
Re-designing aquaculture systems to avoid pollution

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Planetary boundaries

- **Climate change**
 - Atmospheric CO₂
 - Change in radiative forcing
- **Rate of biodiversity loss**
 - Extinction rate
- **Nitrogen cycle**
 - N₂ removed from the atmosphere for human use
- **Phosphorus cycle**
 - P flowing into the oceans
- **Ocean acidification**
- **Global freshwater use**
- **Chemical pollution**
- **Change in land use**
 - Converted to cropland
- **Stratospheric ozone depletion**
- **Atmospheric aerosol loading**

[Rockström et al. 2009. A safe operating space for humanity. *Nature* 461, 472-475]

World Development Report 2008

■ Poverty

- ❑ Three out of four poor people in developing countries live in rural areas
- ❑ 2.1 billion are living on less than US \$ 2 a day and 880 million on less than US \$ 1 a day
- ❑ Most depend on agriculture for their livelihoods

■ Poverty alleviation

- ❑ "GDP (Gross Domestic Product) growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture"
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World Development Report 2008

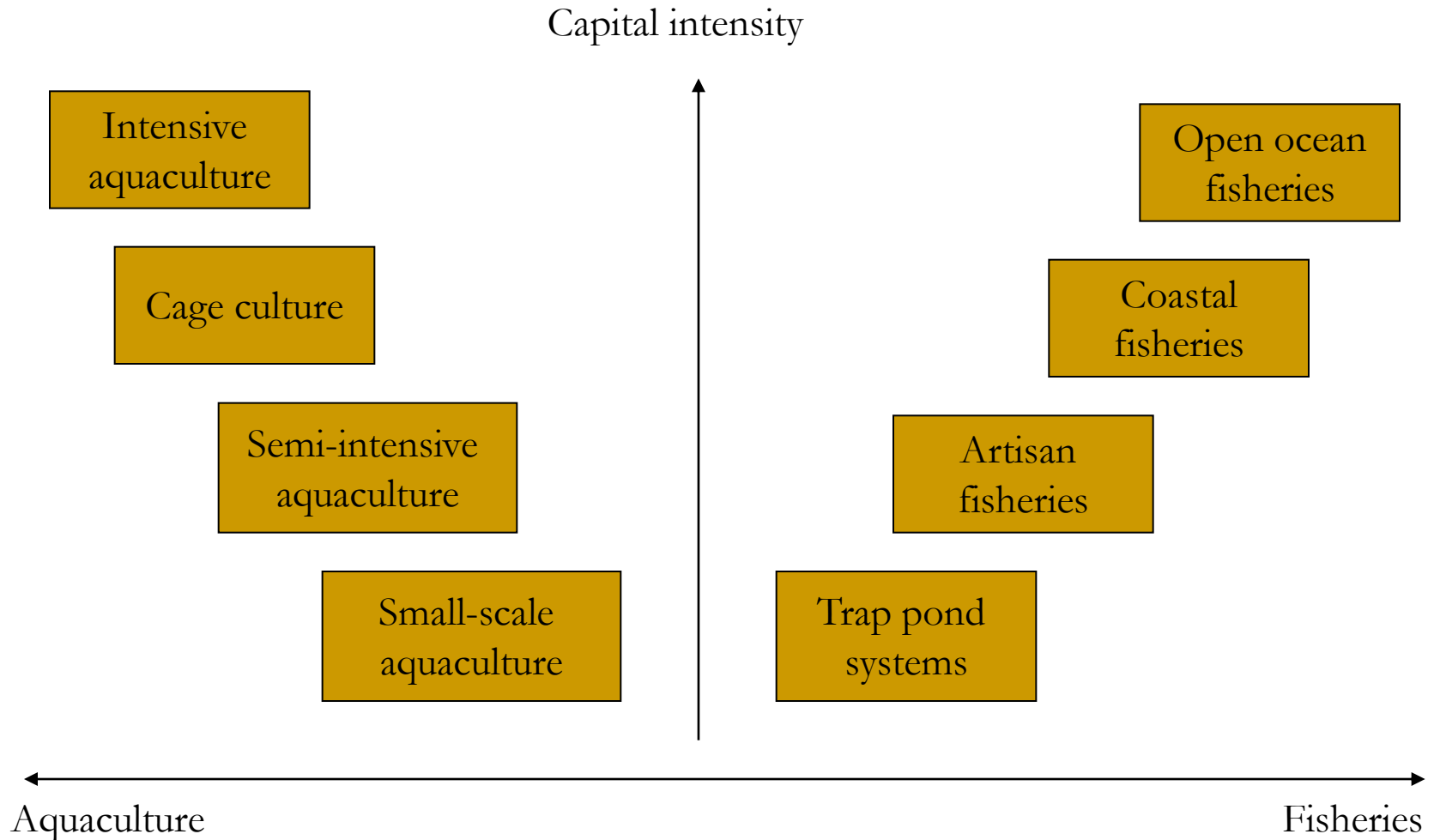
- Pathway out of poverty -
Using agriculture for development
 - "Improving the productivity, profitability and sustainability of small-holder farming"
 - Improve integration between system components at farm level



World Development Report 2008

- Agriculture
 - Crops, livestock, agroforestry and aquaculture
 - A source of livelihoods for an estimated 86% of rural people
 - Developing world
 - 5.5 billion people
 - 3.0 billion people (>50 %) live in rural areas
 - 2.5 billion people (>80 %) involved in agriculture
 - 1.5 billion people (~50 %) in small-holder households
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Aquaculture, fisheries and capital investment



