RESEARCH PROGRAM ON Livestock and Fish

More meat, milk and fish by and for the poor

Report on an ASARECA Workshop on Cage Aquaculture and the Environment
Jinja, Uganda, 14-15 March 2013

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www.worldfishcenter.org

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CGIAR is a global partnership that unites organizations engaged in research for a food secure future. The CGIAR Research Program on Livestock and Fish aims to increase the productivity of small-scale livestock and fish systems in sustainable ways, making meat, milk and fish more available and affordable across the developing world. The Program brings together four CGIAR Centers: the International Livestock Research Institute (ILRI) with a mandate on livestock; WorldFish with a mandate on aquaculture; the International Center for Tropical Agriculture (CIAT), which works on forages; and the International Center for Research in the Dry Areas (ICARDA), which works on small ruminants. http://livestockfish.cgiar.org

Produced by WorldFish for the Lvestock and Fish Research Program

Introduction

The following report provides a summary account of the workshop on Cage Aquaculture and the Environment, held at the National Fisheries Resources Research Institute (NaFIRRI), Jinja, Uganda, 14-15 March 2013. The work was instituted as part of the ASARECA project *Building Public Private Sector Partnership to Enhance the Productivity and Competitiveness of Aquaculture in the ECA Region*. The workshop also contributes to the Targeting Theme of the CGIAR Livestock and Fish Research Program.

The rearing of fish in cages[1] accounts for 10% of global farmed fish production. However, in some sectors, such as salmon farming, it is particularly important, accounting for more than 90% of production. Cage aquaculture generally occurs in public waters - sheltered inshore coastal areas, lakes and reservoirs and rivers - and relies heavily on the supply of the ecosystem services that the water body provides, including:

- space in which the farm is located;
- water to support the fish, supply oxygen and disperse and assimilate potentially harmful wastes and metabolites;
- food (plankton), which supplements that supplied by the farmer.

