Planning for Successful Aquaculture

-by minimizing the environmental impact and selecting the appropriate species-

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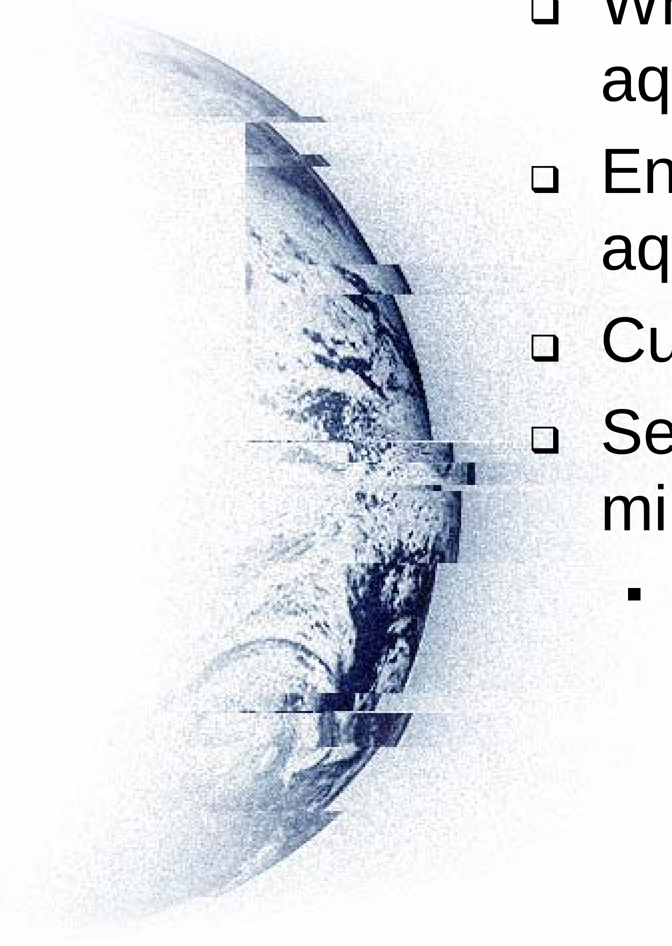
Overview



- What is successful and sustainable aquaculture
- Environmental impacts of extensive aquaculture
- Cumulative environmental effects
- Selection of species for aquaculture that minimize environmental impact
    - Selection of appropriate native species

Acknowledgements

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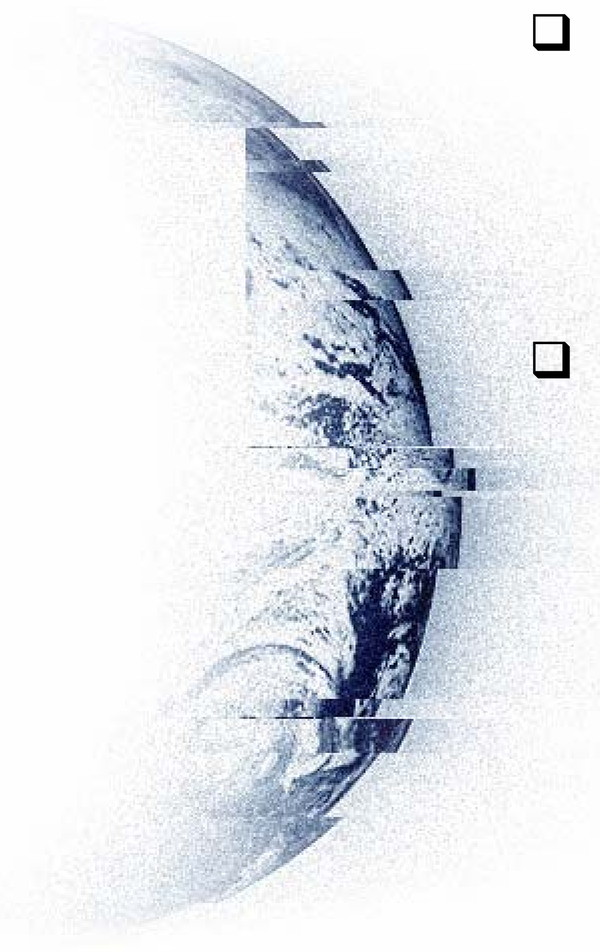
Sustainable aquaculture

- "What is not profitable is not sustainable"
- What the environment can not sustain over an extended period of time is not sustainable
- Where there is no capacity there is no sustainability
- Environment-Economics-Society

Environmental Impact

- Extensive aquaculture
  - Small-holder aquaculture
  - Rural aquaculture
  - Characterized by cultivation of species captured in the wild or from hatcheries, absence of artificial aeration and industrial feed, and use of fertilizers
  - Mainly practiced by communities
- Simple systems
- Small operations
- Low impact?

