Network of Aquaculture Centres in Asia-Pacific

Climate change and aquaculture

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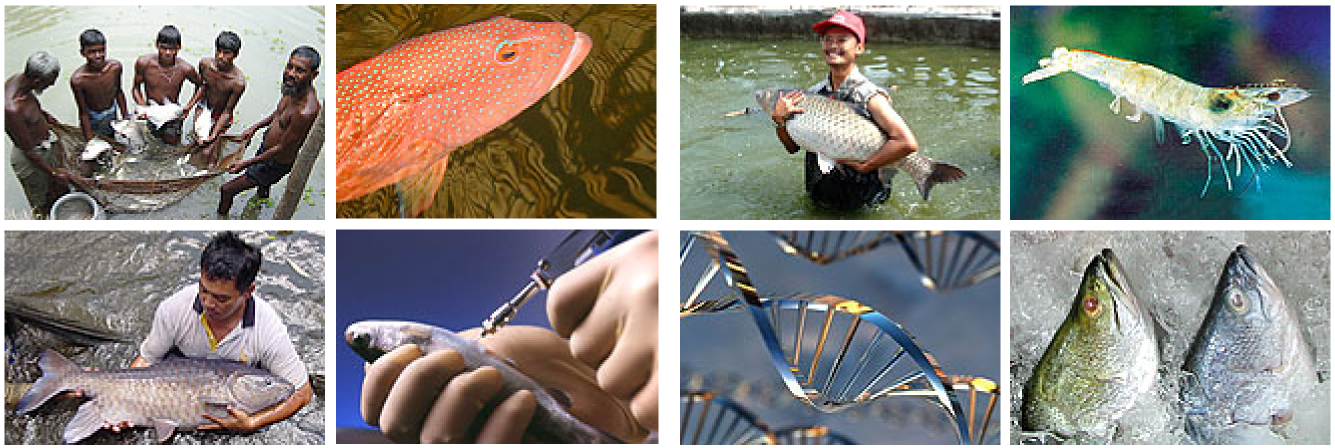
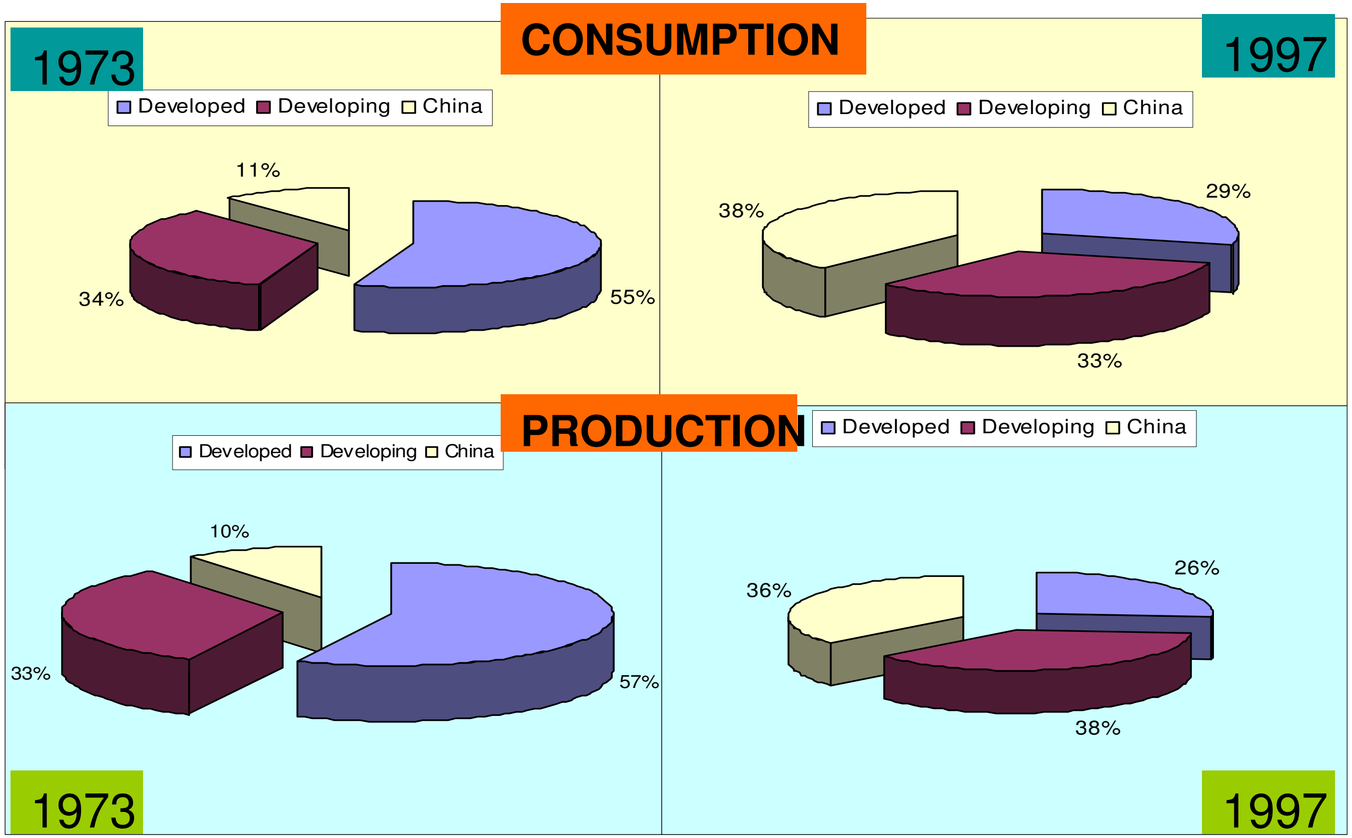