Aquaculture and food production

- The fastest growing food production sector in the world
 - 10 % annual growth over the last two decades
 - Mainly in Asia (90 %)

 - 2009
 - Aquaculture supplying 50 % of total fish and shell-fish for human consumption (FAO, 2009)
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Aquaculture

- Use of water resources for food production
 - Culturing of fish and other aquatic animals
 - Snails, frogs, shrimp, crabs etc.
 - Culturing of water plants
 - Duckweed, azolla, water spinach etc.
 - Stagnant or moving water
 - Different water sources
 - Rivers, lakes, water reservoirs
 - Cage culture
 - Flooded fields, canals
 - Enclosures
 - Ponds
 - Earth ponds
 - Constructed (brick, concrete etc.)
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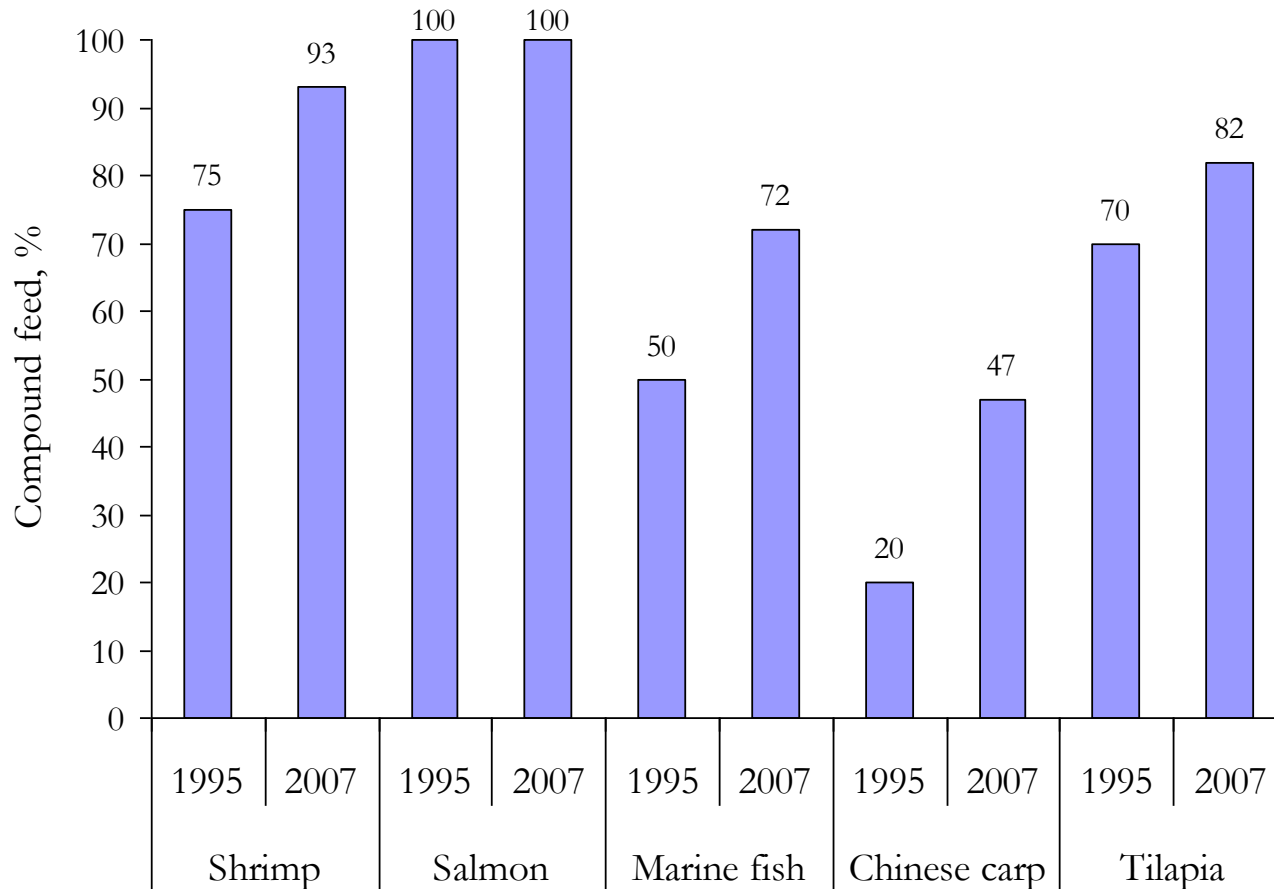
Ponds, cages and enclosures