Environmental Impact



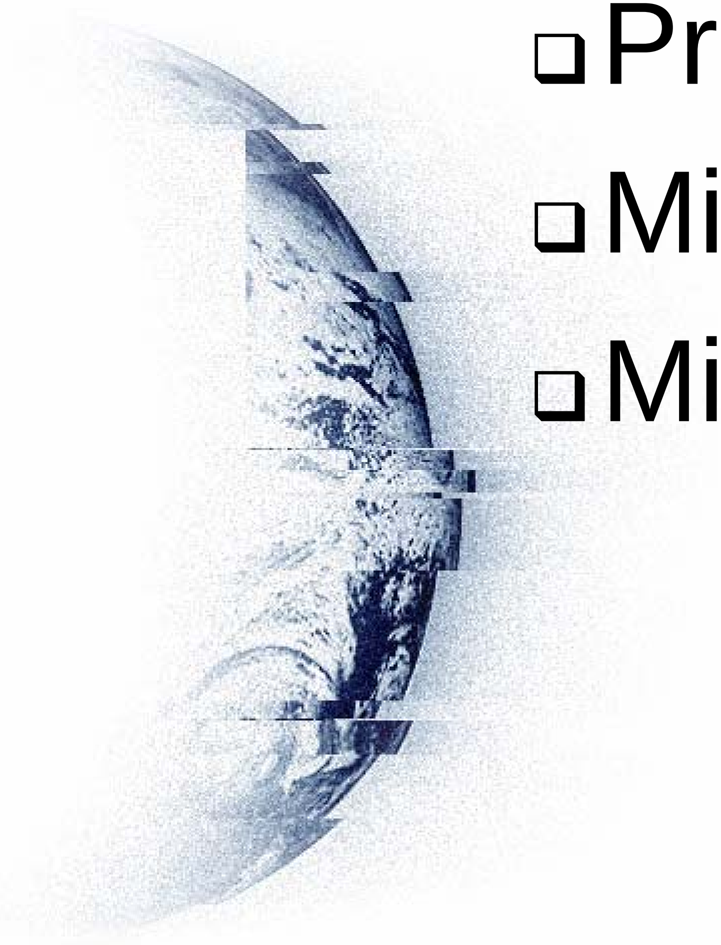
- Same environmental impacts for extensive as for intensive or industrial aquaculture
- Aquaculture is inherently a spatial activity
  - Excludes other land-uses
  - Can result in conflicts in land-use/water use

Environmental Impact

- Habitat destruction
- Discharge of effluents containing high concentrations of organic matter
- Contamination of the aquatic environment and organisms with chemicals
- Introduction of exotic species
- Escapees from aquaculture into natural habitats

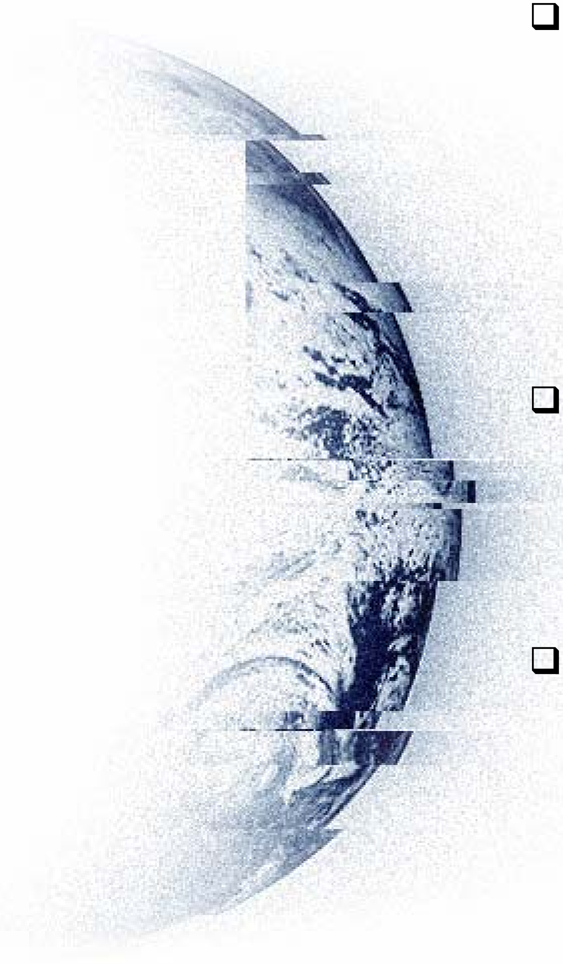
(Choo 2001)