Organization

- **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

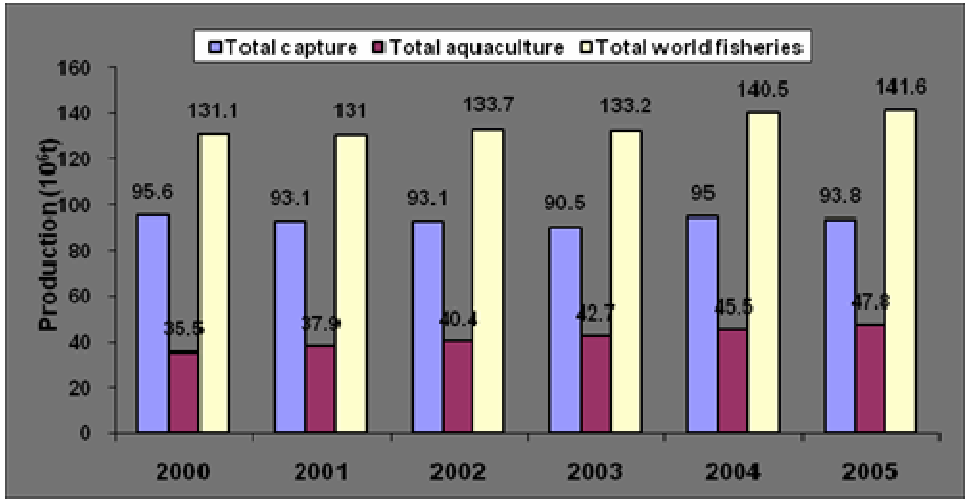
- **Change from a developed country dominated sector to a developing country dominated sector**
- **This trend is being further consolidated**

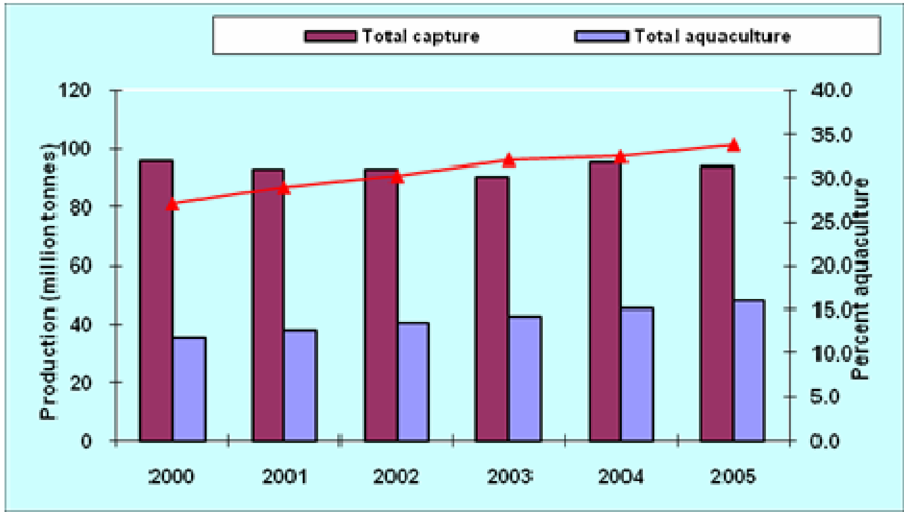


Data based on Delgado *et al.* (2003)

Contributions to total fish supplies

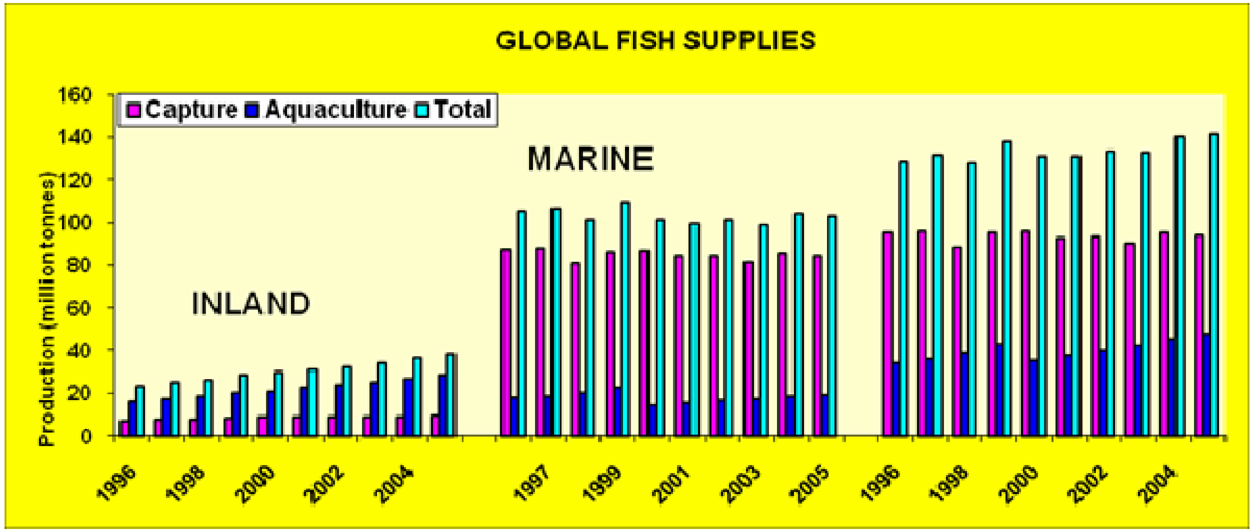
- Capture fisheries almost static
- Contribution from aquaculture increasing

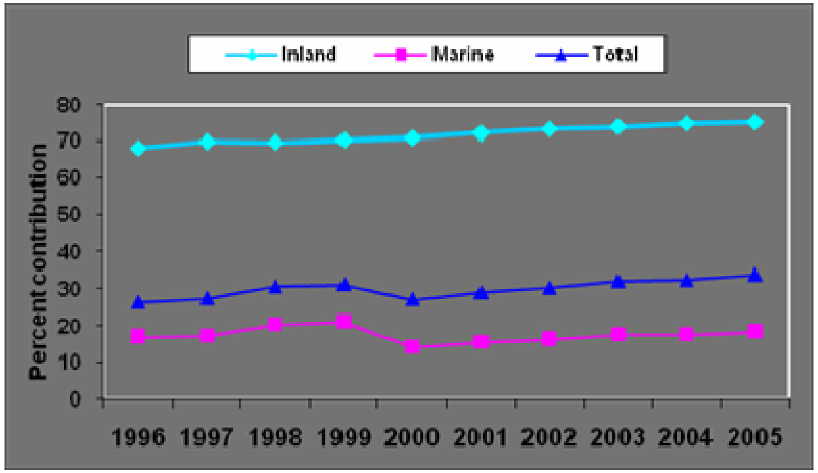




Contribution of aquaculture to total, inland and marine fish production

- 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 Brugére and Ridler, 2004).