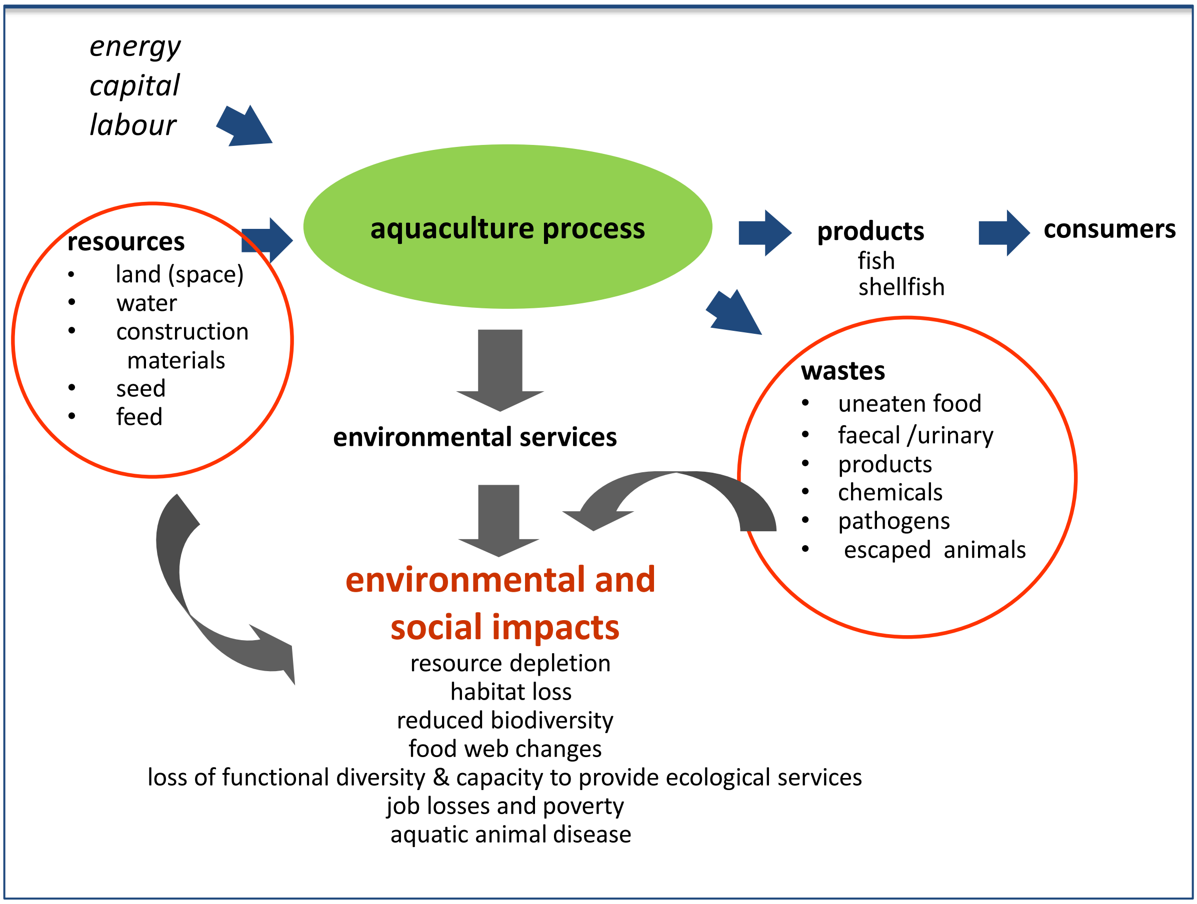


Figure 1: Relationships between cage aquaculture and the environment

[1] '*… rearing facilities in which all sides, including the bottom, are enclosed by wooden, mesh or net screens*; see Beveridge, M C M (2004). *Cage Aquaculture*. 3d Edition. Oxford: Blackwell.

There are many examples, particularly from Asia, that show that unless planned and implemented well cage aquaculture can be a socially and environmentally highly disruptive technology, eroding social and environmental capital and reducing biodiversity and the supply of ecosystem services (Figure 1). This not only undermines the sustainability of cage operations but also impacts on both livelihoods, especially of the poorest, who often have greatest dependency on aquatic natural resources, and on other sectors of the economy such as fishing and tourism.

Cage aquaculture provides opportunities to farm fish in areas where land is scarce, offering opportunities to landless poor to engage. Productivity of cage farming appears very high – up to 500 kg fish m^{-2} of cage y^{-1} (5000 t ha^{-1} y^{-1}). The figures, however, are misleading. First, cage farms are three-dimensional, cage nets often extending 5-10 m in depth. Moreover, a water body cannot be filled with cages; the proportion of water surface that can be sustainably occupied by cages in freshwaters is in the order of 0.1 – 0.5%.

Cage aquaculture has thrived in the coastal waters of Northern Europe, North and South America and in the inland waters of Asia, especially China, Philippines, Indonesia, Vietnam and more recently Bangladesh. However, cage farming has also appeared in Africa, where in addition to providing a source of much needed fish it is also causing concern around governance of common property resources and the exacerbation of anthropogenic pressures on some of the most biodiverse freshwater aquatic ecosystems in the world, which support the livelihoods of millions of poor people. Cage aquaculture currently occurs in Lake Victoria, Lake Tanganyika and Lake Malawi. On the Zambian side of Lake Kariba, there have been at least four applications for large scale cage aquaculture operations in the past 18 months.

The two day workshop was designed to explore these issues among a group of 22 research scientists and farmers from Kenya, Tanganyika and Uganda (Annex 2). The course was designed to raise awareness of environmental issues, the consequences of ignoring these, the tools available to incorporate cage aquaculture into more comprehensive lake management programs and how to mitigate impacts. The workshop consisted of lectures and discussions, visits to two cage farms on Lake Victoria and to the environmental laboratories at NaFIRRI research station (see Fig 2.).

Workshop structure

The workshop was hosted by NaFIRRI and Source of the Nile Fish Farm, both members of the ASARECA project. In addition to field visits, the discussions centered on:

- cage aquaculture technology;
- the origin and quantification of cage aquaculture wastes;
- modeling of waste impacts and environmental capacity;
- the design and implementation of monitoring programs;
- mitigation of impacts.

Copies of water quality manuals[2] were purchased in the UK and sent to Uganda and distributed among delegates, with one copy also being deposited in the NaFIRRI library.

Figure 2. ASARECA Workshop participants visiting cage facilities at SoN cage farm, lake Victoria

[2] Stirling, H. P. (ed.) (1985). *Chemical and Biological Methods of Water Analysis for Aquaculturists*. Bridge of Allan, UK. Pisces Press.