Aquaculture systems

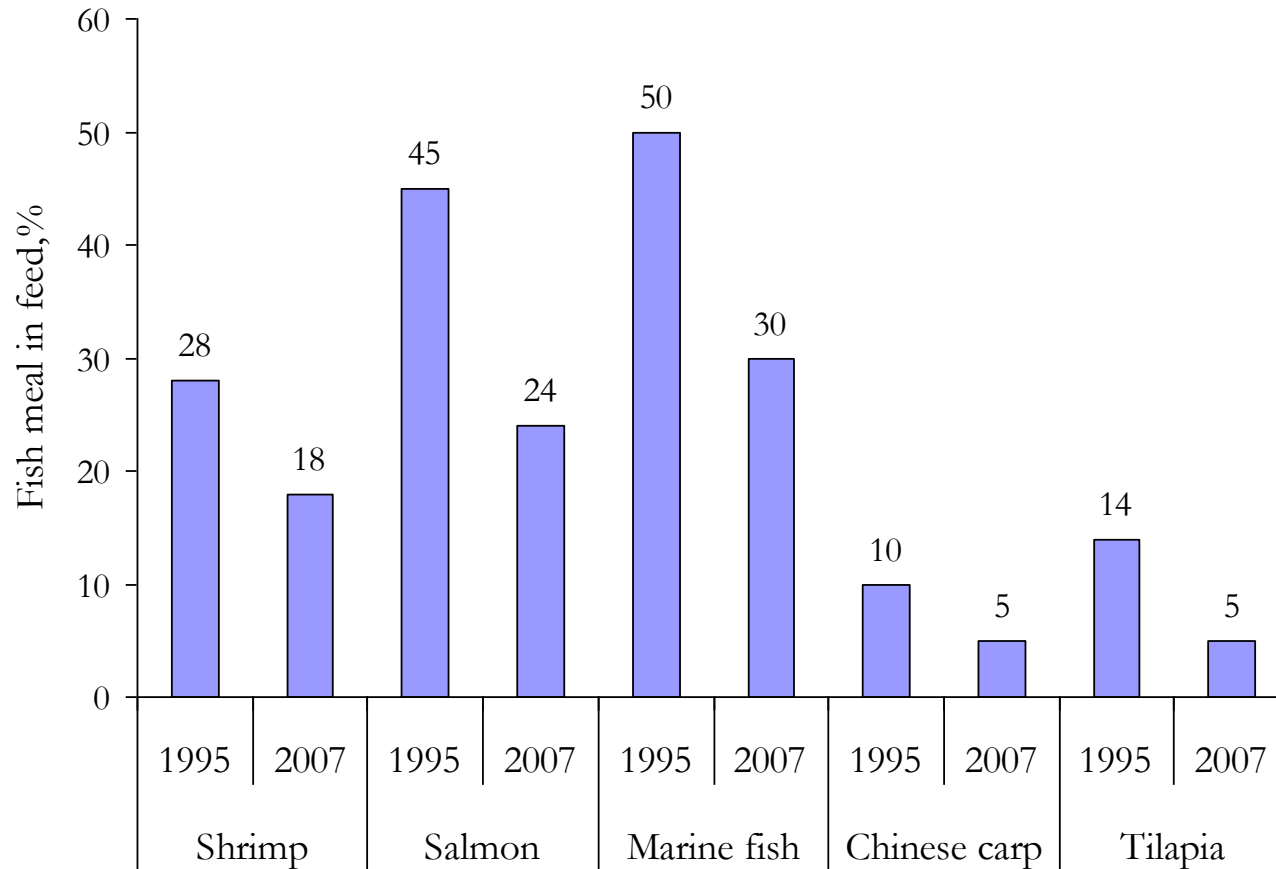
- Different aquaculture systems
 - Extensive
 - Available water resources
 - Wild fish and aquatic animals
 - Small-scale pond cultures
 - No or minimal nutrient input to ponds (irregular waste-feeding)
 - Semi-intensive
 - Small-scale pond cultures
 - Regular nutrient input to ponds (waste-fed)
 - Simple net cages
 - Fattening of cultured fish for marketing
 - Intensive
 - Large-scale cage or pond cultures
 - Feeding of fish
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Compound feed for fish culture



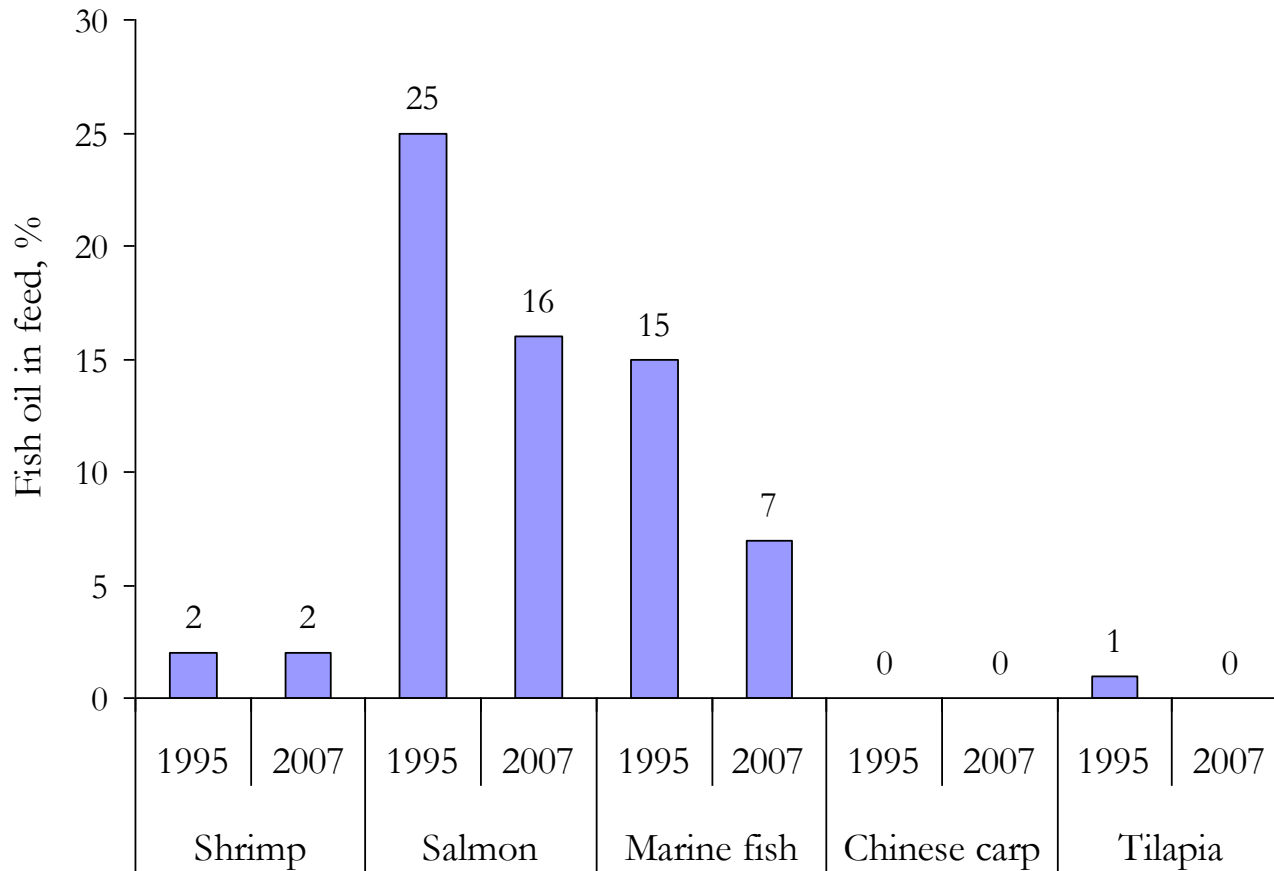
Naylor et al., 2009. PNAS 106, 15103-15110

