Food and Agriculture Organization of the United Nations

GLOBAL SALMON INITIATIVE

FAO FAO/GSI Joint Workshop on "Reducing Feed Conversion Ratios in the Global Aquaculture to reduce carbon and other footprints and increase efficiency"

9 – 11 November 2015, Liberia, Costa Rica

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- 7. Life cycle assessment of three freshwater fish species in Asia: implications on GHG emissions and FCR (David F.H. Robb, Michael MacLeod, Mohammad R. Hasan, Doris Soto, Mohammad Mamun-Ur-Rashid, Rajendran Suresh and La Van Chung)
- 8. Quantifying GHG emissions in aquaculture and identifying mitigation opportunities (Michael MacLeod, David F.H. Robb, Mohammad R. Hasan, Doris Soto, Mohammad Mamun-Ur-Rashid, Rajendran Suresh and La Van Chung)
- 9. The role of FCR as a performance indicator (Doris Soto)
- 10. Improving feeds and FCRs: the perspective from salmon farming (Michael Adler)
- 11. A tool to assess GHG contribution in aquaculture: salmon and other species as cases studies (Jonathan Moir)

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- 12. On reducing 'FCR' in semi-intensive Indian major carp culture in Andhra Pradesh, India (Ramakrishna Ravi)
- 13. History of FCR reduction in marine shrimp and its impact in shrimp farming in Ecuador (Laurence Massaut)
- 14. Management of FCR: the perspective from the shrimp Industry (Roberto Lopez-Ibanez)
- 15. Potential for reducing FCRs in the production of native tilapias in Malawi (Daniel Jamu)
- 16. Application, interpretation and reduction of FCRs and consequences for major feed ingredients (Krishen J. Rana)

A joint FAO-GSI initiative

Objectives of the workshop: the need to address energy issues, GHG emission and mitigation and FCR in aquaculture

Doris Soto
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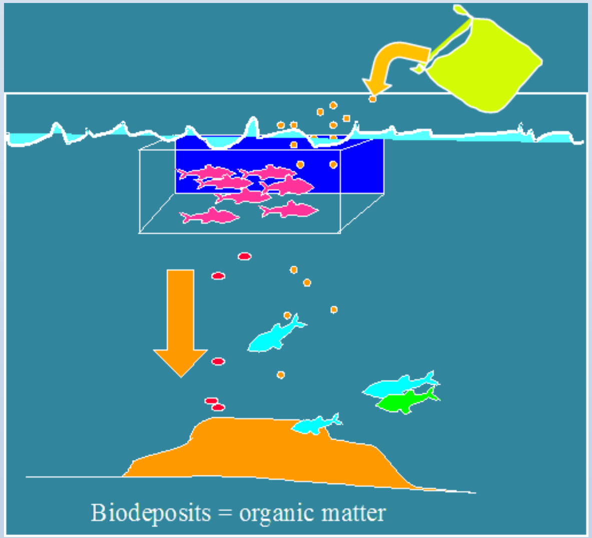
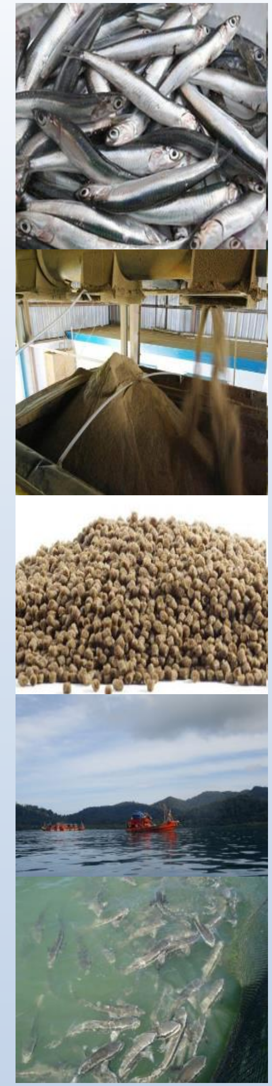


Contribution of aquaculture & fisheries to carbon emissions

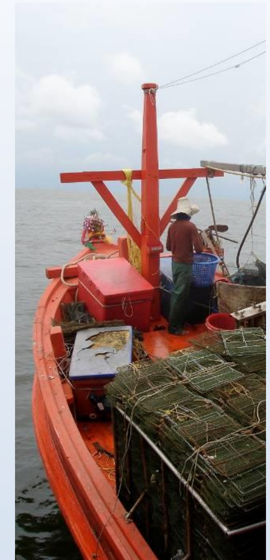
- Green house gas (GHG) contribution of fisheries, aquaculture and related supply chain features are being studied
  - Relatively small in global terms
  - Fuel use alone in global capture fisheries generates 90-130 million tonnes of CO_2

- Estimates vary a great deal
  - Cover different parts of supply chain
  - May not be directly comparable



Need holistic view of GHG in production systems

- A supply chain approach can identify hotspots for GHG emissions
- Likely that fishing vessels are the largest GHG emitters in the sector
  - followed by processing plants
- Aquaculture seems relatively lower than fisheries
  - main GHG emission from feed production & transport
- Different transportation methods
- Fishing vessels
  - All vessels not the same GHG emissions



- Fisheries and aquaculture must do their part to reduce the carbon footprint
- Aquaculture could offer consumers lower GHG emissions & nutritious food alternative

Some facts and issues

- In 2012 at least 65 percent of aquaculture production relied on some sort of feed, and is likely that this percentage is higher today because of the greater increase in the production of fed species than those non fed.
- In general, feeds account for almost 80 percent of energy consumption in intensive systems, and almost the entire use in the semi-intensive. These are likely the main sources of GHG contributions from the sector.
- Feeds are a limiting factor for aquaculture to grow at the needed rate worldwide.
- Reliance on fishmeal and fish oil is not sustainable in the long term.
- Reliance on terrestrial inputs can also be a challenge specially under CC scenarios and freshwater stress.
- Feeding can be more efficient and Food Conversion Ratios (FCRs) can be improved significantly.

- FCRs also offer a measure of the production efficiency and environmental performance because they provide an indication of the undesirable outputs and lost nutrients to the environment, with potential consequences such as accelerated eutrophication, loss of biodiversity and other ecosystem impacts.

Reducing GHG emissions in aquaculture and improving ecological and economic efficiency

- Reducing fishmeal and fish oil in feeds (assuming other ingredients have lower GHG contributions).
- Reducing GHG emissions (all feed components).
- Reducing FCRs especially in the global aquaculture commodity species (carps, tilapia, pangasius) following the 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.

Trends in technical efficiency in salmon farming

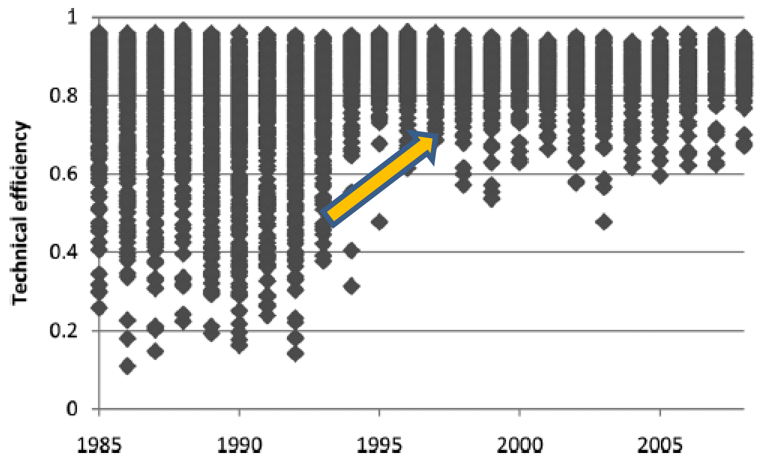
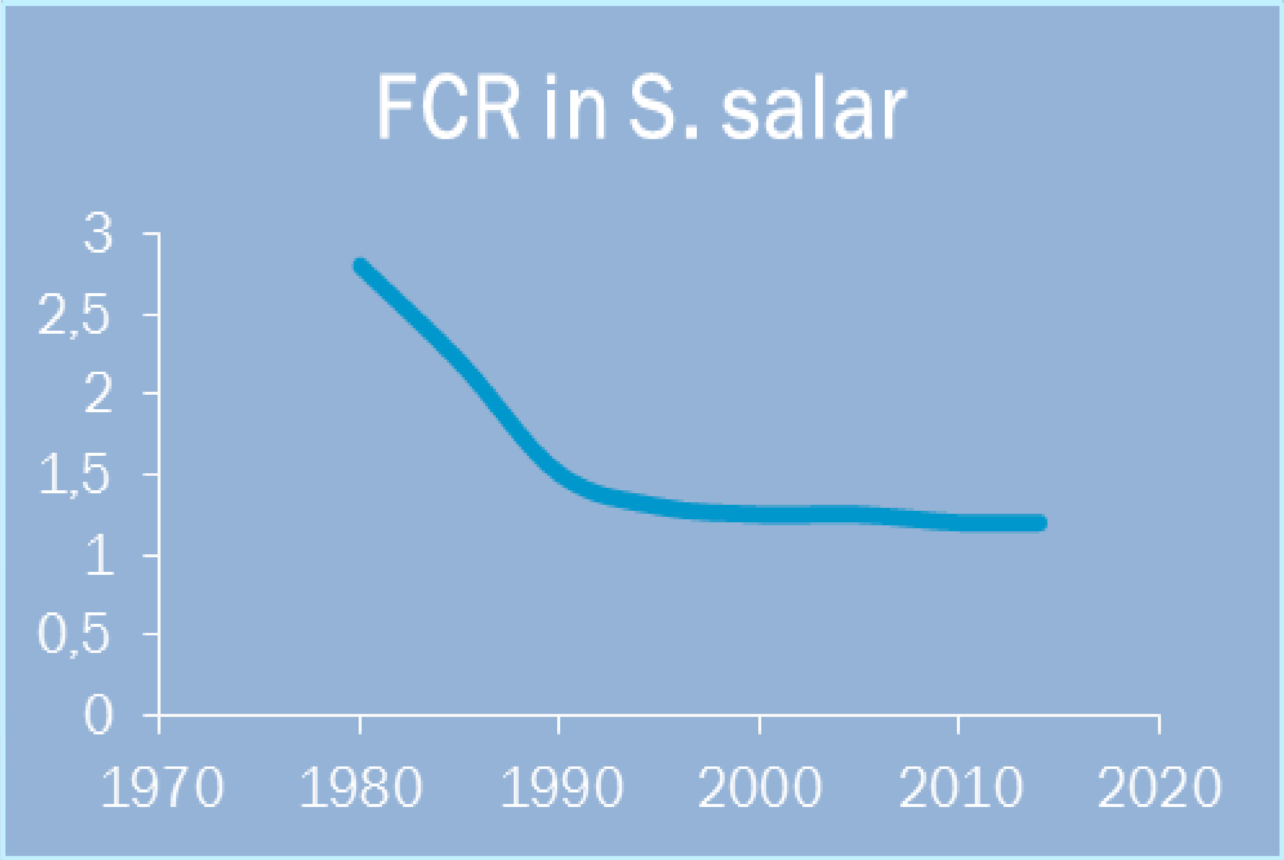


FIGURE 9 Trends in technical efficiency over time.

Asche & Roll (2013) Aquaculture Economics & Management, 17(3): 300-321

Such technological advancements can be transferred to other aquaculture systems and species to increase global aquaculture production and its contribution to food security and development in a sustainable way


FCR in S. salar
3
2,5
2
1,5
1
0,5
0
1970
1980
1990
2000
2010
2020

Objectives of the workshop

- To discuss the potential for reducing aquaculture GHG contributions and increasing sustainability of aquaculture feeding systems in general, through reduction of FCR.
- To discuss and propose a plan of action for the sector through public–private cooperation.

Workshop structure

- Individual presentations and discussions to establish the baseline and common understanding
- Working groups
    - Further reducing the FCRs in high value commodities (salmon, marine shrimp, marine fish)
    - Reducing the FCR in freshwater species and the potential for knowledge and technology transfer from salmon to other systems.
- Plenary discussions

Expected outputs

- A FAO proceedings containing all technical inputs and deliberations and main recommendations especially regarding improving of FCR and technology transfer.
- A dissemination/information document for common public (for well known magazine/s, online news, etc.).
- A plan for cooperation to transfer technology and to boost further improvement.

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Feeding the global aquaculture: supply and demand of feed and feed ingredients

Liberia, Costa Rica, 9– 11 November 2015

Mohammad R. Hasan
Fisheries and Aquaculture Department
FAO, Rome

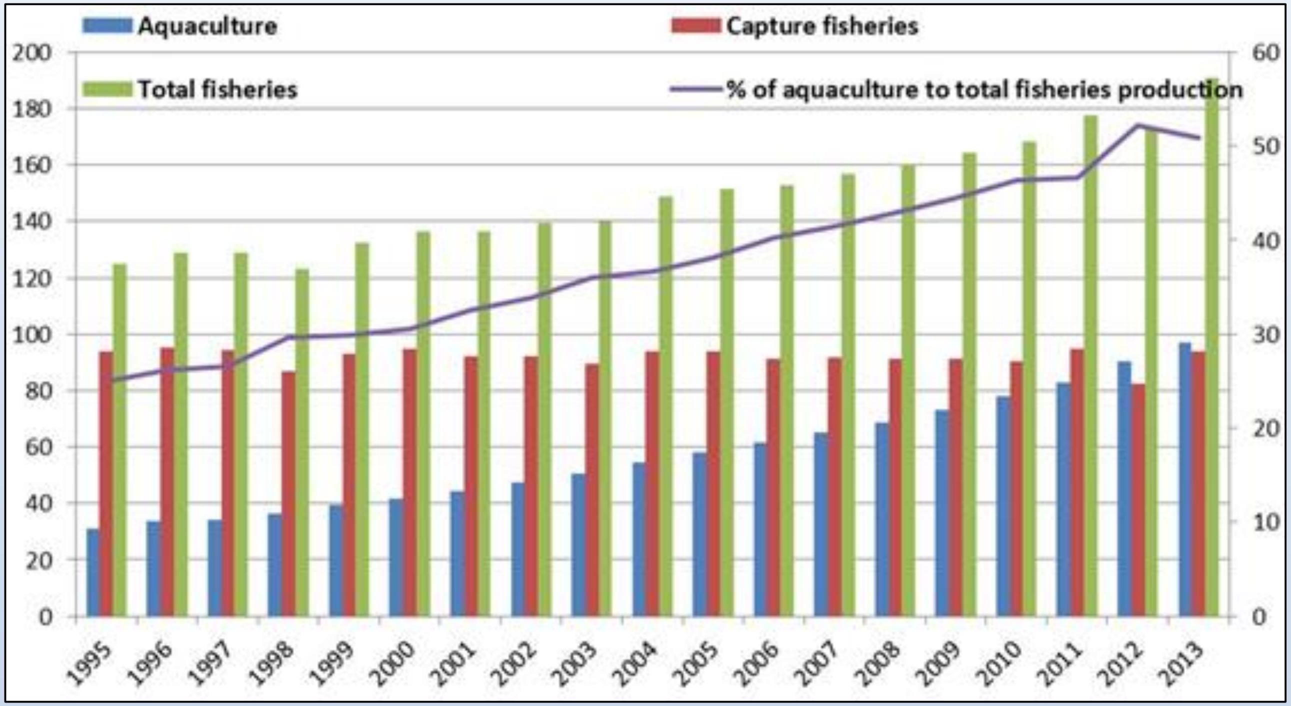


Aquaculture's contribution to global aquatic production increased from 15% in 1988 to almost 51% in 2013

Global trends in contribution of aquaculture to fisheries production (1995-2013)

In 2012, 90 mt, 9.0% APR US$144 billion

In 2012, 66.5mt of aquatic products excluding plants



In 2013, 97.2 mt, 7.7% APR US$157 billion

In 2013, 70.2 mt of aquatic products excluding plants

In 2013, global aquaculture production reached 97.2 million tonnes

Rapid growth of aquaculture has been due to technological advances in equipment and feed and access to greater areas under aquaculture

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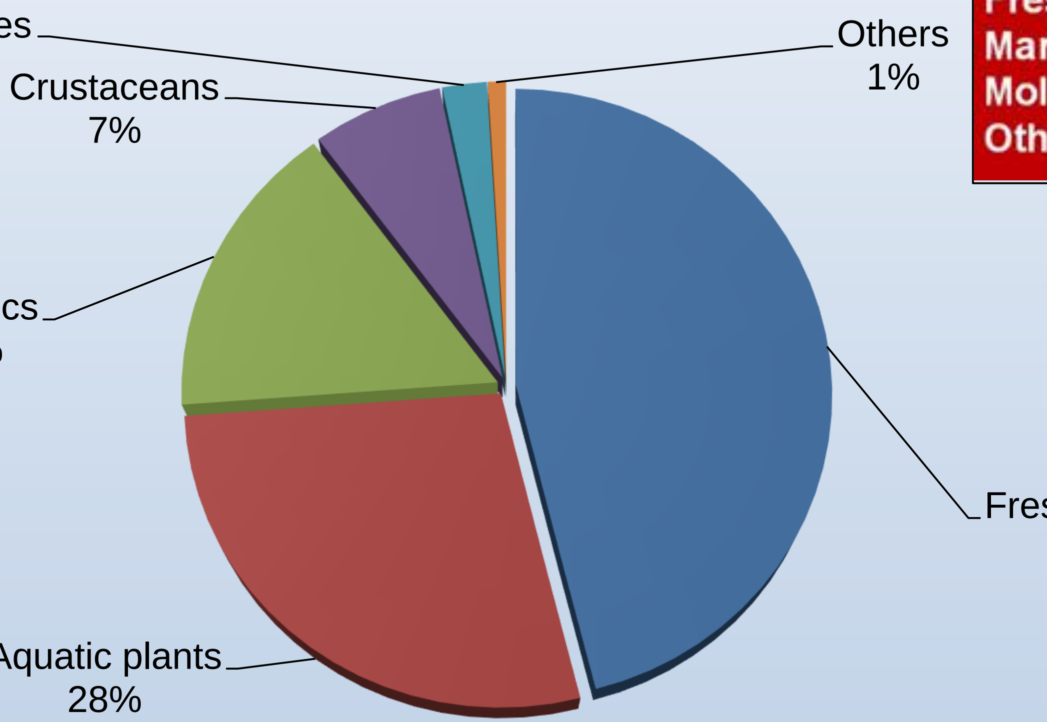
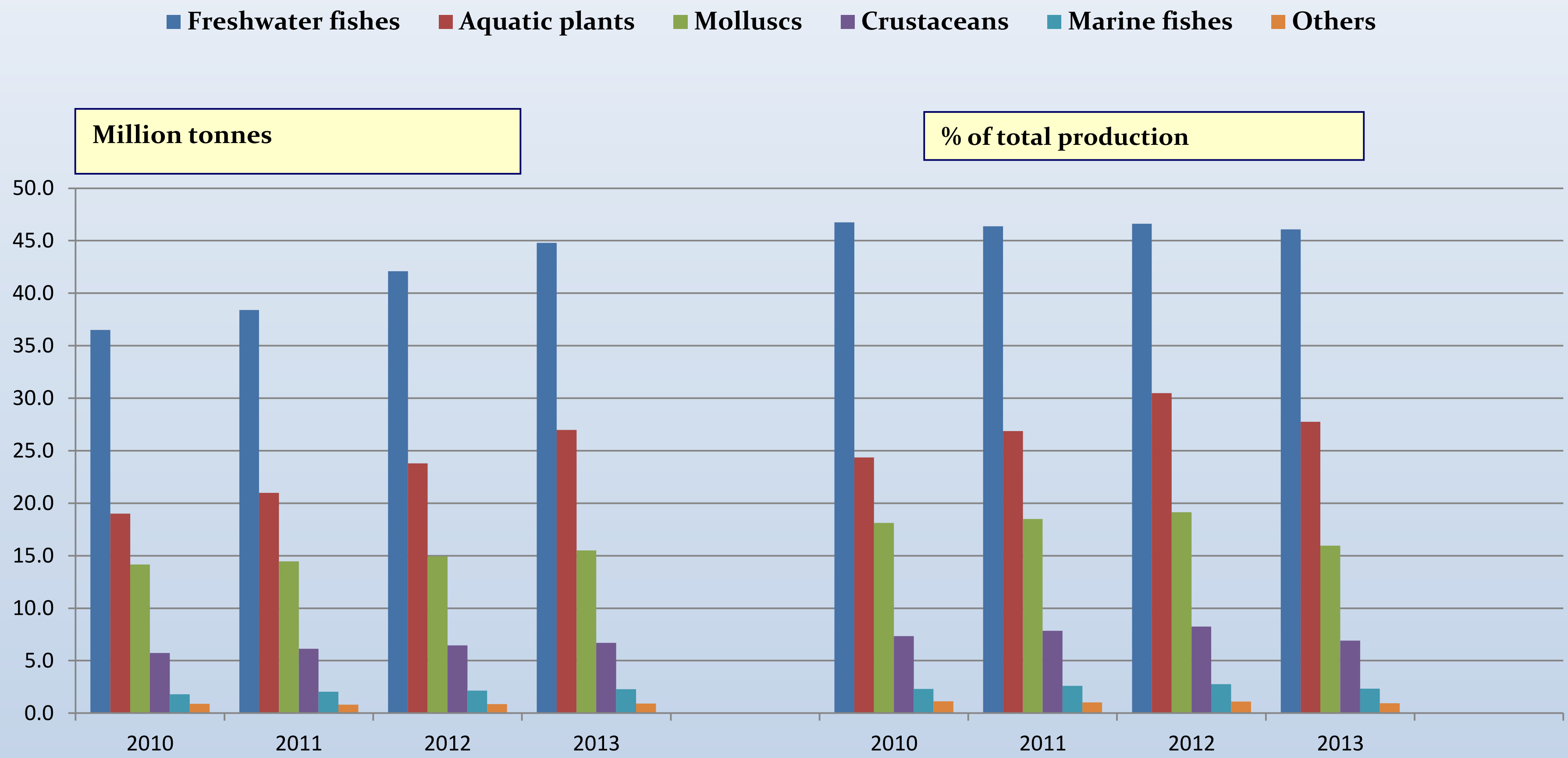
Total global aquaculture production in 2013 – 97.2 million tonnes
over 200 species or species/species-groups of aquatic animals and plants

Aquatic plants	27.0 mt
Crustaceans	6.7 mt
Freshwater fish	44.8 mt
Marine fishes	2.3 mt
Mollusks	15.5 mt
Others	0.97 mt



Total fish & crustaceans in 2013: 53.8 million tonnes

Global output of aquaculture in volume and in percentage during 2010 and 2013 by species group



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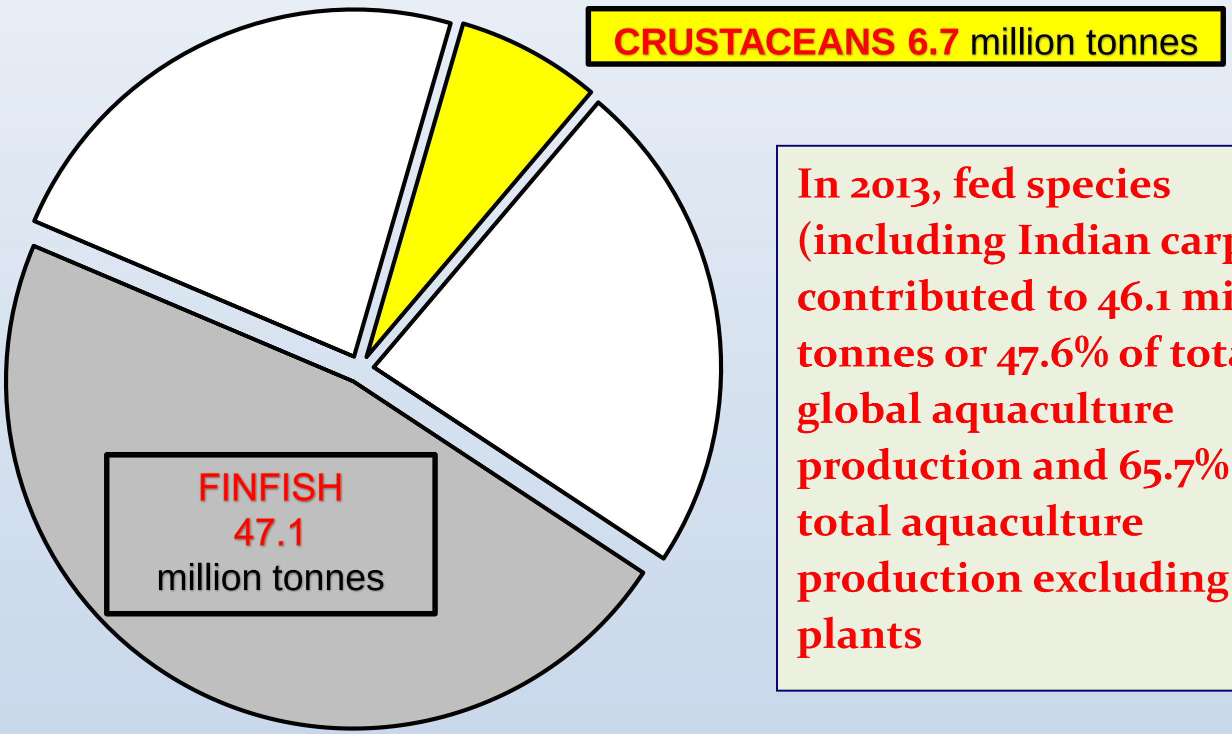
Fed aquaculture species production – 2013 (commercial feeds, farm-made feeds, fresh feeds)

In 2013, non-fed species (silver and bighead) production 7.7 million tonnes



In 2013, fed species (including Indian carps) contributed to 46.1 million tonnes or 47.6% of total global aquaculture production and 65.7% of total aquaculture production excluding plants

In 2013, total fish & crustaceans 53.8 million tonnes

Fed species: 46.1 million tonnes or 47.6% of total global aquaculture production in 2013

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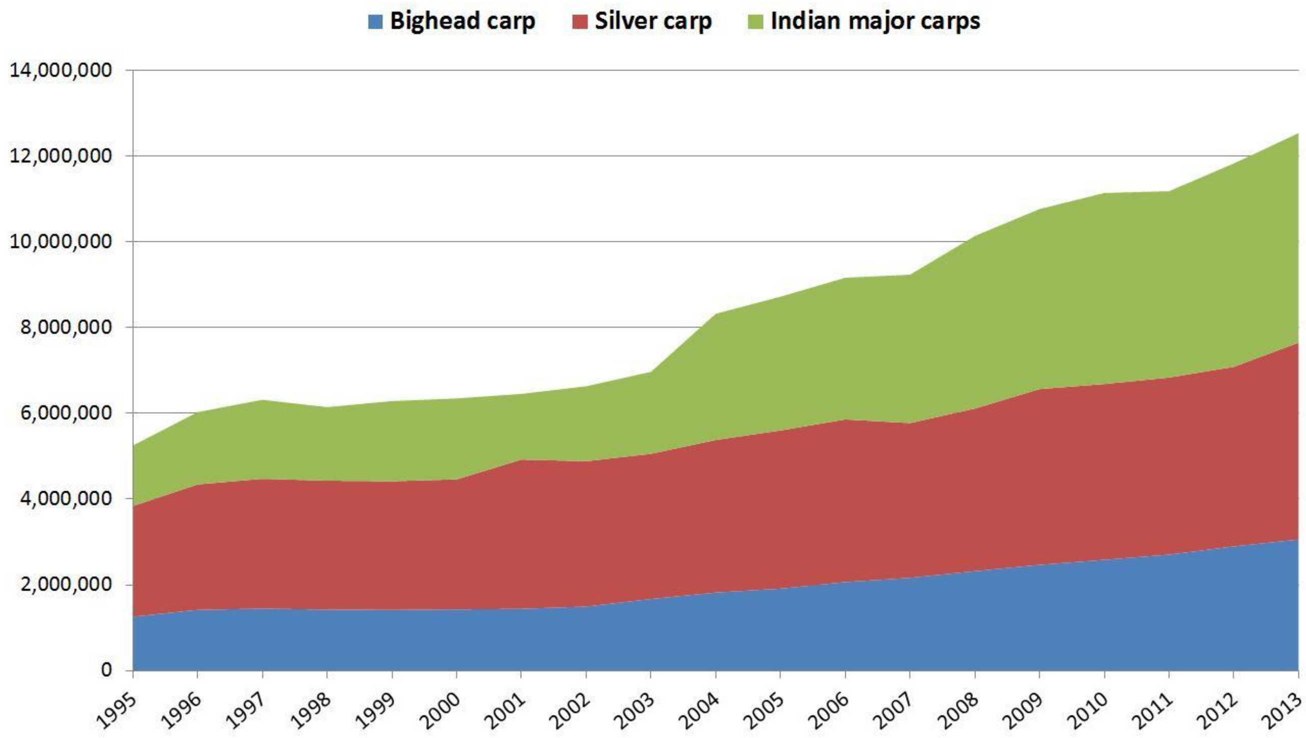
Global aquafeed production

- Total industrial compound aquafeed production has increased from 7.6 million tonnes in 1995 to 34.3 million tonnes (almost 4.5-fold) in 2010, 42.6 million tonnes (4.6 fold) in 2013 with 343% and 426% increase since 1995. These usage are only for fed species excluding Indian major carps.
- Industrial aquafeed production growing at an average rate of 10.1% per year.