Environmental Impact



- Prevention
- Minimization
- Mitigation

Cumulative Effects



- Cumulative effect is an effect on the environment that results from the **incremental**, **accumulating** and **interacting** impacts of an action when added to other past, present, and reasonably foreseeable future actions
- Cumulative effect may result from addition or extraction of materials from the environment as well as from interaction between man-made and natural stressors
- Effects can also result from individually minor yet collectively significant actions taking place over a period of time and/or space

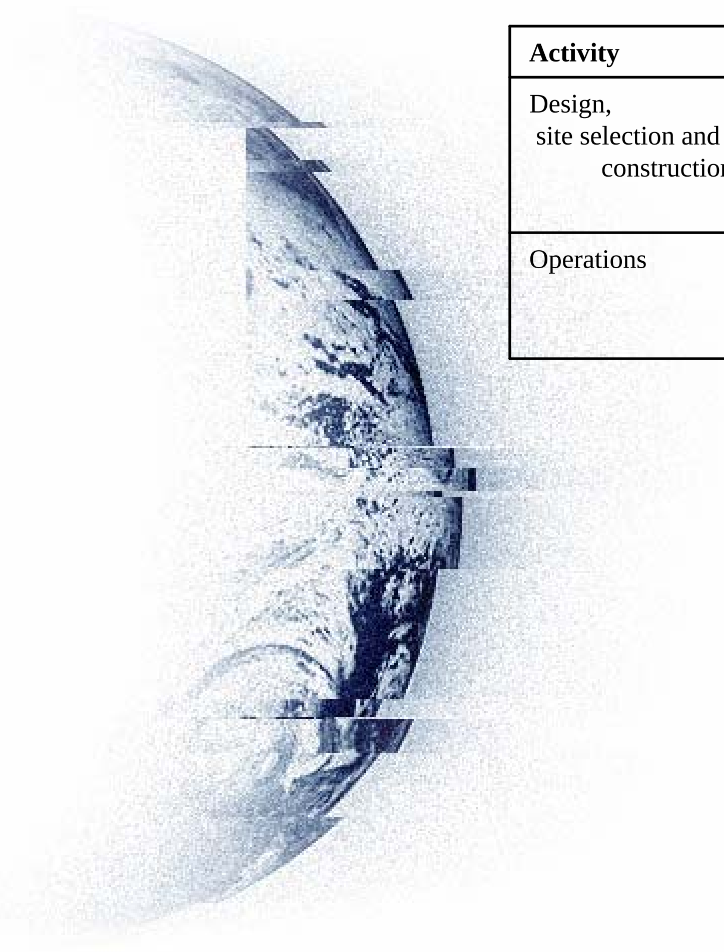
(Dubé 2003)

Cumulative Effects Assessment

- Cumulative Effects Assessment (CEA)
- CEA is the process of predicting, the consequences of development relative to an assessment of an existing environment quality

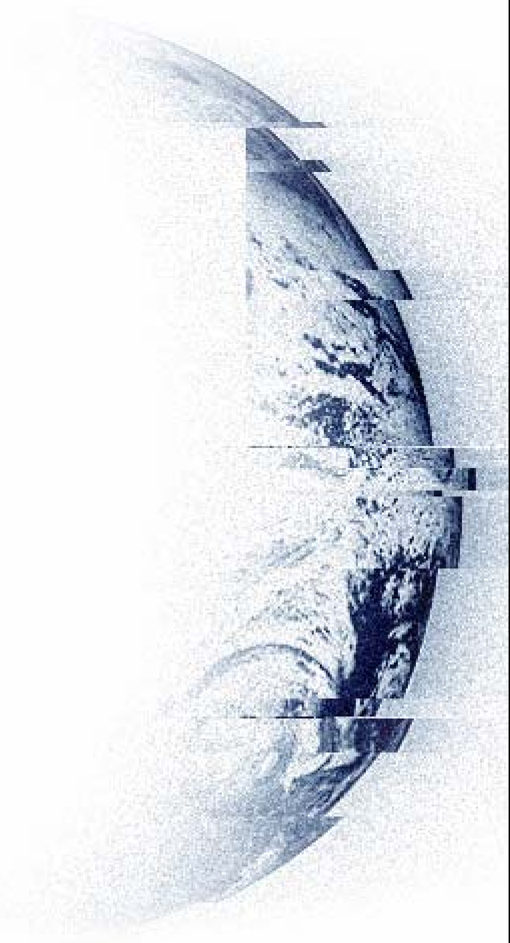
(Dubé 2003)