Forecasts	Needs		Estimated needs from aquaculture ($x10^6$ tonnes)	
	Per caput consumption (kg/ yr)	Total demand ($x10^6$ 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 3. Projected demand for aquaculture production, 2020 (modified after Siriwardene, P.P.G.S, personal communication).

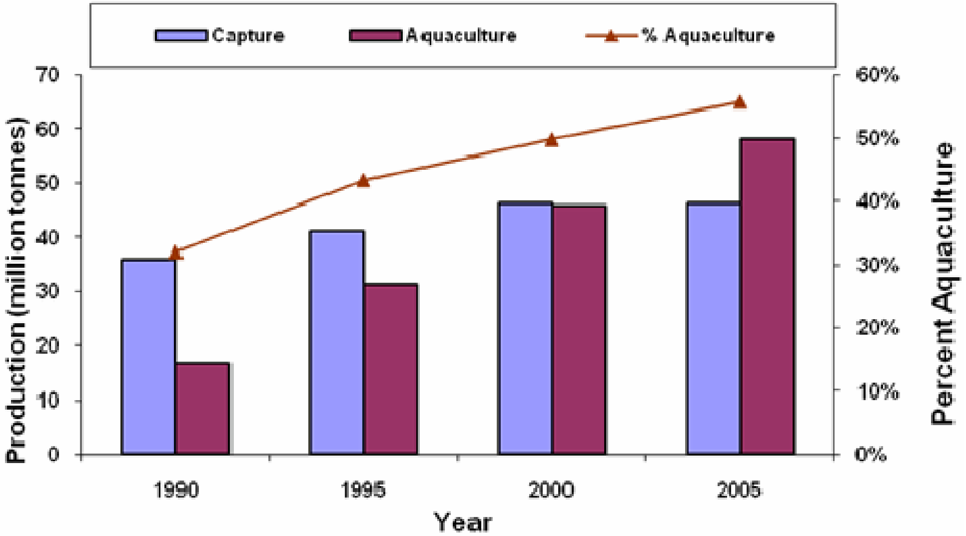
Continent	Food fish demand-2020 (t)	Aq. Production 2003 (t)[a]	Aquculture Demand-2020 (t)[b]	Change (%)
Africa	9,580,553	520,806	3,035,058	482.8
Asia	44,130,913	8,686,136	16,304,098	87.8
China	36,452,838	28,892,005	31,659,237	9.6
Europe	14,156,188	2,203,747	1,937,833	-12.1
L. America & Caribbean	5,869,204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

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 5. Production value as percent of GDP (data Sugiyama *et al.*, 2004)		
	Capture Fisheries	**Aquaculture**
Bangladesh	**1.884**	**2.688**
PR China	**1.132**	**2.618**
Indonesia	**2.350**	**1.662**
Lao PDR	**1.432**	**5.775**
Malaysia	**1.128**	**0.366**
Philippines	**2.184**	**2.633**
Thailand	**2.044**	**2.071**
Vietnam	**3.702**	**3.497**



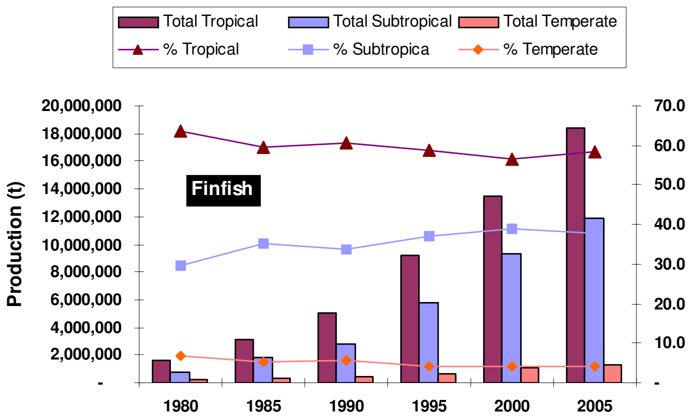
Asian Fish Production

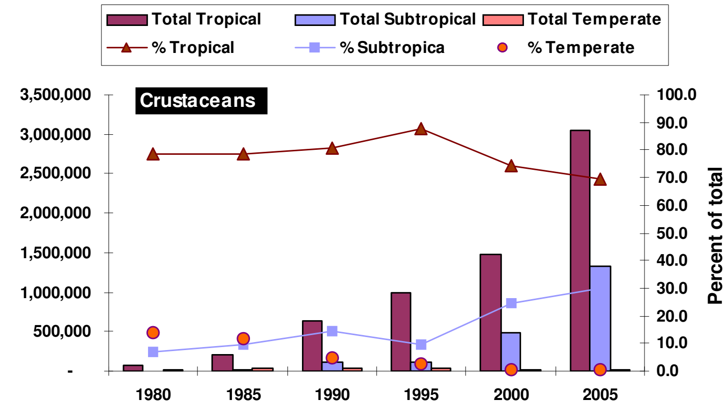
Summary on food fish needs etc.