Contribution of silver carp, grass carp and Indian major carps to global aquaculture production

Chinese non-fed carp production average APR is 4.64% from 1995 to 2013

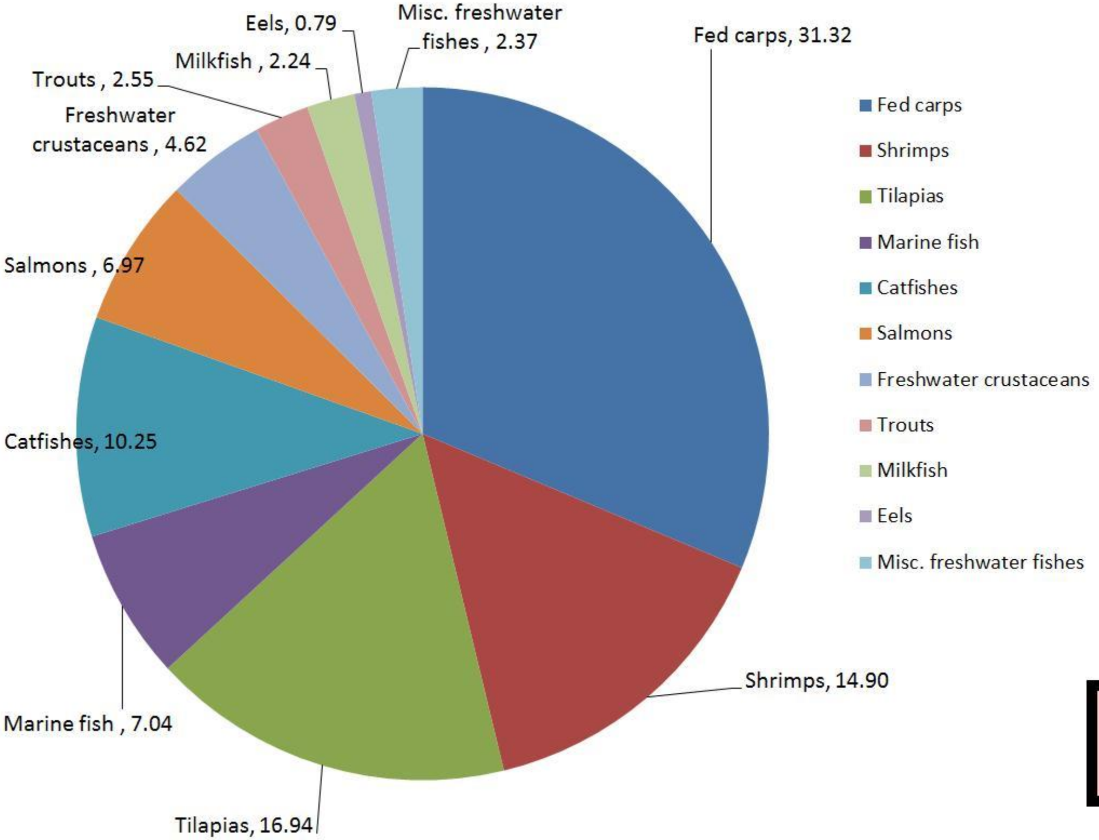
Indian major carp production average APR is 8.91% from 1995 to 2013



Chinese non-fed carp production increased from 3.84 MT in 1995 to 7.65 MT in 2013 while their contribution to global aquaculture decreased from 12.3% in 1995 to 7.87% in 2013

Production of Indian major carps increased from 1.41 MT in 1995 to 4.89 MT and maintained their contribution to global aquaculture between 4.5% in 1995 and 5.0% in 2013

Estimated global production of commercial aquaculture feeds by major species groups in 2013: 42.6 million tonnes (Mt)



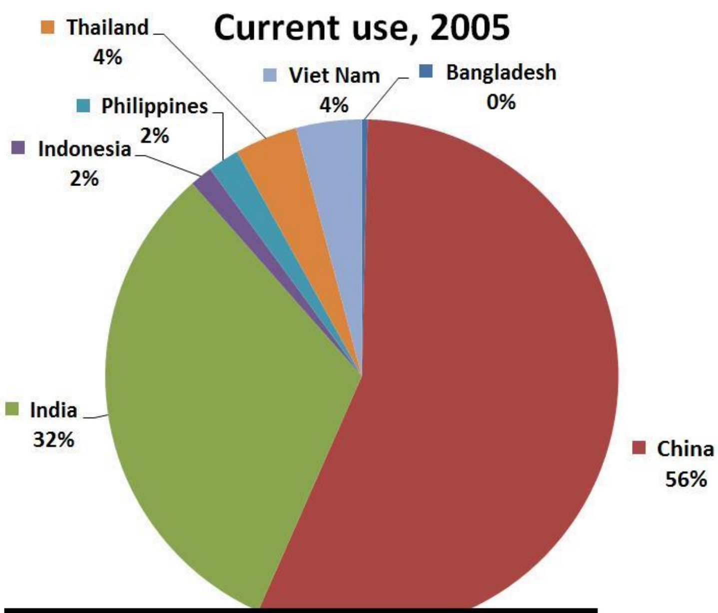
Fed carps	13.3 Mt
Shrimps	6.3 Mt
Tilapias	7.2 Mt
Catfishes	4.4 Mt
Marine fishes	3.0 Mt
Salmons	3.0 Mt
FW crustaceans	2.0 Mt
Trouts	1.1 Mt
Milkfishes	1.0 Mt
Misc FW fishes	1.0 Mt
Eels	0.3 Mt
TOTAL	42.3 Mt

Global aquafeed in 2013 is 42.6 million tonnes

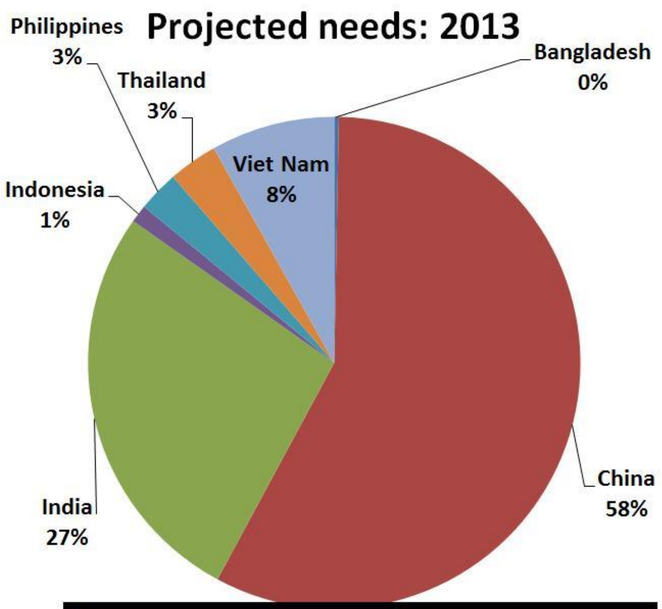
Global farm-made aquafeed = 18.7-30.7 mt, 2006

Current and projected use (mt) of single ingredient and farm-made feeds in aquaculture in selected Asian countries

Feeds	Bangladesh	China	India	Indonesia	Philippines	Thailand	Viet Nam
2005	0.07	10.88	6.16	0.27	0.38	0.76	0.80
2013	0.09	17.69	8.27	0.36	0.83	0.99	2.50



Farm-made feed in 2005 = 19.3 mt



Farm-made feed in 2013 = 30.7 mt

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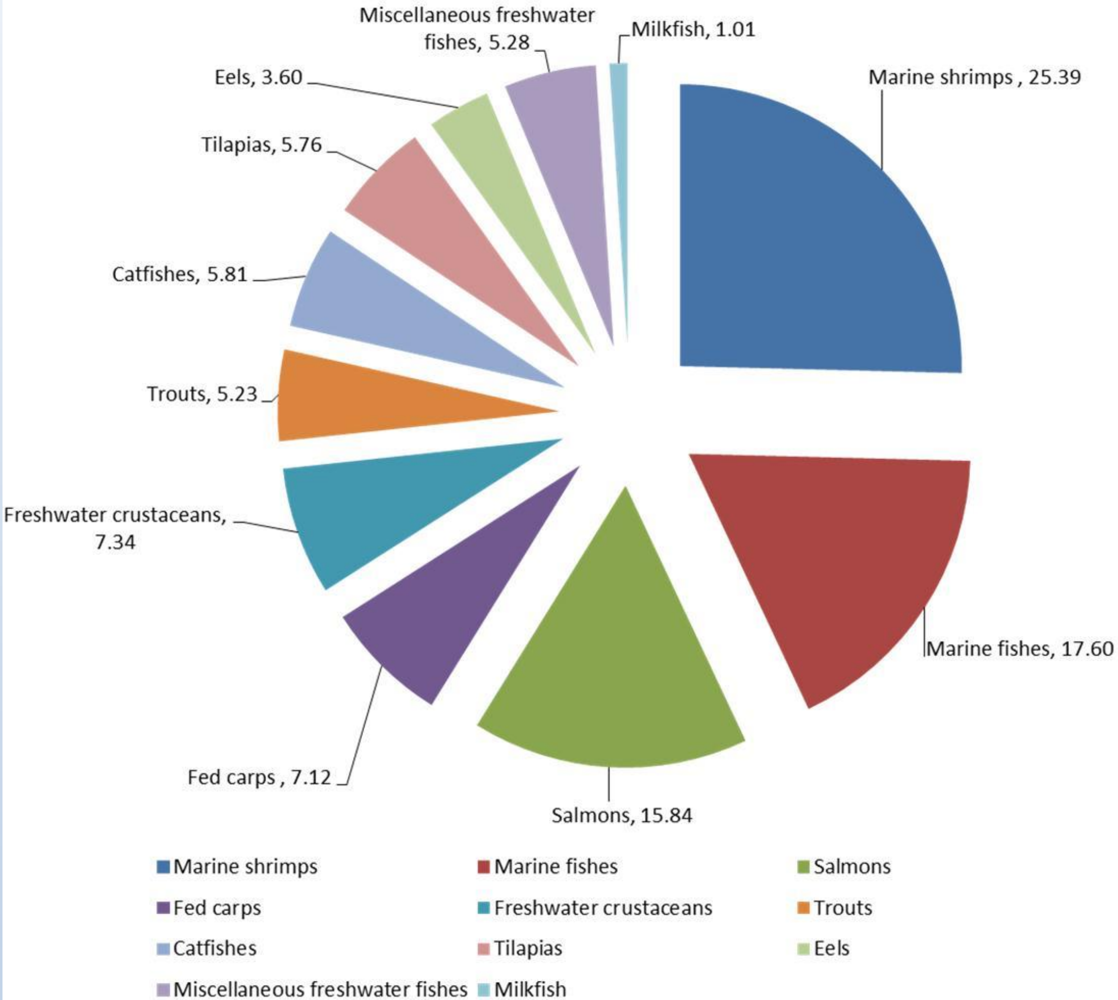
Global consumption of fishmeal (% of total usage in compound aquafeed) by major aquaculture species groups in 2013



Shrimps	952 Tt
Marine fishes	660 Tt
Salmons	594 Tt
Fed carps	267 Tt
FW crustaceans	275 Tt
Trouts	196 Tt
Catfishes	218 Tt
Tilapias	216Tt
Eels	135Tt
Misc FW fishes	202Tt
Milkfish	38 Tt
TOTAL	3.8 Mt

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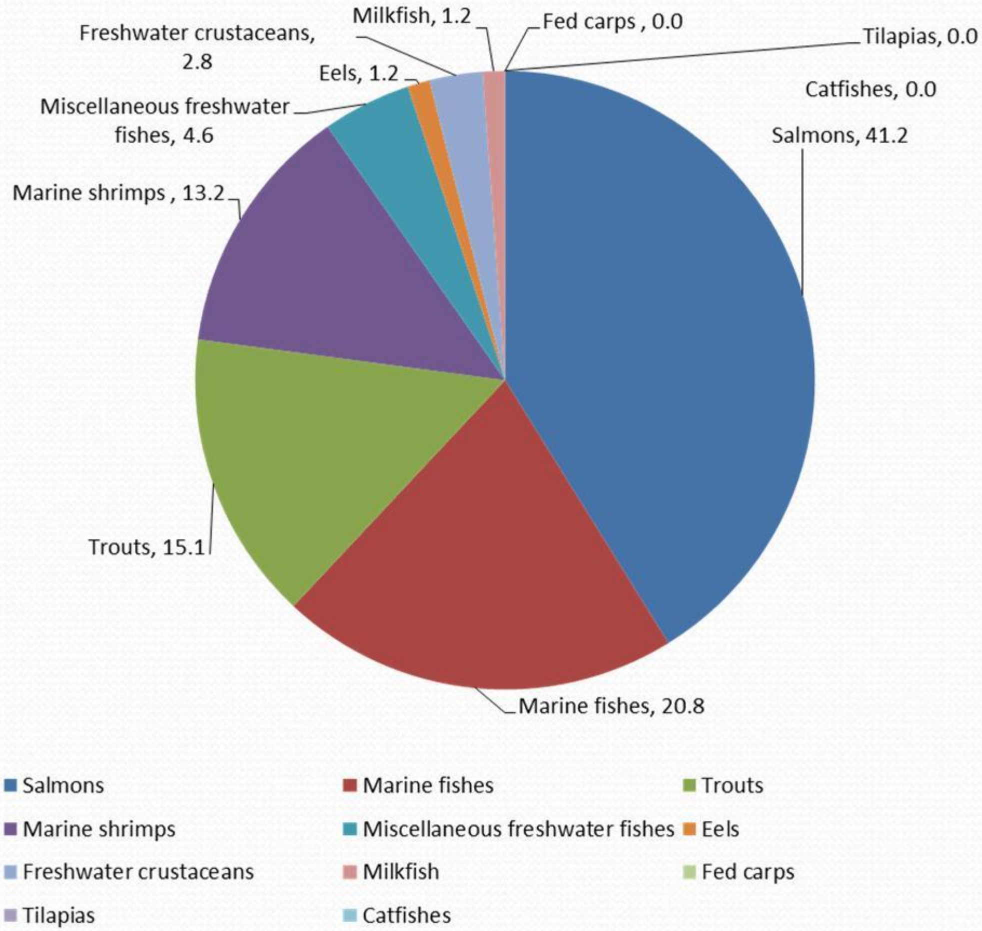
Global consumption of fish oil (% of total usage in compound aquafeed) by major aquaculture species groups in 2013



Salmons	356 Tt
Marine fishes	180 Tt
Trouts	131 Tt
Marine shrimps	114 Tt
Misc FW fishes	40 Tt
Eels	10 Tt
FW crustaceans	24 Tt
Milkfish	10 Tt
Fed carps	0 Tt
Tilapias	0 Tt
Catfishes	0 Tt
TOTAL	865 Tt

ESTIMATED USE OF FEEDS, FISHMEAL AND FISH OIL FOR THE PRODUCTION OF SALMONIDS IN 2010

	Production (thousand tonnes)	Feeds used (thousand tonnes)	Fishmeal used (thousand tonnes)	Fish oil used (thousand tonnes)
Salmons	1 603	2 084	500	271
Trouts	771	1 002	210	130
Total salmonids	2 374	3 086	710	401
Total all fed species	20 439	34 286	3 712	766
Salmonids, % of total	11.6	9.0	19.1	52.3

ESTIMATED USE OF FEEDS, FISHMEAL AND FISH OIL FOR THE PRODUCTION OF SALMONIDS IN 2013

	Production (thousand tonnes)	Feeds used (thousand tonnes)	Fishmeal used (thousand tonnes)	Fish oil used (thousand tonnes)
Salmons	2 283	2 968	594	356
Trouts	837	1088	196	131
Total salmonids	3 120	4 056	790	487
Total all fed species	26 061	42 594	3 754	865
Salmonids, % of total	11.97	9.53	21.0	56.3

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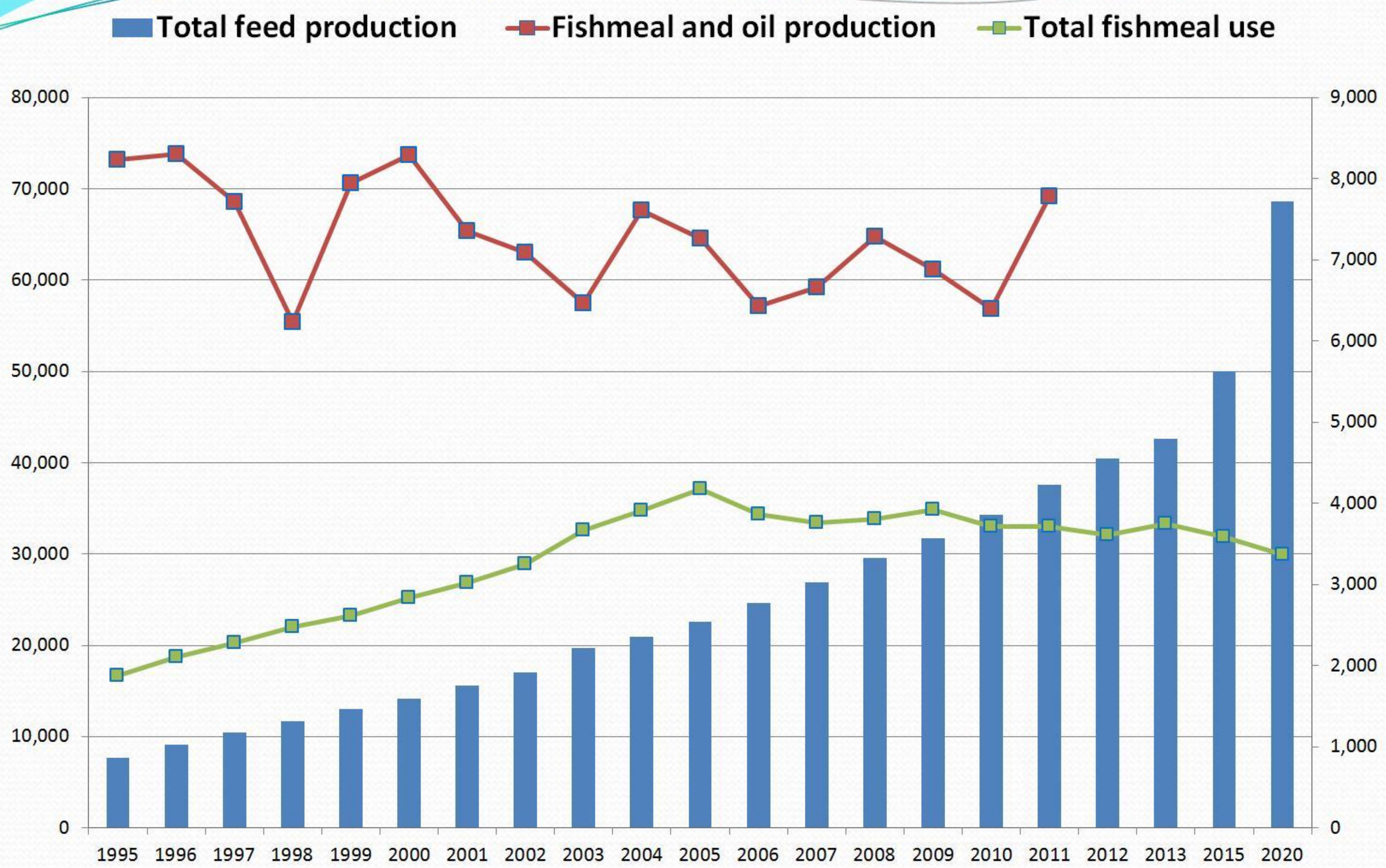
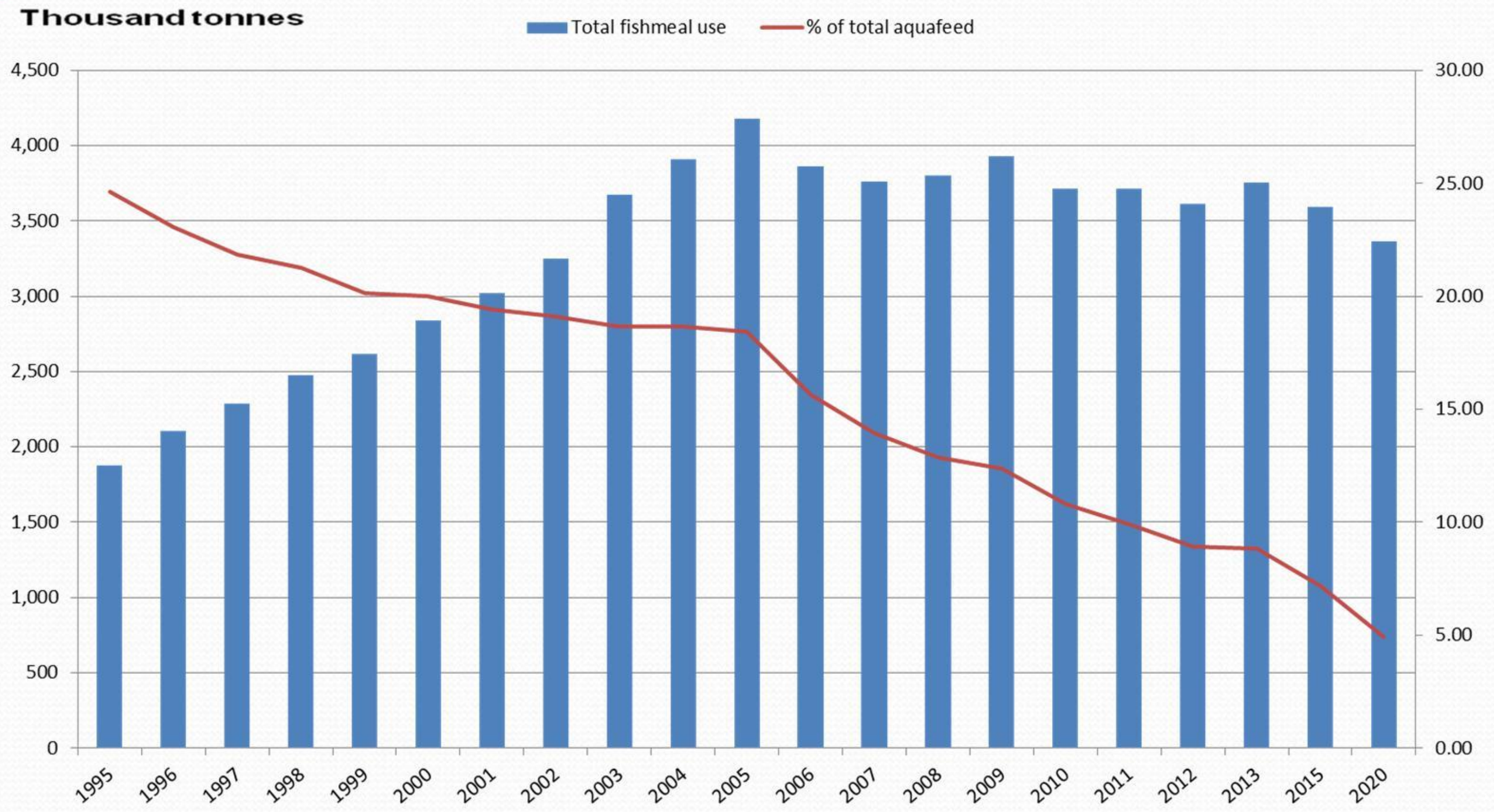
Actual fishmeal and use production and actual and predicted fishmeal use relative to the global production of compound aquafeed