Report structure

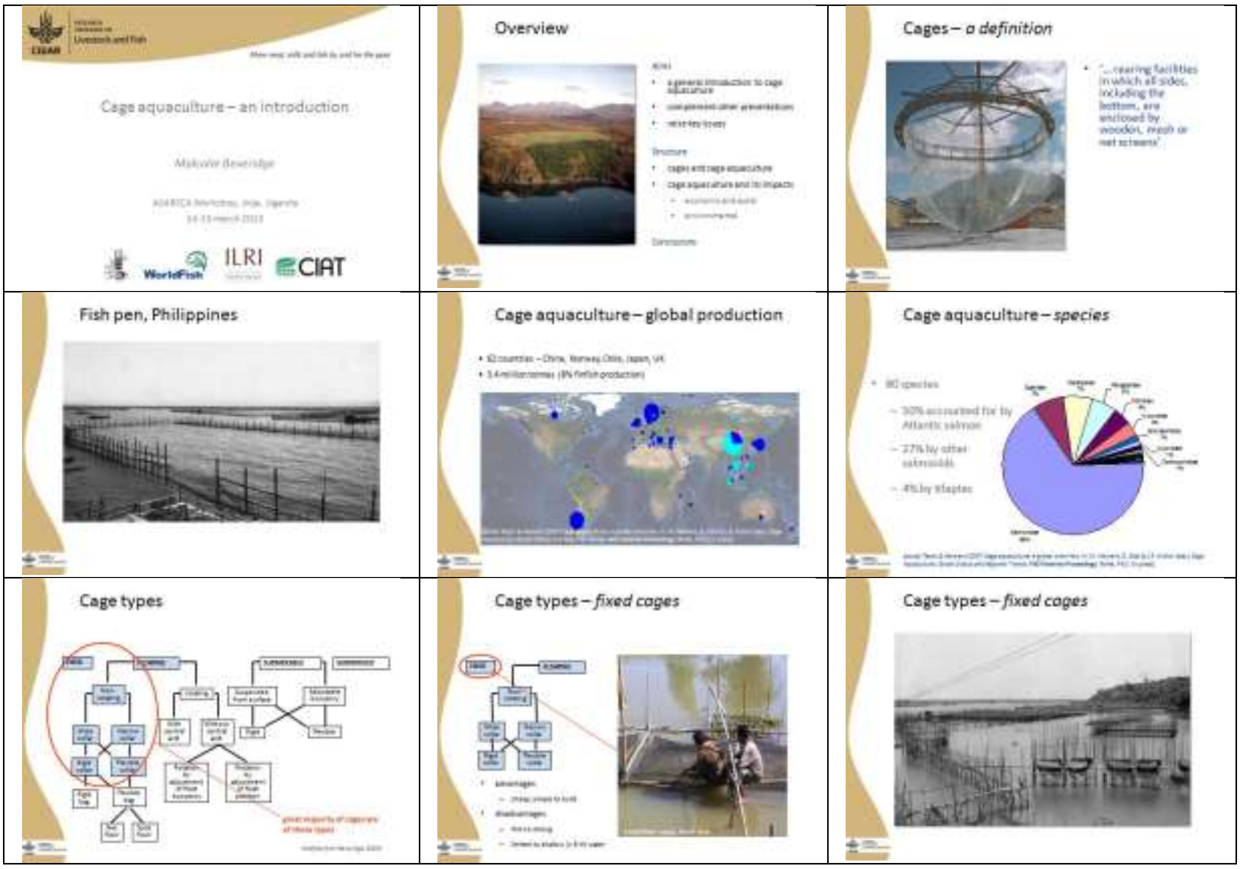
The report consists of the course PowerPoint presentations and a list of references. Annexes 1 and 2 provide the Agenda and list of attendees.

Powerpoint material

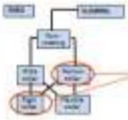
There are six Powerpoint presentations, beginning with an introductory set of slides designed to stimulate discussion on the advantages and disadvantages of cages over other water based and land based aquaculture systems, cage design, installation, management and problems. The five remaining presentations summarize key environmental issues and their management, especially in the context of the ASARECA research project and in development of cage aquaculture in African lakes.

PDFs of all PowerPoint material were also circulated to workshop attendees.

Cage Aquaculture – an Introduction

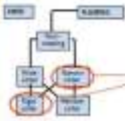


Cage types – *floating cages*



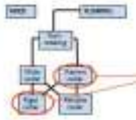
- advantages
  - cheap, simple to build
  - strong
- disadvantages
  - difficult to work from if big

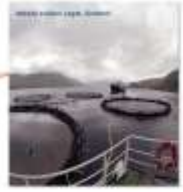
Cage types – *floating cages*



- advantages
  - cheap, simple to build
  - strong
- disadvantages
  - difficult to work from if big

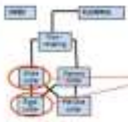
Cage types – *floating cages*





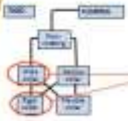
- advantages
  - cheap, simple to build
  - strong
- disadvantages
  - difficult to work from if big

Cage types – *floating cages*



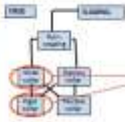
- advantages
  - cheap, simple to build
  - strong (depends on materials and construction)
- disadvantages
  - difficult to work from if big