Matrix of environmental impacts mitigation and monitoring



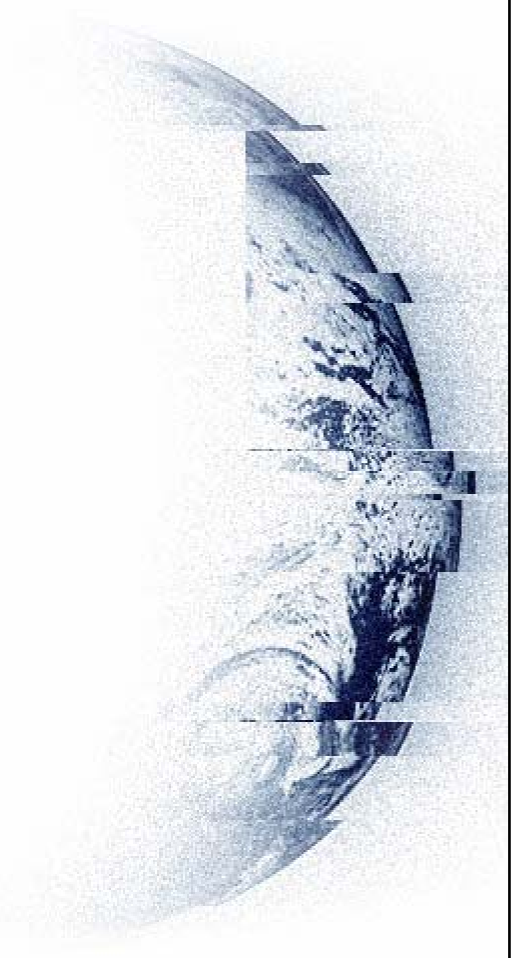
Activity	**Problem/Impact**	**Applicability**	**Mitigation techniques**
Design, site selection and construction			
Operations			

Matrix



Activity	Problem/Impact	Applicability	Mitigation techniques
Design, site selection and construction	habitats preservation		
	Control of nutrient loading		
	Quality and quantity of water supply and receiving water		
	Control of seepage into ground and surface waters		
	Erosion		
Operations	Overfeeding		
	Overcrowding		
	Escapee		
	Disease prevention		
	Impacts from chemical use		
	Erosion		
	Predation		