Fish meal use for fish culture



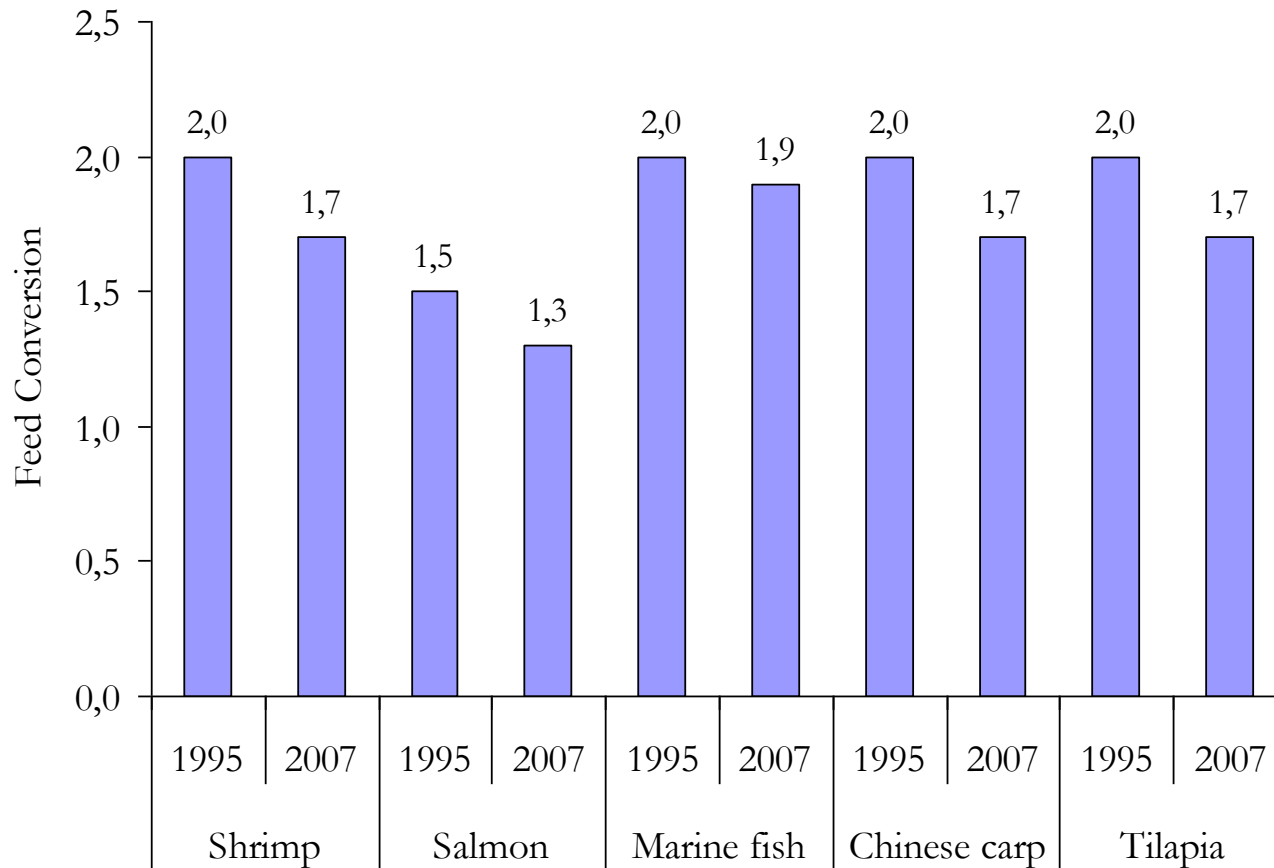
Naylor et al., 2009. PNAS 106, 15103-15110

Fish oil use for fish culture



Naylor et al., 2009. PNAS 106, 15103-15110

Feed conversion in fish



Naylor et al., 2009. PNAS 106, 15103-15110

Global fish supplies

- "Farming can contribute to global (net) fish supplies, only if current trends in fish meal and fish oil use for aquaculture are reversed"