Actual and predicted reduction of fishmeal use relative to the global production of compound aquafeed

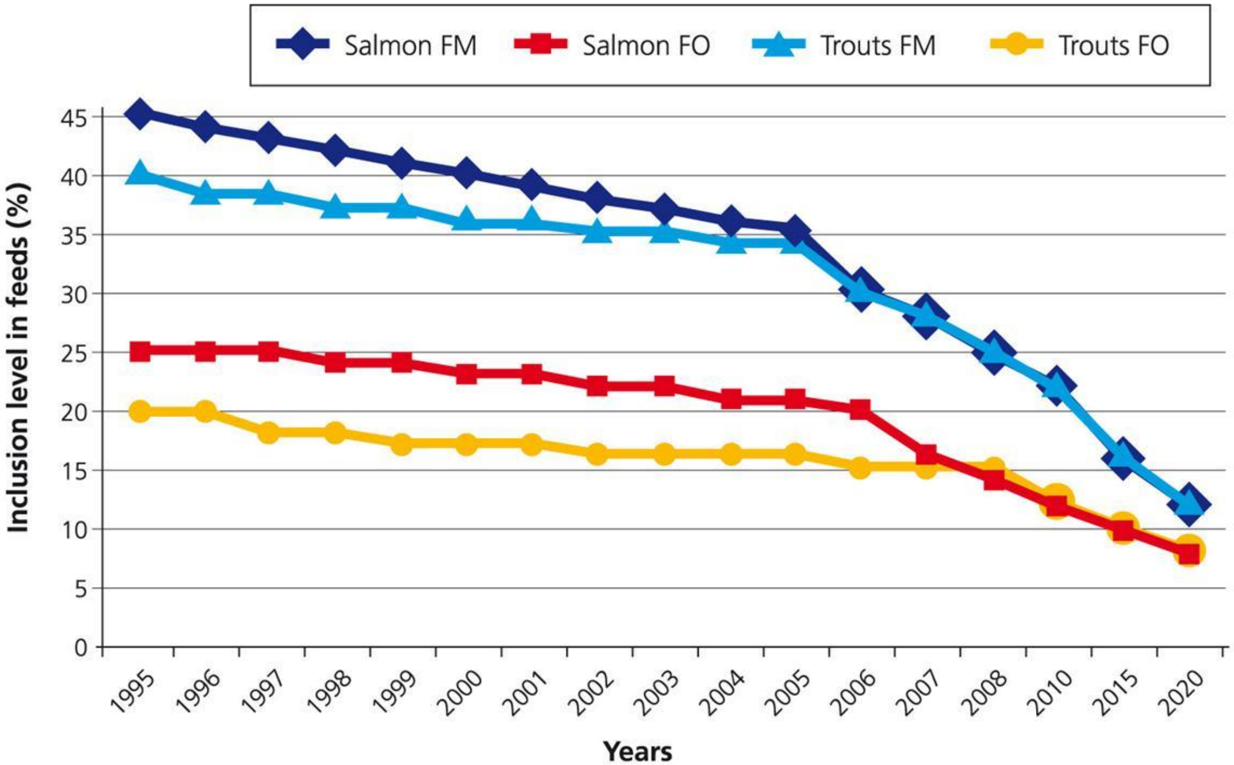


GLOBAL ACTUAL (1995-2008) AND PROJECTED (2008-2020) REDUCTION OF FISHMEAL INCLUSION IN COMPOUND AQUAFEED OF DIFFERENT FISH SPECIES/SPECIES GROUPS

Species/species group	Fishmeal inclusion (%) in compound aquafeed		
	1995	2008	2020
Fed carp	10	3	1
Tilapias	10	5	1
Catfishes	5	7	2
Milkfish	15	5	2
Miscellaneous freshwater fishes	55	30	8
Salmons	45	25	12
Trouts	40	25	12
Eels	65	48	30
Marine fishes	50	29	12
Marine shrimps	28	20	8
Freshwater crustaceans	25	18	8

CHANGES IN THE INCLUSION OF FISHMEAL (FM) AND FISH OIL (FO) IN THE FEEDS FOR SALMONIDS OVER RECENT DECADES AND PREDICTED FURTHER REDUCTIONS

Changes in the inclusion of fishmeal (FM) and fish oil (FO) in the feeds for salmonids over recent decades and predicted further reductions

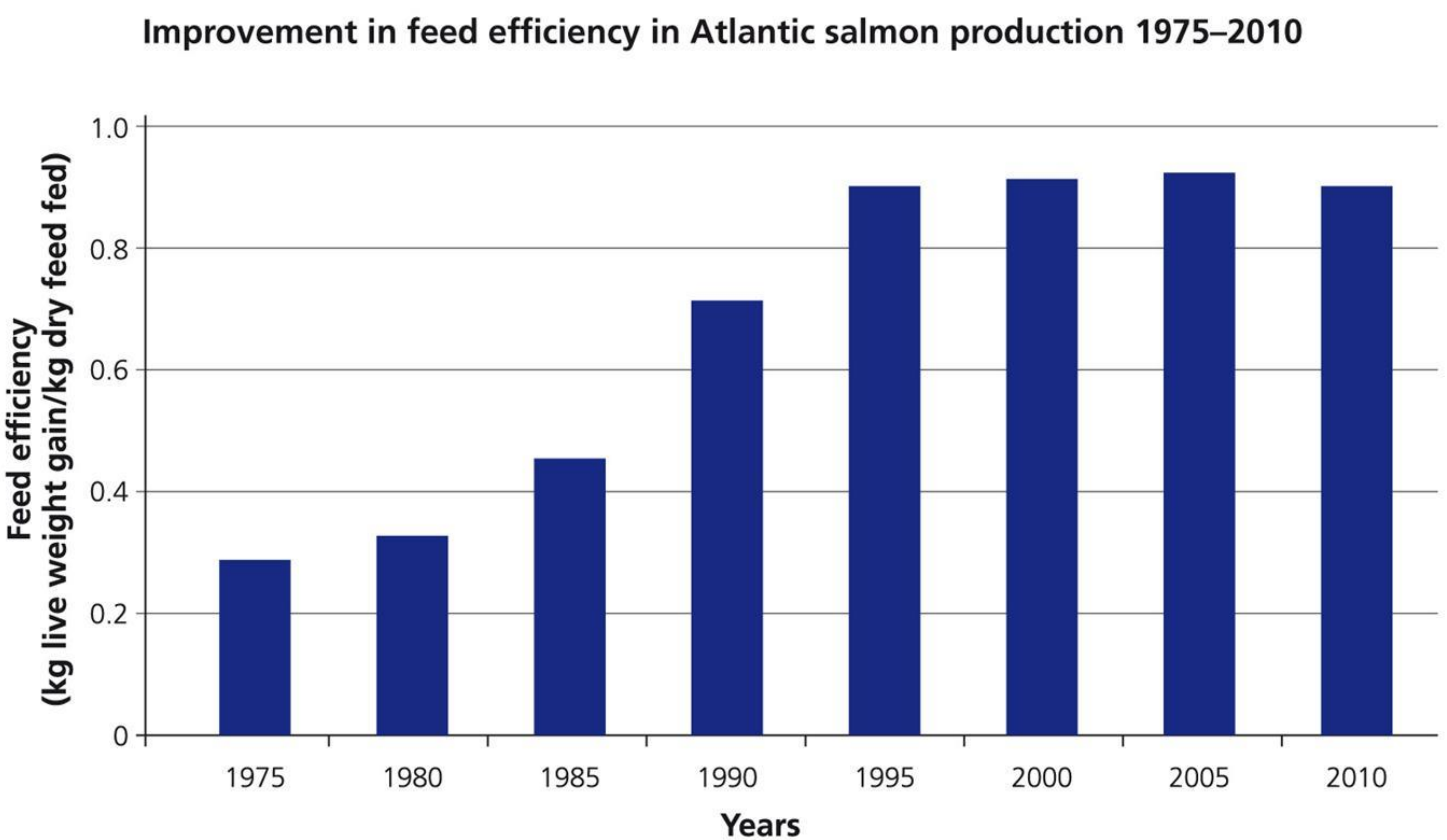


Source: Adapted from Tacon, Hasan and Metian (2011).

BETTER FEED MANAGEMENT TO LEAD REDUCTION OF FCR AND DECREASED FISHMEAL INCLUSION

- With increased feed efficiency and better feed management:
- it is projected that there will be reduction of feed conversion for many aquaculture species (e.g., fed carps, catfishes, tilapias, milkfish, eel, marine fishes, marine shrimps and freshwater crustaceans) dependent on industrially manufactured compound aquafeeds.
- The reported FCR of fed carps dependent upon industrial compound aquafeed is 1.8 in 2008 and it is expected to be reduced to 1.6 in 2020, for catfishes from 1.5 to 1.3 and milkfish from 2.0 to 1.6.
- If this materializes coupled with lower fishmeal inclusion in the diets for the above species/species groups, it can be calculated that there will be about 6 percent reduction in the volume of fishmeal use in spite of the projected 143 and 168 percent increase in the estimated total aquafeed and fed aquaculture production respectively.

IMPROVEMENT IN FEED EEFICIENCY IN ATLANTIC SALMON PRODUCTION 1975 - 2010



Source: Myrseth (2005) and unpublished data of S.J. Kaushik .

Feed ingredient (protein meal and oil) usage (% inclusion level) for major aquaculture species/species groups

Feed ingredients	Inclusion level (%) in compound aquafeed
Plant protein meal	
Soybean meal	3–60
Wheat gluten meal	2–13
Corn gluten meal	2–40
Rapeseed/canola meal	2–40
Cottonseed meal	1–25
Groundnut/peanut meal	≈30
Mustard oil cake	≈10
Lupin kernel meal	5–30
Sunflower seed meal	5–9
Canola protein concentrate	10–15
Faba bean meal	5–8
Field pea meal	3–10
Plant oil	
Rapeseed/canola oil	5–15
Soybean oil	1–10
Rapeseed/canola oil	5–15

Cost of feed as percentage of production cost for selected countries and pond-cultured species

Country	Species mix	Production system	Feed as % of production cost	Yield (tonnes/ha)
China	Tilapia	Ponds – tilapia main crop polyculture + commercial feeds	68 – 84	7 – 9
		Ponds – monoculture + commercial feed		8 – 12
Philippines	Tilapia	Ponds – monoculture + commercial feed	50 – 60	7 – 15
		Ponds – monoculture Farm-made +commercial feed		1 – 3
Viet Nam	Striped catfish	Monoculture + commercial feed	83	325
		Monoculture + farm-made feed	77	398
India	Indian major carps	Typical Indian major carps- mash	54	7
		Zero point culture – Indian major carps	48	5 – 6
		Zero point culture – Indian major carps-mash-pellet	49	?
		Zero point culture –Indian major carps-mash	41	?
Viet Nam	Whiteleg shrimp	Monoculture + commercial feed	66 – 69	9 – 15
Bangladesh	Giant river prawns	Extensive + snail meat	15	0.35
		Improved extensive + farm-made aquafeed	25	0.48
		Semi-intensive + commercial feed	33	0.72
India	Black tiger shrimp	Extensive + farm-made feed	52	0.38
		Modified extensive Commercial feed + farm-made feed	59	1.3
		Semi-intensive shrimp Commercial feed	62	2.8

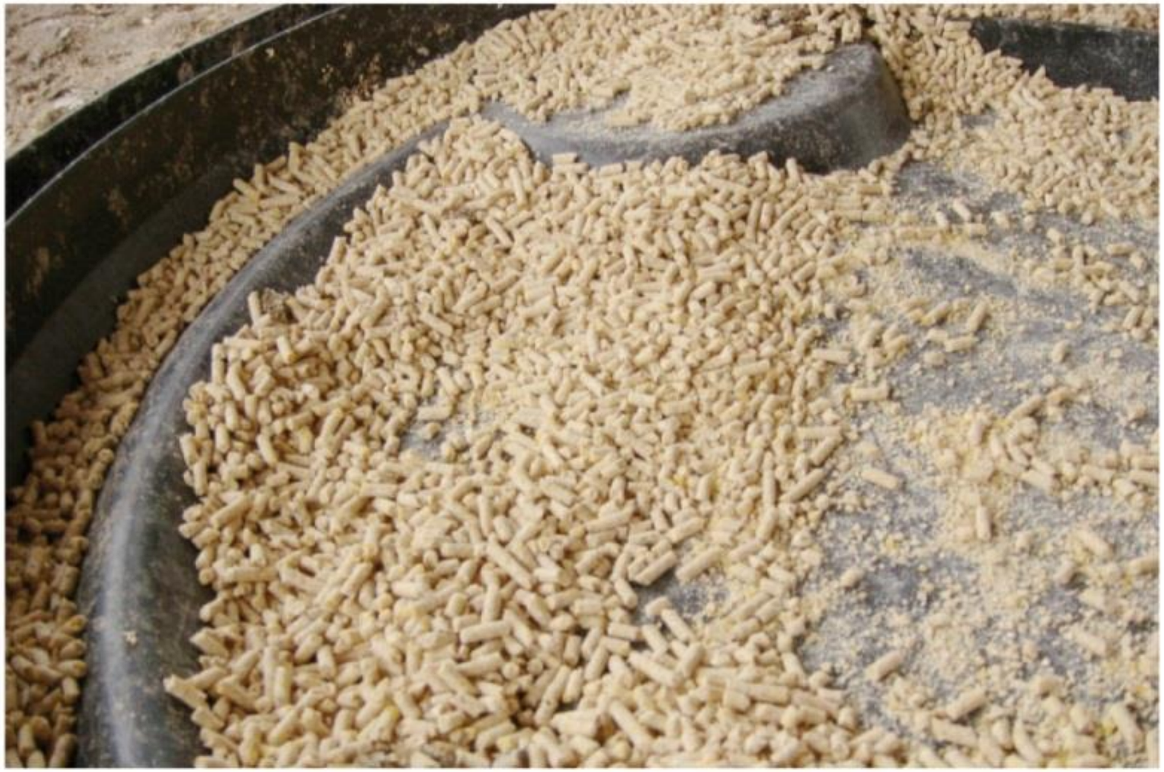
ECONOMIC FEED CONVERSION RATIOS (EFCRS) FOR FEED TYPES USED FOR FARMING FINFISH AND SHRIMP IN PONDS AND CAGES

Feed type	eFCR	Species	Rearing system	Country
Farm-made feed				
Mash	2.3:1 – 4.1:1	Major carps	Pond	India
Mash + pellet	1.9:1	Major carps	Pond	India
Moist pellets	2.9:1	Striped catfish	Pond	Viet Nam
Manufactured pellets				
Sinking pellets	1.5:1	Nile tilapia	Cage	Egypt
Sinking pellets	1.6:1 – 2.0:1	Nile tilapia	Pond	China
Sinking pellets	1.3:1 – 2.1:1	Major carps	Pond	Bangladesh
Extruded pellets	2.0:1	Nile tilapia	Pond	Ghana
Extruded pellets	1.6:1	Striped catfish	Pond	Viet Nam
Extruded pellets	1.5:1 - 1.7:1	Nile tilapia	Pond	Philippines
Extruded pellets	1.2:1 – 1.4:1	Nile tilapia	Cage	Ghana
Extruded pellets	1.0:1 – 1.2:1	Whiteleg shrimp	Pond	Viet Nam
Extruded feeds	1.2:1 – 1.5:1	Nile tilapia	Cage	China
Extruded feeds	1:1	Nile tilapia	Cage	Egypt

LOCALLY PELLETED FEED IN CHINA

[Note the high level of disintegrated pellets and dust]

Locally pelleted feed in China
[Note the high level of disintegrated pellets and dust]



Source: Liu *et al*. (2013).

Focus areas advocated for improving aquafeed performance and feed management and reducing feed costs

Diet performance	Feed management
• Promote nutritionally balanced feeds • Reduce fishmeal content • Increase digestibility • Choose appropriate pellet type	• Maintain appropriate timing of feeding • Alternate higher and lower protein diets • Use mixed feeding schedules • Delay onset of external feeding • Optimise feed administration

Global Aquafeed Production

- An additional 27 million tonnes of aquatic food will be required by 2030 considering the projected population growth and to maintain the per caput consumption.
- Availability of feed will be one of the most important inputs if aquaculture has to maintain its sustained growth to meet its challenge of increased production.
- Aquafeed production is expected to continue growing at a similar rate to 50.0 million tonnes by 2015 and 68.6 million tonnes by 2020.
- If this growth is to be sustained then feed ingredient and feed input supply must grow at a similar rate.

CONCLUSION

- Apart from ensuring the sustained availability of feed ingredients (including fishmeal and fish oil) to meet the growing demand of aquaculture, the other important areas that need to be looked into are:
  - ensuring national quality standards for feed raw materials, feed additives and feeds,
  - improving on-farm feeding and feed management practices and transfer of associated technology at farmers' level,
  - feed formulation and production (e.g., farm-made feed, semi-commercial feed) at local level, and
  - improving the capacity, production technology and associated support services of small-scale feed manufacturers.

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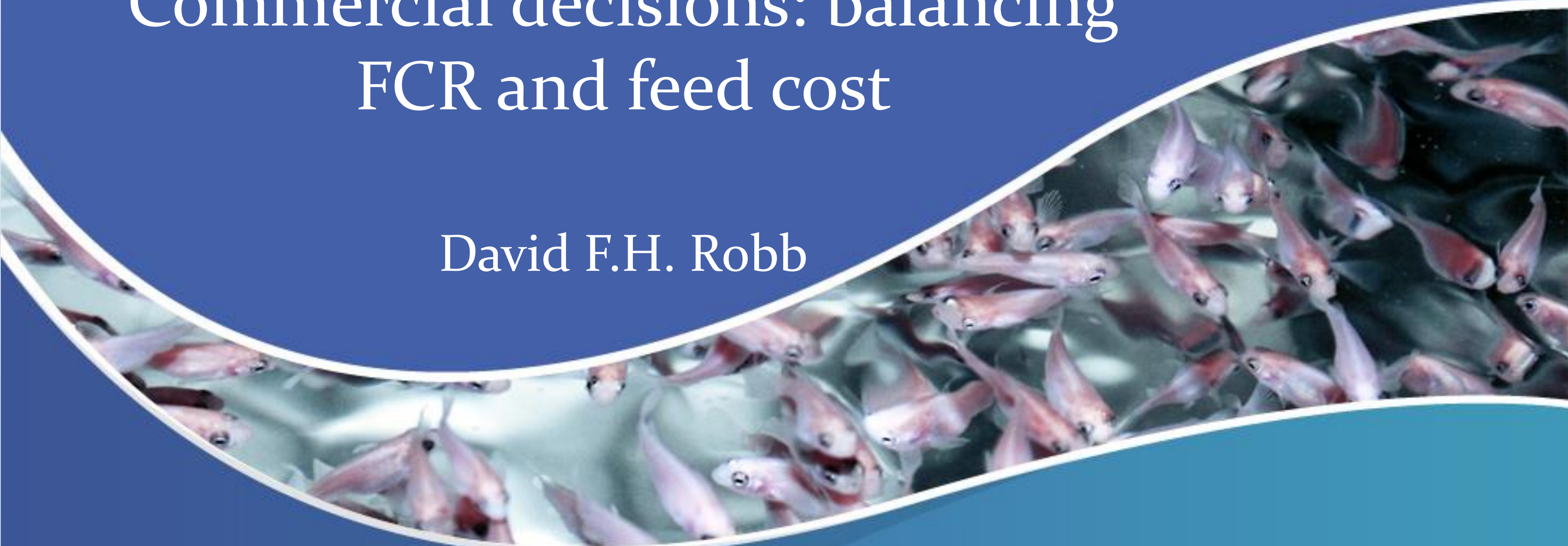
Commercial decisions: balancing FCR and feed cost

David F.H. Robb



Summary

- Feed cost is a major factor in aquaculture
- Combination of:
  - Feed price
  - How well it converts to market size fish (eFCR)?
- Increasing absolute efficacy (bFCR) of the feed costs money
  - More digestible nutrients available
- Many other risk factors affecting practical efficacy
  - For example mortalities
- Farmers assess the other risks of increasing eFCR
- Often buy the cheaper feed with a higher bFCR

Cost drivers in aquaculture

- Costs of aquaculture vary greatly
  - Species requirements
  - Intensive vs extensive
- In more detail:
  - Infrastructure investment
  - Fish costs (purchase of fingerling)
  - Labour cost
  - Health (cost of treatments and mortalities)
  - Feed

Feed costs

- Feed costs range from 45% to 80% of cost of production
  - Salmon feed cost is relatively low compared to total, as other costs are quite high
  - Striped catfish feed is relatively high compared to total, as such little investment in the farms is carried out

- However, the price of salmon feed is three to four times that of striped catfish feed

Feed costs

- Feed costs to farmers are a multiple of:
  - Feed price
  - Economic FCR

- Economic FCR = $\frac{Total\ Weight\ of\ Feed\ Fed}{(Final\ Biomass\ -Initial\ Biomass)}$

- Economic FCR is an important measure
- It is the sum of impacts from:
  - Biomass growth
  - Mortalities
  - Poor husbandry
    - Feed management
    - Water quality management

Drivers of eFCR

- Feed quality: digestibility and nutritional balance
  - Biological FCR
- Feed management
  - How to feed and how much to feed?
- Water quality
  - Oxygen is required for good digestion
  - Other issues will impact fish health
- Fish health
  - How well can the fish actually digest the feed and grow?
- Mortalities
  - How much feed was used to grow fish that died before harvest?
  - Mortality of small fish costs less than of large fish

Nutritional balance

- Fish require certain nutrients for healthy growth
  - Excess of a nutrient will cause:
    - Waste
  - Deficiency of a nutrient will cause:
    - Need to eat more to obtain that nutrient
      - Waste other nutrients
    - Slower growth
    - Possible nutritional deficiency disease
- Feed formulators should balance the content of the feed with the known nutrient requirements of the fish

Nutritional balance

- The major nutrients groups are:
  - Protein
    - Focus on amino acids (especially essential ones)
  - Lipid
    - Focus on fatty acids
  - Carbohydrates
    - Especially starch
  - Vitamins and minerals

Nutritional balance

- Primary considerations are:
  - Total protein available for growth
  - Protein to energy ratio
    - Energy comes from protein, lipid and carbohydrate
- These determine potential growth rate for given conditions
- Within the protein, the focus is on supplying essential amino acids in the ratio required
  - Non-essential amino acids are not normally limiting
- Normally use lipid and carbohydrate for energy
  - Spares protein (expensive)
  - Use of carbohydrate depends on species

Feed digestibility

- Although nutrients may be in the feed, it is important that they are absorbed by the fish and are available for growth
- Different protein sources have different digestibilities
  - Crude protein *per se* is not a good indicator
  - Protein content and protein digestibility are expensive

Raw material	Crude protein (%)	Digestible protein (%)	Digestibility (%)
Fishmeal (Peru)	65	64	98
Blood meal (batch dried)	77	57	75
Blood meal (spray dried)	81	65	80
Soybean meal	42	37	88
Wheat bran	11	5	44
Rice bran	8	3	38

Source: NACA feed calculator and personal database

Drivers of feed price

- Capital cost: equipment (fixed/tonne)
- Energy (fixed/tonne)
- Labour (fixed/tonne)
- Raw materials: feed ingredients (variable/tonne)
- Profit margin added
  - 4-8% EBIT is expected range
  - Profits not large, but stable
- Have to price the feed to be attractive to farmers
  - They have to be profitable too

Drivers of feed price

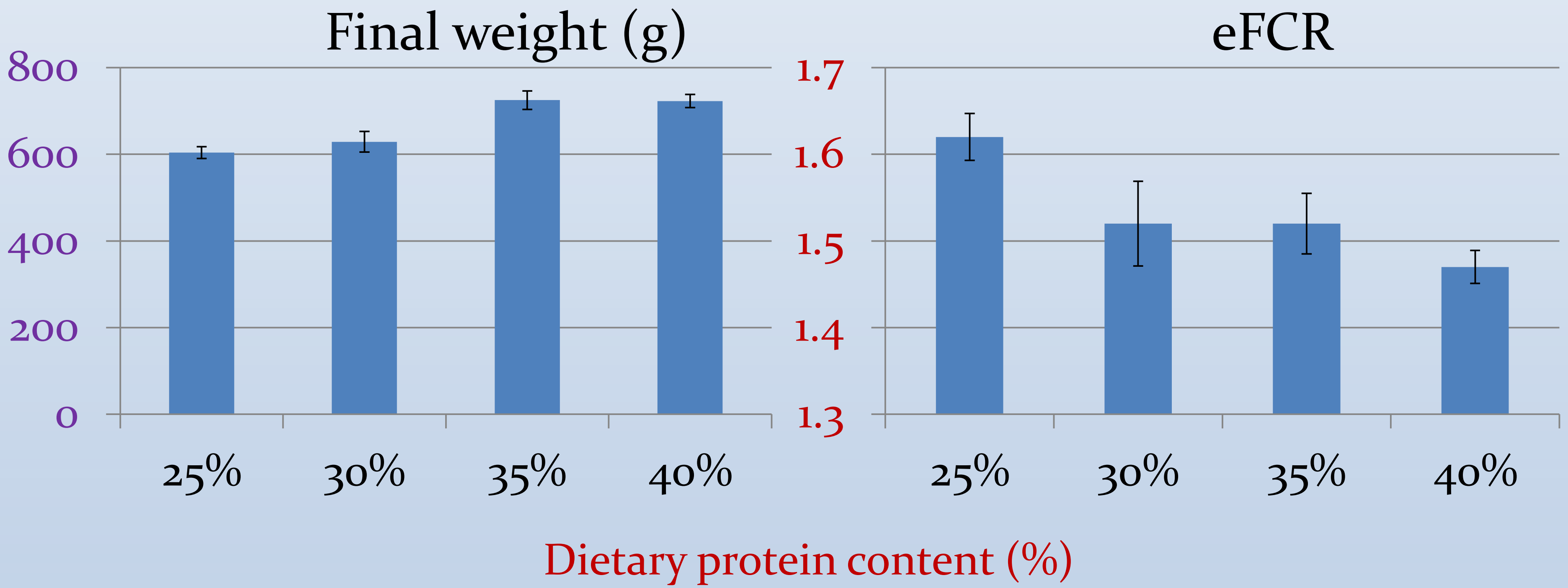
- Raw materials are the major cost of production of feed
- Prices are driven by:
  - Protein content of proteinaceous materials
  - Global market
  - Local availability
- In general:
  - Vitamins, minerals and additives have the highest cost/tonne
    - Used in very small doses
  - Fishmeal, fish oil and high protein ingredients are next most expensive
  - Carbohydrate providers (e.g. cassava) are generally cheaper
  - Low quality protein materials are the cheapest