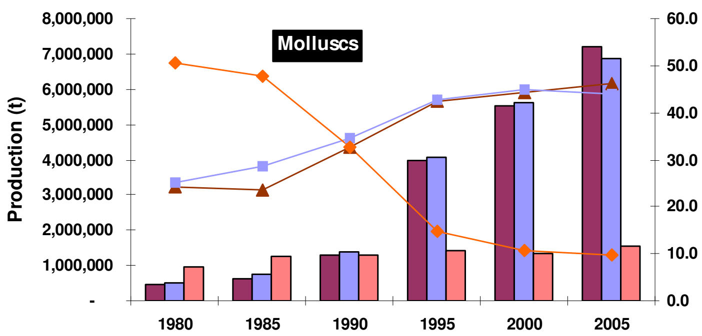
- **Major changes in the production and consumption over the last three decades**
- **World will need an extra ~ 40-60 x 10^6 t of food fish by 2020**
- **Aquaculture production has increased ~ 33% to total fish supplies**
  - Accounts for ~45% of current global consumption
- **Aquaculture expected to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

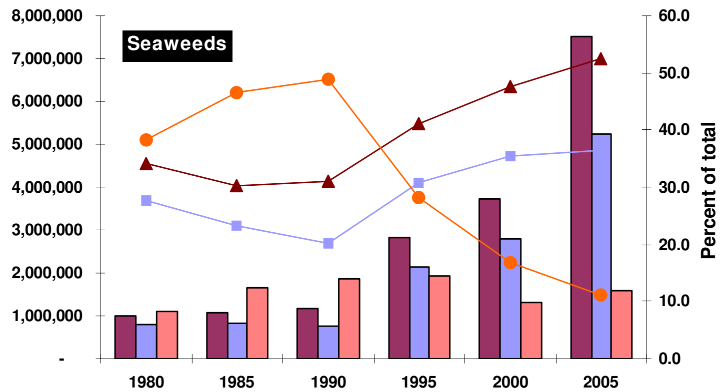
Aquaculture production: by climatic regions

- Great bulk of aquaculture occurs in tropical & sub-tropical regions
- With some commodities the contribution from temperate regions have declined; why?



