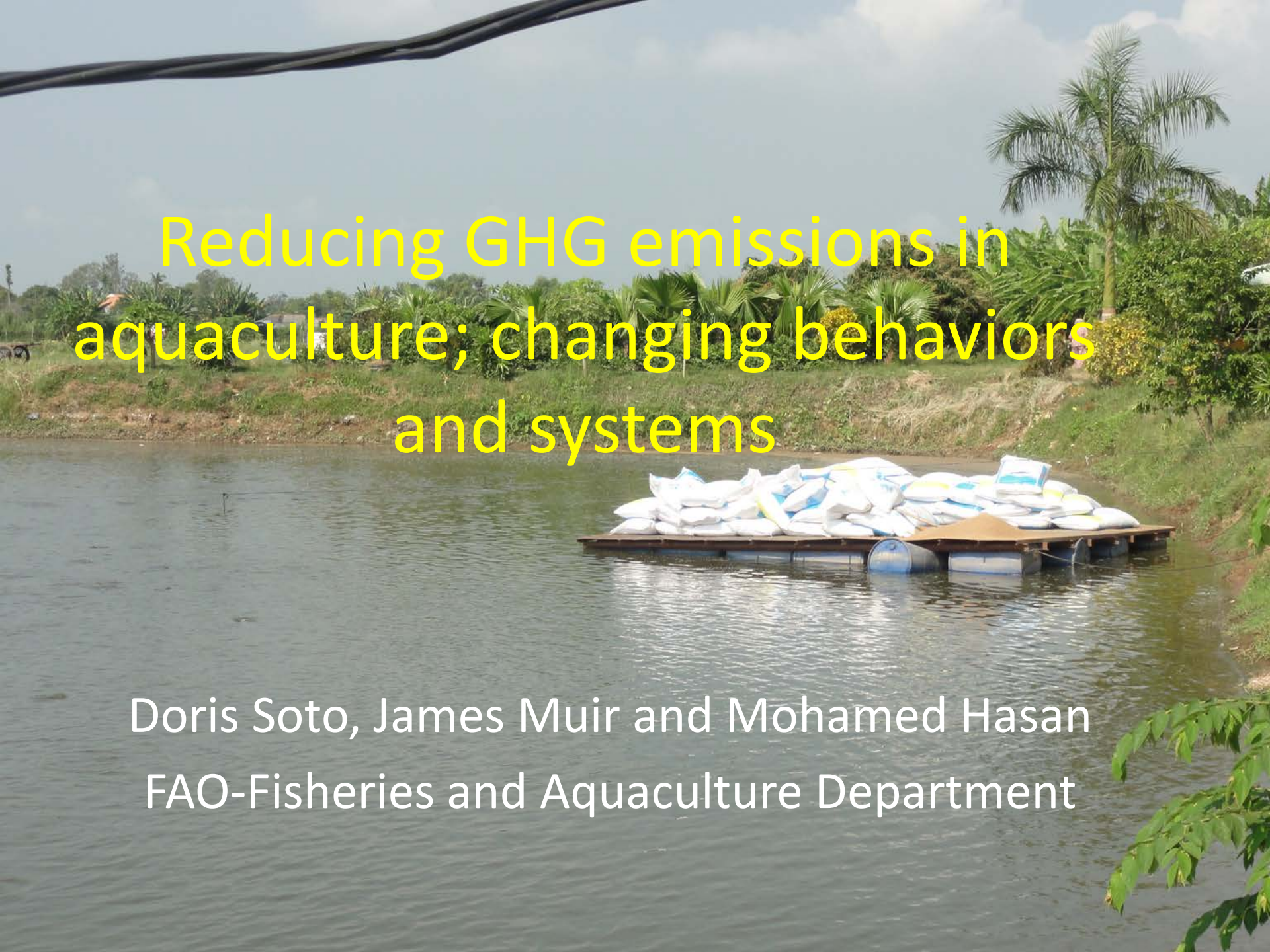

Reducing GHG emissions in aquaculture; changing behaviors and systems

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