[Naylor et al. 2000. *Nature* 405, 1017-1024]

- Aquaculture's share of global fish meal consumption ~ 70 % and of global fish oil consumption ~ 90 %

[Naylor et al., 2009. *PNAS* 106, 15103-15110]

Striped catfish (*Pangasianodon hypophthalmus*) or "ca tra" production

- The Mekong delta
 - An Giang, Can Tho, Dong Thap, Vinh Long
- >680,000 tonnes produced in 2007
 - 645 million US \$
 - 90 % for export
- Average farm size 4 ha
- Commercial feed used by most (97 %) farms



Striped catfish (*Pangasianodon hypophthalmus*) or "ca tra" production

- Discharge of N
 - 47.3 kg N per tonne of fish produced
 - >30,000 tonnes of N into the Mekong river
- Health management
 - Chemical treatment
 - Antibiotics
 - Feed additives
 - Regular water exchange



What can be done?

- Reduce the use of fish meal and fish oil in aquaculture and livestock production
 - Plant based protein feed sources
 - Choice of fish species for culture
 - Integrated production systems
 - Integrate aquaculture, crop and livestock production
 - Use closed fish production systems with control of nutrient and particle flow
 - Ponds or other land-based systems
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Plant based protein sources

- Fish species
 - Carnivorous
 - Salmonid species, cod, perch, snakehead
 - Omnivorous
 - Carp, tilapia, catfish
 - Herbivorous
 - Carp
 - Carbohydrate digestive and metabolic capacity
 - Major limiting factor
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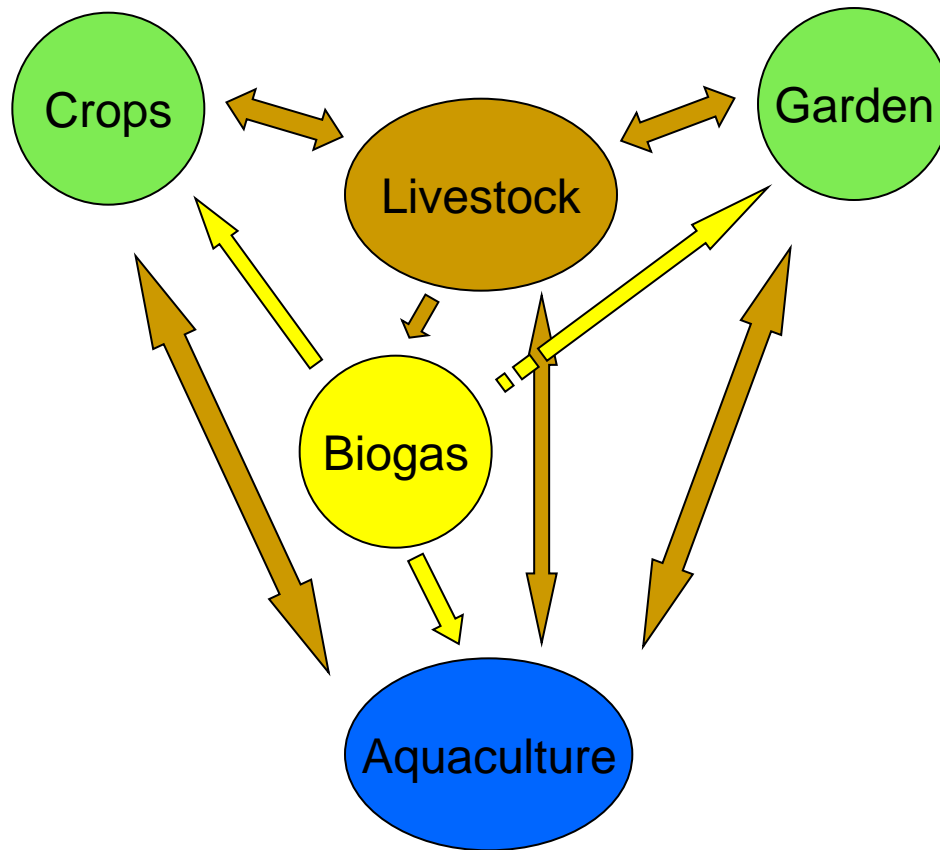
Carbohydrate in fish diets

Fish species	Carbohydrate of diet, %
Salmon	10
Rainbow trout	15
Channel catfish	25
Common carp	30-40
Indian carp	20-30

Integrated farming

- Integrated farming involving aquaculture
 - Definition
 - ”The concurrent or sequential linkage between two or more activities, of which at least one is aquaculture”
 - Benefit
 - Synergistic rather than additive effects
 - The link
 - Use (recirculation) of nutrients within the system
 - Mainly nitrogen (N) and phosphorus (P)
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Integrated aquaculture and livestock production



Integrated systems improve sustainability

- Nutrient recycling
 - Nutrients retained in pond sediments and water.
 - Nutrient concentration
 - Cost effective gathering of nutrients from common property. Fish harvest nutrients through waste.
 - Diversity
 - A range of livestock, utilize a variety of available feed resources. Polycultures within aquatic systems.
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Integrated systems improve sustainability (cont.)

■ Stability

- Livestock **reduce perturbation** on households during time of physical or social stress. A water body improves the stability of **water availability** for the whole farming system.

■ Capacity

- Livestock improves **soil quality and fertility**, grazing may improve **species diversity**. Increased water and nutrient holding improves **productive capacity** around the pond.