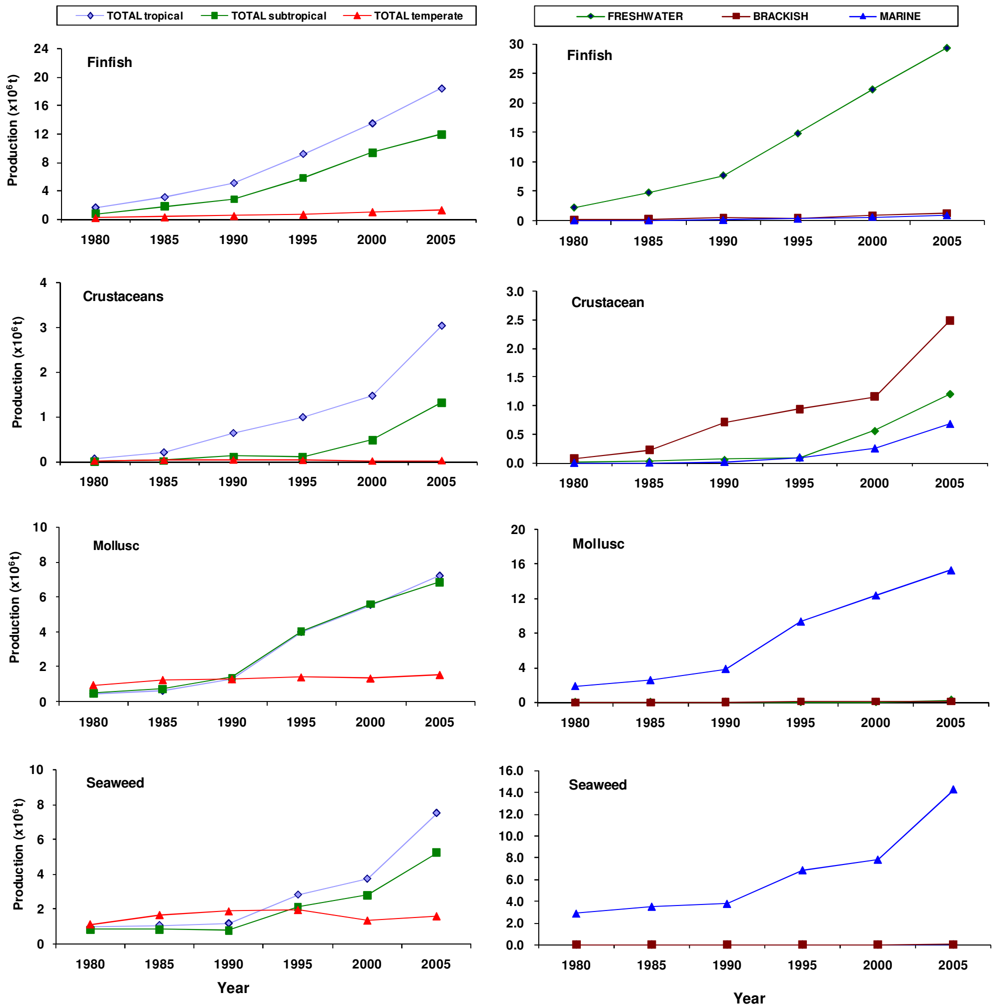




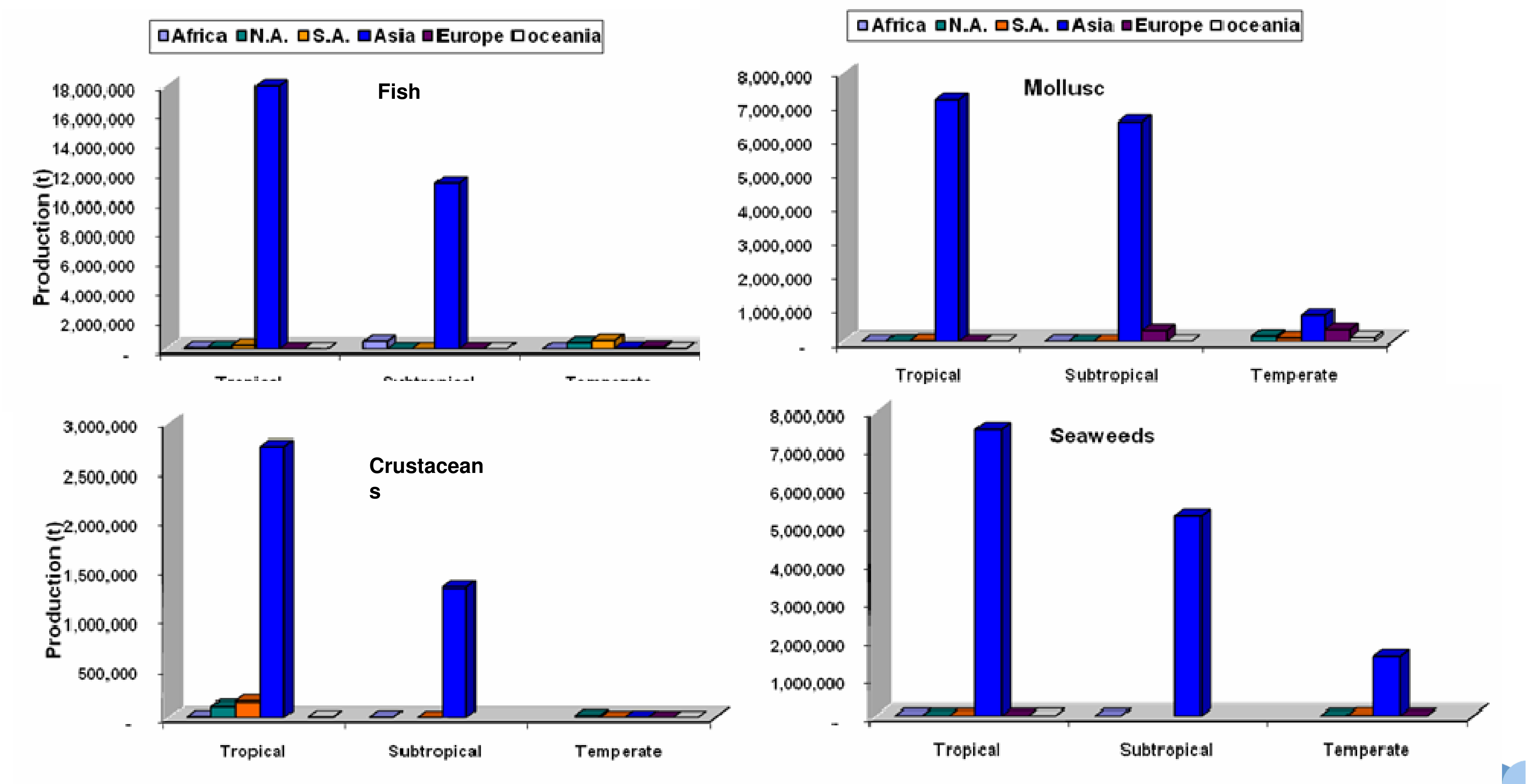


Aquaculture production: by climatic regions/ environment

- **For all commodities highest production in tropics & sub tropics and in fw (except seaweeds)**

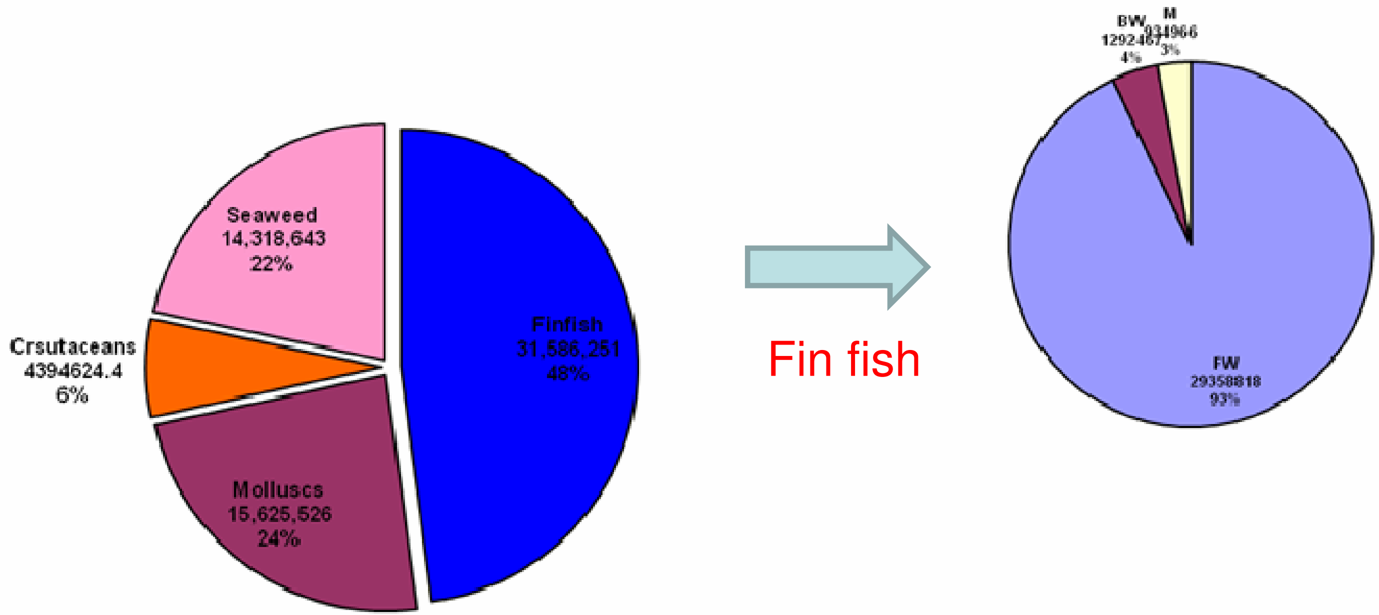


Aquaculture production: by climatic regions/ continents



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 fish40 %
- 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 x 10^6 loss of stock
  - Large number of escapees
    - Possible impacts on biodiversity?