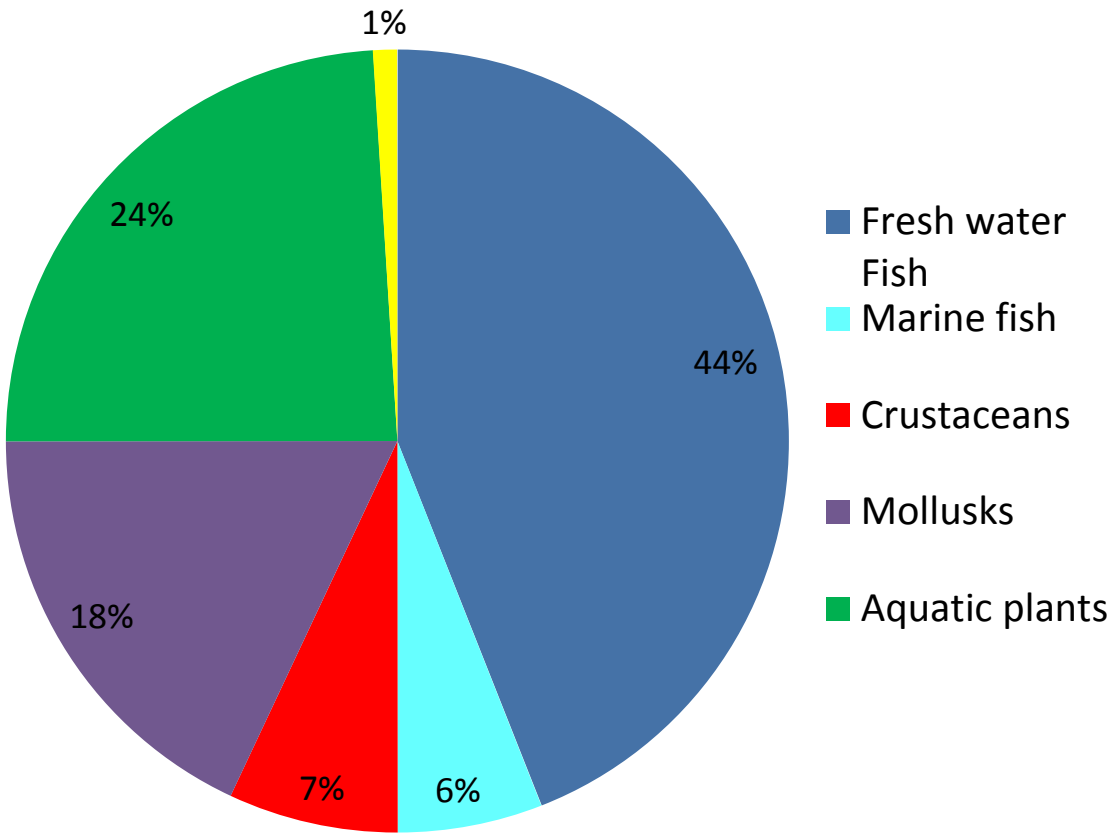
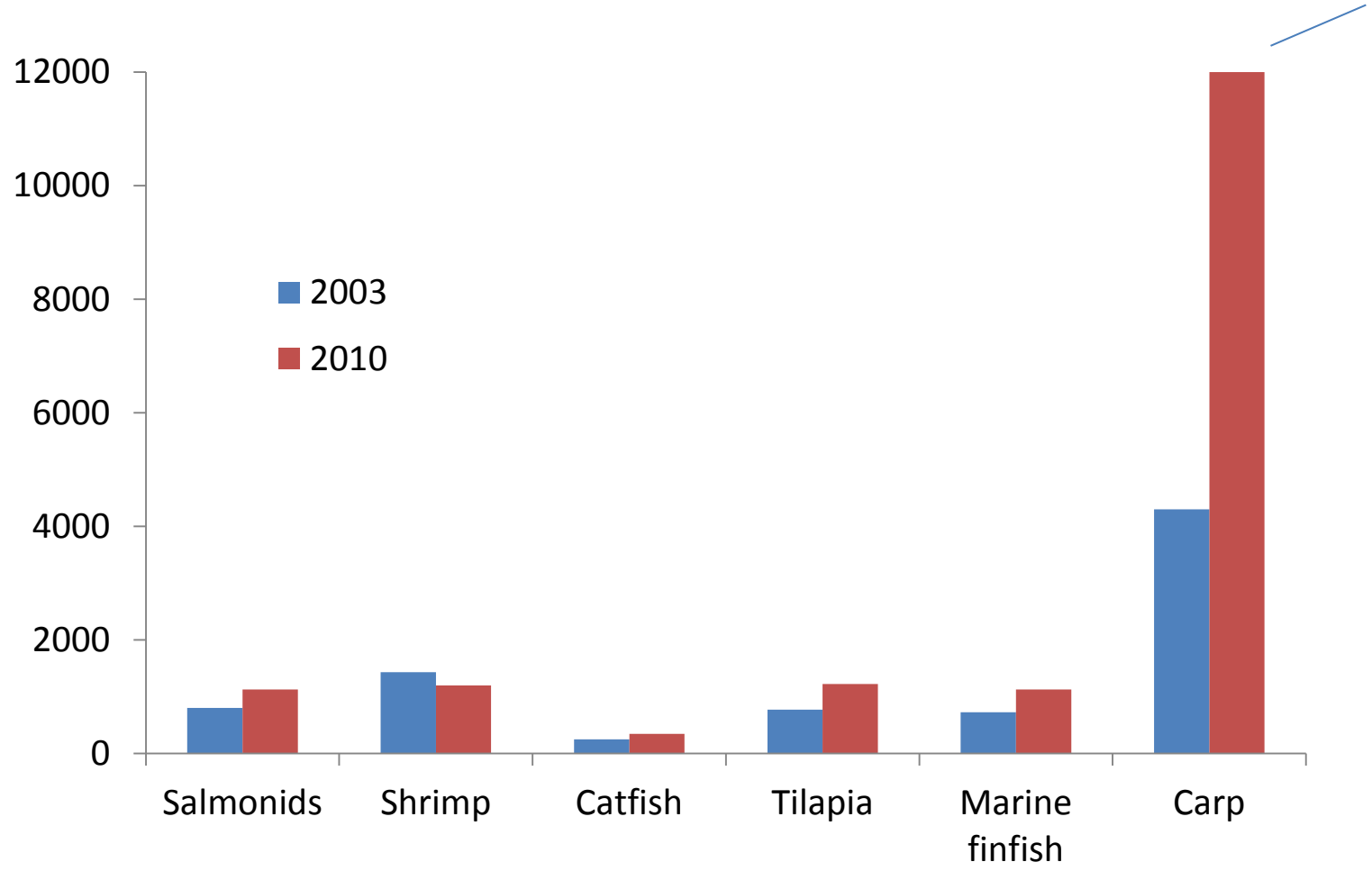
Global contributions to GHG in aquaculture