■ Economic efficiency

- Cash income from livestock products. Polyculture increases opportunities for strategic marketing of fish.
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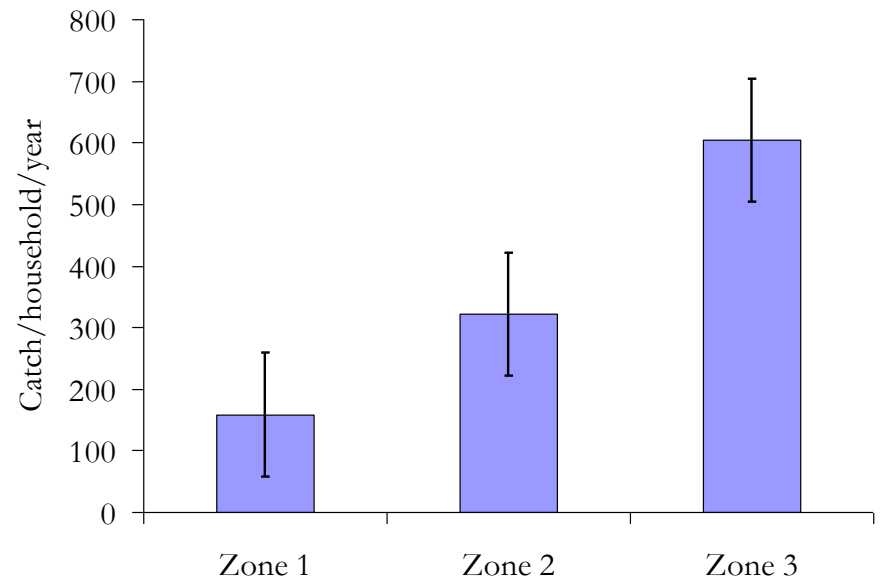
Rice-fish systems

- Common in the lower Mekong River basin
 - Lowland rural households
 - Cultivation of rice
 - Dominating agricultural activity
 - Rice, bulk of carbohydrates and protein in the diet
 - Fish and other aquatic animals cultivated in the ricefields
 - The most important source of animal protein in the diet

Area	Fish consumption (kg/caput/year)
NE Thailand	20-32
Cambodia	14-57

Rice-fish systems

- Seasonal fishery
 - Rainy season
 - Migration of wild fish and other aquatic animals
 - Use stored nutrients and photosynthesis
 - Traps and trap ponds
- Quality of the water resource will influence the catch



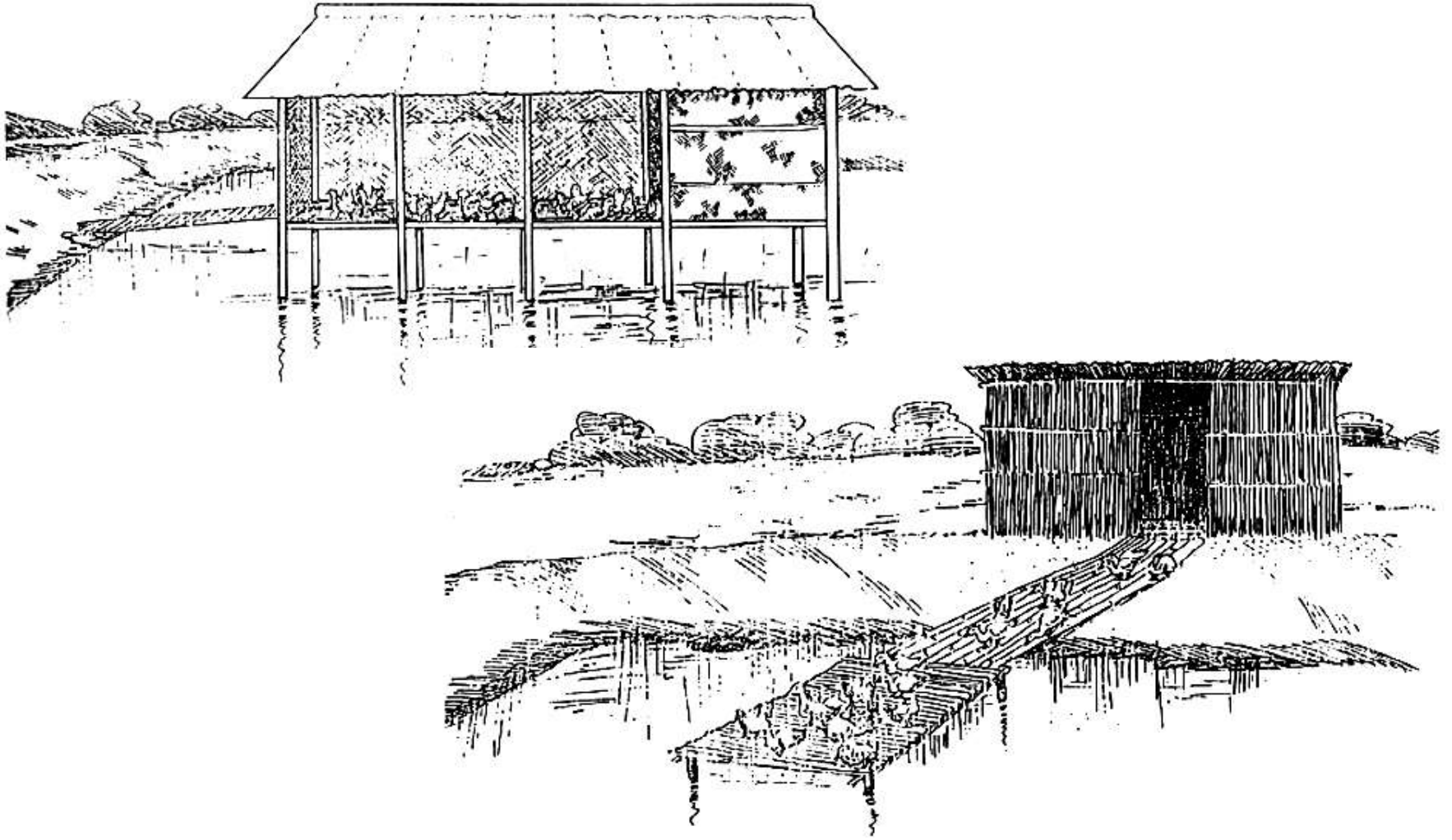
Gregory and Guttman (2002)