Feed quality

- The quality of the feed is set by:
  - Nutritional balance
  - Digestibility
- Feed price is determined by the desired quality and the raw material cost
  - Formulators use least cost formulation to achieve a given nutritional goal from raw materials available
- Achieving greater nutritional balance and digestibility will cost more
- But it will also reduce the biological FCR
  - The best potential FCR for a fish eating this feed
- Generally, feed producers will offer what the farmers will pay for

Example of FCR and feed cost

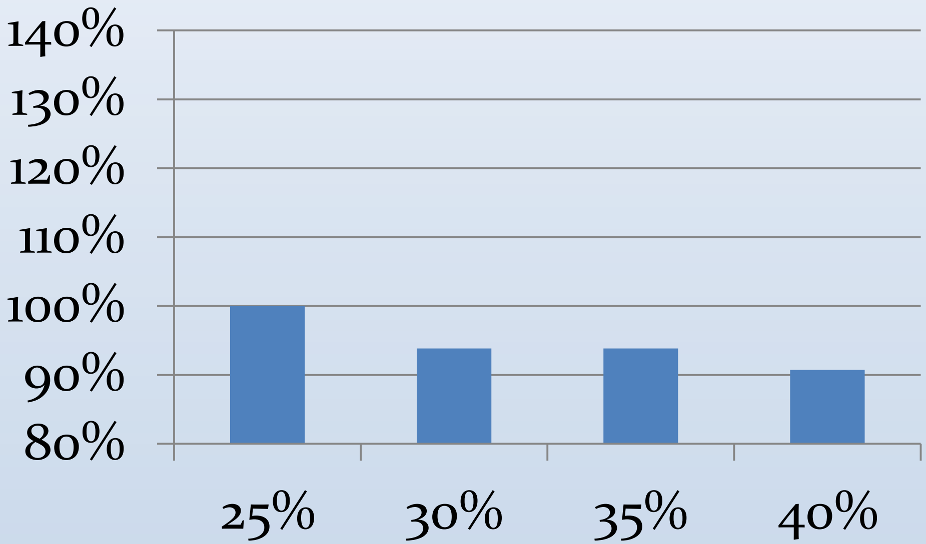
- Striped catfish typically receive a diet of 25 to 28% protein
- Is this optimal?
- Trial from 12 g to harvest



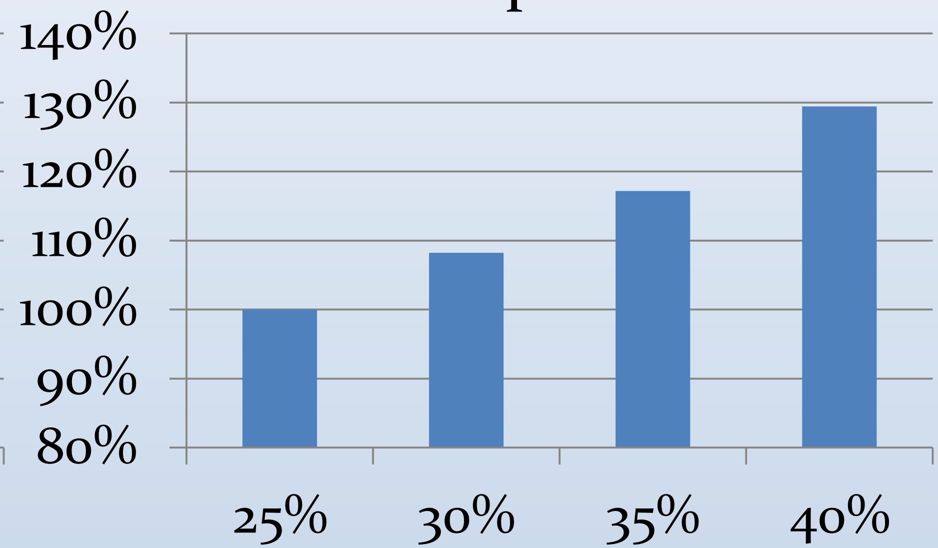
Example of FCR and feed price

- Look at costs and benefits:

FCR ratio



Feed price ratio



Dietary protein content (%)

- Over focus on FCR has a high cost

On-farm drivers of FCR

- Biological FCR of feed is determined by feed quality
- Feed management
- Water quality
- Fish health
- Mortalities

Feed management

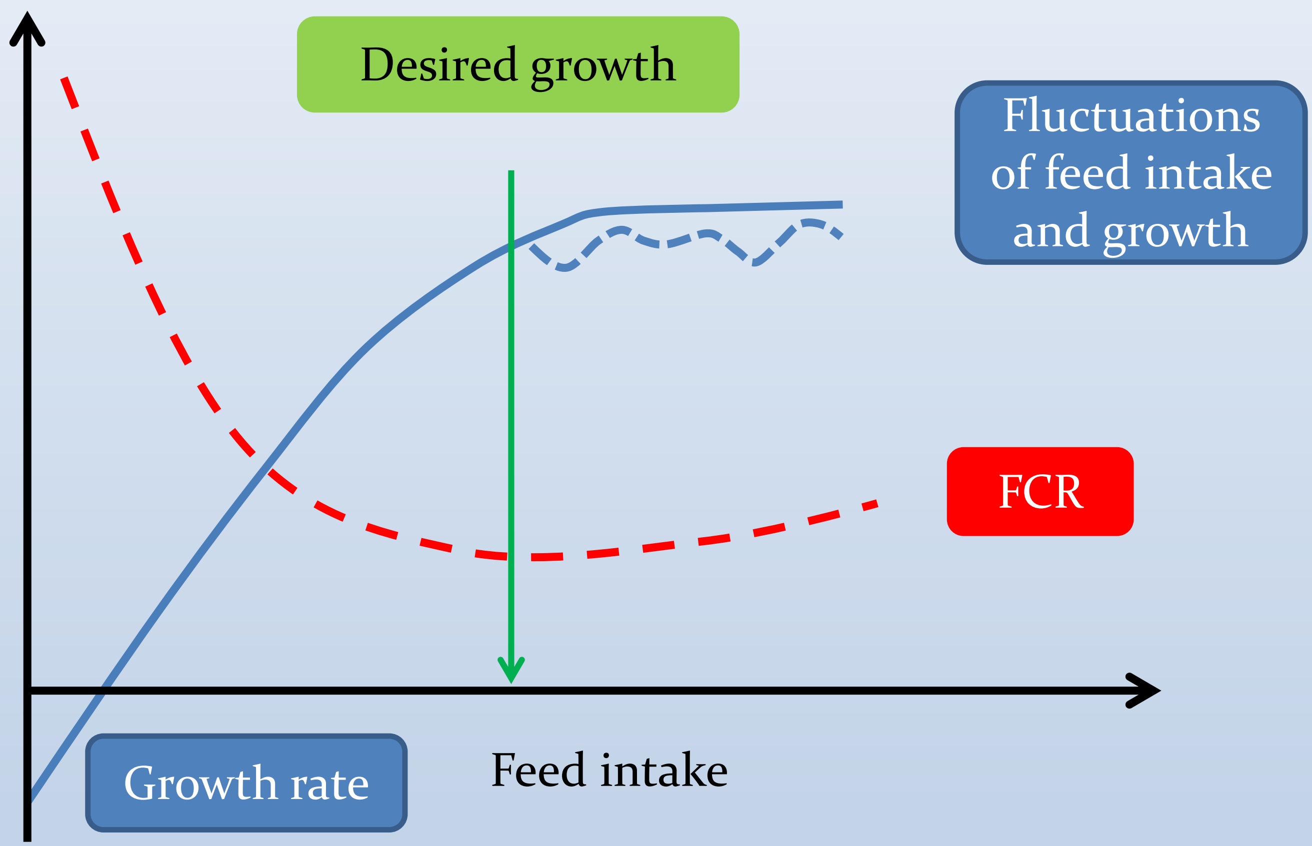
- Farmed fish eat for:
  - maintenance
  - growth
- Minimum amount of feed required will provide maintenance
  - There will be no growth, but fish should remain healthy
- Below this level, fish will loose weight and have health risks
- Above this, fish should grow
- There will also be a maximum growth rate
- Above this, feed is purely wasted

Feed management

- At low feeding rates:
  - Most feed is used for maintenance
  - Growth is low
  - FCR will be very high
- At optimal feeding rates:
  - A portion of feed is used for maintenance
  - Growth is good and healthy
  - FCR will be at its lowest
- At high feeding rates:
  - Maintenance is covered
  - Growth is at maximum
  - Extra feed is wasted
  - FCR rises above optimal

How much to feed?

- Feeding attempts to achieve the most efficient growth rate for a set of conditions



How to feed?

- Knowing the biomass, we can calculate how much feed is required to get optimal growth and FCR
- Challenge is to:
  - Get enough feed into the unit
  - Allow all fish to eat equally
- Farmer must calculate how much to feed
- Commonly break feeding up into meals
  - Allows fish to digest feed slowly
  - All feed should be consumed at each meal
  - But costs more for labour/less time for other jobs

Feed management

- It is very typical to under feed, compared to optimal
  - Biomass not known
  - Too few meals per day – direct cost
  - Fear of wasting feed – direct cost

- Outcome is to increase FCR above potential (bFCR of the feed)
  - Direct cost
  - Slower growth – potential cost
  - Risk of reduced health – potential cost

Water quality

- Water quality impacts fish growth and FCR:
  - Less oxygen reduces feed digestion
  - Poor water quality impacts overall fish health
- Pond farms are particularly at risk of water quality fluctuations
  - Generally costs money to change water
  - Operate at lower than optimal water qualities
- Water quality is at risk from high FCR:
  - More faeces and waste feed = worse water quality
  - Situation gets worse

Fish health and mortalities

- Reduced fish health increases FCR
  - Fish uses more feed for maintenance – bFCR ↑
  - Appetite reduces – eFCR ↑
  - Some treatments require stop feeding – eFCR ↑
  - Other treatments, such as anti-biotics, reduce appetite and growth – eFCR ↑

- Mortalities during production directly impact eFCR
  - Feed was used to grow these fish
  - No sales revenue will come from the mortalities
  - eFCR ↑

Fish health and mortalities

- Fish inputs
  - Quality of fish arriving at farm is important
  - Farmers often buy cheap inputs – cheap for a reason!
  - Sick/stressed fish will always have a bad start – eFCR ↑
- Diseases and parasites
  - Often predictable in annual timing
  - Magnitude of impact varies
  - Treatments not always available/used correctly/ effective
  - Can impact small or large fish
  - Longer the fish are in the water, the greater the risk

Fish health and mortalities

- Poor health and mortalities are (relatively) unpredictable
- Farmers assume risks for these events
- Excellent production should have 1-5% mortalities (salmon)
- Striped catfish normally shows about 20% mortalities
- However, heavy mortalities can lead to 70% mortalities or even complete wipe-out of farms

Commercial decisions by farmers

- Farmers know the cost of feed/tonne
- They have a guide on the bFCR achievable
  - Absolute protein content of feed
  - Protein/energy ratio in feed
  - Feed digestibility and other quality parameters
- But many uncertainties regarding eFCR
  - Feed management
  - Water quality fluctuations
  - Fish health
  - Mortalities

Commercial decisions

- Generally, farmers focus on buying feed which will grow the fish quickly
  - Faster growth means less exposure to disease risks
  - More fish likely to survive to harvest

- Focus on price is a major factor
  - If growth is assured, other prices must be minimised

Commercial decisions

- Reducing FCR has an impact on feed price for a given growth
  - Raw materials are normally more expensive
- Farmers need to be certain that there will be a reduction in eFCR to cover the extra feed price

- Too many uncertainties:
  - Water quality fluctuations
  - Reduced health
  - Mortalities
  - Market price

Conclusions

- If there are two feeds on the market, A and B:
  - Growth rate is the same
  - FCR: A < B
  - Price: A > B

- In very many occasions, farmers will buy the cheaper feed
- Too many uncertainties in the farming process

- Farmers need help to control these

Thank You

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Historical overview of FCR for farmed striped catfish (*Pangasianodon hypophthalmus*) in Viet Nam: a case study

Liberia, Costa Rica, 9– 11 November 2015

Nhu Van Can
Department of Agriculture and Rural Development
Dong Thap Province, Viet Nam

Content

1. Introduction
2. The history & present status of pangasius farming in Viet Nam
3. The historical overview of aquafeed for Pangasius
   – Aquafeed & production systems
   – Present pangasius feed value chain analysis
4. Present on-farm feeding and feed management practices
5. Major issues and recommendations for improvement of feed efficiency

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Introduction: aquaculture in Viet Nam

Total fishery production 2014: 6.3 million tonnes

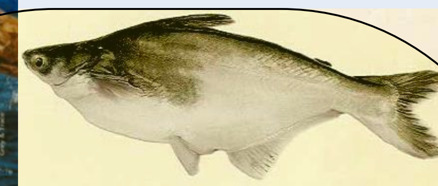
Aquaculture production: *3.62 million tonnes (57.5%)*

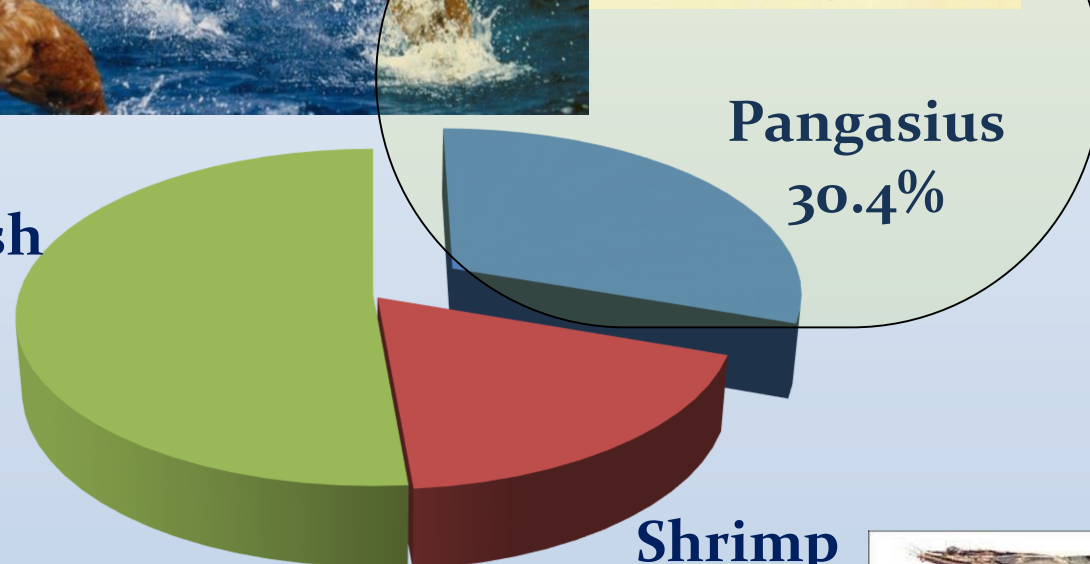
-Total value: 188,084 billion VND

Area: 39,734 km²

Aquaculture production: 69%

Introduction: key aquaculture species





Source: D-Fish statistics (2014)

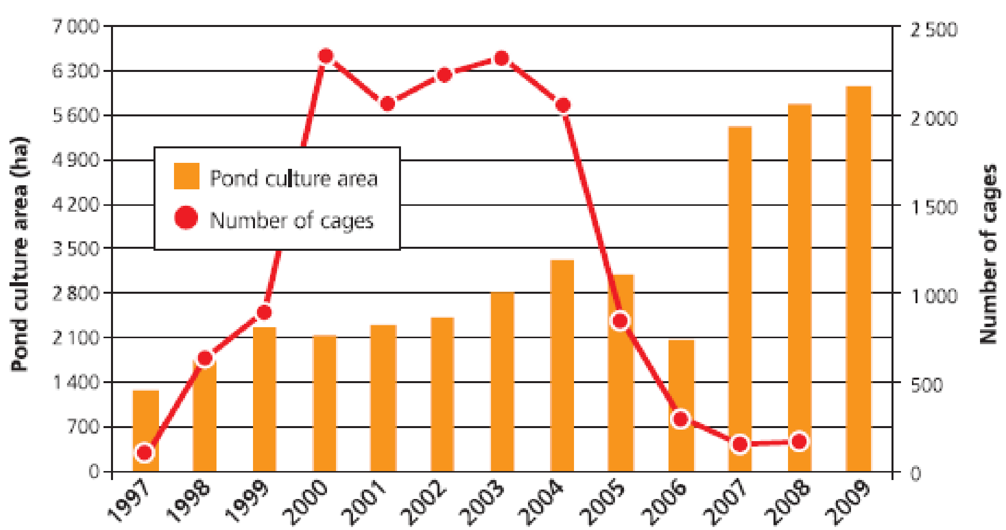
History of pangasius farming

	Period	Culture method	Feed	Seed
1	1940-1950	Small ponds (An Giang, Dong Thap)	Natural feed	Wild caught
2	1981-1982	Intensive production in small ponds	Natural and moist farm-made feed	Wild caught
3	1996-1999	Intensive production in ponds and cages	Moist farm-made feed	Wild caught + artificially bred
4	2001 -2004	Expand production in ponds and cages.	Moist farm-made & dried pellets	Artificially bred
5	2005 - present	Change from cages and net pen to super intensive production in ponds	Dried floating pellets	Artificially bred

Source: S. S. De Silva and N. T. Phuong (2011)

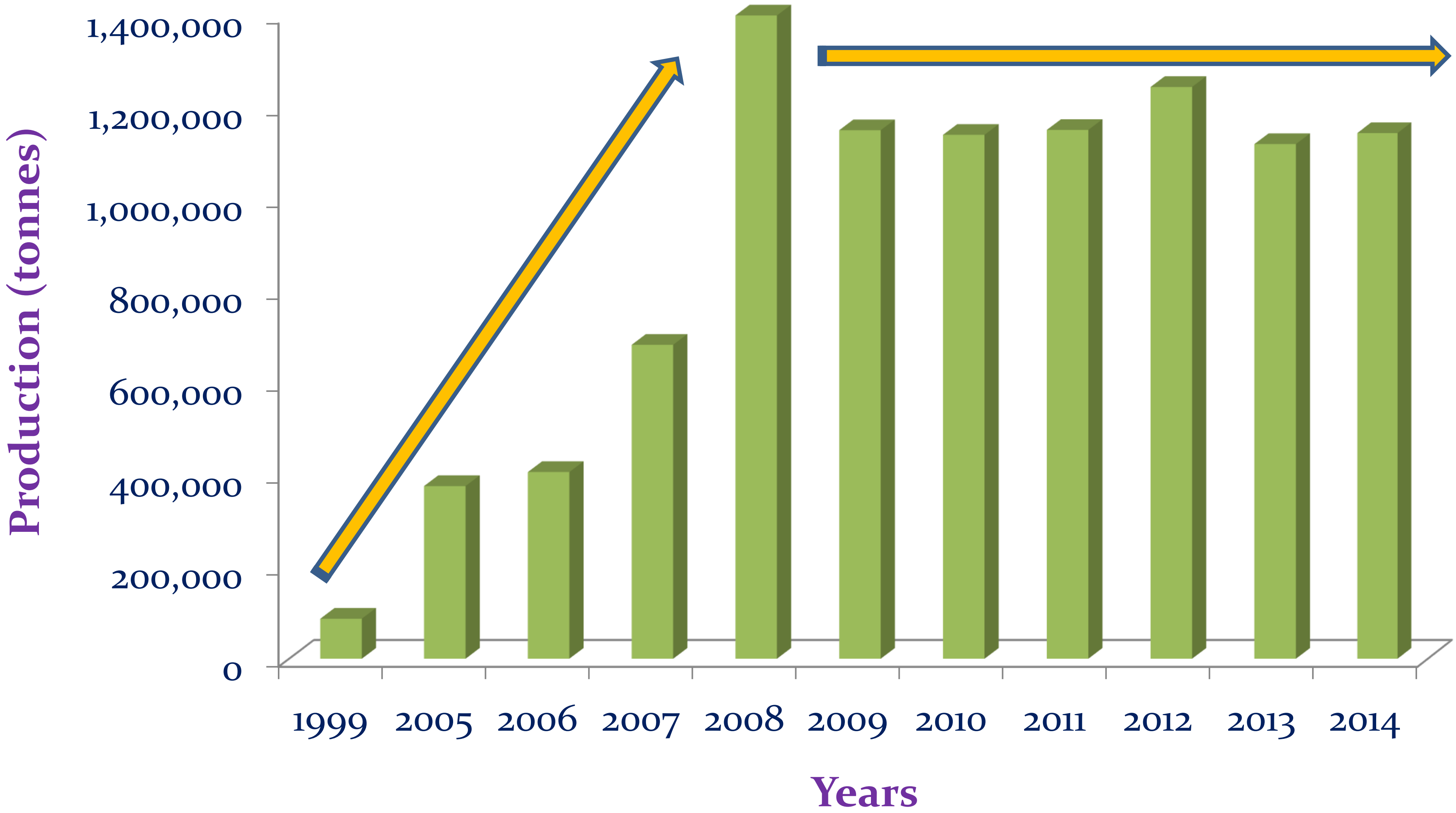
Changes in farming systems

Changes in production systems used for farming striped catfish in Viet Nam



Source: Nguyen (2013).

Changes in production

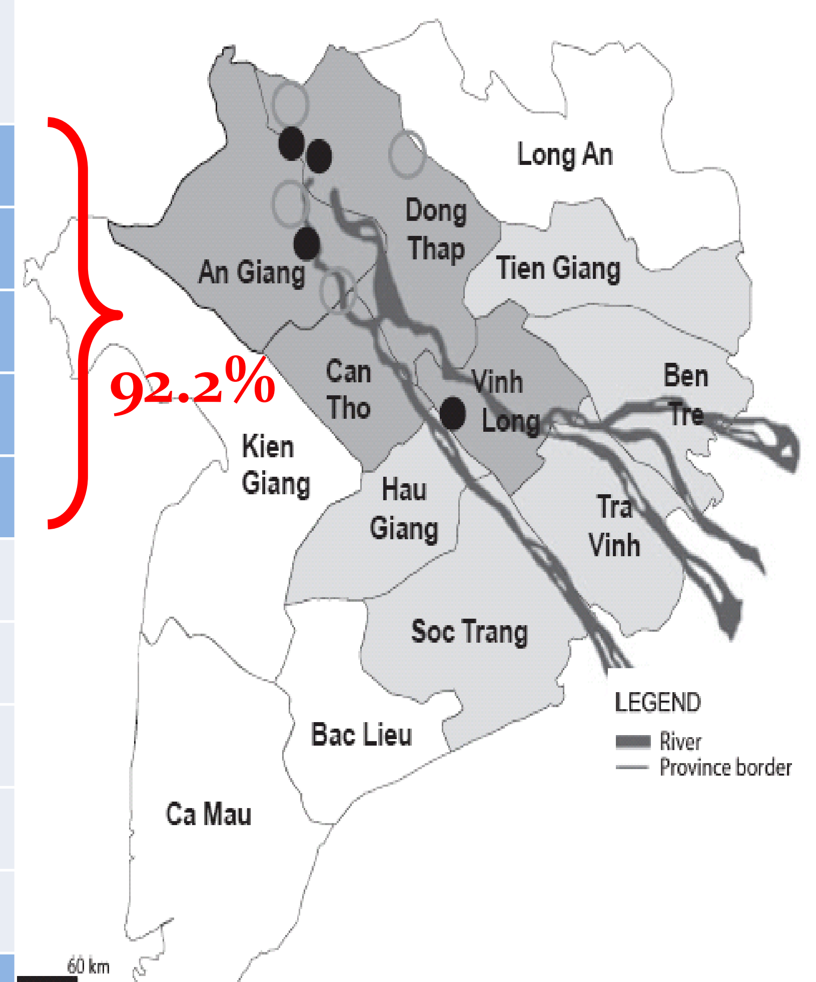


Present farming area and production

(D-fish, 2015)

Province	Farming areas (ha)	Production (tonne)	(%) areas
Dong Thap	2,039.5	372,146	39.5
An Giang	1,139.0	233,581	22.1
Can Tho	831.0	150,634	16.1
Ben Tre	500.0	160,000	9.7
Vinh Long	250.0	96,000	4.8
Hau Giang	126.4	45,478	2.5
Tien Giang	114.5	36,014	2.2
Soc Trang	100.0	16,100	1.9
Tay Ninh	48.0	8,939	0.9
Tra Vinh	11.3	6,277	0.2
Total	**5,159.7**	**1,125,169**	**100.0**

92.2%



Source: De Silva and Phuong (2011)