- Global aquaculture production
- 61 million tonnes in 2011



Estimated energy (tera joules) associated with global production per main species group (Muir in press)



Reducing GHG emissions in aquaculture

- Reducing fishmeal and fish oil in feeds (assuming other ingredients have lower GHG contribution)
- Reducing the GHG emission (all feed components)
- Reducing FCRs specially in the global aquaculture bulk (carps, tilapia, pangasius) following salmon model (??).
  - This avenue is very attractive as it is win-win!,
  - nevertheless yields (both biomass and economic must be maintained)
- Reducing GHG emissions and enhancing carbon sink in pond aquaculture (more research needed of course)
- Promoting the farming of more energy efficient species and systems
- Enhancing non fed aquaculture systems

Reducing GHG emissions from feed and feeding

- Feed composition; FM, FO vs terrestrial sources
  - Geographical regions, species and systems
    - Sourcing of FM, FO
    - Sourcing of terrestrial inputs (soy, canola etc.)
- Feed conversion factors and yields
  - Species and systems
  - Regions

- In 2008, global compound aquafeed production was estimated at 29.2 million tonnes. This figure is projected to rise to 71.1 million tonnes by 2020 (Tacon, Hasan and Metian, 2011).
- Fish-in fish-out ratios (FIFO), forage fish equivalence ratios (FFER), forage fish dependency ratios (FFDR) are typical indicators for FM, FO use
- While FCR provides the most simplistic indication of the feed efficiency,

Economic feed conversion ratios (eFCRs) for feed types used for farming finfish and shrimp in ponds and cages. (Source Rana and Hasan, FAO FTP, in press)

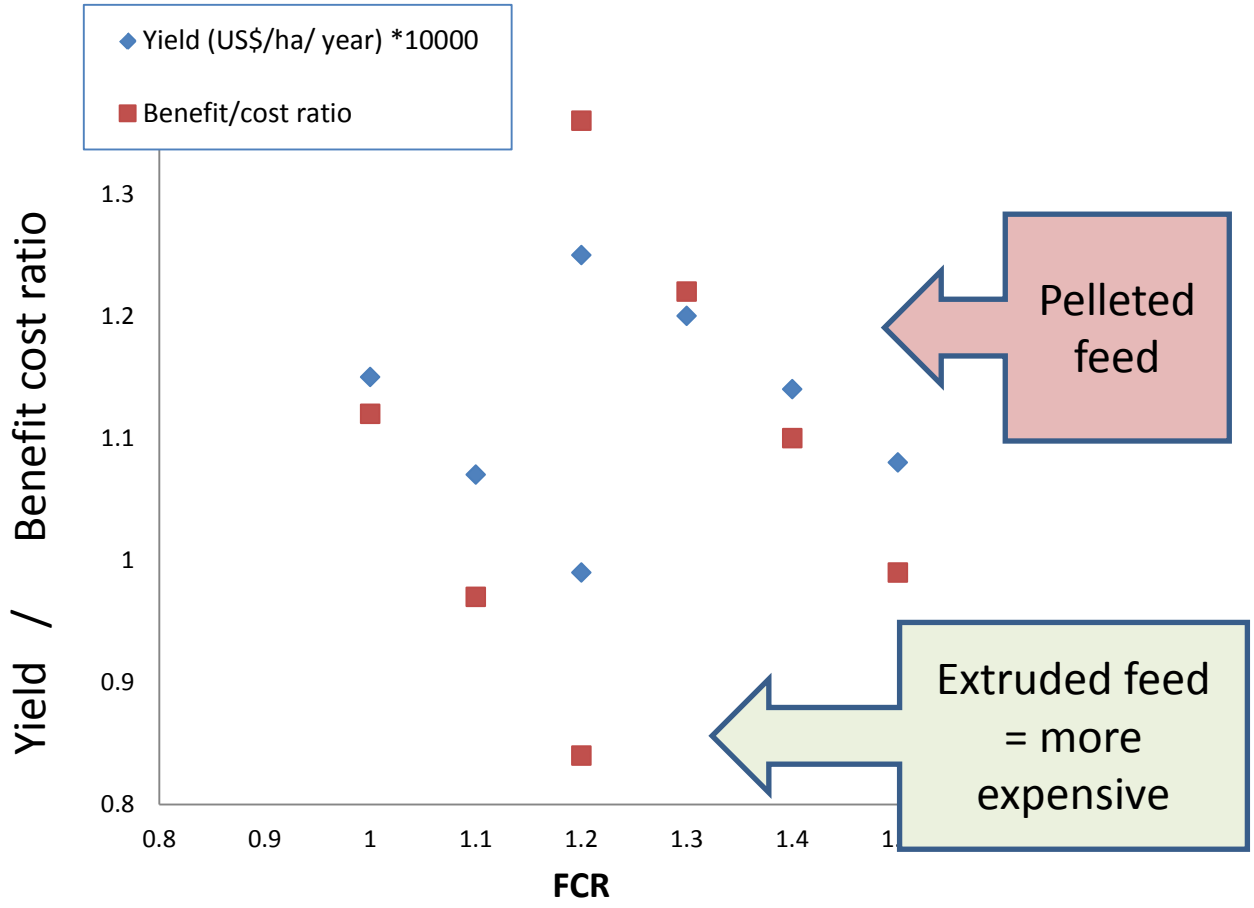
Feed type	eFCR	Species	Rearing system	Country	Reference
Farm made					
Mash	2.3–4.1	Major carps	Pond	India	Ran
Mash + pellet	1.9	Major carps	Pond	India	Ran
Moist pellets	2.9	Striped catfish	Pond	Viet Nam	
Manufactured pellets					
Sinking pellets	1.5	Nile tilapia	Cage	Egypt	El-Sayed (2013)
Sinking pellets	1.6–2.0	Nile tilapia	Pond	China	Liu et al. (2013)
Sinking pellets	1.3–2.1	Major carps	Pond	Bangladesh	Sarder (2013)
Extruded pellets	2.0	Nile tilapia	Pond	Ghana	Awity (2013)
Extruded pellets	1.6	Striped catfish	Pond	Viet Nam	Nguyen (2013)
Extruded pellets	1.5–1.7	Nile tilapia	Pond	Philippines	Romana-Eguia, Larona and Catacutan (2013)
Extruded pellets	1.2–1.4	Nile tilapia	Cage	Ghana	Awity (2013)
Extruded pellets?	1.2–1.2	Whiteleg shrimp	Pond	Viet Nam	Hung and Quy (2013)
Extruded feeds	1.2–1.5	Nile tilapia	Cage	China	Liu et al. (2013)
Extruded feeds	1	Nile tilapia	Cage	Egypt	El-Sayed (2013)

