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Salmon cages intensive</td>
<td>na</td>
<td>na</td>
<td>56</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Salmon</td>
<td>11.9</td>
<td>87</td>
<td>99</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Norwegian farmed salmon</td>
<td>na</td>
<td>na</td>
<td>66</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Trout ponds</td>
<td>na</td>
<td>na</td>
<td>28</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Grouper/ seabass cage f.</td>
<td>na</td>
<td>na</td>
<td>95</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Carps, intensive recycle</td>
<td>na</td>
<td>na</td>
<td>56</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Carp, recirculating</td>
<td>22</td>
<td>50</td>
<td>50</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Carp ponds feeding &amp; fertilizer</td>
<td>na</td>
<td>na</td>
<td>11</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Carp, semi-intensive</td>
<td>26</td>
<td>61</td>
<td>27</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Catfish ponds</td>
<td>na</td>
<td>na</td>
<td>25</td>
<td>GJ t⁻¹</td>
</tr>
<tr>
<td>Catfish</td>
<td>5.4</td>
<td>108</td>
<td>114</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Tilapia</td>
<td>0</td>
<td>24</td>
<td>24</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Norwegian chicken</td>
<td>na</td>
<td>na</td>
<td>55</td>
<td>MJ kg⁻¹</td>
</tr>
<tr>
<td>Swedish beef</td>
<td>na</td>
<td>na</td>
<td>33</td>
<td>MJ kg⁻¹</td>
</tr>
</tbody>
</table>
Aquaculture impacts on climate change
Comparison of carbon emissions/contributions to greenhouse gases from animal husbandry and aquaculture

- Carp farming more “energy friendly”
- Shrimp at the lowest end
  - Why
    - Intensive
    - External energy inputs needed
    - Feed efficiency low
    - Processing cost high

Table 10. Ranking of selected foods by ratio of edible protein energy (PE) output to industrial energy (IE) inputs, expressed as a percentage. Data from Tyedmers and Pelletier, 2007. For original references please refer to these authors.

<table>
<thead>
<tr>
<th>Food type including technology, environment and locality</th>
<th>% PE/IE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carp extensive, freshwater, various</td>
<td>100-111</td>
</tr>
<tr>
<td>Seaweed, mariculture, Caribbean</td>
<td>50-25</td>
</tr>
<tr>
<td>Chicken, intensive, USA</td>
<td>25</td>
</tr>
<tr>
<td>Tilapia, extensive, freshwater ponds, Indonesia</td>
<td>13</td>
</tr>
<tr>
<td>Mussels, marine long lines, Scandinavia</td>
<td>10-5</td>
</tr>
<tr>
<td>Tilapia, freshwater, Zimbabwe</td>
<td>6.0</td>
</tr>
<tr>
<td>Beef, pasture, USA</td>
<td>5.0</td>
</tr>
<tr>
<td>Beef, feed lots, USA</td>
<td>2.5</td>
</tr>
<tr>
<td>Atlantic salmon, intensive, marine net pen, Canada</td>
<td>2.5</td>
</tr>
<tr>
<td>Shrimp, semi intensive, Colombia</td>
<td>2.0</td>
</tr>
<tr>
<td>Lamb, USA</td>
<td>1.8</td>
</tr>
<tr>
<td>Seabass, intensive marine cage culture, Thailand</td>
<td>1.5</td>
</tr>
<tr>
<td>Shrimp, intensive culture, Thailand</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Aquaculture impacts on climate change

*Comparison of carbon emissions/ contributions to greenhouse gases from animal husbandry and aquaculture*

- Shrimp “energy expensive” product
- High foreign exchange earnings: e.g. Thailand 2.4 billion $
- Energy budgets different between species
- Asia- main center of production: controversy
  - *P. vannamei* (exotic) vs *P. monodon* (indigenous)
- Based on energy cost *P.m* preferred
- Needs to be taken into account in future introductions

Table 11. Comparative life cycle impact assessment results of block tiger prawn and IQF Pacific white-leg shrimp. #- Munkung, 2005; @- Munkung et al., 2007

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Block (1.8 kg) of black tiger prawn</th>
<th>4 (x 453 g) pouches of IQF Pws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abiotic depletion</td>
<td>kg Sb eq</td>
<td>0.32</td>
<td>0.19</td>
</tr>
<tr>
<td>Global warming (GWP100)</td>
<td>kg CO₂ eq</td>
<td>19.80</td>
<td>27.31</td>
</tr>
<tr>
<td>Human toxicity</td>
<td>kg 1,4-DB eq</td>
<td>1.79</td>
<td>3.04</td>
</tr>
<tr>
<td>Fw aquatic ecotoxicity</td>
<td>kg 1,4-DB eq</td>
<td>0.25</td>
<td>0.41</td>
</tr>
<tr>
<td>Mar. aquatic ecotoxicity</td>
<td>kg 1,4-DB eq</td>
<td>1660.00</td>
<td>2071.00</td>
</tr>
<tr>
<td>Terrestrial ecotoxicity</td>
<td>kg 1,4-DB eq</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Acidification</td>
<td>kg SO₂ eq</td>
<td>0.07</td>
<td>0.14</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>kg PO₄ eq</td>
<td>0.22</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Aquaculture impacts on climate change