Flooding and salinity intrusion in Mekong delta

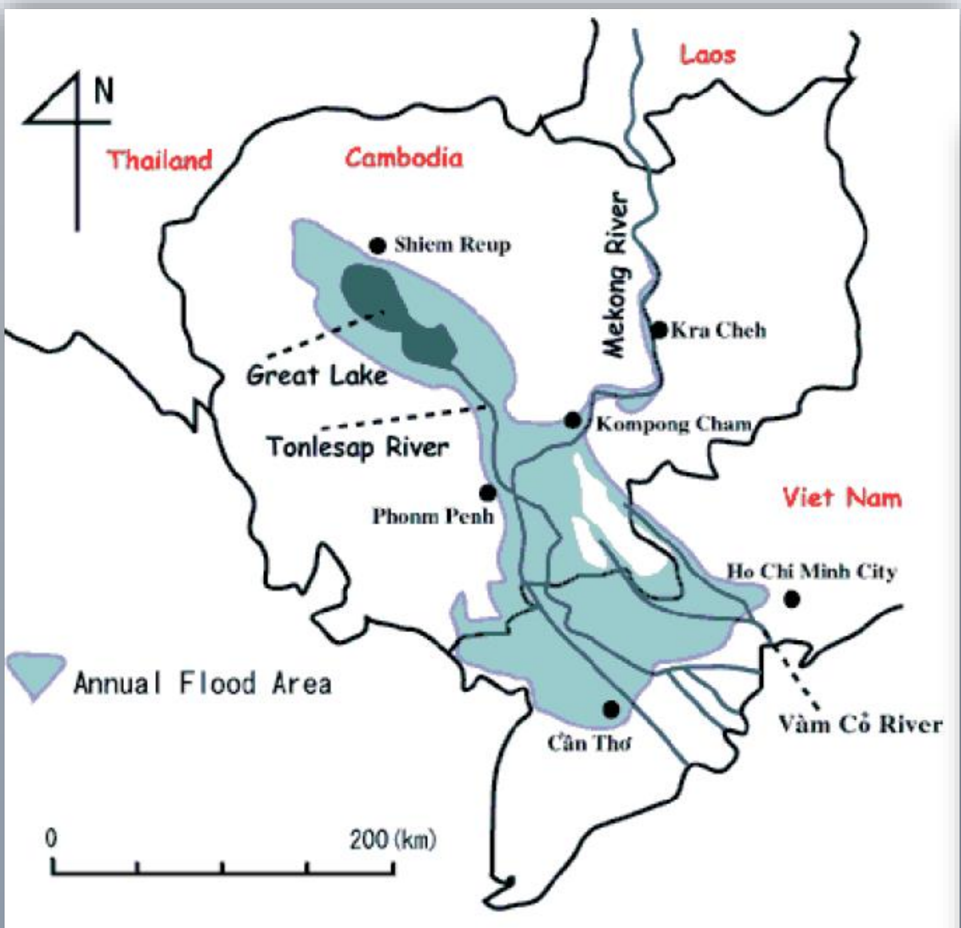
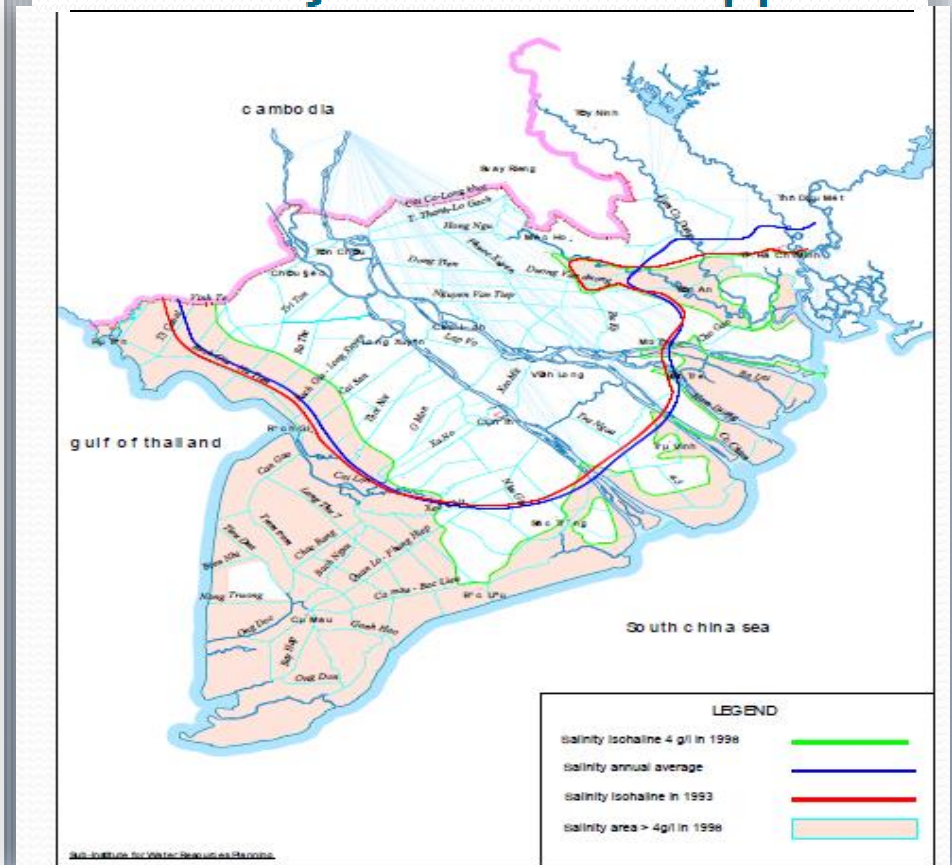


Fig. An image of flood area of Cambodia - Mekong Delta

Isohaline of Salinity Intrusion at 4 ppt



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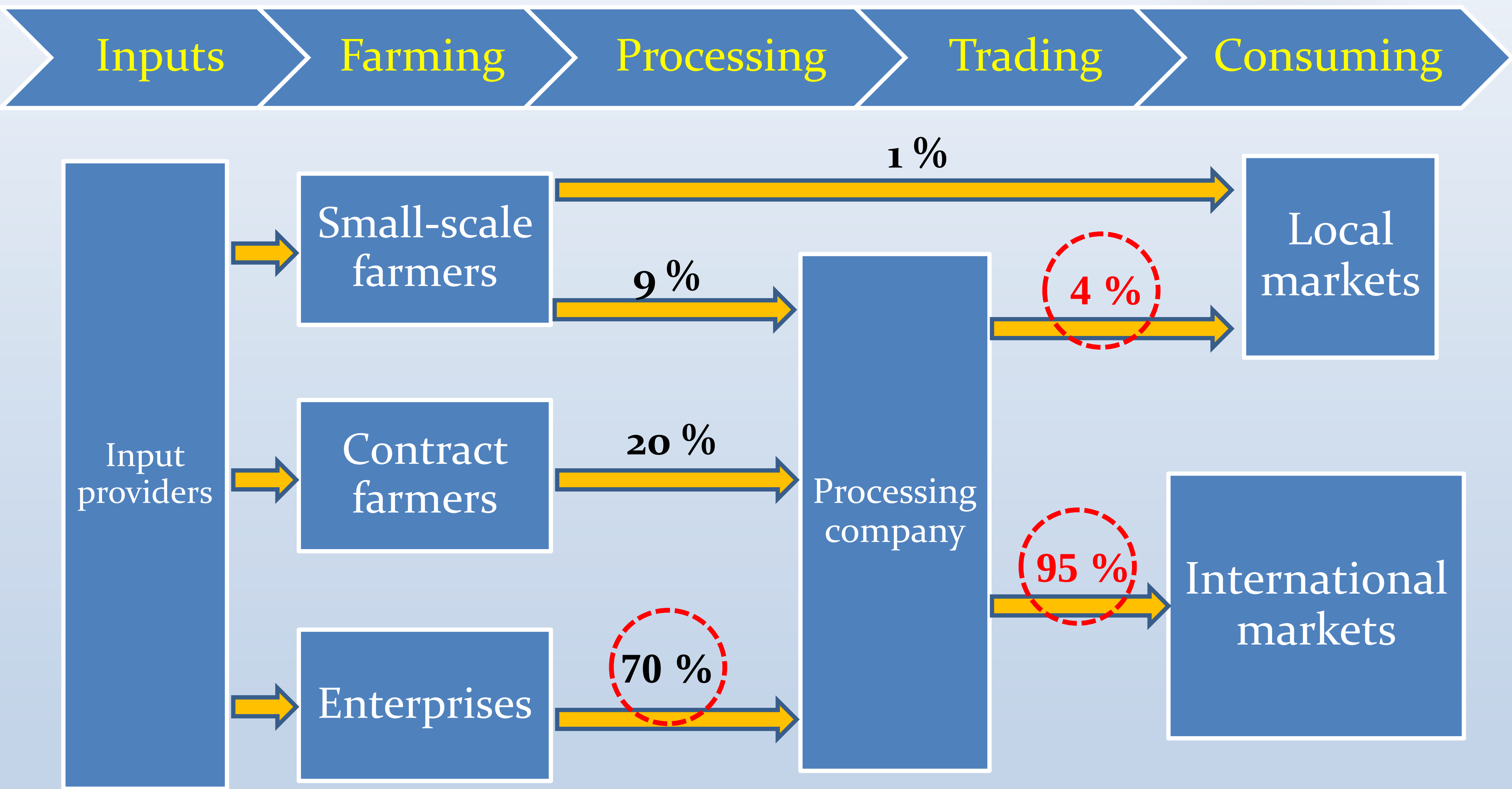
Pangasius value chain - 2014
(MARD - 2014)



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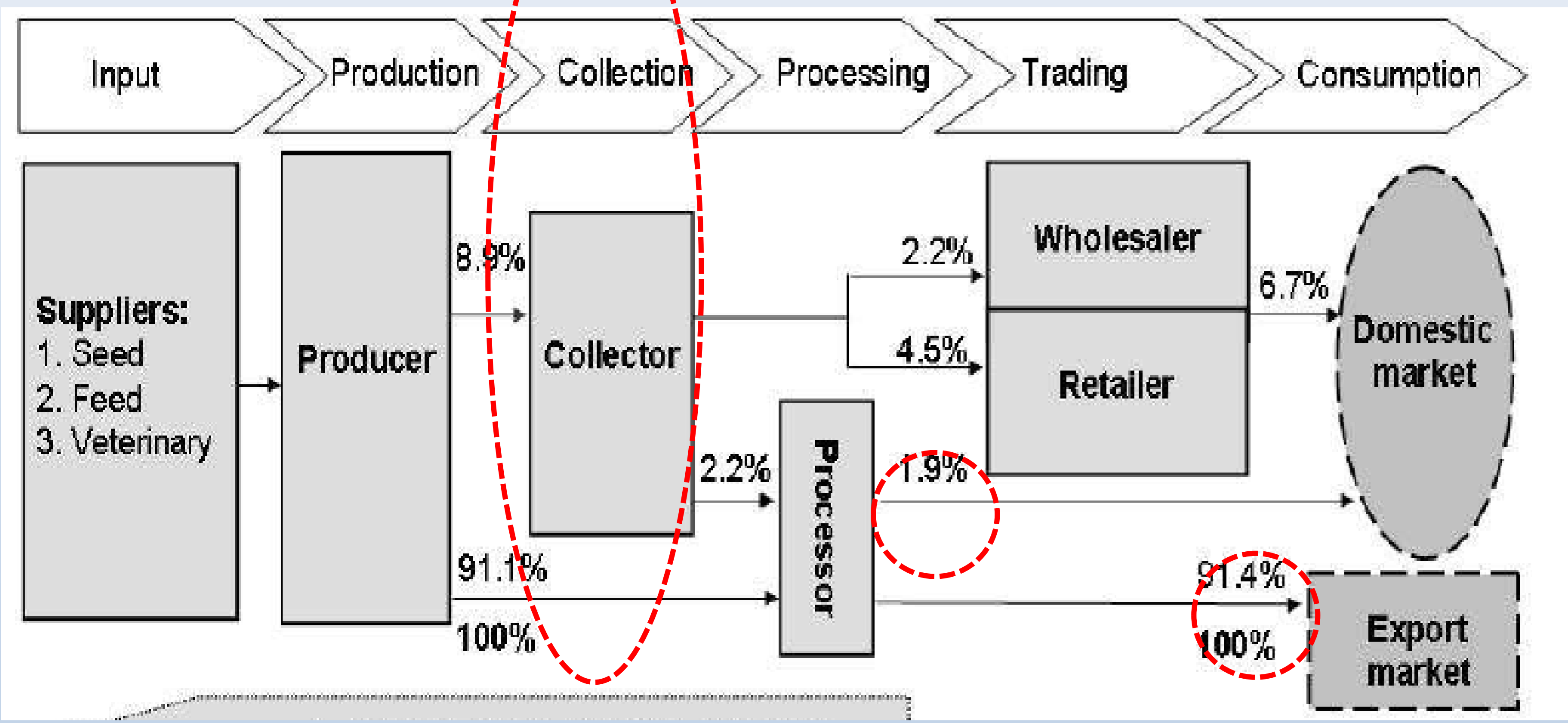
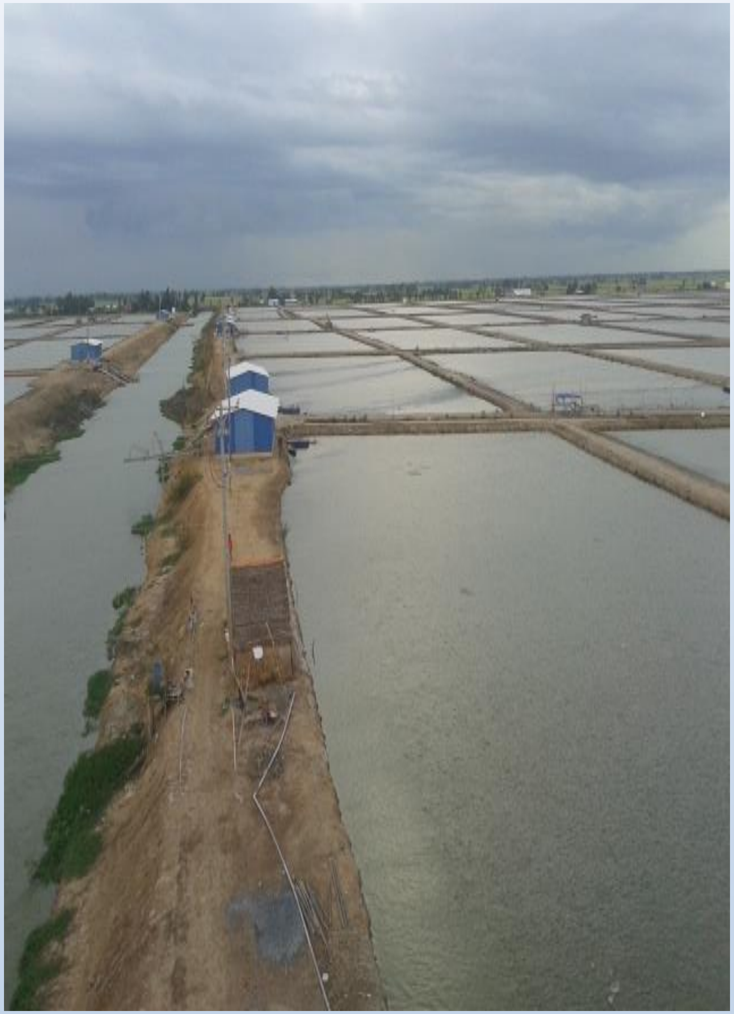
Pangasius value chain - 2010

(Kiem *et al.*, 2010)

Inputs | Farming | Processing | Trading | Consuming



Pangasius farming description



Parameters	Value (Mean±SD)
Pond depth (m)	3.8±0.7
Grow-out cycle (months)	7.96±1.14
Stocking density (tail/m²)	48.4±19.7
Survival rate (%)	73.1±8.5
Productivity (tonnes/ha/cycle)	345±137
FCR	1.57±0.06

History of pangasius feed & production systems

Cage culture (1960-2005)
Productivity: 100-120kg/m³
Feed type: Moist feed
FCR: 2.5-3.0

Net pen culture (2003-2005)
Productivity: 300-500 ton/ha
Feed type: dry floating pellets
FCR: 1.5-2.0

Pond culture (2005 – present)
Productivity: 300-500 ton/ha
Feed type: dry floating pellets
FCR: 1.47-1.70

Present feed value chain description

Ingredients providers

- Local products: available & quality variable
- Import products: high cost

Feed manufactures

- 48 manufactures, 5,020,580 tonnes/year
- 100% extruded floating pellets
- 5 farm-made prods, 9,500 tonnes/year
- Production cost: 11.489±701 VND/kg
- Profit margin: 3.09%

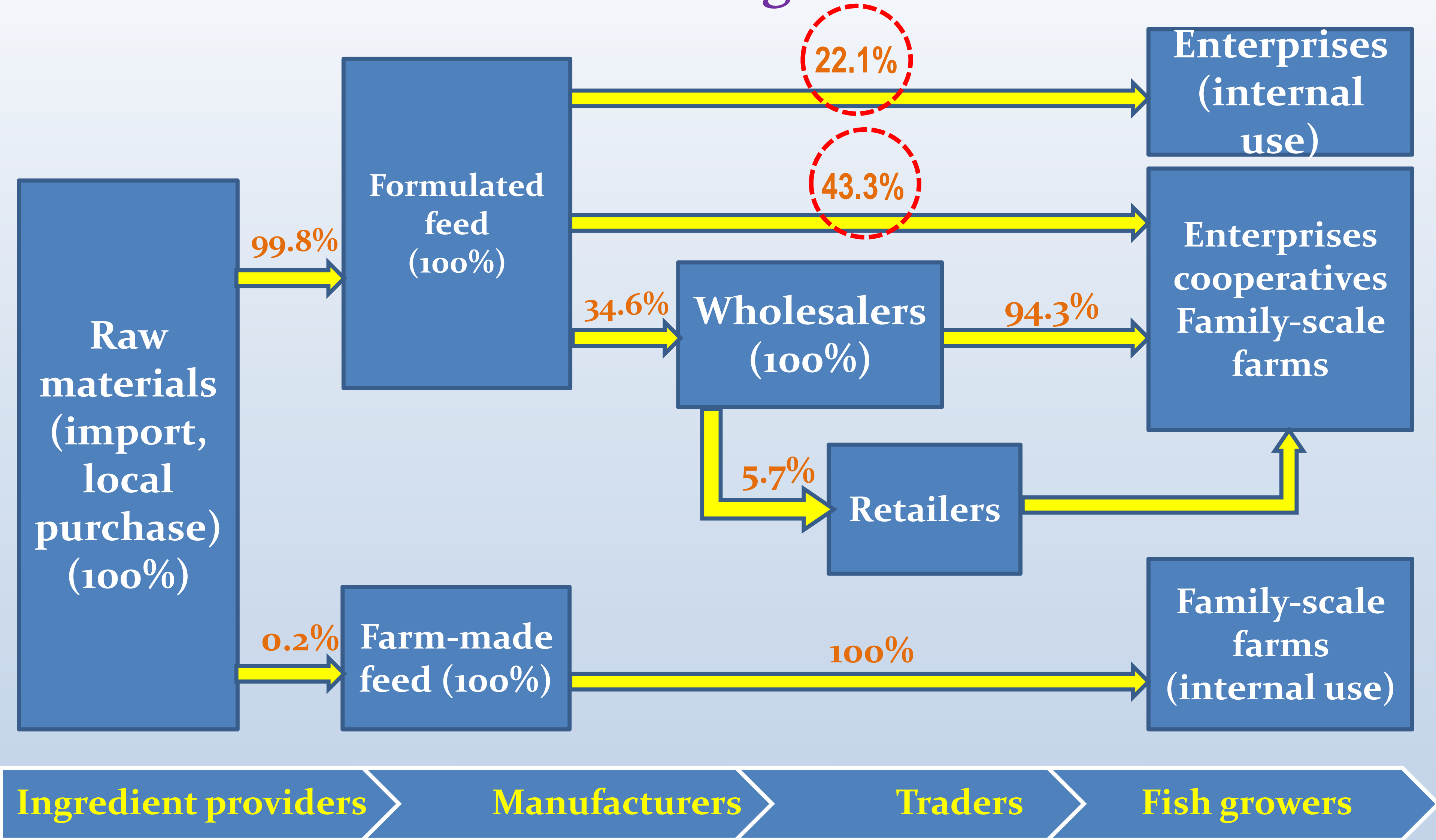
Feed traders

- 547 feed traders
- Profit margin: 5.53% (sale commission)

Fish growers

- Total 5,168.6 ha; 1,143,797 tonnes
- 143 enterprises; 3,388 ha (65.6%)
- 1,490 family-scale farms; 1,571.4 ha (30.4%)
- 11 cooperatives; 208.8 ha (4.0%)

Production flow through feed value chain



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Production cost of pangasius feed

Items/tonne of feed	Average cost (VND/tonne)	Percentage (%)
Feed inputs (ingredients/raw materials)	**9,349,572**	**83.81**
Labor and management	703,391	6.30
Premixes and additives	606,600	5.44
Power, fuel, electricity, water	364,580	3.27
Others	234,967	2.11
Storage and transport	221,141	1.98
Sale commission	**96,253**	**0.86**
Quality analyses, inspection & monitoring	56,720	0.51
Maintenance and spare parts	39,750	0.36
Research and technology	**20,000**	**0.18**
Training and capacity building	**3,000**	**0.03**
Total	**11,156,186**	**100.00**

Production cost of farmed pangasius

Items/kg of fish	Average cost (VND)	Percentage (%)
Feed	17,635	79.66
Fingerling	1,577	7.12
Banking interest	822	3.71
Medicine & chemical	583	2.64
Others	488	2.20
Employee	477	2.15
Harvesting	199	0.90
Pond preparation	198	0.89
Environment treatments	159	0.72
Total	22,137	100

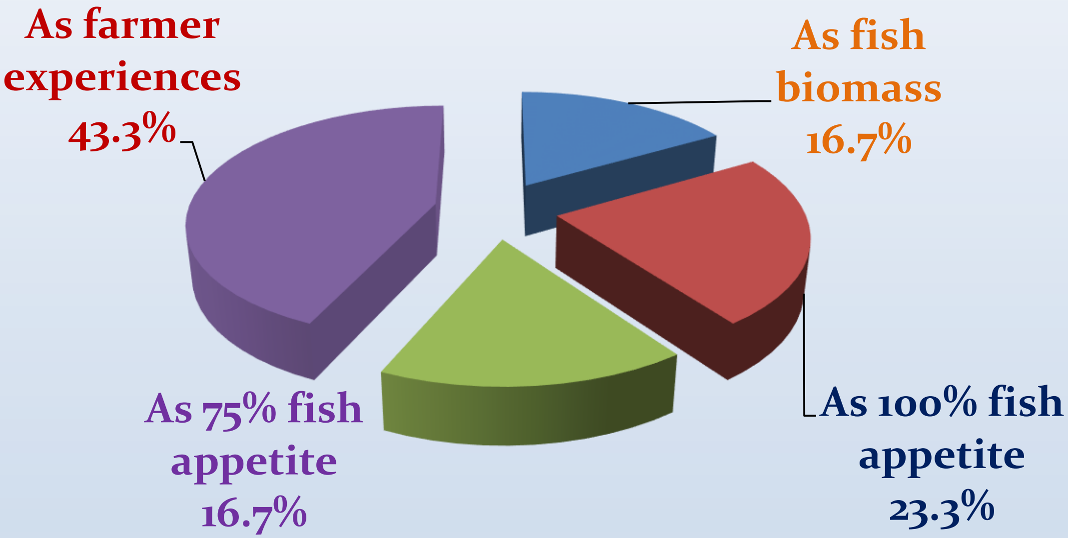
Present pangasius feed description

	Crude protein (%)	Cost (VND/kg)	FCR
Mean	26.27±1.91	11,489±701	1.57±0.06
Range	22-30	10,000-13,500	1.47-1.70(*)
Mode	26	12,000	1.6

(*) “Linkage contract” when accept FCR=1.48

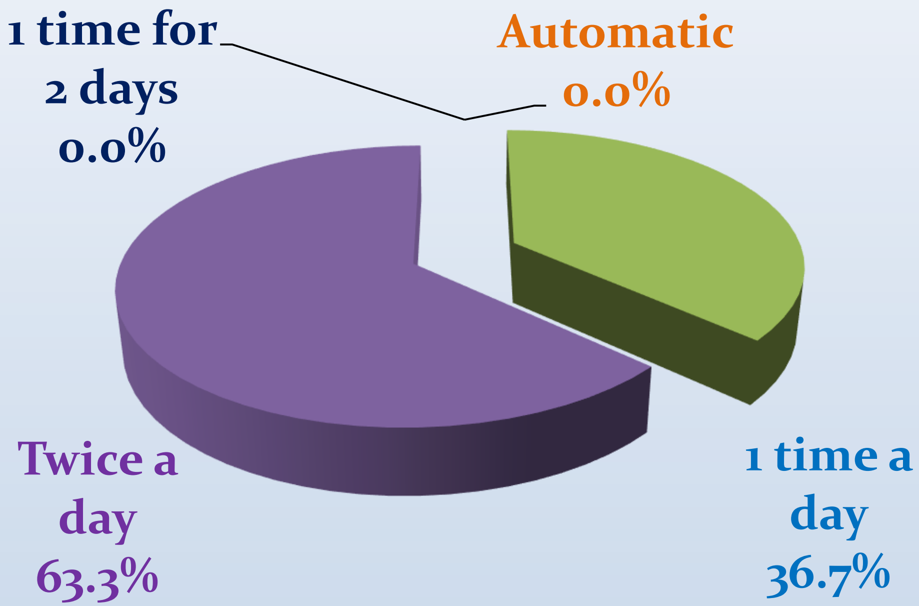
- 100% dried floating pellets
- Packing bags: 20-40kg
- Pellet diameters: 10-12 cm

On-farm feeding: how farmers feed pangasius?



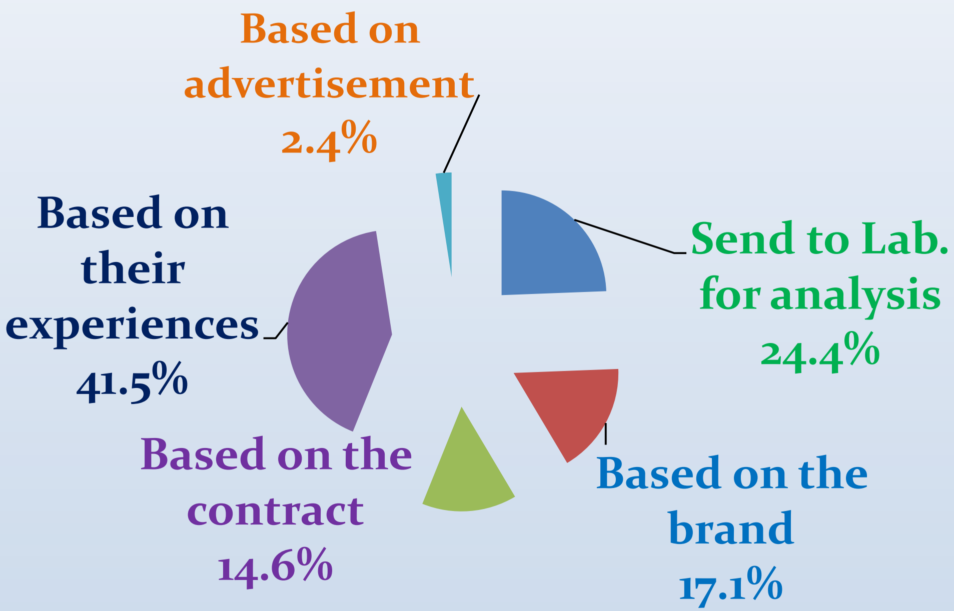
- ✓ Mainly based on experiences (43.3%)
- ✓ Rely on pangasius cost (feed ration and brand)
- ✓ Variable ways to determine the feed ration

On-farm feeding:
present on-farm feeding frequency?