In general farm made feeds result in higher FCR

Many factors affect FCR in freshwater fish and the relationship with GHG emission not always linear

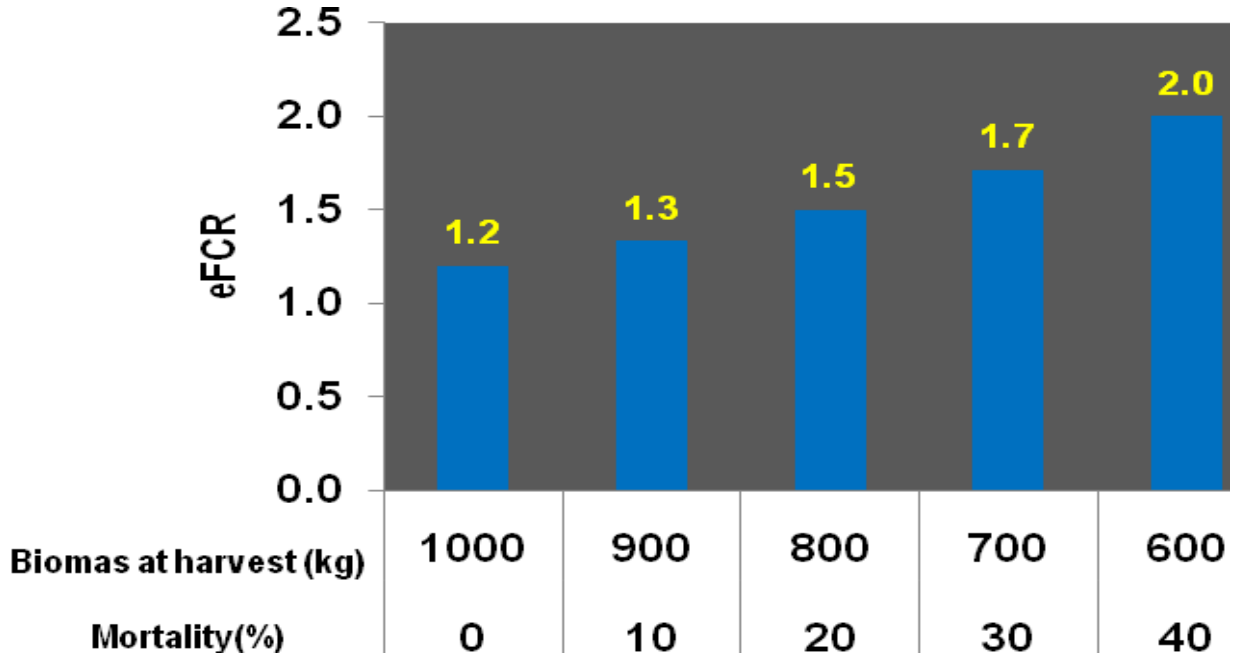
- Home made vs commercial feed; Pellets extrude, mash etc
- Protein content and source
- Mortality plays a big role
- Feeding management including use of fertilizers
- There is a cost in reducing FCRs
- Often yield (economic and flesh) do not go hand on hand with eFCR

Often, minimizing FCR also has implications for yield



Intensive tilapia pond culture systems in Egypt. Production based on a 1ha farm model stocked at a rate of 5 fish/m^2 and a production of 14.5 tonnes/ha/year . Source: Shipton, T.A. and Hecht, T. 2013 (in : Hasan, M. ed. FAO FTP 583, in press)