Integration of livestock and fish

- Integration of livestock and fish
 - ”The use of livestock manure in fish culture”
 - On-farm; direct use of fresh manure
 - Off-farm; collected and transported to end user



Manure collection



Input of animal and other organic waste

- Input has to be properly balanced to pond productive capacity
 - Pond design (water depth)
 - Frequency of waste addition
 - Size and species of fish
 - Harvest strategy
 - Dissolved oxygen (DO)
 - Critical for pond productivity to maintain adequate water quality, in particular DO
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The pond ecosystem

Living organisms
(Biotic community)

**”The producers” and
”Consumers”**

Non-living community

Inorganic and organic
compounds

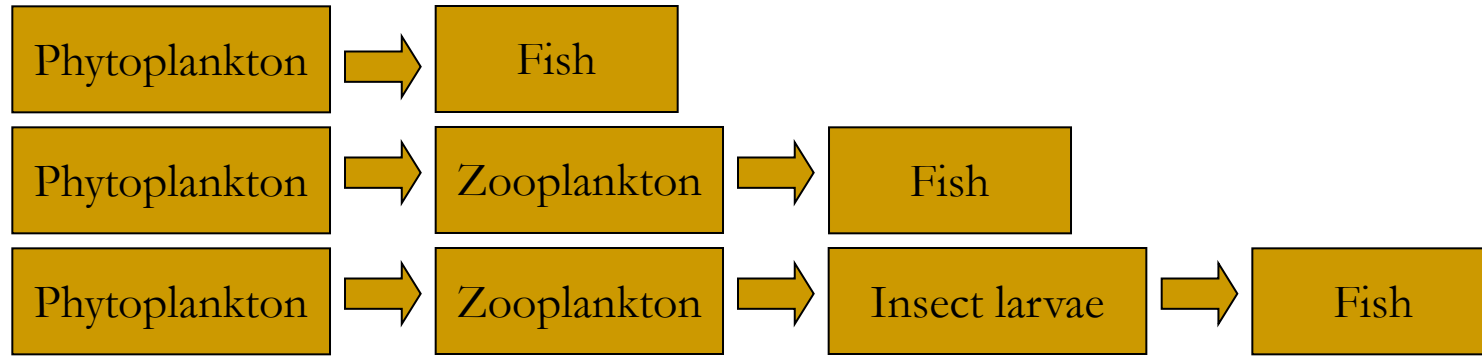
The pond ecosystem

- Autotrophic food chain
 - ”The producers”
 - Solar energy dependent
 - Plant-based
 - Phytoplankton
 - Macrophytes
- Heterotrophic food chain
 - ”The consumers”
 - Invertebrates
 - Fish
 - ”The decomposers”
 - Microorganisms
 - Organic matter