- **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

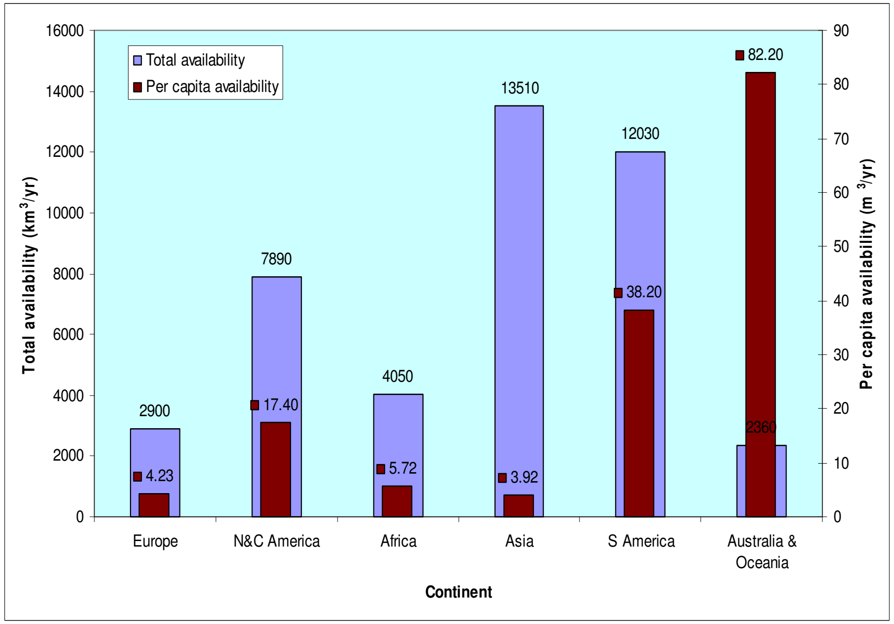
- **Adaptive measures:**
  - Not many available
- **However:**
  - Encourage cluster insurance
  - Enables a resurrection of the businesses
  - Impacts on production temporary

- **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-Brahamaputra 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 (m^3/ t) for different animal food products (data from Zimmer and Renault, 2003) and comparison with needs for aquaculture.	
Product	**Water demand**
Beef, mutton, goat meat	13500
Pig meat	4600
Poultry	4100
Milk	790
Butter + fat	18000
Common carp (intensive/ ponds)[a]	21000
Tilapia (extensive/ ponds)[a]	11500
Pellet fed ponds[b]	30100
a- Muir,1995 ; b- Verdegem et al., 2006	



From Nguyen & De Silva, 2006; based on data from *Shiklomanov, 1998*

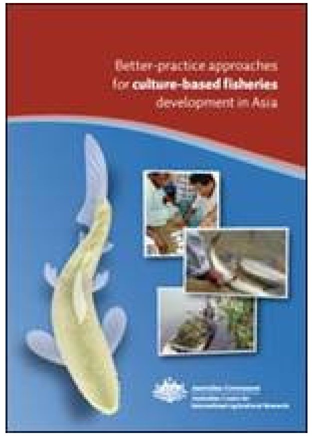
Water stress:

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:

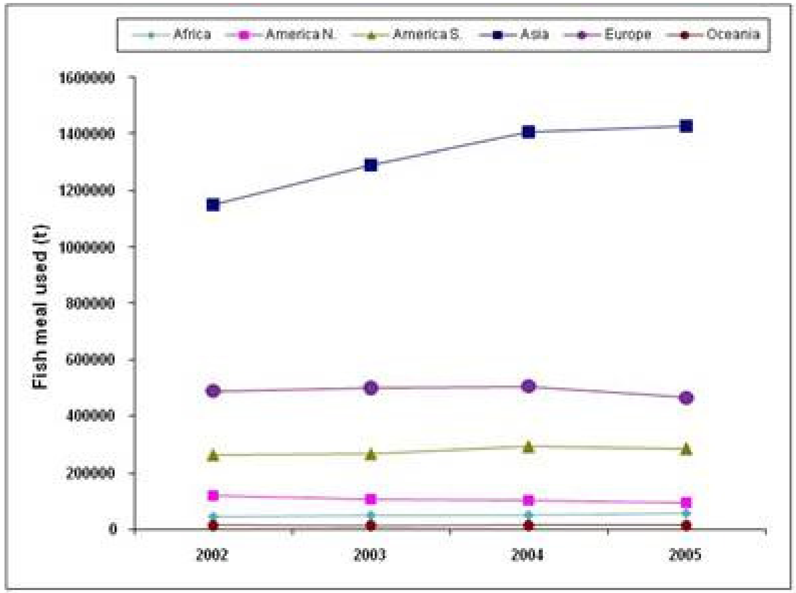
- **In 2003, globally:**
  - aquaculture sector consumed 2.94 million tonnes of fish meal (53.2 percent of global fish meal production
  - equivalent to
    - 14.95 to 18.69 million tonnes of forage fish/ trash fish/ low valued fish, primarily pelagics
  - production based on pelagics in the sub-tropical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

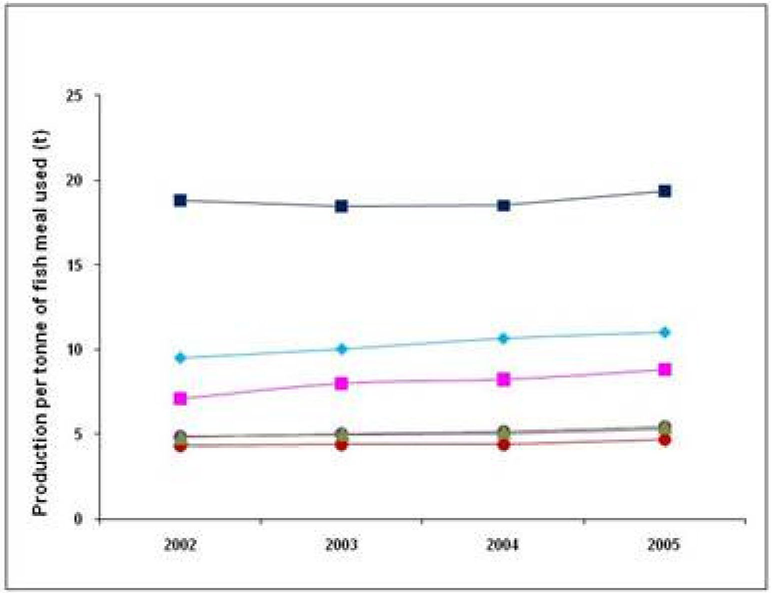
- **Ocean productivity in the North Atlantic will plummet 50 percent and world wide by 20 percent (Schmittner, 2003).**