- ✓ High feeding frequency
- ✓ Possible of over feeding – high FCR and environmental deterioration
- ✓ Starving: when face selling difficulty

On-farm feed management: how farmers know the feed quality?



- ✓ Mainly based on experiences (41.5%) – long time of farming
- ✓ The quality stability become important factor
- ✓ The contracted farmers: no chance for feed selection

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On-farm feed management: transportation, storage?

- Transportation by famers: 32.3%; by providers: 67.7%
- 90% farms have good warehouse for feed storage
- Feed storage time:
  - At farm: 12.5±8.9 days (3-30 days, mostly 7-10 days)
  - At feed traders: 21±29 days
  - At manufacturer: 38±30 days

Summary: advantages

- ✓ Pangasius industry is concentrated/ present of integrated enterprises & linkages/ high productivity/ low production cost
- ✓ Feed value chain is well-organized/high competition
- ✓ Almost 100% dried floating pellets
- ✓ Minimize middle man: direct deals (43.3% feed production; 22.1% integrated enterprises)
- ✓ Good storage/transportation facilities

Summary: major issues

- Feed is major contribution of production cost (80%)!
- Low & weak linkages (especially small-scale farms)
- Feed production:
  - Over production capacity
  - Quality: crude protein low & variable (22-30%); high FCR (1.57)
  - Very low investment for R&D, capacity building
- On-farm feeding and management:
  - Mainly experience based, manual feeding
  - High feeding frequency, possible of over feeding

Recommendation how to improve feed efficiency ?

- Research on feed quality improvement
  - Appropriate formulation for different developmental stages
  - High digestible protein - reduce FCR
- Improvement of on-farm feeding and feed management practices
  - Capacity building for farmers (training, workshop…)
  - Appropriate feeding regime, feeding protocol
  - Develop effective feeding systems
- Improve linkages of stakeholders: balance the supply-demand

Thank for your attention!

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Nile tilapia in Bangladesh & striped catfish in Viet Nam: perspectives on farming and FCR

Liberia, Costa Rica, 9– 11 November 2015

Mohammad Mamun-Ur-Rashid, La Van Chung and David F.H. Robb

Bangladesh: overview

- Total area – 143 998 km^2
- Open inland water – 39 100 km^2 – 27%
- Aquaculture – 7 893 km^2 – 20% of water

- 4^{th} largest inland capture fishery in world – 957 095 tonnes (2012)
- 5^{th} largest farmed fish producer in world – 1 726 066 tonnes (2012)

- Fisheries contribute 22.60% of total agriculture GDP

FAO (2014) & Bangladesh Economics Review (2014)

Bangladesh: freshwater production

System	Water area(ha)	Production (tonnes)	Productivity
Pond	371 309	1 526 160	4 110 kg/ha
Seasonal cultured water body	130 488	193 303	1 481 kg/ha
Oxbow lake (*baor*)	5 488	6 514	1 187 kg/ha
Shrimp farm	275 274	216 447	786 kg/ha
Pen culture	6 775	13 054	1 927 kg/ha
Cage culture	7	1 447	22 kg/m^3

Source **: Fisheries Statistical Report of Bangladesh (2014), DOF, Bangladesh**

Bangladesh

- Pond production summary in 2014:
  - Nile tilapia: 298 062 tonnes
  - Striped catfish: 371 068 tonnes
  - Major carps: 728 695 tonnes
  - Climbing perch also important

- Often using mixed culture
- Represents 65-85% of pond production

Source **: Fisheries Statistical Report of Bangladesh (2014), DOF, Bangladesh**

Bangladesh: Nile tilapia

- Introduced in 1974
- Nile tilapia *(Oreochromis niloticus)*
- Raised in ponds
- Low technology

- Mainly small farmers
- 209 605 tonnes production in 2013 (FAO, 2015)
- Mainly domestic market

Bangladesh: feed production

2014 Survey: Results

- Started as farm-made feeds
- Moving towards commercial feeds
- Total fish feed production: 1.7 million tonnes
- Commercial pellet feed: 1.3 million tonnes
- Semi-auto pellet feed: 0.4 million tonnes
- Number of registered feed mill: 112
- Number of feed mill operation: 80
- Tilapia feed production: 45-55% of production
- Tilapia floating (commercial) feed: 65-70%
- Tilapia sinking (commercial) feed: 30-45%

Bangladesh: farming conditions

2014 Survey: Results

- Average farm size: 3 ha – range 0.48 to 12.9 ha
- Number of ponds: 4 – range 1 to 8
- Age of farm: 12 years – range 1 to 19

- Relatively low water exchange – high cost of fuel
- Use of manure and fertilisers to get plankton growth

- Mainly a duo-culture: tilapia plus one other
  - Chinese carp, Indian major carps, striped catfish, etc.
  - Two farms had 5 species
  - Tilapia were 70 to 90% of numbers

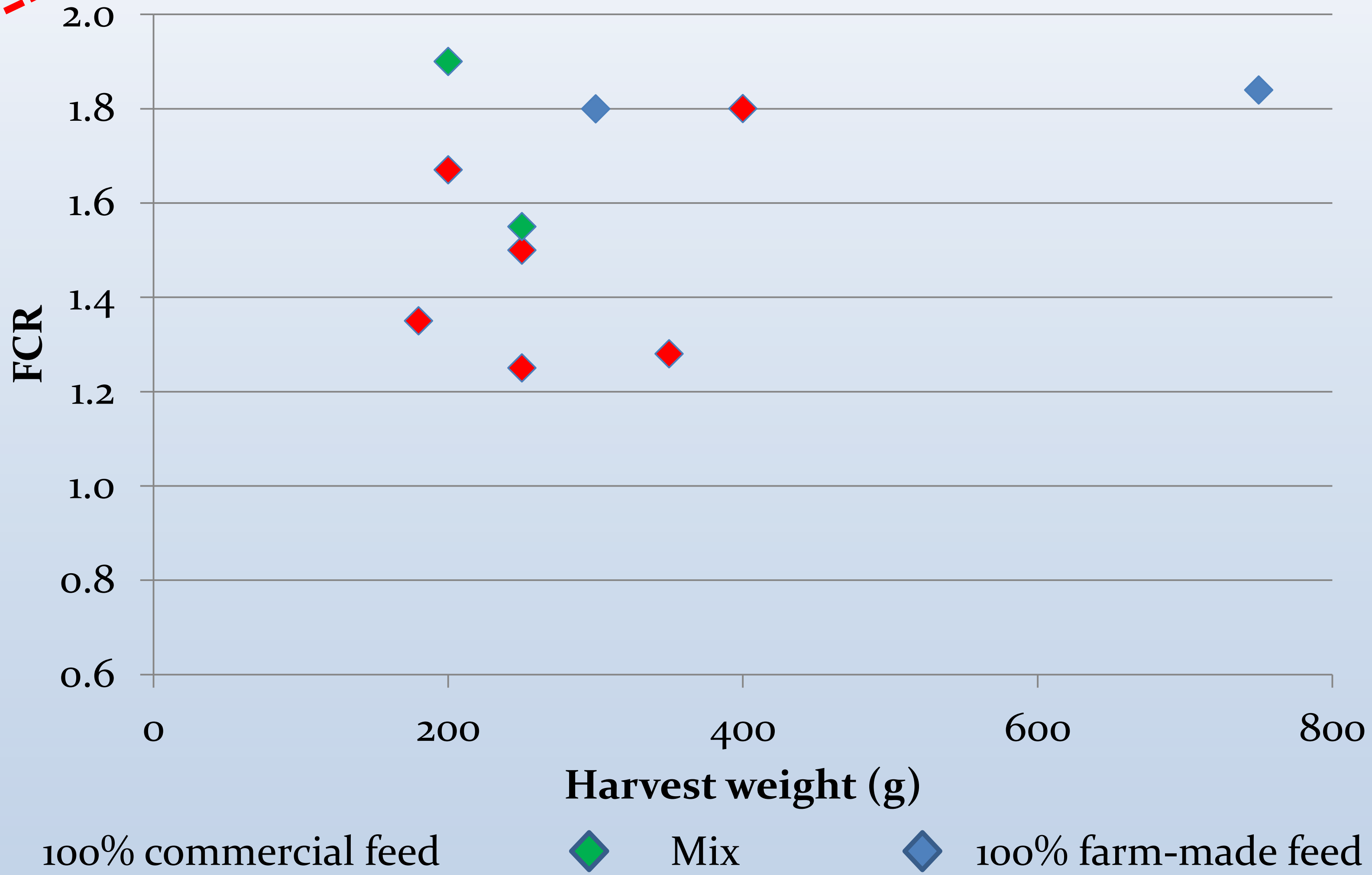
Bangladesh: farm conditions

2014 Survey: Results

- Inputs:
  - 15 g average: range 1 – 50 g
- Harvest:
  - 310 g average: range 180 – 750 g
  - 52 tonnes/year average: range 10 to 300 tonnes/year
- Productivity:
  - 1.93 kg/m^2 average: range 0.37 – 3.53 kg/m^2
- Grow out time:
  - 184 days average: range 120 – 270 days

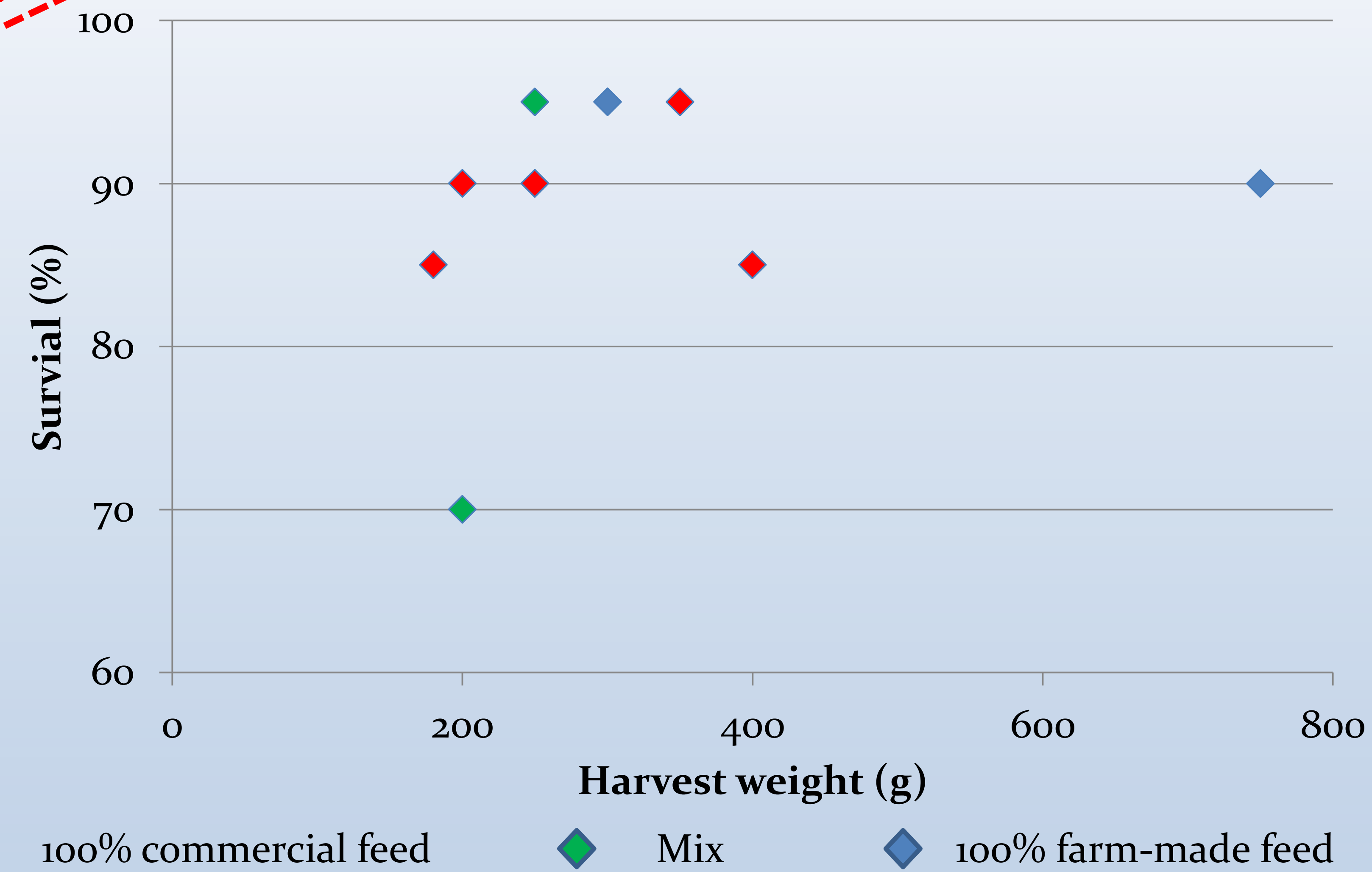
Bangladesh: FCR range

2014 Survey: Results



Bangladesh: survival

2014 Survey: Results



Viet Nam: overview

- 3rd largest country for aquaculture production
  - Total production in 2012 and 2013: 3 103 351 and 3 220 071 tonnes respectively (FAO, 2015)
- Long coastline for marine
  - Shrimp, shellfish and fish
- Freshwater aquaculture concentrated in large river deltas to north and south
- Striped catfish is the biggest production – export market
- Tilapia, snakehead and carps also popular – domestic market

Viet Nam: striped catfish

- Native of Mekong River
- Farmed throughout Mekong Delta
  - Rapid growth since late 1990's

- Mainly for export
  - Portion sized, white, frozen fillets
  - Some market for whole, head-off and gutted or unskinned
  - Very small domestic market

Viet Nam: striped catfish

- After hatching, fish feed on plankton for a few days
  - Blooms stimulated by adding nutrients such as egg yolk protein and soybean meal

- Fish soon come onto powdered feed
  - Commercial feed, ground to fine powder
- Pellets used throughout growout to harvest at 800-1 000 g

Viet Nam: feed

- Farmers used to make farm-made feed
  - Mix raw materials into a mash
- Extruded feeds developed in late 1990's
- Production spread with growth of industry
- Now >60 registered mills (2012)
- All farms using commercial feeds now
- No reported use of farm-made feed

Vietnam: feed

- Research on striped catfish nutrition is very limited
- Used information from channel catfish (United States of America)
- Balanced with price
  - Much lower protein than recommended

Viet Nam: feed management

- Most grow-out ponds fed from boat
  - Large quantity of floating feed tipped from boat
  - Very high competition for feed
  - Many fish will not eat

- Number of meals very restricted
  - 2-3/day for small fish
  - 1/day for large fish

Viet Nam: water quality

- Water quality assessed mainly by eye (water colour)
- Striped catfish can breath air
  - Farmers do not worry about dissolved oxygen
    - Regularly lower than 1 mg/l at the surface
- Poor water quality ensues
  - Stress on the fish
  - Reduces:
    - Feed digestion
    - Fish health

- Water changed by pumps or tidal exchange:
  - 10%/day by pumps
  - 30-40% every 3 or 4 days by tide

Viet Nam: fish health

- Bacterial diseases are the main health issue for striped catfish
- 80% survival is considered reasonable
- 20-30% survival is not unusual

- Treatments are often limited:
  - Poor diagnosis
  - Inappropriate use of medicines
  - Old / adulterated medicines


SULFAMETHOXAZOLE B.P.


ROQUETTE
NEOSORB


Natural Feed Additives
HP Beta - Glucan
Perfect Immunity Stimulator
NET WT. 20kg


BLEA - JI
Dry Cholorine 70%

Viet Nam: farming conditions

2014 Survey: Results

- Average farm size: 4.6 ha – range 2.5 ha to 7.0 ha
- Number of ponds: 5 – range 3 to 8
- Water depth: 3.9 m – range 3.3 to 5.0 m
- Age of farm: 9 years – range 9 to 13

- Regular exchange of water by pump or by tide
- No use of manure or fertilizers

- Complete mono-culture
  - Stocking density very high
  - Water quality very low

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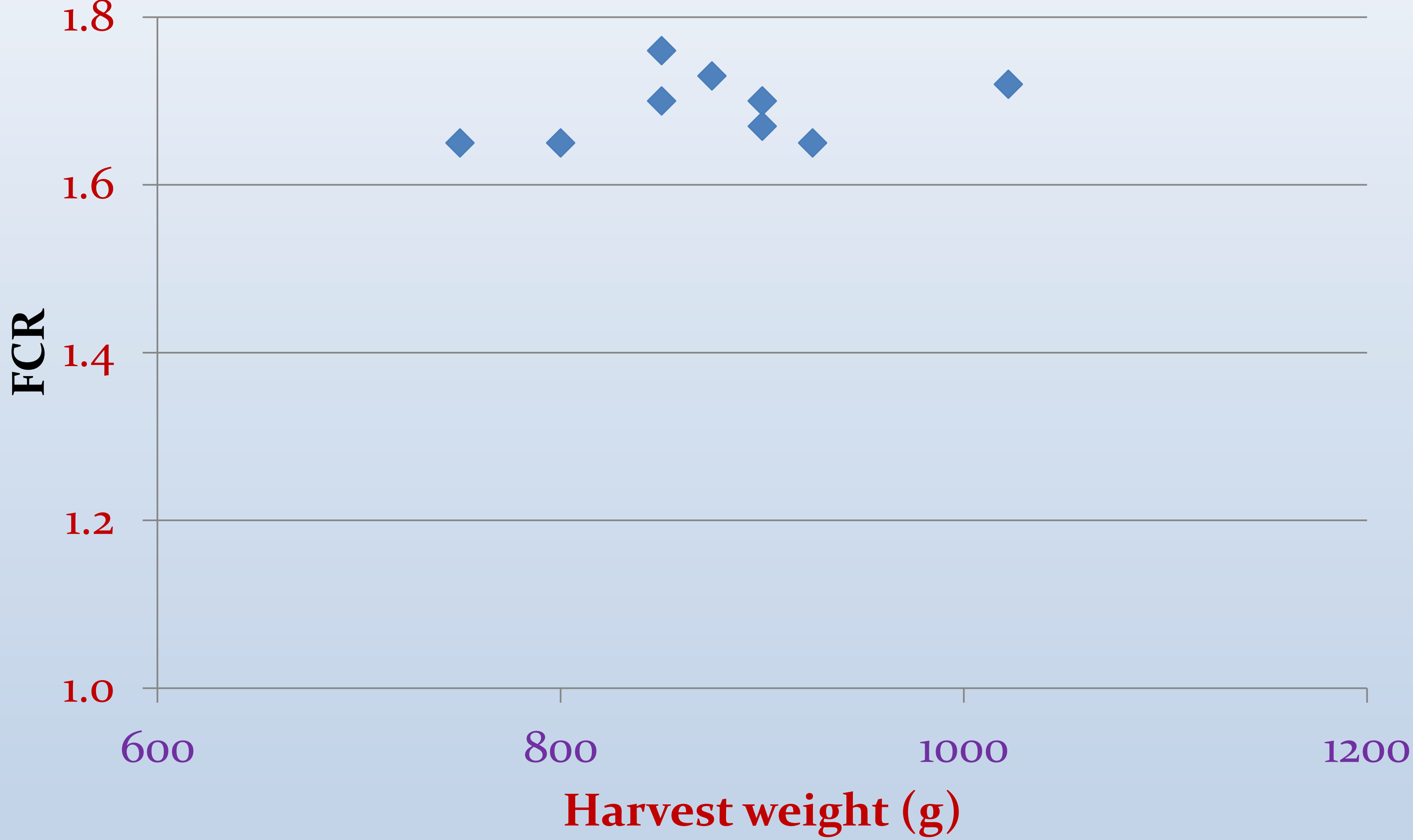
Vietnam: farm conditions

2014 Survey: Results

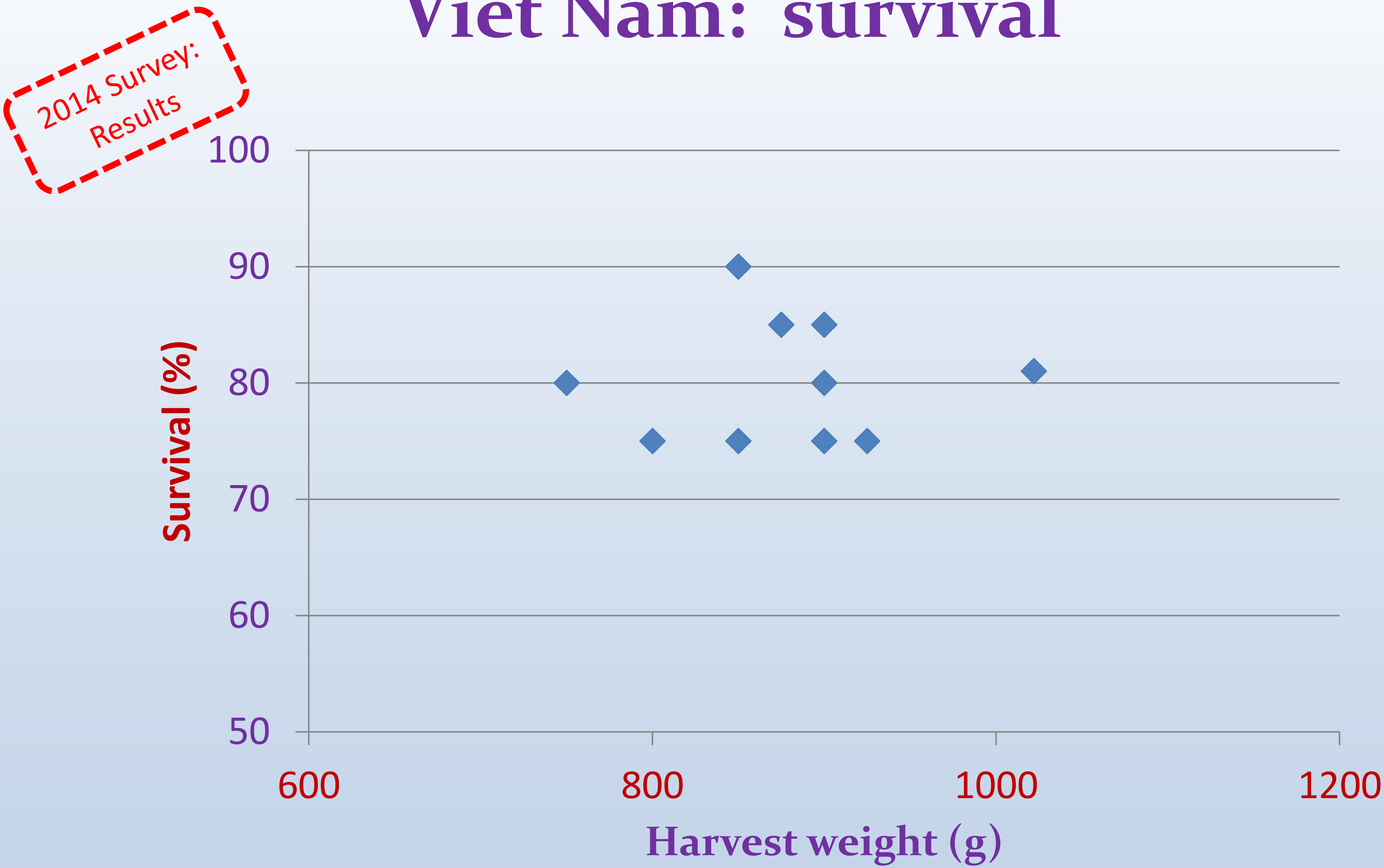
- Inputs:
  - 27 g average: range 20 – 30 g
- Harvest:
  - 880 g average: range 750 – 1 020 g
  - 1 480 tonnes/year average: range 1 125 to 2 160 tonnes/year
- Productivity:
  - 34.9 kg/m^2 average: range 22.3 – 60.0 kg/m^2
- Grow out time:
  - 220 days average: range 190 – 245 days

Viet Nam: FCR range

2014 Survey: Results



Viet Nam: survival



Conclusions

- Farm conditions vary a lot in both countries
  - Fish quality at input
  - Farm/pond size
  - Water quality
- Feed quality will also vary considerably
  - Protein quality and digestibility
  - Anti-nutrients

- Standardising approaches will help to develop methods to consistently reduce cost and FCR

Thank You

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Greenhouse gas emissions from Indian major carp farming in India

Liberia, Costa Rica, 9– 11 November 2015

Rajendran Suresh
78A, 9th Cross, Arulanada Ammal Nagar
Thanjavur 613 007, Tamil Nadu, India

Carp farming in India

- India, second largest aquaculture producer
- Major contributor for Indian aquaculture - Indian major Carps
- Indian major carps– catla, rohu and mrigal
- Major aquaculture activities – Andhra Pradesh and West Bengal
- Annual Indian carp production – 3 417 493 tonnes (94% of Indian total freshwater fish production)
- India – 70% of Asian major carp production
- Indian major carp farming – practiced more than 5 decades
- Provides employment, income and cheap protein for Indian rural population

Indian major carps – culture practices

Polyculture of Indian major carps

Catla

Catla catla

Rohu

Labeo rohita

Mrigal

Cirrhinus cirrhosus

Indian major carps – culture practices

Culture systems – pond culture

  

Culture period – year-round (8-10 months)

Indian major carps – culture practices

Seed stocking

Stocking density
- 5 000-10000/ha

Stocking size
- 50-200 g

Stocking ratio
- Catla -10%
- Rohu-90%

Indian major carps – culture practices

- Manuring
  - Cow dung
  - Poultry manure
- Fertilization
  - Urea
  - DAP/SP

Indian major carps – culture practices

- Feeding
  - Natural food
  - Mash
  - Sinking pellet
  - Floating pellet

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Indian major carps – culture practices

Fish production	• 5-10 tonnes/ha
Marketing	• Domestic • Whole iced Fish

Scope of the Study

Goal

- To analyze GHG emission arising from the production of Indian major carps in India

Purpose

- To understand where and how GHG emission arise in Indian major carp farming in India
- To develop cost effective ways of improving performance and reducing emissions from Indian major carp farming