Cage types – *floating cages*



- advantages
  - strong
- disadvantages
  - expensive

Cage types – *floating cages*



- advantages
  - strong
- disadvantages
  - expensive

Livestock and Fish

problems

Water hyacinth

- A problem that can affect cages
- Solutions
  - siting
  - cage design

Water hyacinth – *submersible fixed cages*

Predators

CGIAR Research Program on Livestock and Fish

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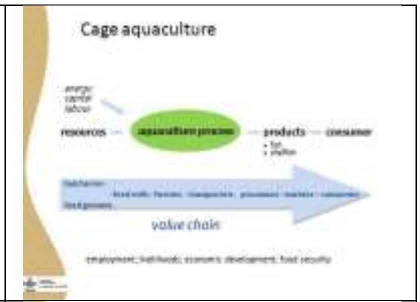
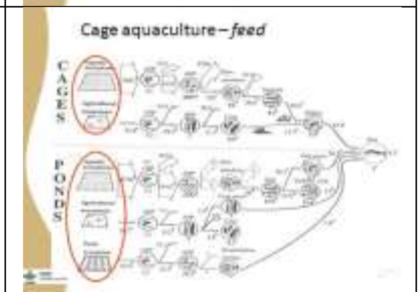
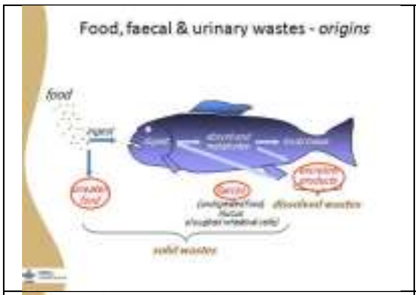
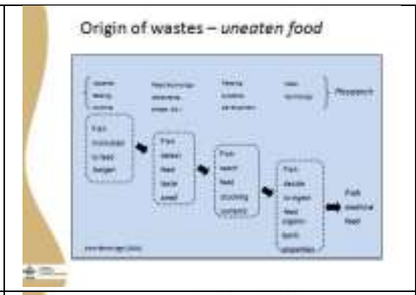
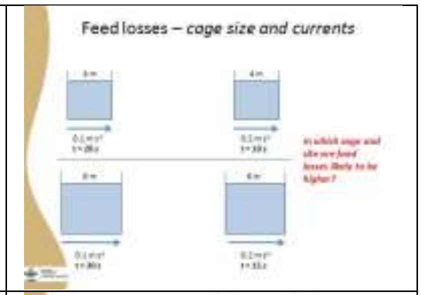
Cage Aquaculture and the Environment I. Resource Use and Wastes

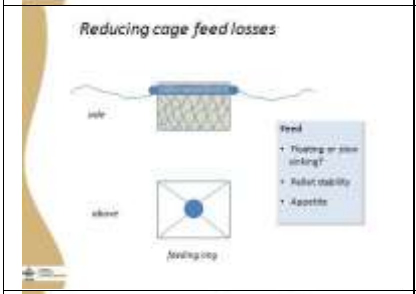





Food, faecal & urinary wastes - origins
food
ingest
uneaten food
solid wastes
dissolved wastes


Origin of wastes – uneaten food
Research
Fish
Fish
Fish
feed


Feed losses – cage size and currents
In which cage and site are feed losses likely to be higher?


Reducing cage feed losses
side
above
feeding ring
Feed
Floating or slow sinking?
Pellet stability
Appetite


Wastes – escaped farmed fish
causes
Losses due to routine escapes ~ 0.01%; losses due to storm or predator attacks ~ 100%


Wastes – escaped farmed fish
Ecology and genetics
Socioeconomics


Wastes – escaped farmed fish
Technology


Wastes – chemicals and medicines
feed additives
antifoulants
medicines
antimicrobials (bacteria, fungi, etc.)
parasiticides
sterilants
hormones


Wastes – chemicals and medicines


Wastes – chemicals and medicines
Concerns about impacts on the environment, on wild fish and on humans
Much research and good advice
American Fisheries Society, IDE, FAO


Livestock and Fish
CGIAR
Quantifying feed associated wastes

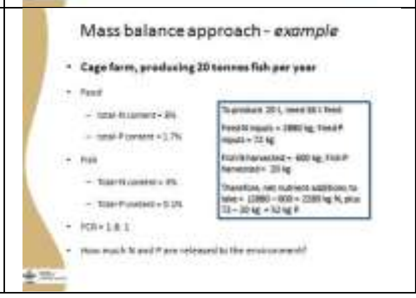

Why and what?
LAKE ECOSYSTEM

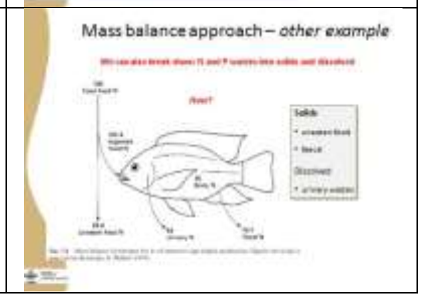

Eutrophication and ecosystem services
Eutrophication affects the supply of ecosystem services