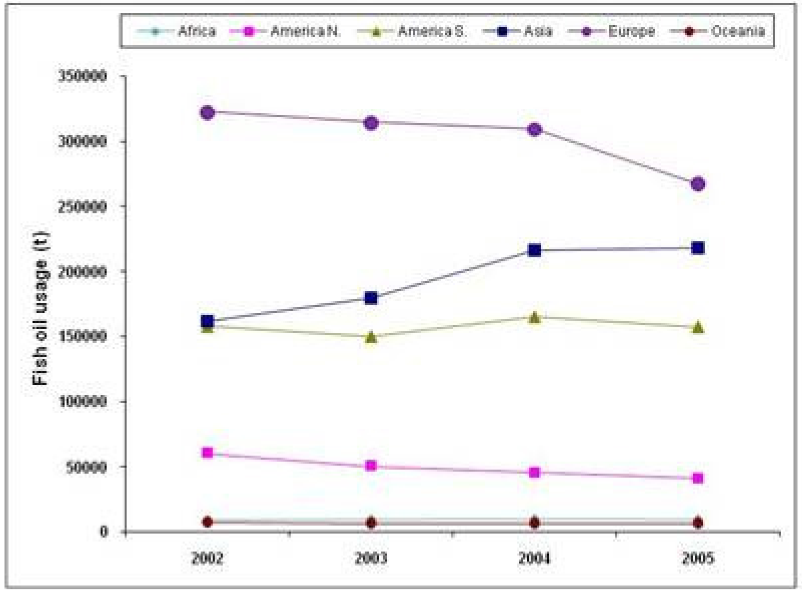
- **El Niño influences on the Peruvian sardine and anchovy landings**
  - consequently on global fish meal and fish oil supplies and prices (Pike and Barlow, 2002).

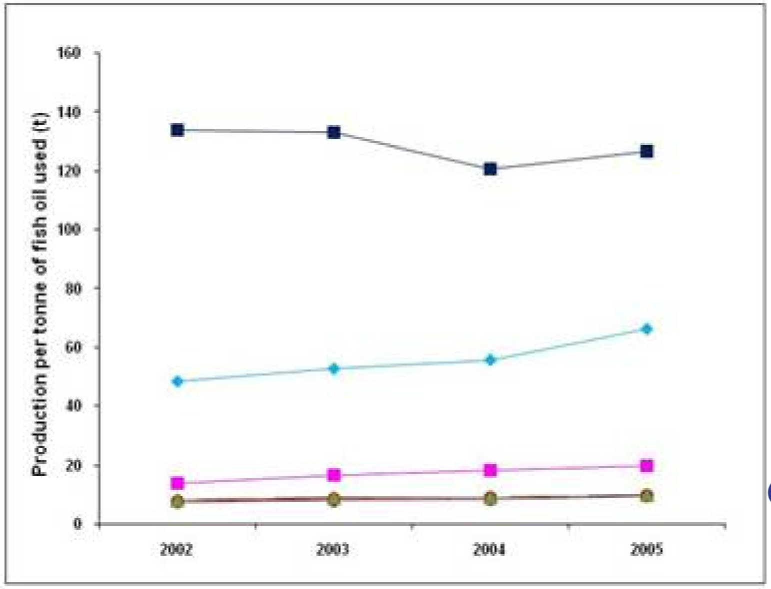
- **Changes in the North Atlantic Oscillation winter index (Schmittner, 2003),**
  - higher winter temperatures
  - could influence sandeel (*Ammodytes* spp.) recruitment.

Climate change: indirect impacts on aquaculture: Fish meal & oil usage in aquaculture