Matrix

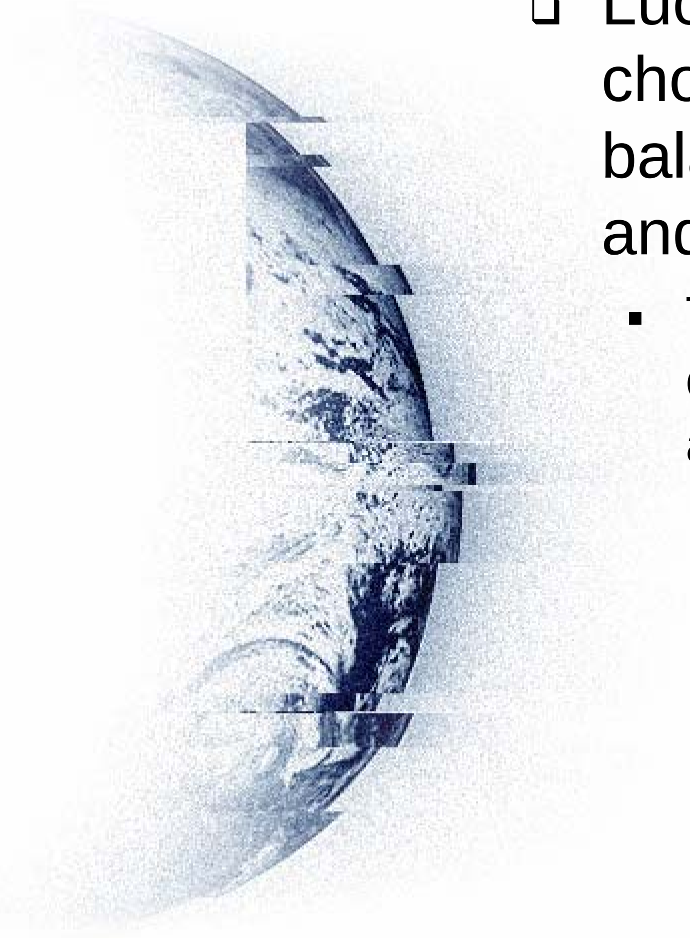


Activity	Problem/Impact	Applicability	Mitigation techniques
Design, site selection and construction	Habitat preservation	Pond	Choose already cleared areas whenever possible. Reuse existing ponds before digging new ones. Do not place pond in low area that can be flooded during rainy season. The area occupied by ponds shall be smaller than that of the natural vegetation. Ponds should be spaced well apart. Vegetation should be retained and replanted as much as possible.
		Cage	Avoid setting cages in areas with aquatic vegetation.
	Control of nutrient loading	Cage	Set cages in areas with good current flow. Currents help to remove sediments and replenish oxygen. When setting cage do it according direction of prevailing wind to prevent debris from collecting between them.
		Pond	Consider integrated culture to reduce nutrient loading. Filter feeders help for maintenance of water quality by consuming plankton and prevent eutrophication. Use of policulture (at least one herbivorous) to consume excess of food.
	Quality and quantity of water supply and receiving water	Pond/cage	Identify potential sources of water contamination and avoid siting were may exist conflict with other water users or were there are already other sources of discharge in receiving waters including aquaculture facilities. Identify limiting factors related with carrying capacity and determine treatment requirements for waste water. Ensure that effluent quality will not have significant impact on down stream riparian uses and fish habitat. Identify parameters of water monitoring to detect water changes. Consider water treatment methods.

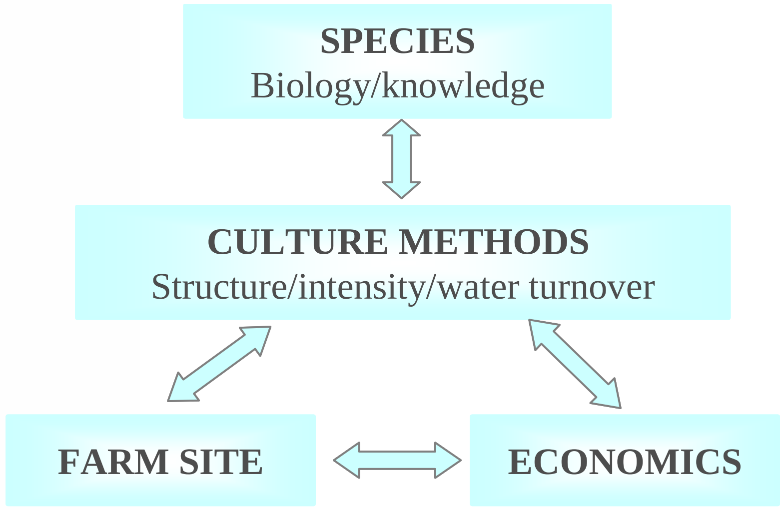
Selection of Species

- Species with well known and proven aquaculture performance and known breeding and growing technique are obviously preferred by aquaculture operators (Van der Mheen, 1994)
- Different criteria have been used to select the appropriate species for aquaculture.
- Species have be selected according to the objectives of culture, for example to
  - Increase protein supply to the poor,
  - Increase export to earn foreign exchange
  - Increase waste recycling in a polyculture system (Pillay, 2003)

Selection of Species



- Lucas and Southgate (2003) define the choice of aquaculture species as the balance between the biological knowledge and economics of the species
  - The interrelationship between cultured species, culture methods, farm site and economics in aquaculture practices



Selection of Species

- Native freshwater fish farmed in Africa based on information from Changadeya *et al.* (2003)

Species	**Countries**
Clarias gariepinus	Malawi, Nigeria, Rwanda, South Africa, Tanzania, Zambia.
Oreochromis andersonii	Zambia
Oreochromis aureus	Côte d'Ivoire
Oreochromis macrochir	Zambia
Oreochromis mossambicus	Malawi, Mozambique, South Africa, Swaziland
Oreochromis niloticus	Congo, Egypt, Gabon, Ghana, Kenya, Mozambique, Senegal, Tanzania, Uganda, Zambia
Tilapia rendalli	Malawi, Swaziland, Tanzania, Zambia
Tilapia zilli	Uganda

Selection of Species

- The species evaluation was done in **three phases**
- For the first phase, data from Fishbase (2005) on the main biological characteristics of wild fish, was used

Maximum length	The maximum length individuals of a certain species are likely to reach.
Maximum weigh	The maximum weigh of an organism.
Average length at first maturity	Average length at which fish of a given population mature for the first time.
Age at first maturity	Average age at which fish of a given population mature for the first time.
Classification of fish	Fish are classified according to the position they occupy in the food chain. Primary producers, herbivores, detrivores, omnivores and carnivores.
Main food	Feeding type indicators.