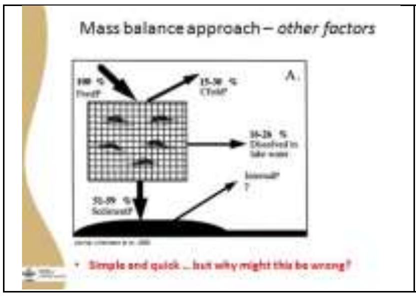

Lake ecosystem services

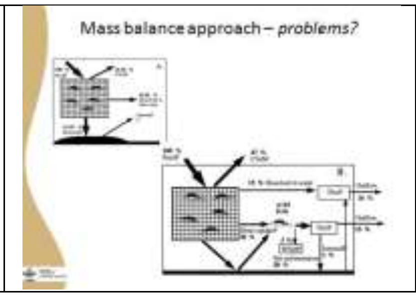

Lake ecosystem services - impacts
water
pollution


Direct measurement
what can you tell from direct measurement?


Mass balance approach - example
Cage farm, producing 20 tonnes fish per year
Feed
Fish
FCR = 1.8 : 1
How much N and P are released to the environment?

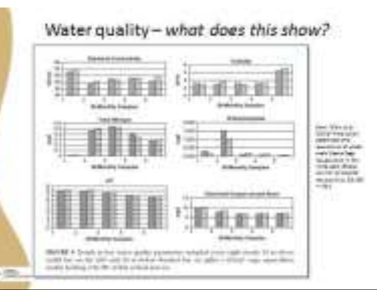

Mass balance approach – other example
How?
Solids
Dissolved

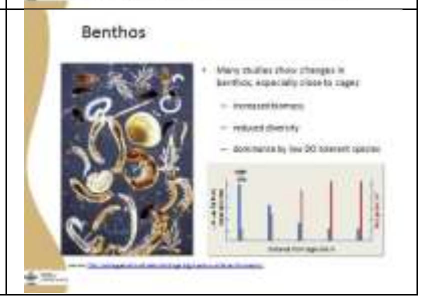


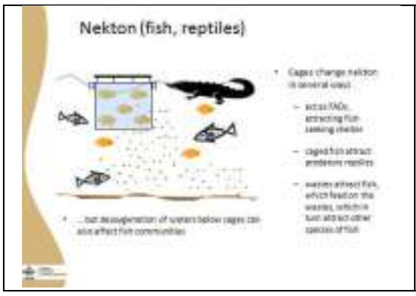


Cage Aquaculture and the Environment II. Impact of Wastes on the Environment

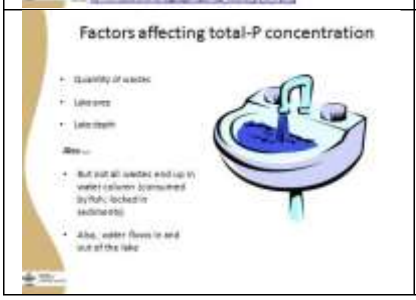
5

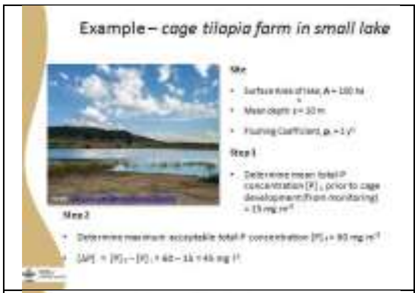




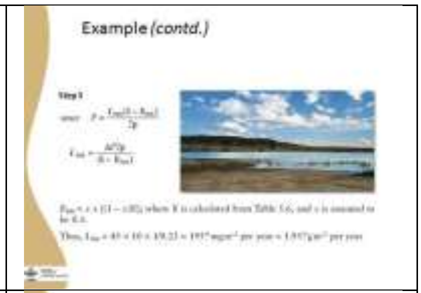


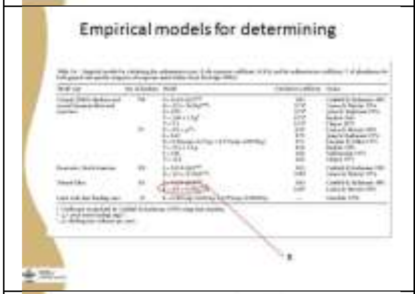
Cage Aquaculture and the Environment III. Modeling and Managing Impacts