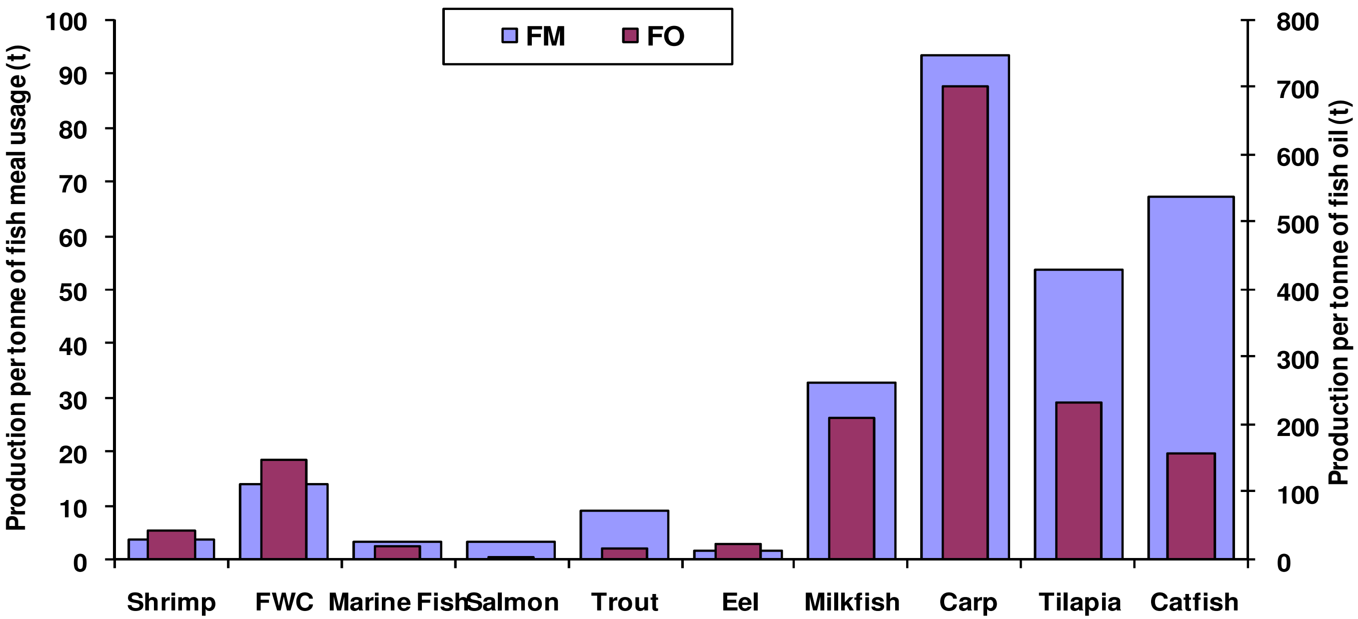






Climate change: indirect impacts on aquaculture: Fish meal & oil usage in aquaculture

- **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



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**
  - associate occurrence of harmful algal blooms-HABs (Smayda, 1990).
  - 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 <3ºC.
  - 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 biodiverse 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 biodivessity (?)
- **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).

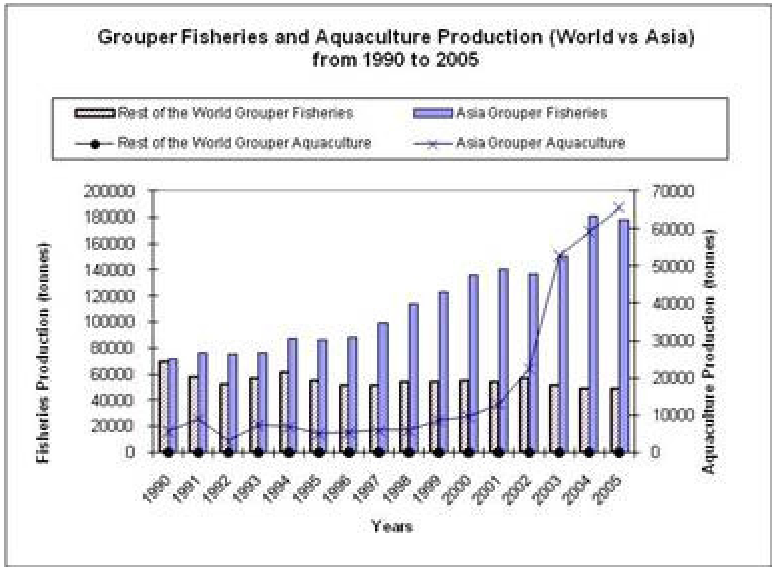
- **the drivers of coral reef destruction is different from the past**
  - these are predominantly climate change associated drivers

- **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 with 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.**

Napolean Wrasse
Critically endangered:
now cultured



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 TgCO_2 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 live stock 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 green house 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.

System	Industrial energy consumption			
	Direct energy	Indirect energy	Total	Units
Semi-intensive shrimp f.[@]	55	114	169	GJ t^{-1}
Thai shrimp[#]	na	na	45.6	MJ kg^{-1}
Marine shrimp[$]	54.2	102.5	156.8	MJ kg^{-1}
Salmon cage f.[@]	9	99	105	GJ t^{-1}
Salmon cages intensive[@]	na	na	56	GJ t^{-1}
Salmon[$]	11.9	87	99	MJ kg^{-1}
Norwegian farmed salmon[#]	na	na	66	MJ kg^{-1}
Trout ponds[@]	na	na	28	GJ t^{-1}
Grouper/ seabass cage f.[@]	na	na	95	GJ t^{-1}
Carps, intensive recycle[@]	na	na	56	GJ t^{-1}
Carp, recirculating[$]	22	50	50	MJ kg^{-1}
Carp ponds feeding & fertilizer[@]	na	na	11	GJ t^{-1}
Carp, semi-intensive[$]	26	01	27	MJ kg^{-1}
Catfish ponds[@]	na	na	25	GJ t^{-1}
Catfish[$]	5.4	108	114	MJ kg^{-1}
Tilapia[$]	0	24	24	MJ kg-1
Norwegian chicken[#]	na	na	55	MJ kg^{-1}
Swedish beef[#]	na	na	33	MJ kg^{-1}

Aquaculture impacts on climate change
Comparison of carbon emissions/ contributions to green house 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.

Food type including technology, environment and locality	% PE/ IE
Carp extensive, freshwater, various	100-111
Seaweed, mariculture, Caribbean	50-25
Chicken, intensive, USA	25
Tilapia, extensive, freshwater ponds, Indonesia	13
Mussels, marine long lines, Scandinavia	10-5
Tilapia, freshwater, Zimbabwe	6.0
Beef, pasture, USA	5.0
Beef, feed lots, USA	2.5
Atlantic salmon, intensive, marine net pen, Canada	2.5
Shrimp, semi intensive, Colombia	2.0
Lamb, USA	1.8
Seabass, intensive marine cage culture, Thailand	1.5
Shrimp, intensive culture, Thailand	1.4

Aquaculture impacts on climate change

Comparison of carbon emissions/ contributions to green house 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

Impact category	Unit	Block (1.8 kg) of black tiger prawn[#]	4 (x 453 g) pouches of IQF Pws[@]
Abiotic depletion	kg Sb eq	0.32	0.19
Global warming (GWP100)	kg CO_2 eq	19.80	27.31
Human toxicity	kg 1,4-DB eq	1.79	3.04
Fw aquatic ecotoxicity	kg 1,4-DB eq	0.25	0.41
Mar. aquatic ecotoxicity	kg 1,4-DB eq	1660.00	2071.00
Terrestrial ecotoxicity	kg 1,4-DB eq	0.02	0.02
Acidification	kg SO_2 eq	0.07	0.14
Eutrophication	kg PO_4 eq	0.22	0.19

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 12. The production of cultured finfish (x10^3t) feeding low on the trophic chain in 1995 and 2005 and the overall growth in the ten year period.

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

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_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?**