Selection of Species

- Critical biological data for freshwater fish of Angola (Fishbase 2005)

Species	Classification	Age at first maturity (year)	Average length of maturity (cm)	Optimal growth temperature	Maximum length (cm)	Maximum weight (Kg)	Main food
Chrysichthys nigrodigitatus	Omnivore	1.3	27.5	23-26 °C	65.0	2,4	Plants/detritus, animals
Clarias gariepinus	Omnivore	2-3[1]	70.2	25-30°C[2]	170.0	60.0	Nekton, mainly animals
Clarias ngamensis	Omnivore	1.6	29.2	N/A	73.0	4.0	Nekton, mainly animals
Heterobranchus longifilis	Carnivore	5.5	59.7	22-23 °C	150,0	55.0	Detritus, mainly animals
Hemichromis fasciatus	Carnivore	0.6	13.1	23-25 °C	20.4	0.3	Zoobenthods, mainly animals
Oreochromis andersonii	Detrivore	2.3	26.6	18-33 °C	61.0	4.7	Mainly plants detritus
Oreochromis macrochir	Detrivore	2.9	28.0	18-35 °C	27.1	1.4	Mainly plants, detritus
Serranochromis angusticeps	Carnivore	1,1	21.1	N/A	41.0	2.5	Nekton, mainly animals
Tilapia guineensis	Herbivore	0.9	12.7	22-26 °C	30.0	N/A	Zoobenthods, plants, detritus
Tilapia rendalli	Herbivore	N/A	27.3	24-28 °C	45.0	2.5	Mainly plants, detritus, animals
Tilapia sparrmanii	Herbivore	1.5	14.9	22-25 °C	23.5	0.45	Mainly plants, detritus, animals

Selection of Species

- To be able to compare objectively the different species it was decided to give each species a score on the scale of 1-3 for each selection criteria
- Species that showed an average score above 2 were selected for the second stage

CRITERIA/SCORE	1	2	3
GROWTH PERFORMANCE			
Grow rate (cm/year)	10 <	10 - 20	>20
Maximum length (cm)	40<	40 - 50	>50
REPRODUCTIVE BIOLOGY			
Average length at first maturity	1 5 <	15 - 30	> 30
FEEDING HABITS			
Classification of fish by feeding types	Carnivorous	Omnivorous	Herbivores and Detrivore
MARKET VALUE			
Market demand (Local selling price – USD/kg)	< 5	5 - 10	>10

Selection of Species

- First stage of selection

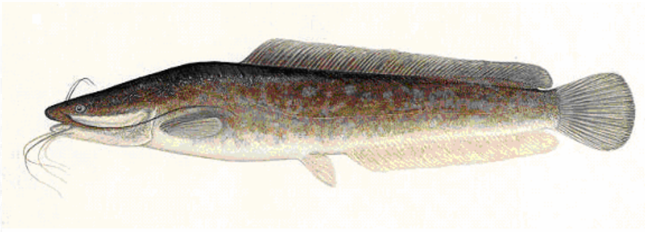
Species	Growth in nature		Reproduct biology	Feeding	Market value	Average
	Grow rate	Maximum length	Length at first maturity	Classification of fish	Local selling price	
Chrysichthys nigrodigitatus	3	3	2	2	N/A	**2.5**
Clarias gariepinus	3	3	3	2	3	**2.8**
Clarias ngamensis	2	3	2	2	3	**2.4**
Heterobranchus longifilis	2	3	3	1	3	**2.4**
Hemichromis fasciatus	3	1	1	1	N/A	**1.5**
Oreochromis andersonii	2	3	2	3	2	**2,4**
Oreochromis macrochir	1	1	2	3	2	**1.8**
Serranochromis angusticeps	2	2	2	1	N/A	**1.8**
Tilapia guineensis	2	1	1	3	2	**1.8**
Tilapia rendalli	N/A	2	2	3	2	**2.2**
Tilapia sparrmanii	1	1	1	3	2	**1.6**

Selection of Species

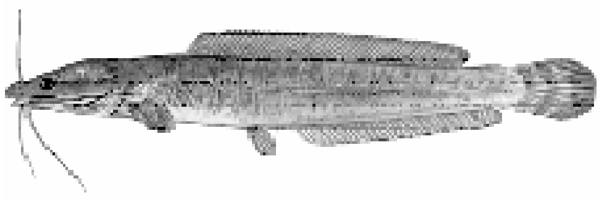
- Only six species survived the first stage

Chrysichthys nigrodigitatus

Clarias gariepinus

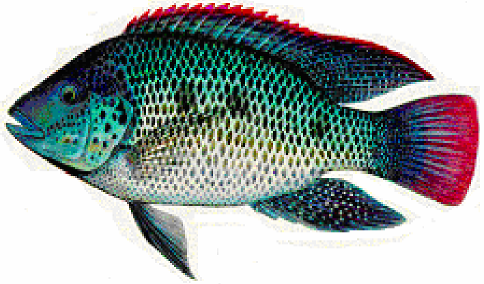


Clarias ngamensis

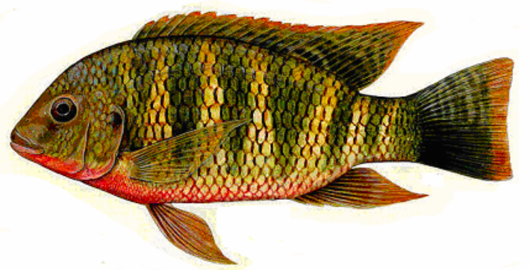


Heterobranchus longifilis

Oreochromis andersonii



Tilapia rendalli



Selection of Species

- The second phase of species evaluation used only relevant information regarding critical aspects of interest in inland aquaculture
- These aspects are
  - how fast the species grow in captivity
  - fecundity and frequency of spawning
  - age at first maturity (only for the ongrowing stage)
  - as well as capacity of feeding on supplementary food in captivity