Mortality effect on eFCR

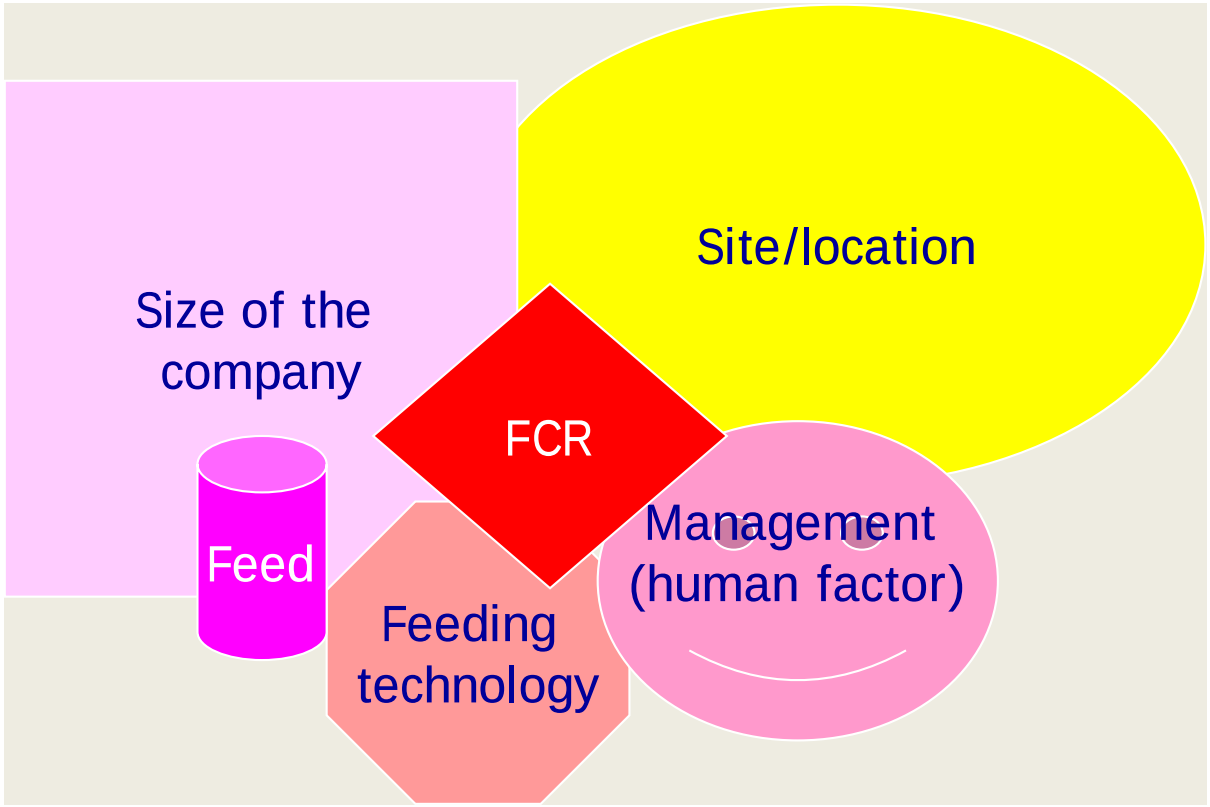


Hypothetical model; Rana and Hasan , FASO FTP in press

Potential impact of FCR reduction for catfish, tilapia and carps

- Global
- Regional
- Is it possible? Yes and the efforts to reduce FCR are most always win/win

The Feed conversion rate can be a good indicator of farming efficiency, economic and environmental performance (inc. nutrient losses and eutrophication potential, food waste, GHG contribution etc.)



An environmental performance indicator for salmon farming companies in southern Chile