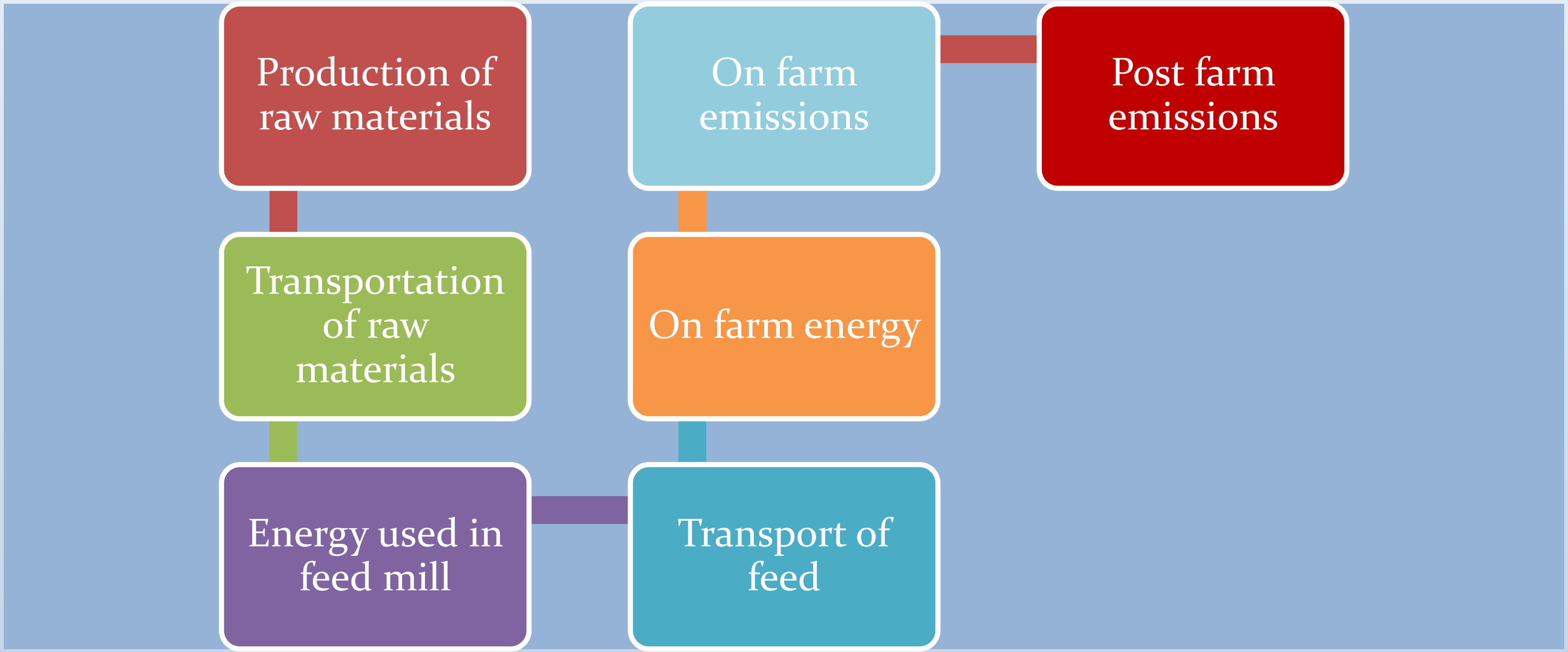
Model

- To quantify emission from point of production to marketing

Aquaculture and GHG emission

- Aquaculture – rapid development over the last 20 years
- Predictions – continued growth to meet global demand
- Variety of species, technologies and intensities
- Feed- major input for aquaculture development
- Fish feed from a range of raw materials
- GHG emission associated with aquaculture

Sources of emission from aquaculture



Methodology

1. Field survey
2. Modelling of EI

Field Survey
- 6 feed mills
- 12 fish farms

Survey instrument
- Raw material questionnaire
- Feed mill questionnaire
- Feed distribution questionnaire
- Fish farm questionnaire
- Fish markets questionnaire

Survey period
- May to September, 2014

Methodology

- Model for quantifying GHG emission
  - Excel-based model (“aquaculture LCA model v1.1”)
  - Quantifying the emissions arising from feed product
  - On-farm emissions
  - Emissions arising post farm

Methodology

Quantifying the emissions arising from feed production

- Percent of each feed material in each ration
- Nutritional values of the rations
- Non-LUC emissions arising from production of the feed materials
- LUC emissions arising from production of the feed materials
- Origin of each feed material and the transport distance
- Average road/rail distance from place of production to feed mill
- Average road distance from the feed mill to fish farm
- Average distance feed is transported from feed mill to farm
- Amount of packaging used for feed
- Emission factors for transport and packaging
- Emission factors for energy used in the feed mill

Methodology

On-farm emissions

- On farm energy use
- Quantifying pond N_2O emissions
  - Determining the amount of N available for conversion to N_2O
  - Determining the rate at which the surplus N is converted to N_2O
- Emissions embedded in fingerlings and fertiliser

Emissions arising post farm

- Emissions arising in post-farm transport
- Emissions embedded in packaging
- Emissions from post-farm processing

Indian major carps – culture practices

Sample size	• 12 Indian major carp farms in Andhra Pradesh
Farming areas	• Low lying areas, nearer to rivers/canals • Access to freshwater
Pond area/depth	• 2.40 to 60 ha • 2 to 3 m

Indian major carps – culture practices

Species	Catla (10%)	Rohu (90%)
Stocking size	210 g	160 g
Survival	98%	

Indian major carps – culture practices

Manuring

- Cow dung /poultry manure

Fertilizing

- Urea / SP/DAP

Feeding

- Mash (farm-made / commercial) / sinking pellets / floating pellets

Indian major carps – culture practices

Production details

Culture period - 230 days (180 to 300 days)

Harvest size – rohu – 1 240 g (1 000 to 2 000 g) Catla – 2 340 g (1 350 to 3 000 g)

Total harvest (kg)/sq. m. of water – 0.995 (0.777 to 1.571)

Average production/ha – 10 tonnes/ha (7 to 15 tonnes/ha)

eFCR – 1.8 (1.0 to 5.0)

Indian major carps - on farm energy use

Energy use

- Pumping water
- Lighting

Energy sources

- Diesel/petrol
- Electricity

Type of Energy used (No. of farms used)	Average	Minimum	Maximum
Diesel (l/t of fish harvested) 8/12	12.9	0.6	40
Petrol (l/t of fish harvested) 9/12	3.6	0.6	10
Electricity (kWh/t of fish harvested) 10/12	76.3	9.5	150

Indian major carps - marketing

Markets

- Local assembly centres (10 -100 km)
- Distant markets – Howrah, Siliguri (1 100 - 1 700 km) and many other markets

Packing

- Plastic box (4 500 g)-65 kg fish + ice
- Styrofoam box (700 g) 625 g ice/1 000 g fish – summer
  450 g ice/1 000 g fish - winter

Transport

- Trucks (17 to 21 tonnes)

Feed raw materials

Feed raw materials for carps

- Origin – within India
- 50% feed premix from Indonesia (1 mill)

Diverse from all over the country

- Diversity of agricultural production
- source of fishmeal

Raw material categories

Protein sources	Carbohydrate sources
Lipid sources	Micro-ingredients and additives

Raw materials used in carp feed in India

Protein sources

Animal origin	Plant origin
Fishmeal Meat & bone meal Poultry meal	Soybean full fat Rapeseed meal Cottonseed meal Groundnut oilcake De-oiled mustard oilcake Maize gluten DDGS

Raw materials used in carp feed in India

Lipid sources (animal origin)	• Fish oil • Poultry fat
Carbohydrate sources (plant origin)	• Maize • Rice bran whole • De-oiled rice bran • Broken rice
Micro-ingredients & additives	• Salt • Vitamin-mineral mix

Raw material inclusion ranges for Indian major carps feeds in India

Raw materials used	Minimum (%)	Maximum (%)	Mills using
Fishmeal	0.5	5	3
Meat & bone meal	5	5	1
Poultry meal	4	4	1
Soybean meal	15	40	6
Rapeseed	8	15	3
Mustard oil cake	5	8	1
Maize gluten	5	7	1
Groundnut oil cake	3	7	3
Cottonseed meal	5	10	4

Raw material inclusion ranges for Indian major carp feeds in India

Raw materials used	Minimum (%)	Maximum (%)	Mills using
DDGS	5	10	2
De-oiled mustard cake	7	7	1
Rice bran	5	15	3
De-oiled rice bran	8	35	6
Maize	0	15	6
Broken rice	4.5	10	5
Fish oil	1	10	2
Poultry fat	1	1	1
Premix[1]	50	50	1

Raw material transport

Rail freight

- Rajasthan – de-oiled mustard oilcake, rapeseed meal
- West Bengal – de-oiled rice bran

Lorry freight – bulk of raw materials

- Truck size – 15 to 30 tonnes

Feed production

- **Steam pelleting**
  - Electricity major energy source
  - Other fuels used – diesel, fuel oil, gas, rice husk, coal
- **Extrusion pelleting**
  - For floating pellets
  - More expensive & energy consuming

Packaging

Material used	• HDPE • overcome rough handling & exposure to rain
Bag sizes	• Mostly 40 kg • One mill 50 kg
Average material weight/tonnes of feed	• 0.69 kg/tonnes

Feed transport

- Mostly on trucks – 15 to 18 tonnes
- Large and medium farmers – directly from feed mills
- Small farmers – nearby traders
- Transport distance – 40 km (1.5 to 350 km)

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GHG Emission from carp farming in India

Emissions from cradle to farm gate

- EI per kg live weigt at farm gate ($gCo_2e/kgLW$) = 1 840

Emissions from the production of feed materials

- Single source of emissions accounting for 43% of the EI for major carps
- Feed materials to the total EI is a function of the feed material's EI and FCR
- The carp rations have high (18-20%) amounts of high EI grains

GHG Emission from carp farming in India

Emissions from the transport of feed materials	• Transport emissions are lower • Predominance of domestic production
Emissions from energy use in the feed mills	• Energy used are low quality fuels • Energy reduction offset by high electricity EF
Emissions from the transport of feed	• Transport distance and mode of transport • Low (short transport distance/trucks)

GHG emission from carp farming in India

Emissions from on-farm energy	On farm energy use for major carps
Depends on the rate of energy use	Electricity - 258 MJ/tonne of fish
Diesel and electricity dominate	Diesel - 424 MJ/tonne of fish
Pumping and lighting	Petrol - 118 MJ/tonne of fish

GHG Emission from carp farming in India

Pond N_2O

- Pond N_2O represent a significant % of the total emissions

Pond N_2O	Values for IMC
Pond N2O, EF: 0.71% (gCO2e/kgLW)	198
Pond N2O, EF: 1.8% (gCO2e/kgLW)	503
Pond N2O, EF: 0.71% (% of total GHG)	11%
Pond N2O, EF: 1.8% (% of total GHG)	23%

GHG Emission from carp farming in India

Nitrogen use efficiency (NUE)

- Nitrogen consumed converted to fish biomass
- kg N out (fish protein): kg N in (feed, manure and fertilizer)

NUE for major carps – 0.33 (0.26 to 0.40)

- 25% (range: 11–36%) of the nitrogen consumed can be converted to fish biomass

GHG Emission from carp farming in India

Emission embedded in fertilizers

- Emissions are low and proportional to the amounts applied

Average fertilizer application rates for major carp farming

Fertilisers	Units	Values
Urea	kg in/t LW out	6.8
DAP	kg in/t LW out	27.6
SP	kg in/t LW out	54.8
Potash	kg in/t LW out	2.2

GHG Emission from carp farming in India

Emissions embedded in fingerling

- Significant proportion of the total emissions in the Indian major carps (25%)
- Due to: (a) the fingerling being larger on average (170 g); (b) higher electricity EF

EI of the fingerlings (kg CO2e/kg fingerling)

- Feed - 0.78
- Electricity - 2.74
- Diesel - 0.23
- Total - 3.75

GHG Emission from carp farming in India

Emissions arising from land use change (LUC)

- Contribute the significant difference to the total EI of fish produced

Feed material EI at PoP using different soy methods

Feed Type	No LUC	Feedprint area	GLEAM default	GLEAM PAS 2050	GLEAM One Soy	GLEAM reduced time-frame	Total % of soybean/ meal
Carp_nursery	713	926	713	713	713	713	34%
Carp_starter	675	873	675	675	675	675	28%
Carp_grower	662	852	662	662	662	662	26%

GHG Emission from carp farming in India

Post farm-gate emissions

Average post-farm transport distances and modes

- Post-farm supply chains are for whole fish sold domestically

Transport Type	Transport Distance	Mode of Transport
Road transport of whole (dead) fish from farm to wholesale (km)	44	Large truck
Road transport of whole (dead) fish from wholesale to retail (km)	1128	Large truck

GHG emission from carp farming in India

Post-farm emissions (gCO2e/FU)

Emission Factors	Emission Levels
Domestic transport	87
International transport	0
Processing	0
Packaging	91
Ice	34
Total	213
Functional unit (FU)	kg of whole fish at retail point

Emissions intensity (EI) of fish from cradle to farm gate for major carps

Components	EI at farm gate (gCO2e/KgLW)
Feed Non LUC	794
Feed Transport : POP to Feed Mill	60
Feed Mill Energy use	118
Feed Packaging	0
Feed Transport form Feed Mill to Farm	55
On Farm : Energy Use	105
On Farm : Pond N20 EI = 0.71	198
Embedded Fertiliser	57
Fingerlings	453
Total	**1840**

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How could the emissions intensity of aquaculture be improved?

Improving the EI

- Where emissions are high?
- How could be reduced?

Feed material production

- Reducing EI of feed materials
- Substituting high EI materials

Raw material/ feed transport

- POP to mill, mill to farm
- Limited Scope

How could the emissions intensity of aquaculture be improved?

Feed mill energy use	• Fuel switching - use of biomass
Improving feed Conversion	• Optimising feed (feed management) • Water quality & fish health management
On-farm energy use	• Reduce pumping – RAS • Fuel switching – electricity to diesel

How could the emissions intensity of aquaculture be improved?

On farm N_2O

- Reducing surplus N
- Reducing N_2O EF

Post-farm emissions

- Reducing transport distances
- Size of trucks
- Change of packing materials

Challenge, opportunity and strategy to reduce GHG emission from aquaculture industry

Challenge

- Raw material production and transport
- On farm

Opportunity

- Feed formulation, FCR
- Post farm

Strategy

- Mitigation measures – technically feasible, economically viable and socially acceptable

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Dr. Michael Macleod SRUC, Edinburg United Kingdom.	GHG emission modelling

Thank You for your kind attention.....

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Life cycle assessment of three freshwater fish species in Asia: implications on GHG emissions and FCR

Liberia, Costa Rica, 9– 11 November 2015

David F.H. Robb, Michael MacLeod, Mohammad R. Hasan, Doris Soto, Mohammad Mamun-Ur-Rashid, Rajendran Suresh and La Van Chung

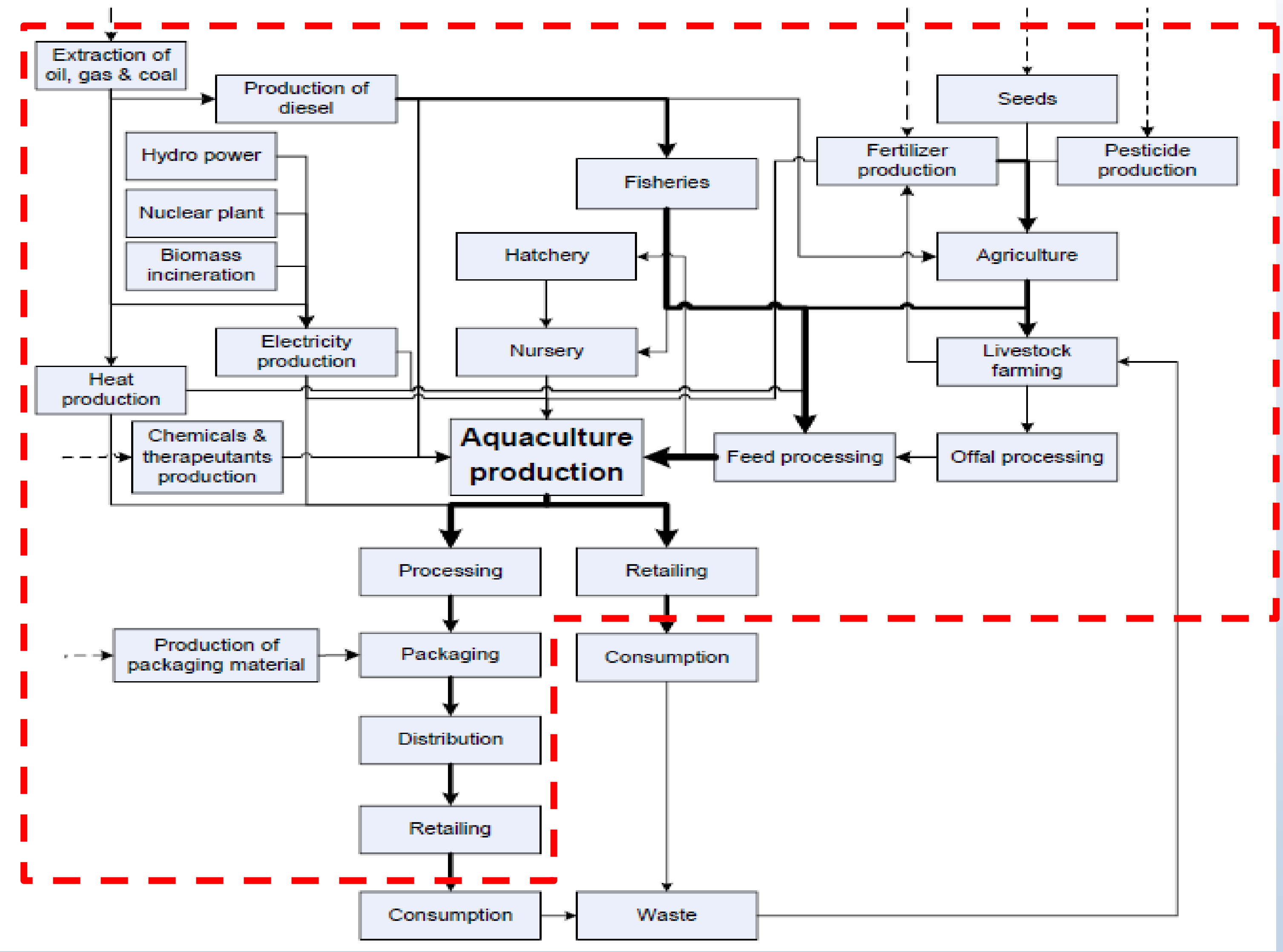
Study aim

- Indian major carps, Nile tilapia and striped catfish are very popular fish for farming in Asia
- Relatively little is known about GHG emissions in their production and distribution
- FAO commissioned an initial study on the subject
- Study where and how GHG emissions arise along selected value chains
- Highlight areas where improvements can be made
- Highlight areas where insufficient information is available and more in-depth studies are required

Study scope

- Review of previous studies showed that EI (emissions intensity) was likely to be affected by:
  - Feed raw material production
    - Type of material
    - Efficiency of crop production
    - Previous land use
    - Origin
  - Raw material processing and transport
    - Energy use
  - Feed production and transport to farm
    - Energy use and process efficiencies
  - Fish rearing
    - Efficiencies of farming and feed
  - Transport to market and processing
    - Energy and processing yields

Study scope



Extraction of oil, gas & coal
Production of diesel
Hydro power
Nuclear plant
Biomass incineration
Electricity production
Heat production
Chemicals & therapeutants production
Fisheries
Hatchery
Nursery
Aquaculture production
Seeds
Fertilizer production
Pesticide production
Agriculture
Livestock farming
Feed processing
Offal processing
Processing
Retailing
Production of packaging material
Packaging
Distribution
Retailing
Consumption
Consumption
Waste

Study systems

- Bangladesh:
  - Nile tilapia (*Oreochromis niloticus*)
    - Rapidly growing industry: 123 712 and 209 605 tonnes respectively in 2012 and 2013
    - Changing from small-scale, home based
- India:
  - Indian major carps (mainly *Catla catla* and *Labeo rohita*)
    - Large production: 3.26 and 3.40 million tonnes respectively in 2012 and 2013
    - Farming at low density, but changing feed source
- Viet Nam:
  - Striped catfish (*Pangasianadon hypophthalmus*)
    - Rapid growth of production: 1.18 and 1.15 million tonnes respectively in 2012 and 2013
    - Farming at high density with commercial feeds

***Source* : FAO (2015)**

Methodology

- One project member was identified in each country
- Questionnaires developed for 3 stages:
  - Feed production
  - Farming
  - Processing and transport to market

	Bangladesh	India	Vietnam
Commercial Feed	5	6	5
Farm-made Feed	4	4	0
Farms	10	12	10
Market	10	12	10

Questionnaires

- Feeds (commercial or farm-made):
  - Raw materials and logistics
  - Formulations, energy use and packing
  - Feed logistics: method and distance
- Fish
  - Species
  - Farming method
  - Pond details
  - Production details
  - Energy use
- Market
  - Processing? Energy and packaging
  - Logistics

Fish Farm Questionairre: Please fill in the white boxes

Interview Date

FFQ1: Farm Details

1.1	Species (proportions if more than one)	
1.2	Farm location (eg address or GPS co-ordinates)	
1.3	Farm size (land and water area)	

FFQ2: Farming Method

2.1	Pond	
2.2	Cage in pond	
2.3	Cage in river	
2.4	Cage in lake	

Notes

FFQ3: Pond Details

3.1	If ponds - area of ponds (m2)	
3.2	When were ponds setup?	
3.3	What was previous land use?	
3.4	Are manures used? How much?	
3.5.1	Manure type 1	
3.5.2	Manure type 2	
3.5.3	Manure type 3	

Notes

Please note manure type and amount used/yr

FFQ4: Production Details

4.1	Fingerling size at input (g)	
4.2	Fish size at harvest (g)	
4.3	Minimum FCR	
4.4	Average FCR	
4.5	Maximum FCR	
4.6	Average Survival	
4.7	Average grow-out time	
4.8	Total harvest per year (t)	
4.9	Total feed per year (t)	

Notes

FFQ5: Energy use

5.1	Are machines used?	
5.2	Diesel (litres/t fish)	
5.3	Petrol (litres / t fish)	
5.4	Electricity (kW / t fish)	

Notes

Please note uses of energy and splits
eg pumping, lighting, etc.