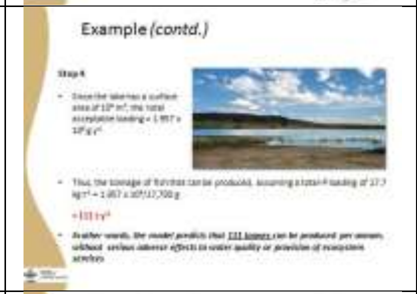



Example – cage tilapia farm in small lake
Site
Step 1
Step 2

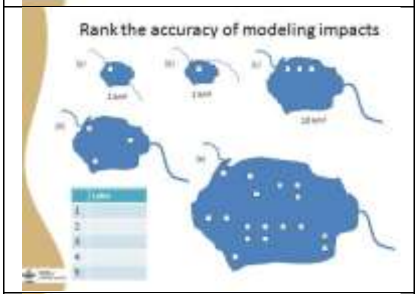

Maximum acceptable (--) and ideal (–) fresh water total-P concentrations

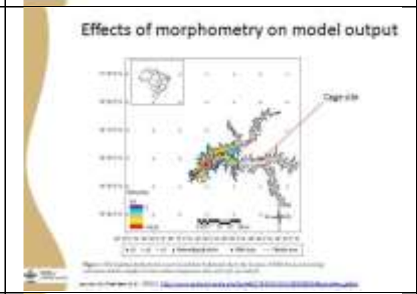

Example (contd.)
Step 3


Empirical models for determining

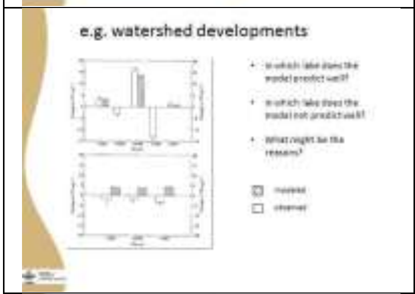

Example (contd.)
Step 4


But ....
Do you believe it?

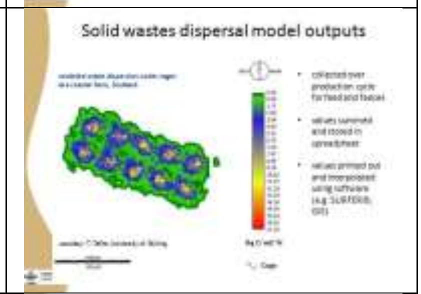

Rank the accuracy of modeling impacts

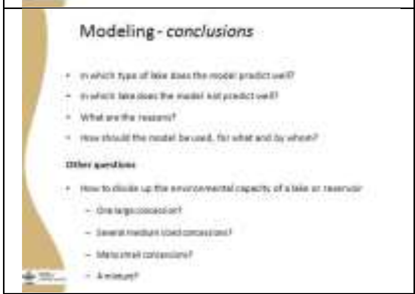

Effects of morphometry on model output
Cage site


e.g. watershed developments
Fish cages

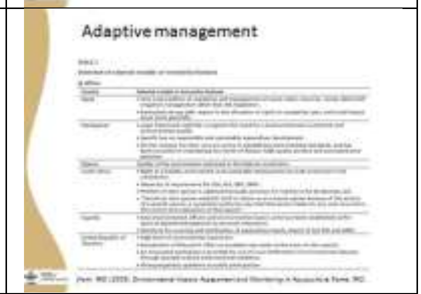

e.g. watershed developments
What might be the reasons?


Modeling solid wastes dispersal
based on the principles that


Solid wastes dispersal model outputs


Modeling - conclusions
What are the reasons?
Other questions


Adaptive management
Other questions


Adaptive management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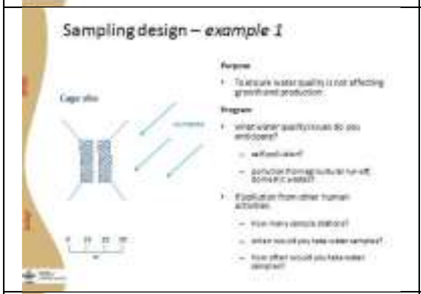
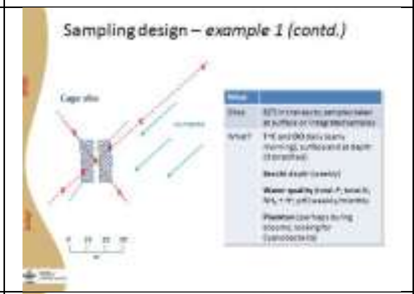
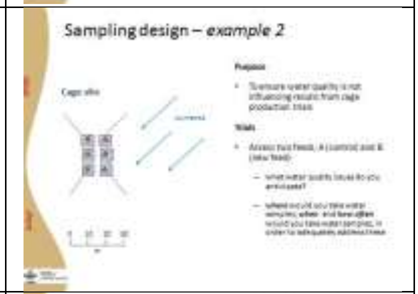
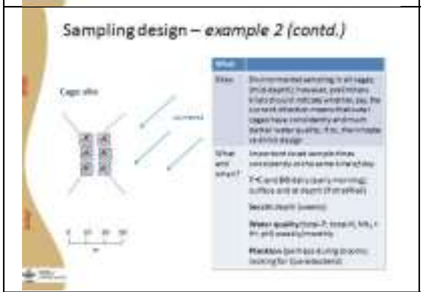
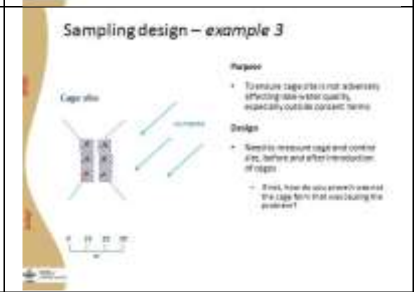
Cage Aquaculture and the Environment IV. Environmental Monitoring