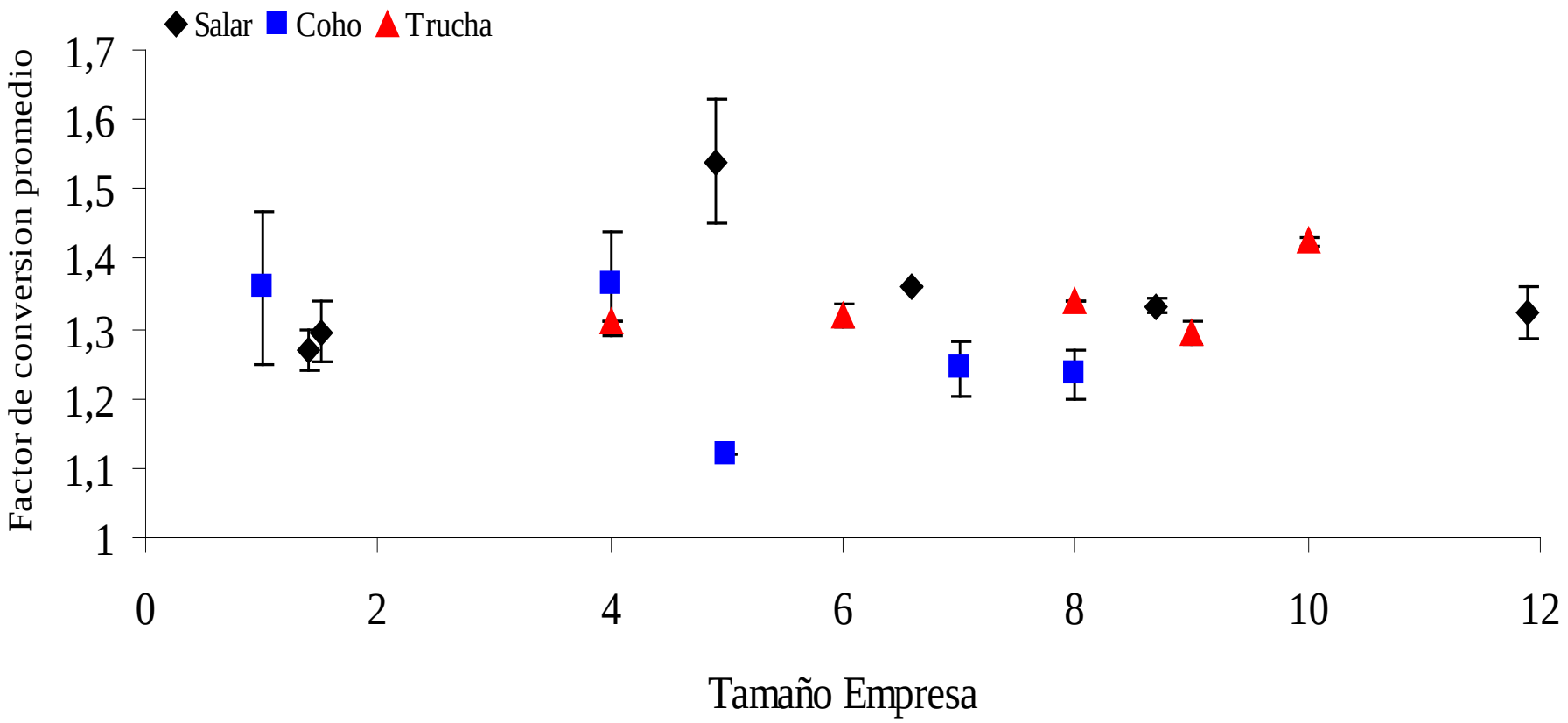
- During 2004 and mid 2005 there was an effort born in the industry interest to have an indicator for bench marking to improve performance of companies associated to INTESAL
- A multiple component score card was elaborated and tested in the field:
  - Production efficiency (PEF)
  - Feed conversion factor (FCR)
- Our hypothesis was that larger companies would perform better (per tonne of salmon produced) than smaller ones

(Test case study;
Soto , Peralta and Norambuena, internal Report;)

Size of the company (% production of industry in 2004)	Marine farms
0,8	2
1,4	2
1,5	4
2,4	3
2,6	2
3,9	3
4,7	4
4,9	5
6,2	3
6,6	3
8,7	3
11,9	3
Total 55,6	**37**

Variables and indicators measured	
Production volume	Age of the farm site (years)
FCR	Technology (%)
PE (gr/month)	Culture density (fish/m3,Kg/m3)
Mortality (%)	Size of the company (%)
Length of the cycle (months)	No of manual feeders (pers.)
Weight at harvest (Kg)	Cage volume (m3)
Net P in sediments (mg/Kg)	
Physical variables	**Environmental integrated indicators**
Mean depth (m)	Environmental condition
Qualitative current (1-5)	Image

Feed conversion factor and size of the farming enterprise



Multivariate model to estimate Feed Conversion Rate in Atlantic salmon

	Slope	Probability	R^2
Dependent variable			
FCR		<0,00838	0,6434
Model intercept	1,0718	0,000000	
Independent variable			
No of feeders (people)	0,015620	0,004954	
Feeding technology	-0,000491	0,563433	
Production biomass per farm	0,000053	0,040610	

Yield, in terms of biomass seemed to result in larger FCRs, economic yield is not clear

- Clearly to focus on FCR is not that simple; consideration of yield, economic benefits and the different production and geographical scales need to be taken in account
- Can we focus on the feed source to reduce GHG emission??
- Should we rather look at the systems?

GHG emission from feed sources for different species

- Feeds for different species have different GHG foot print
- FM and FO are often the larger contributors
- Do alternative feed sources contribute less?
- Not enough information so far on sources of different components

Species	Type of feed	$kgCO_2e/kg$ DM
Tiger prawn	Industrial feed	1.22 – 1.61
Atlantic salmon	Industrial feed	1.35 – 1.55
Rainbow trout	Industrial feed	1.27 – 1.52
Nile tilapia	Industrial feed	0.77 – 1.28
Nile tilapia	Industrial feed	0.88 – 1.67
Nile tilapia	Industrial feed	0.68 – 1.02
Nile tilapia	Industrial feed, China	0.97 – 1.41
Nile tilapia	Farm-made feed, Thailand	1.11 – 1.17
Striped catfish	Industrial feed, Viet Nam	0.78 – 0.99
Striped catfish	Farm-made feed, Viet Nam	0.61 – 0.81

Hasan, M. unpublished

GHG estimated for Atlantic salmon feeds (Hasan and Muir, unpublished)