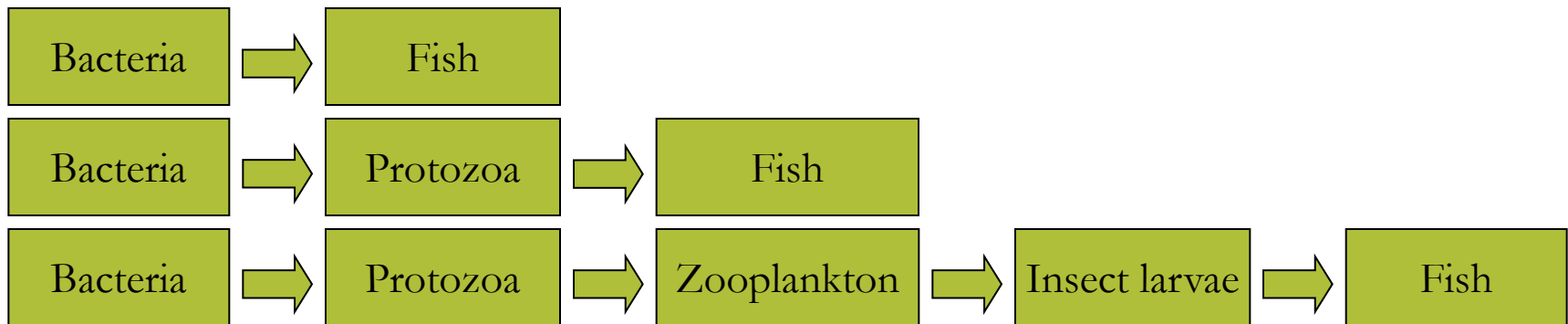


The pond ecosystem

Autotrophic food chain



Heterotrophic food chain



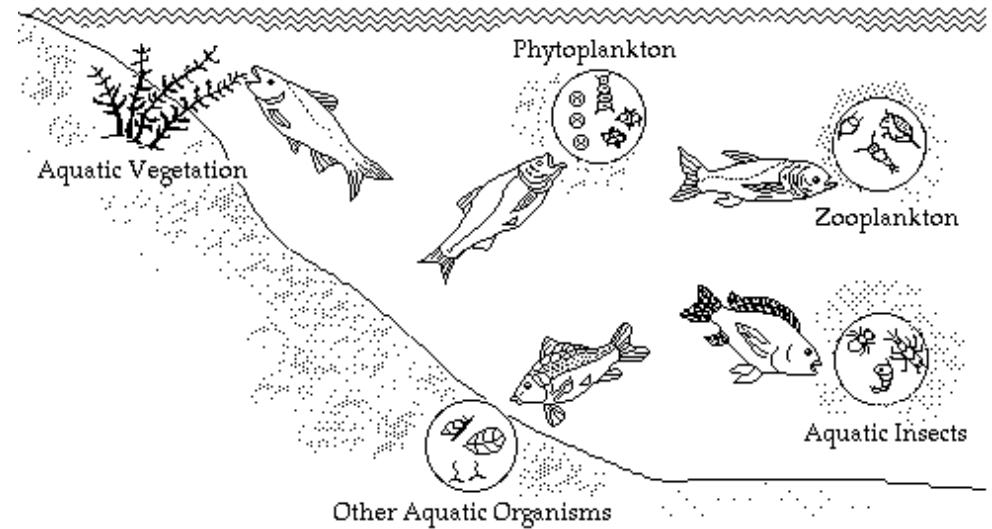
The VAC farming system

- VAC
 - youn (garden), ao (pond), chuong (livestock)
- Red River delta in Vietnam
 - Rice-based farming systems
 - Limited arable land
 - Farm size $\sim 5000 \text{ m}^2$
 - Recycling of nutrients within the system
 - Small-scale aquaculture
 - Pond input; grass, pig manure and rice bran

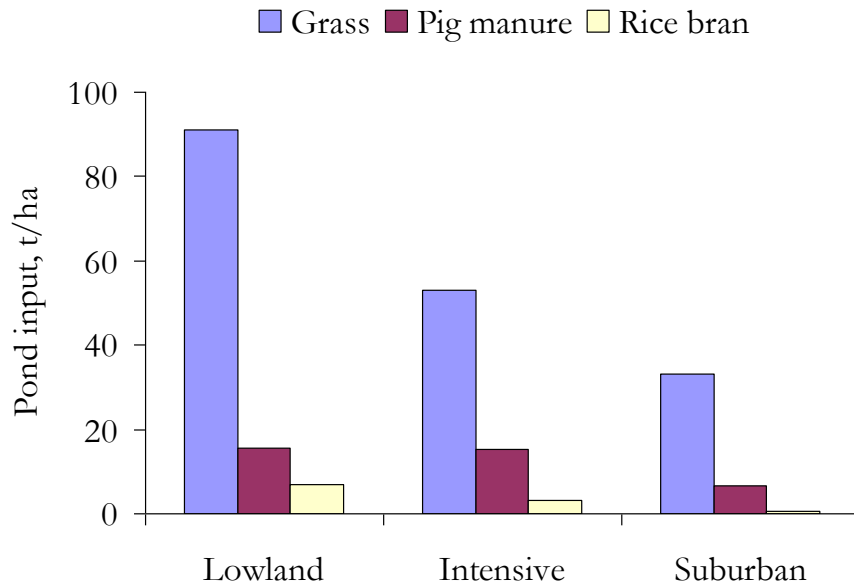


VAC fish pond

- Fish species
 - Carp
 - Common carp
 - Chinese carp
 - Grass
 - Silver
 - Indian carp
 - Mrigal
 - Rohu
 - Other
 - Bighead & mud carp
 - Tilapia
 - Catfish



VAC - major pond input



- Fish production
 - 1900-3400 kg/ha/year on average
 - Range 30-6700 kg/ha/year

Luu et al. (2002)

Public health and use of animal waste

- Livestock and fish
 - Involved in both passive and active transfer of a range of parasites and diseases to humans
 - Trematodes, nematodes and cestodes
 - Intermediate hosts for human parasites
 - Use of anti-microbials and chemotherapeutants
 - Transfer of pathogens
 - Faecal coliforms, Salmonella, bacteriophage
 - Minimize cross-contamination
 - Hygiene
 - Improved sanitation
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The environment will benefit from integration of aquaculture and livestock

- Can stabilize nutrient and water use
 - Reduce run-off and leaching of nutrients
 - Reduce percolation into subsoil
 - Improve efficiency of water use on-farm
 - Conservation and storage of rain and run-off water in ponds and dams
 - Reduce methane production
 - Grazing of soil-water boundaries by fish support aerobic conditions
 - Biodiversity can improve
 - Use of indigenous fish in culture
 - Combine wildlife and livestock
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In summary

- Reduce the use of fish meal and fish oil in aquaculture and livestock production
 - More use of plant based protein feed sources
 - Select omnivorous or herbivorous fish species for culture
 - Develop integrated production systems
 - Integrate aquaculture, crop and livestock production
 - Sun-driven production systems
 - Fish polyculture
 - Use closed fish production systems with control of nutrient and particle flow
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Thank you for your attention!