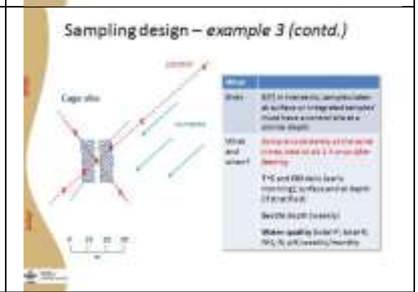


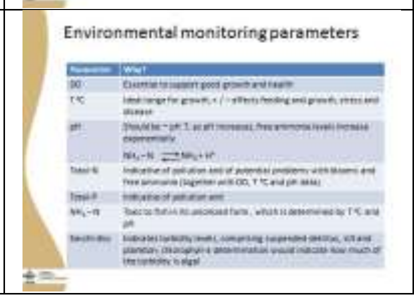


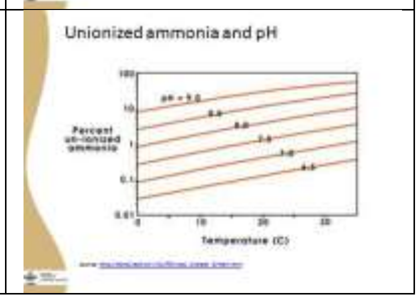


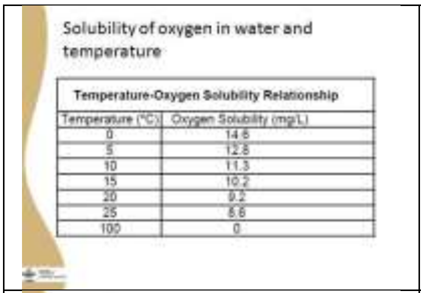




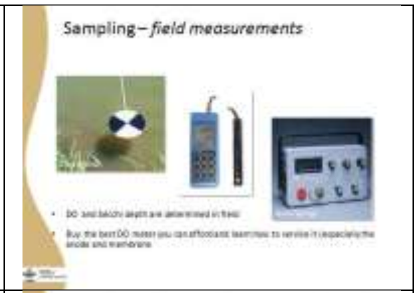


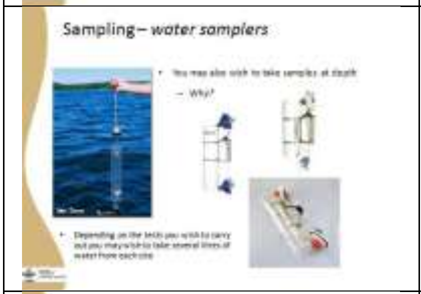


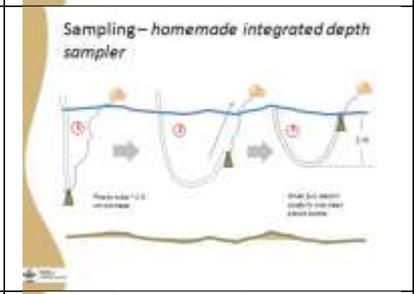


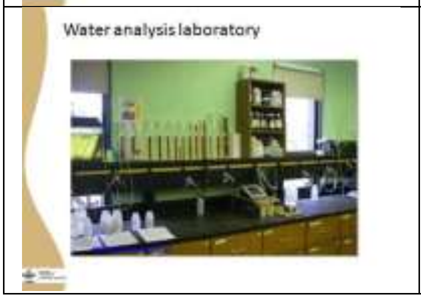


Temperature (°C)	Oxygen Solubility (mg/L)
0	14.6
5	12.8
10	11.3
15	10.2
20	9.2
25	8.6
100	0









Cage Aquaculture and the Environment V. Mitigation of Impacts

Siting

- Which site is likely to have least impact on the lake environment?
- Which site is likely to have greatest impact on the lake environment?