Diets	Fry	Fingerling	Grower	Marine grower	Broodstock
% Soybean	0	5	12	12	10
% Ground wheat	14.1	13.1	8.2	7.4	14.1
% Corn gluten meal	0	10	10	8	0
% Fishmeal, herring	60.5	40.1	32.4	28.8	35.7
% Other marine protein sources	2	5	3	6	7
% Terrestrial animal byproducts	2	15	16	16	13
% Brewer's yeast	4	0	0	0	4
% Fish oil	10.4	14.8	19.4	25.8	19.2
% additives	2	2	2	2	2
$kgCO_2e$/kg DM	**1.55**	1.4	1.44	1.4	1.35

GHG estimated for Nile tilapia industrial feeds in intensive system (Hasan and Muir unpublished)

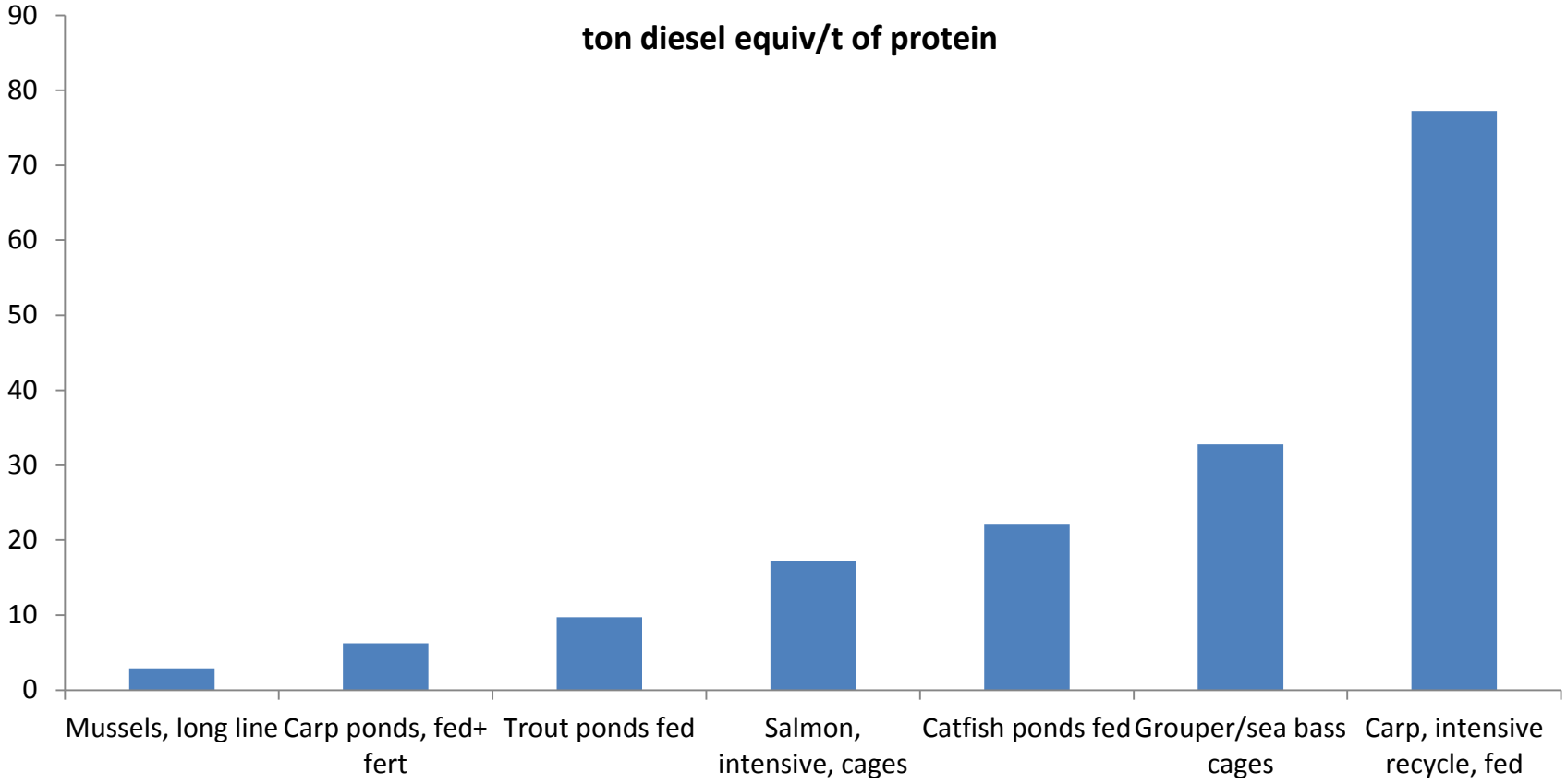
Diets	Pre-starter	Starter	Grower	Finisher
% Soybean meal	62.4	38.5	27.3	21.1
% Grain processing by-products	10	34.6	45	45
% Corn	0	0	3.1	14.9
% Cassava	6.7	10	10	10
% Fishmeal, unknown origin	15	12	10	5
% Fish oil	4	3	3	2
% additives	1.9	1.9	1.6	2
$kgCO_2e/kg$ DM	**1.28**	**1**	**0.87**	**0.77**

- We need to translate this information in more accurate estimates of GHG emission per kilo of fish