Selection of Species

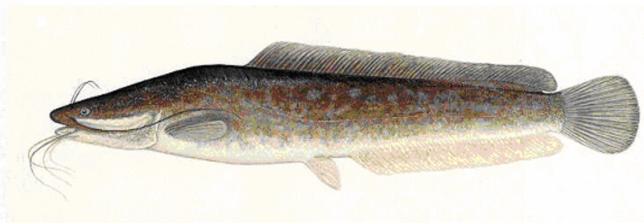
- The third phase of species selection looked at both of the previous phases in combination for the six remaining species

SPECIES	AQUACULTURE POTENTIAL
Chrysichthys nigrodigitatus	- Growth in captivity – N/A. - Reproductive biology – N/A. - Feeding habits – N/A. -
Clarias gariepinus	- Growth faster in captivity conditions - Reproductive biology; easy breeding, does not spawn naturally in captivity, easy to spawn in hatchery, high fecundity. - Omnivorous fish, wide food spectrum. -
Clarias ngamensis	- Growth in captivity – N/A. - Reproductive biology – N/A. - Feeding habits – N/A. -
Heterobranchus longifilis	- Growth in captivity – N/A. - Reproductive biology – N/A. - Feeding habits – Predatory fish. - Used to control Tilapia in aquaculture. -
Oreochromis andersonii	- Growth faster in captivity conditions; reach market size in short time in semi-intensive and intensive aquaculture system. - Reproductive biology; easy to hold and breed in captivity, able to spawn in ponds; high fecundity and also high frequency of spawning. - The category of feeding is favourable to maintain on a low-quality diet based on agricultural by-product.
Tilapia rendalli	- High growth capacity; easy to hold and breed in captivity. - Able to spawn in ponds; high fecundity and also high frequency of spawning - The category of feeding is favourable to maintain on a low-quality diet based on agricultural by-product.