- **All farming/food production needs energy inputs**
- **Aquaculture offers resilience and elasticity**
  - Most aquaculture based on organisms feeding low in the food chain
  - Some aid in direct carbon sequestration: molluscs, seaweeds

<table>
<thead>
<tr>
<th>Species</th>
<th>1995</th>
<th>2005</th>
<th>Growth %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver carp</td>
<td>2,584</td>
<td>4,153</td>
<td>60.7</td>
</tr>
<tr>
<td>Grass carp</td>
<td>2,118</td>
<td>3,905</td>
<td>84.4</td>
</tr>
<tr>
<td>Common carp</td>
<td>1,827</td>
<td>3,044</td>
<td>66.6</td>
</tr>
<tr>
<td>Bighead carp</td>
<td>1,257</td>
<td>2,209</td>
<td>75.7</td>
</tr>
<tr>
<td>Crucian carp</td>
<td>538</td>
<td>2,086</td>
<td>287.7</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>520</td>
<td>1,703</td>
<td>227.5</td>
</tr>
<tr>
<td>Rohu</td>
<td>542</td>
<td>1,196</td>
<td>120.7</td>
</tr>
<tr>
<td>Catla</td>
<td>448</td>
<td>1,236</td>
<td>175.9</td>
</tr>
<tr>
<td>Mrigal carp</td>
<td>421</td>
<td>330</td>
<td>21.6</td>
</tr>
<tr>
<td>Black carp</td>
<td>104</td>
<td>325</td>
<td>212.5</td>
</tr>
<tr>
<td>Total</td>
<td>10,359</td>
<td>20,187</td>
<td>94.9</td>
</tr>
<tr>
<td>Fw fish (net)</td>
<td>2,581</td>
<td>5,591</td>
<td>116.6</td>
</tr>
<tr>
<td>Total (fw)</td>
<td>12,940</td>
<td>25,778</td>
<td>99.2</td>
</tr>
<tr>
<td>All fin fish</td>
<td>15,616</td>
<td>31,586</td>
<td>102.2</td>
</tr>
</tbody>
</table>
Aquaculture impacts on climate change

- **Unfortunately:**
  - Aquaculture is targeted by lobby groups
    - Based on shrimp & salmon culture
      - Adoption of BMPs
      - Small scale farmers – organic farming
  - These account for < 8% of total aquaculture production
  - But high valued & visible; industrial

- **Aquaculture**
  - Possibly one of the least “energy costly” of the food production sector
  - Many questions still need to be answered
    - carp aquaculture use minimal industrial energy but have a potential significance in the carbon cycle, fixing CO\textsubscript{2} through phytoplankton
    - are fertilization and phytoplankton based aquaculture systems
      - more climate/ carbon friendly than more intensive forms which utilises considerable quantum of external energy inputs
Aquaculture impacts on climate change

- The story cannot be ended by addressing climatic change influences on aquaculture per se.
  - aquaculture does not occur in a vacuum
  - to mitigate further exacerbation of global climate change the world
    - unified action to reduce green house gas (GHG) emissions
    - one of the options is to reduce the dependence on fossil fuels as an energy source
    - do so by increasing the dependence on biofuels.

- The first generation production of biofuels
  - conversion of plant starch, sugars, oils and animal fats into an energy source that could be combusted to replace fossil fuels.
    - the most popular is bio-ethanol, produced by fermentation of a number of food crops such as maize, cassava, sugar cane and the like (Worldwatch Institute, 2006).
    - Brazilian sugarcane bio-ethanol is observed to have the highest net GHG mitigating potential (Macedo et al., 2004).
Aquaculture impacts on climate change

- **As the world looks to biofuels as an alternative**
  - ripple effect on food crops, prices, availability, access, food security and poverty, and overall impact on sustainable development (Naylor et al., 2006).

- **Aquaculture and most forms of animal husbandry depend on some of the food crops used for biofuels production for feeds, directly and indirectly.**

- **The equation on climatic changes on aquaculture therefore, is not straight forward**
  - many other factors have to built into this complex equation to bring about adaptive measures
    - not only for aquaculture but for climate change
    - has to be evolved collectively and not sector by sector.
Aquaculture impacts on climate change

- Is aquaculture overall aid carbon sequestration?