Livestock and Fish

Feeds, feeding and waste recovery and dispersal

Feeds

- There's much work to be done to improve the nutrition quality of farm feeds, such as:
  - Phyto-bound P, which is unavailable to fish and is passed out in faeces
  - Stability of pellets in water

Feeding

- Huge improvements can be generated through studying and applying better feeding methods

Feeding strategies

- e.g. contrast two 1000 t farms
- *farm a*
  - low pollution feeds (P-content 0.8%)
  - careful feeding: FCR 1.1:1
- *farm b*
  - standard feed (1.3%)
  - careless feeding: FCR 1.5:1
- **Calculate the P-wastes from each farm**

Feeding strategies

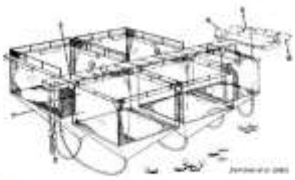
farm a

- low pollution feeds (P-content 0.8%)
- careful feeding: FCR 1.1:1
- (1000 x 0.08 x 1.1) - (1000 x 0.048) =

farm b

- standard feed (1.3%)
- careless feeding: FCR 1.5:1
- (1000 x 0.15 x 1.5) - (1000 x 0.048) =

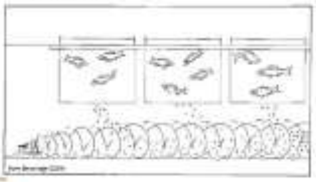
Cage waste recovery systems



- This design didn't work; other, simpler designs can, such as those that are designed to remove mortalities

Waste dispersal systems

Not a good idea ... !



Livestock and Fish

escapes

Losses

- Losses can be substantial
- Work with staff to carry out a HACCP-type analysis to identify where losses occur and how much
- Introduce cost-effective measures to reduce losses

Anti-predator initiatives

- Tidy away spilled feed and feed bags
- Use anti-predator nets
- Have staff around the farm as often as you can
- Keep a dog

Theft and vandalism

- Fishers and their dependents may fear impacts of farm on their livelihoods
- They may resent no-fishing zones
- Farms may have to work hard to reduce tensions and losses

Livestock and Fish

disease

Disease

- Disease largely caused by introductions of fish from outside the farm
- Poor conditions on the farm
  - dead fish, open feed bags and spilled feed that attract birds and vermin
  - poor hygiene (nets, etc.)
- Other stressors
- Tidy away spilled feed and feed bags
- Use anti-predator nets

Livestock and Fish

Water quality problems

Stock management and aeration

- Reduce feeding
- Aeration?

CGIAR Research Program on Livestock and Fish

livestockfish.cgiar.org

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Annex 1. ASARECA Cages Workshop

Aims: To develop a shared understanding among project partners of cage fish farming and environment interactions and the economic and social consequences.

Outcome: improved environmental management of cage fish farms

Time	Activity	Who
DAY 1: 14 March		
09.00	**Welcome and introductions** • Introductions • Workshop overview	
0915	**Cage aquaculture – an introduction** • What are cages • Why cages - alternatives? • Global importance • Cage design, construction and installation • Siting • Production - stocking, feeding, management, harvesting • Problems (predation, storms, water hyacinth, vandalism) • Social aspects	
10.00	*Coffee*	
10.30	**SoN farm visit*** • Travel to farm • Meeting with staff • Introduction to SON • Visit to cages and discussion	Allen and co
14.00	*Lunch*	

14.30	**Cage aquaculture and the environment I : resource consumption and wastes**
	• Environmental issues and their origins
	• Resource consumption
	• Wastes
	  o Definition
	  o Uneaten food, faecal and urinary wastes
	  o Medicines
	  o Parasites and other disease agents
	  o Escaped fish
	• Quantifying wastes
	  o Mass balance equations
	• Fate of wastes
	  o Solids
	  o Dissolved faction	

15.30	*Tea*	
	• Visit to NaFIRRI cages, Jinja	
1600	**Cage aquaculture and the environment II: impacts** • Water and plankton • Sediments and benthic community • Fish communities and fisheries	
17.00	*Workshop close*	

DAY 2: 15 March		
09.00	**Cage aquaculture - general discussion**	
09.45	**Cage aquaculture and the environment III: modeling and managing impacts** • Environmental capacity • Models and modeling • Lake scenarios (small, simple; large; large, dendritic) • Use of model outputs – adaptive management • Use of solids waste dispersal models	
10.30	*Coffee*	
11.00	**Cage aquaculture and the environment IV: environmental monitoring** • Who and why? • Sampling design • Sampling • Analysis	
12.00	**Visit to environmental laboratories, NaFIRRI, Jinja**	
13.00	*Lunch*	

14.00	**Cage aquaculture and the environment V: mitigating impacts**
	• Reducing wastes
	    o Feeds, feeding and FCRs
	    o Reducing escapes
	    o Reducing disease issues
	    o Waste dispersion and collection
	• Mitigation through siting and site management
	• Aeration
	
	Final discussion	

15.00	*Tea*	
15.30	***Workshop close***	

Annex 2: Workshop Attendees

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