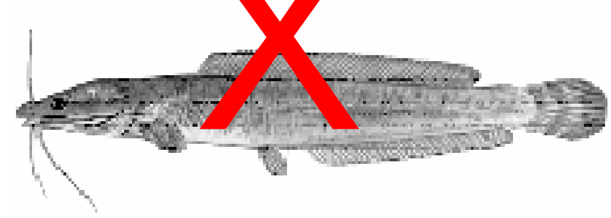
Selection of Species

Chrysichthys nigrodigitatus

Clarias gariepinus

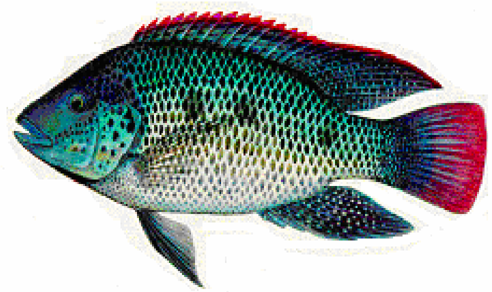


Clarias ngamensis



Heterobranchus longifilis

Oreochromis andersonii



Tilapia rendalli

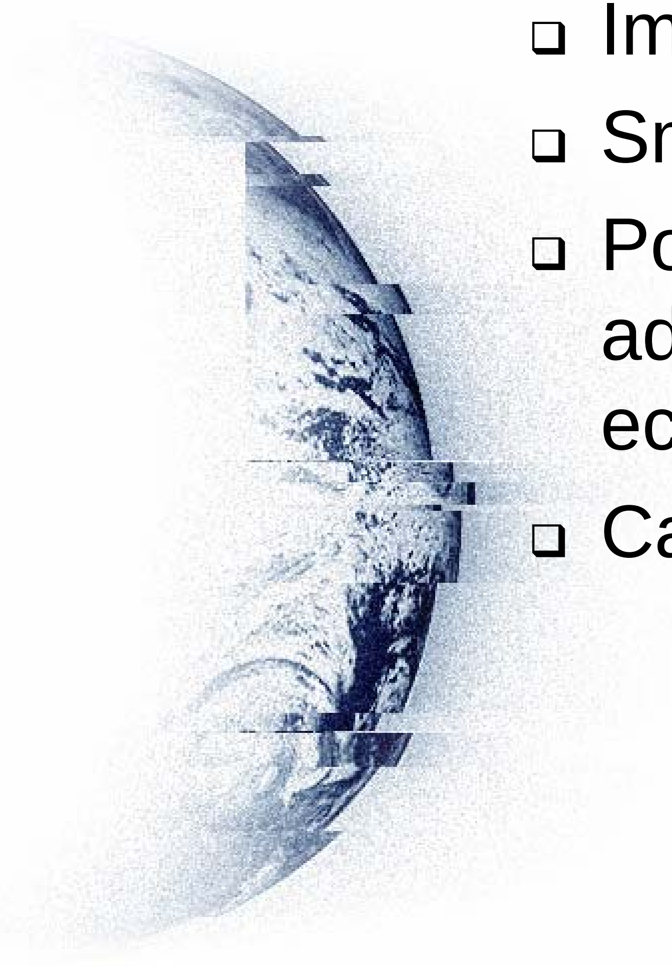
COMMENTS

SPECIES SELECTED	RURAL AQUACULTURE	INDUSTRIAL AQUACULTURE

Oreochromis andersonii and Tilapia rendalli	• The culture duration is seasonal
	• Lower stocking density with small tilapias harvested from the wild.
	• In pond culture, attain maturity early, with high level of uncontrolled reproduction.
	• Tilapia in culture produces larges seed so; avoid collection of seed from the wild.
	• Not reproductive control, culture of male and female together results in reproduction before market size
	• The solution to mitigate it is the practice of polyculture witch small carnivorous fish to reduce tilapia recruitment.
	• Not intentional fertilization. Some time use organic fertilizers to increase primary productivity and promote a succession of organism within the aquaculture pond.
	• The fish are able to utilize natural foods.
	• Limited only for own consumption and local market
		• The culture duration depend of type of aquaculture system
		  o Semi – Intensive system – 6 - 9 months.
		  o Intensive system – 4 - 6 months
		• High stocking densities
		• Use reproductive control. Early maturities not represent some problem because reliable technologies are available to control this reproduction (monosex culture)
		• Early maturity would ensure easier availability of breeders for hatchery operations, so this permit hatchery production of seed in adequate quantities to guarantee seed for restocking and to sell
		• Improved seed quality.
		• Semi-intensive and intensive systems require artificial feeds with high protein content.
		• Formulated feeds are used according the target of species for the minimum possible cost.
		• In semi-intensive system manure and inorganic fertilized is applied.
		• Wide market opportunities.

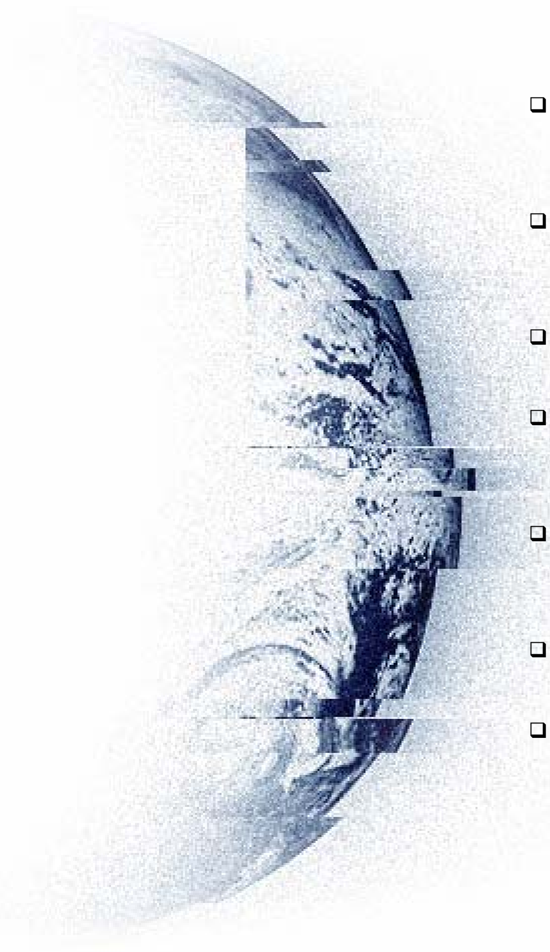
Clarias gariepinus	• Do not reproduce in captivity, • Do not spawn naturally so seed supply may be a problem in the future. • Limited market, for own consumption and local market	• Maintenance of brood stock in hatchery. • Do not reproduce in captivity; this is advantage for intensive aquaculture. • Artificial reproduction has to be induced in hatchery. • Simple methods for brood stock and fry rearing management. • Wide market opportunities:

In conclusion



- Important not to ignore these issues!
- Small steps towards sustainability
- Possible to find solutions that address environmental and economic concerns
- Capacity building!

Bibliography



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