Not enough information so far and very complex to address

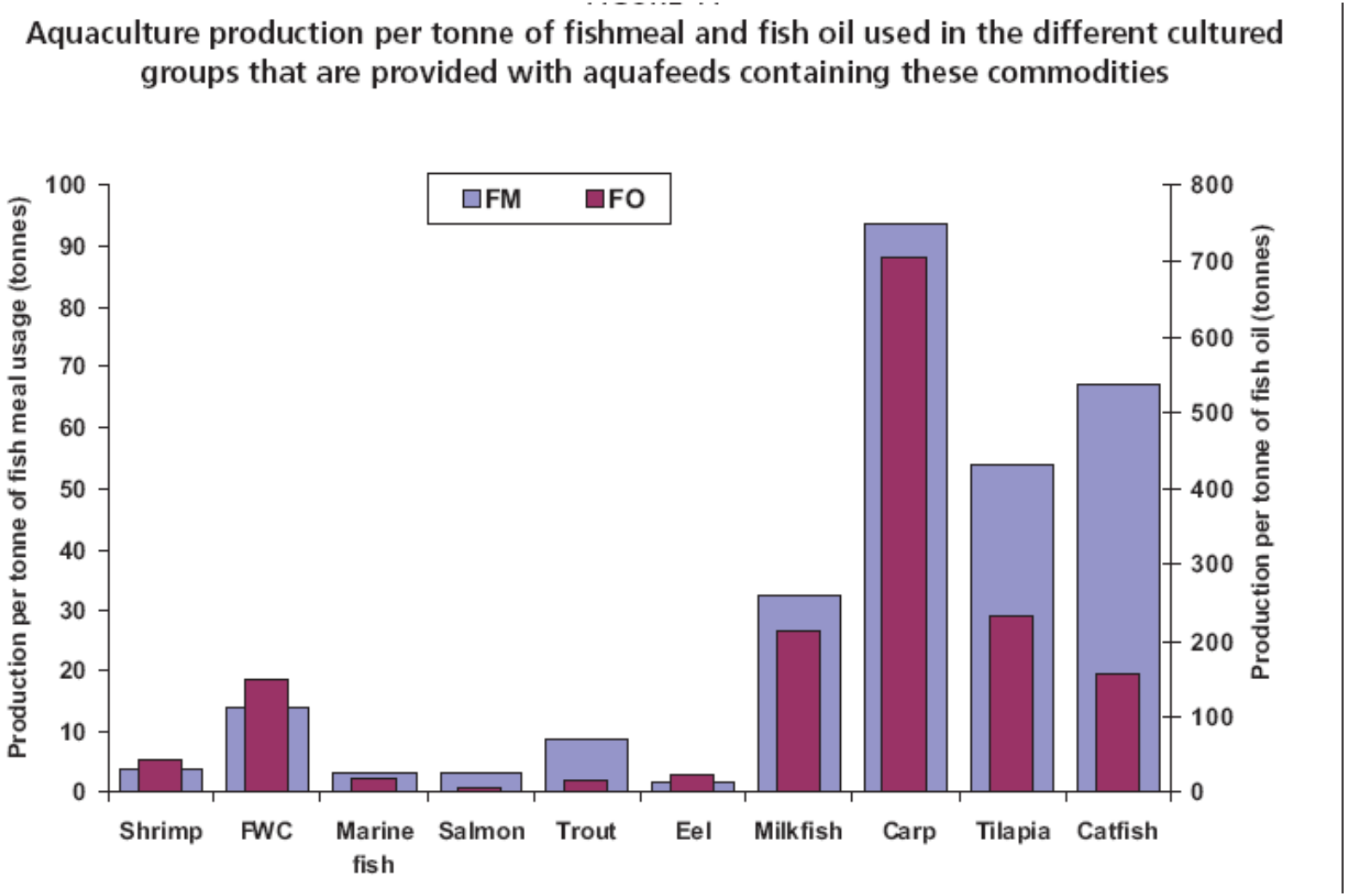
- Not enough information on the sources, some sort of traceability needed
- May be more standardised sources for major production sectors?
- Traceability issues to satisfy?
- Some times home made feeds have less GHG but is not always the case
- Home made feeds tend to have larger FCRs than industrial feeds
- Need to do the cross analysis FCR and feed source

Energy used per tone of fish protein



(Muir, in prep)

Promoting more efficient aquaculture systems in terms of energy use, protein yield?



De Silva and Soto 2009, FAO FTP 530

No fed systems

- Mussel farming, oysters, sea cucumbers etc.
- Culture based fisheries

  – Clearly such farming systems have a much lower or minimal GHG emission per tone of production. Yet is unclear their indirect contribution as sources or facilitating sinks

Integrated multitrophic systems

- Fed catfish and major carps
- Fed shrimp and oysters
- Etc.
  - No evidence that integrated systems reduce GHG emissions, in fact polyculture systems do not necessarily reduce FCRs, and often they increase but yields can be larger, more income for the farmer in small scale extensive systems
  - The tendency of poly culture is to decline and give way to monoculture

Win-win options?

- Hypothesis that better managed systems will perform better across most criteria
- Complexity of tradeoffs may make it difficult to fine-tune systems to meet specific goals – eg FCRs, GHGs, yields, sediment impacts, social capital....
- But perhaps feasible to identify 'sweet spots' – classes of better performing systems/ operating conditions?

How to better address the challenges above??

- What kind of policies, incentives?, use of carbon credits ?
- How to address GHG reduction in the industrial large scale vs small scale farming (e.g. salmon and shrimp vs freshwater fish, catfish tilapia, carps etc.)
- How to measure and verify reductions (particularly for financing)