FFQ6: Feed Type

6.1	Farm-made (%)	
6.2	Commercial (%)	
6.3	Name of Commercial Feed Mills	
6.4	Pond fertiliser (kg)	
6.5	Mash (%)	
6.6	Moist pellet (%)	
6.7	Sinking presseed pellet (%)	
6.8	Extruded pellet (%)	
6.9	Extruded floating pellet (%)	

Notes

If commercial, what are feed names?
If farm-made feed, fill in raw materials sheet

Notes

Survey results

- Surveys conducted May to September 2014
  - Feed: 4 232 data points
  - Farms: 2 471 data points

- The survey was limited:
  - Small scale to get an impression for each country
    - 5 feed factories
    - 10 farms
    - 10 markets
  - Highlight where data is weak or missing
  - Further studies are required

Bangladesh

Bangladesh: Nile tilapia

- Feeds:
  - Use of farm made feed is declining, but still popular
    - Farmers using a mix of up to 10 materials
  - Commercial feeds much more available
    - Mills are large and sell through middlemen
    - Mix of domestic and imported materials
- Farms:
  - Dhaka, Khulna and Sylhet Divisions
  - Typically small-scale in the survey, 1 to 6 ponds
  - 0.6 to 13 ha total water area
  - Fertilisers or manures added in some farms
  - Stocking densities are low and polyculture common
  - Grown to 300-400g in 6 months
- Markets
  - Mainly local, sold whole
  - May be sold in a local market and then on to Dhaka

India

India: Indian major carps

- Feeds:
  - All farms used commercial feeds – 4 used home made also
  - Large feed mills
  - Almost all Indian raw materials
- Farms:
  - Survey only in Andhra Pradesh – major state for Indian major carps
  - Rohu (90%) and catla (10%) polyculture
  - Mainly single pond, 3 to 18 ha – a 60 ha farm had 5 ponds
  - Fertilisers and manures used by all farms
  - Harvest after 180 to 300 days:
    - Rohu at 1-2 kg
    - Catla at 3 kg
- Markets:
  - Local markets initially, by truck
  - On-selling to Howrah, Siliguri or Kolkata
  - Sold whole, packed on ice

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Viet Nam

Viet Nam: striped catfish

- Feeds:
  - Farm-made feeds barely used (none in survey)
  - Commercial feeds widely available from small to big mills
  - Often sold through middleman
  - Raw materials mix of domestic and imported
- Farms:
  - All based in Mekong Delta
  - Monoculture of fish to 800-1 000 g at harvest
  - Intensive growth for 190 – 240 days
  - Farm size 2.5 – 7 ha total water area, with 3 to 8 ponds
  - No manures or fertilizers used
- Markets:
  - Fish taken by boat to processing factory
  - Mainly filleted, but some gutted or even sold whole
  - Very few sold locally – mainly downgrades
  - Global export of frozen product by sea freight in containers

Feed use

- Use of commercial feeds increasing
- More mills making it more available
- Easier for farmers to buy complete feeds
- Bangladesh and India using a mix of commercial and farm-made feeds in some farms
- Only a small number of farms used farm-made feed solely

	Bangladesh	India	Viet Nam
Number surveyed	10	12	10
Mash	0	25%	0
Moist pellet	0	0	0
Steam pellet (sinking)	70%	17%	0
Extruded pellet (floating)	60%	83%	100%

Feeds overview: raw materials

- Farmers making home-made feeds generally knew little about the source of raw materials
  - Bought through traders
- Commercial feed mills could provide reasonable details
  - Allowed good modelling estimates for commercial feeds

Feed overview: raw materials used

Protein sources		Carbohydrate sources		Micro-ingredients	
Material	**Country**	**Material**	**Country**	**Material**	**Country**
Fish trimmings meal	V	**Cassava**	V	**Salt**	V
Fishmeal	B, I	**Molasses**	B	**Premix**	V
Dry fish	B	**Maize**	B, I		
Meat and bone meal	B, I, V	**Rice bran**	B, I, V		
Poultry meal	B, I	**Wheat products**	B, V		
Blood meal	V	**Broken rice**	I		
Single cell protein	B	**Rice polishings**	B		
Soybean	B, I, V				
Canola meal	V				
Rapeseed meal	B, I				
Copra meal	V				
Cottonseed meal	I	Lipid sources			
Groundnut oil cake	I	**Material**	**Country**		
Guar meal	B	**Fish oil**	I		
Mustard oil cake	B	**Poultry fat**	I		
Maize gluten	I				
DDGS	I, V				

Feeds overview: raw material sources

- For commercial feeds only – not enough data for farm-made feeds
- Bangladesh:
  - Some raw materials sourced domestically
  - High quality protein imported (fishmeal and meat & bone meal)
  - Plant meals – domestically produced or imported from India
  - Carbohydrates – domestically produced
- India:
  - All materials sourced domestically
  - Mainly from outside Andhra Pradesh
- Viet Nam:
  - Protein sources all imported, except fishmeal
  - Carbohydrate sources all domestic, except wheat

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Feed overview: nutrient balance

- Nile tilapia: low in total protein and energy, but ratio balanced

Fish size (g)	Crude protein (%)	Digestible protein (%)	GE (MJ/kg)	DE (MJ/kg)	D/DE (g/MJ)
1 - 25	30.7 - 34.6	25.0 - 29.7	16.1 - 17.5	10.6 - 11.7	22.5 - 25.5
25 - 50	28.7 - 30.4	22.9 - 26.0	16.2 - 16.9	10.3 - 10.7	22.1 - 24.3
50 - 100	25.1 - 30.4	19.5 - 24.7	16.1 - 16.7	9.3 - 10.5	21.1 - 23.6
100 to harvest	25.1 - 29.0	19.0 - 23.4	16.1 - 16.6	9.0 - 10.5	21.1 - 22.2

- Major carps: very low total protein and energy, only some balanced

<50	26.8 - 31.3	21.6 - 26.1	16.2 - 18.9	10.2 - 12.9	17.9 - 25.9
50 - 100	25.0 - 31.3	18.1 - 26.1	16.1 - 18.9	8.8 - 12.9	17.9 - 26.9
100 - harvest	23.0 - 28.6	16.0 - 23.1	16.1 - 18.2	7.8 - 11.9	18.9 - 25.3

- Striped catfish: low total protein and too much energy

25 - harvest	24.3 - 27.7	19.7 - 23.1	16.2 - 16.9	10.0 - 11.2	19.8 - 21.7

Farms: production data

	Bangladesh	India		Vietnam
Species	Nile tilapia	Rohu	Catla	Striped Catfish
Stocking weight (g)	15 (1 – 50)	160 (50 – 300)	210 (50 – 600)	27 (20 – 30)
Harvest weight (g)	310 (180 – 750)	1240 (1000 – 2000)	2340 (1350 – 3000)	880 (750 – 1020)
Harvest/year (tonnes)	52 (10 – 300)	135 (22 – 700)		1480 (1125 – 2160)
Harvest per area of water (kg/m²)	1.930 (0.367 – 3.529)	0.995 (0.777 – 1.571)		34.9 (22.3 – 60.0)
Grow out time (days)	184 (120 – 270)	230 (180 – 300)		220 (190 – 245)
eFCR	1.59 (1.10 – 2.00)	1.8 (1.0 – 5.0)		1.69 (1.57 – 1.89)
Survival (%)	88.5 (70 – 95)	98.3 (90 – 100)		80.1 (75 – 90)

Survival was estimated from numbers stocked and numbers harvested
Indian farmers did not count fish stocked, so figure is unlikely to be accurate

FCR by farm

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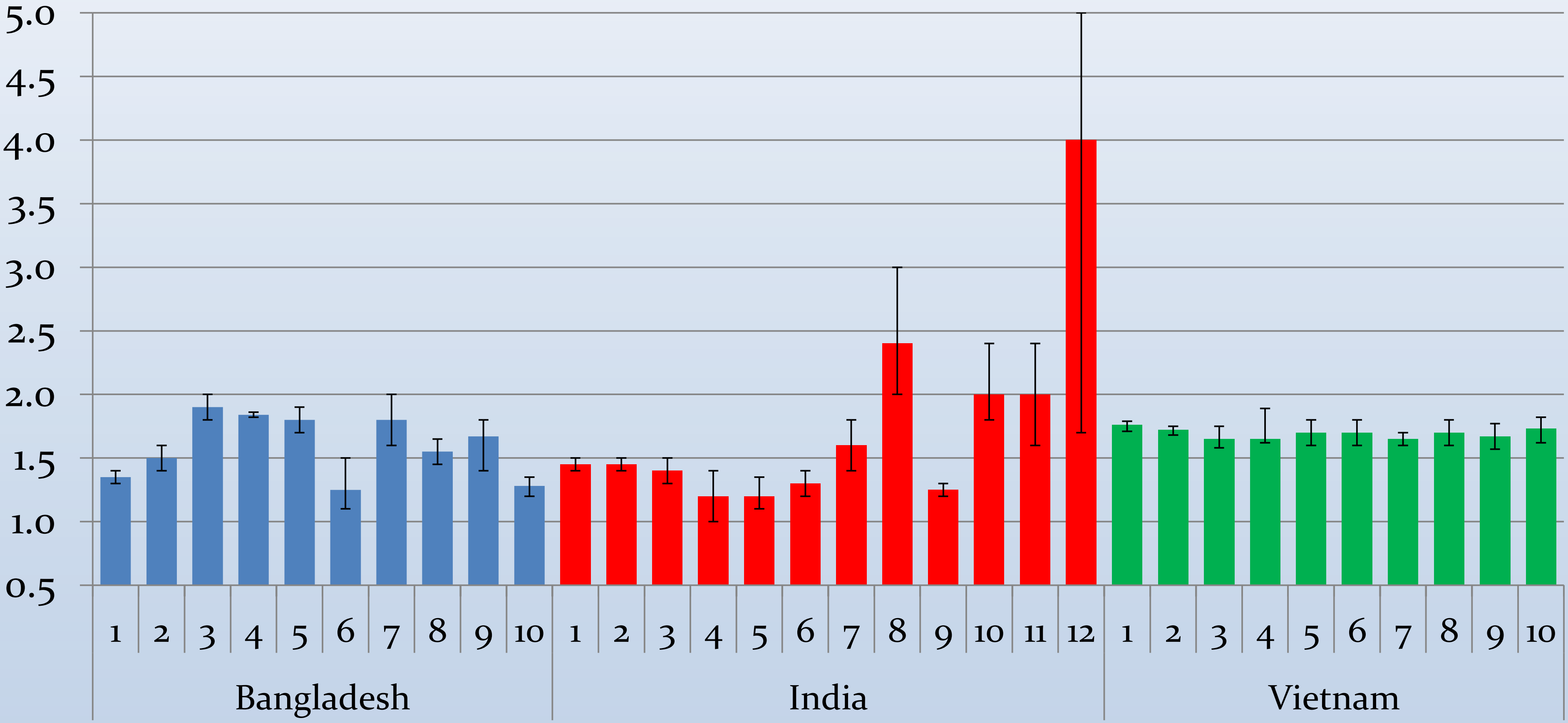
- Average, minimum and maximum reported by each farm



Farms: energy use

- Energy use per tonne of fish at harvest

	Bangladesh	India	Viet Nam
Tidal water exchange	0 /10	0 / 12	3 / 10
Diesel (l/tonne)	3 / 10 26.4 (6.4 – 36.8)	8 / 12 12.9 (0.6 – 40)	2 / 10 0.75 (0.5 – 1.0)
Petrol (l/tonne)	0 / 10	9 / 12 3.6 (0.6 – 10)	0 / 10
Electricity (kWh/tonne)	8 / 10 150 (74.3 – 360)	10 / 12 76.3 (9.5 – 150)	7 / 10 80.7 (50 – 115)

Farms: fertilizers and manures

- Not used for striped catfish in Viet Nam
- Fertilizers popular in India – only urea and TSP in Bangladesh

	Bangladesh	India	
Type	Cow dung	Cow dung	Poultry manure
Use	3 / 10	7 / 12	11 / 12
Dose (kg/m²)	0.10 (0.08 – 0.12)	0.72 (0.25 – 1.33)	0.76 (0.25 – 1.11)
Type	Urea	Urea	
Use	6 / 12	3 / 12	
Dose (g/m²)	26 (3 – 79)	21 (19 – 25)	
Type	TSP	DAP	SP
Use	5 / 12	8 / 12	9 / 12
Dose (g/m²)	13 (2 – 30)	32 (<1 – 52)	64 (<1 – 250)

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Market overview

- Bangladesh:
  - 80% sold dead, packed on ice, transported by truck
    - 20% sold live
  - Small harvest: sold locally (2 – 15 km from farm)
  - Large harvest: large markets (80 – 180 km from farm)
    - Gazipur, Tongi, Dhaka or Sylhet
- India:
  - Sold dead, whole packed on ice, transported by truck
  - Initial short journey (10 – 100 km) to assembly centre
  - Longer journey to market (1 100 – 1 425 km)
    - Howrah, Siliguri, Assam and Kolkata
- Viet Nam:
  - Taken by boat for processing (20 – 100 km journey)
  - Majority filleted, but some sold gutted or whole frozen
  - Truck to container port (80 – 220 km), then global shipping

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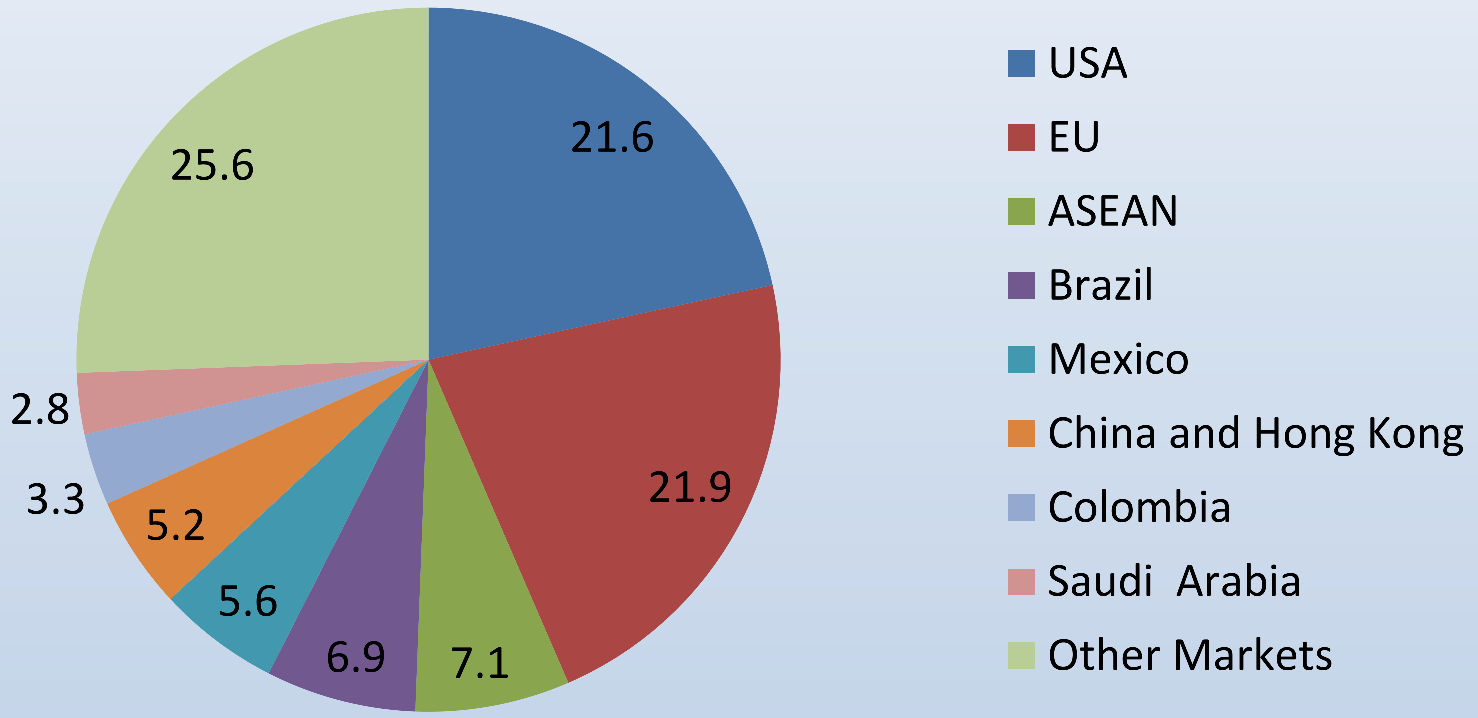
Markets

- Markets were so diverse, it was difficult to model and show useful outputs
- Especially in Viet Nam:



***Source*: VASEP (2014).**

Key multipliers of model output

- Some factors are especially important as they magnify effects

- eFCR
  - Overall efficiency of feed has a huge effect
  - Cause of inefficiencies not known from this survey
    - Poor feed?
    - Poor feed management?
    - Fish health/mortalities?
- Mortalities
  - Magnify the area of land and quantity of energy per tonne fish produced
  - Impact directly on eFCR

Possible causes of increased eFCR

- Poor nutritional targets of feed
  - Unbalanced or inappropriate nutrition
- Poor raw material quality
  - Reduced digestibility/anti-nutrients in feed
- Feed management
  - Under or over feeding
- Water quality management
  - Low oxygen and increased ammonia
- Fish health
  - Reduced appetite and digestibility
- Mortalities
  - Loss of biomass from calculations

Possible causes of mortalities

- Diseases
  - Bacterial seem to be the major issue in Viet Nam
  - Viruses will also be present
  - Parasites
- Water Quality
  - Chronic stress from low oxygen and high ammonia
  - Farmers look to reduce costs by not changing water
- Theft
  - Can occur especially near harvest size

Conclusions

- Only a small snap-shot study
- Gives indication of major changes happening
  - Much greater use of commercial feeds
  - Big variation in farming methods
  - Big variation in results
- Standardising will help reduce variation
  - Bring up performance of poorer operations
  - Reduces waste

Thank You

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Quantifying GHG emissions in aquaculture and identifying mitigation opportunities

Liberia, Costa Rica, 9– 11 November 2015

Michael MacLeod, David F.H. Robb, Mohammad R. Hasan, Doris Soto, Mohammad Mamun-Ur-Rashid, Rajendran Suresh and La Van Chung

Overview

- Explanation of the method
- Overview of the results
- Discussion of how and why GHG emissions arise in aquaculture
- Discussion of what we need to know to identify opportunities to reduce emissions.

Method overview

Initial scoping: review of the literature, identification of key emissions categories, data required to quantify them and data available >> survey design.

Feature	Description
System boundaries	Cradle to retail point
Functionality	Descriptive and static, with capacity for varying some key parameters (FCR, N_2O EF, land use change (LUC) method).
Data sources	Combination of primary data from the surveys and secondary data from a range of sources (e.g. FeedPrint, SEAT project, Feedipedia).
GHG categories included	See following slides

GHG categories: pre fish farm

Emissions from the production of crop feed materials

- N_2O from feed crop growing, except N_2O from biomass burning and biological fixation of N.
- CH_4 from flooded rice cultivation.
- CO_2 from energy use in crop production (field work and processing).
- CO_2 from land use change (LUC), but not from changes in carbon stocks from land under constant management practices.

Other emissions included

- CO_2 from the production of non-crop feeds (fishmeal, lime and synthetic amino acids), but not from cleaning agents, medicines etc.
- CO_2 from fertiliser production.
- CO_2 from energy use in feed blending.
- CO_2 from energy use in transportation of feed materials and compound feed.
- CO_2 from the manufacture of feed packaging, but not from energy used in the manufacture of on-farm buildings and equipment.

GHG categories included: on fish farm

Emissions category	Gas	Included?
Enteric fermentation	CH_4	NA
Anaerobic decomposition of organic matter (excreted volatile solids and uneaten feed)	CH_4	n
Direct and indirect N_2O from excreted N and uneaten feed	N_2O	y
Emissions arising from direct fertilisation of pond	N_2O	y
N_2O from the animal	N_2O	n
Direct on-farm energy use for pumping and lighting etc.	CO_2	y
LUC arising from pond construction	CO_2	n
Pond cleaning and maintenance	CO_2	n
CO_2 sequestered in carbonates	CO_2	n
CO_2 sequestered in pond sediments	CO_2	n

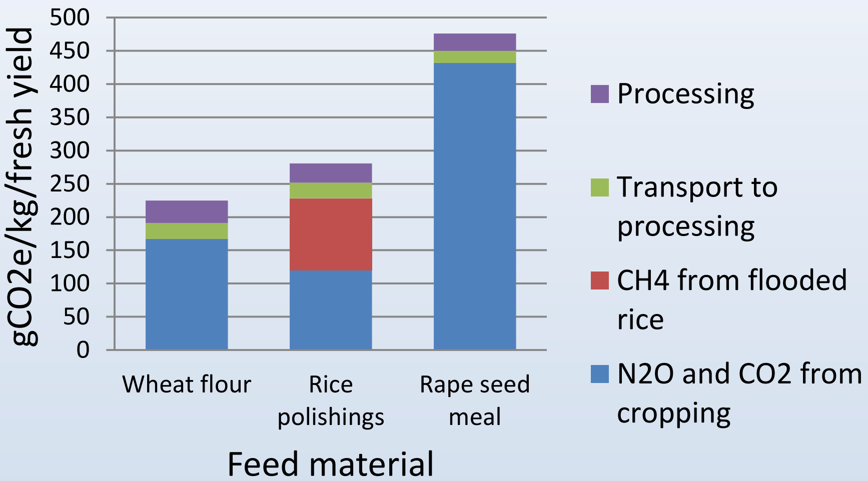
GHG categories included: post fish farm

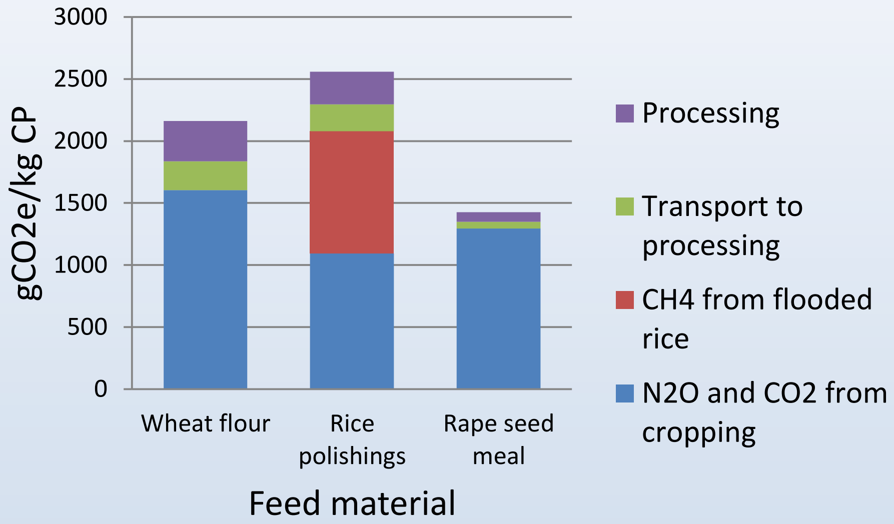
Emissions category	Gas	Included?
Transport of live striped catfish to processing	CO_2	y
Transport of striped catfish fillets from processing to place of export	CO_2, HCFCs(?)	y
Shipping of striped catfish fillets from Viet Nam to point of entry into importing country	CO_2, HCFCs (?)	y
Transport of whole dead tilapia/carp from farm to wholesale	CO_2	y
Transport of whole dead tilapia/carp from wholesale to retail	CO_2	y
Primary processing (including chilling) of striped catfish	CO_2 , HCFCs	y
On-site waste water treatment	CO_2, CH_4	n
Emissions from animal waste or avoided emissions from on-site energy generation from waste	CO_2, CH_4	n
Emissions related to co-products e.g. rendering material, offal, hides and skin	CO_2, CH_4	n
Manufacture of packaging	CO_2	y
Retail refrigerant and energy use	CO_2, HCFCS	n
Retail losses and waste disposal	CO_2	n
Post-retail energy use	CO_2	n
Post-retail losses and waste disposal	CO_2, CH_4	n

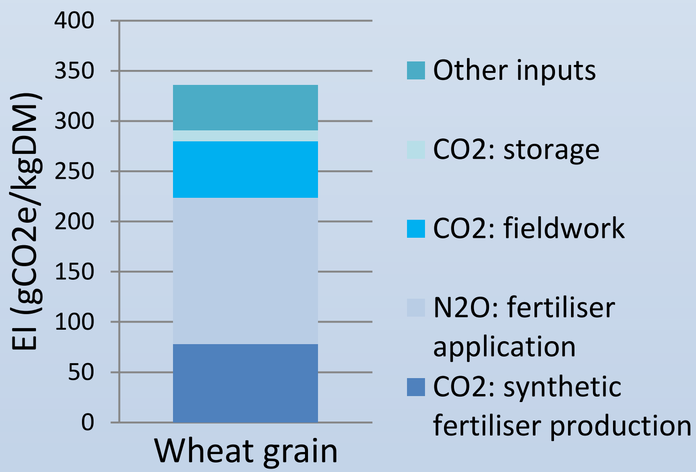
Feed emissions method– key points

- Ration composition: derived from the feed mill surveys.
- Emissions from the production of feed materials: used FeedPrint augmented with other sources to fill data gaps.
- Emissions arising from land use change: used six different approaches.
- Emissions from transporting feed materials, blending and producing packaging: based on feed mills surveys and default emissions factors.
- FCRs: derived from farm surveys.

Crop feed materials emissions intensity (EI)







- Feed material EI depends on efficiency of cultivation > yields, nutrient use efficiency, tillage regime, equipment type and use etc.
- Functional unit affects the EI.
- Different crops can have quite different emissions profiles, e.g. rice products: CH_4, soy products: CO_2 from LUC.

Emissions from feed transport and milling

- Survey provided information on:
  - Feed material country of origin.
  - Feed transport mode and distance within Viet Nam, India and Bangladesh.
  - Rates of energy use and fuel types within feed mills.
  - Feed transport distance and mode from mill to farm.
- Transport emission factors (EFs) derived from literature and expert opinion, but somewhat uncertain.
- Place of production to feed mill
  - Emissions vary reflecting the greater reliance on imports in Viet Nam (soy from United States and Argentina), and Bangladesh (soy from USA, meat and bone meal from the EU).
- Mill to farm
  - India: shorter transport distances.
  - Viet Nam: longer distances but use of boats lowers emissions.
- Feed mill energy use
  - Depends on factors such as the types of feed materials and energy sources. India and Viet Nam have higher rates of energy use per kg of feed produced, but this is offset by their use of biomass energy.

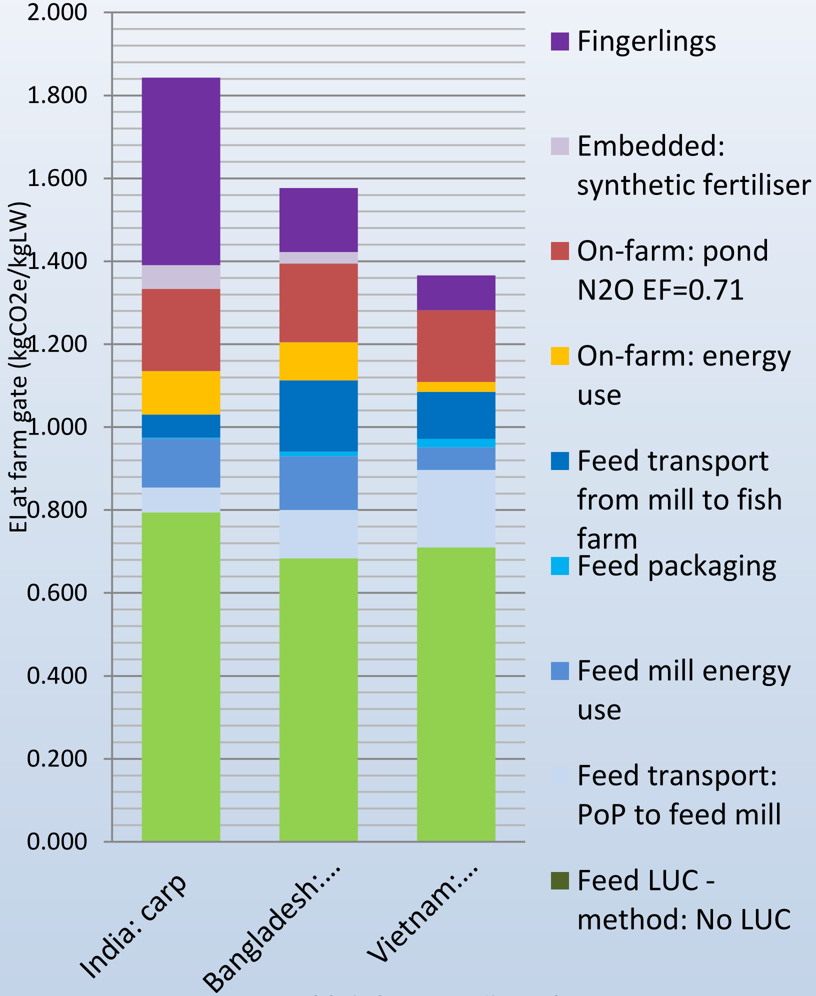
On fish farm N_2O and CO_2 methods

- **Pond N_2O**: Hu *et al.* (2012) "nitrification and denitrification processes are influenced by many parameters (dissolved oxygen concentration, pH, temperature, etc.), the N_2O emission from different aquaculture systems could vary greatly, depending on the environmental conditions.". In order to (partly) reflect this variation, two rates of conversion of N to N_2O were used:
  - 0.71% (based Henriksson *et al.*, 2014a)
  - 1.8% (based on Hu *et al.*, 2012)
- Rates of N excretion calculated based on the following assumptions:

Parameter	Value	Basis
% of manure N taken up by algae etc.	25%	Assumption
% of synthetic N taken up by algae etc.	25%	Assumption
% of algae N ingested by fish	95%	Assumption
% of feed N ingested by fish	95%	Hu *et al* (2012, figure 1)
% of ingested N retained	23%	Hu *et al* (2012)

- **CO_2 from on-farm energy**: based on energy consumption rates and fuel types reported in the farm survey.
- **Carbon sequestration in pond sediments** was omitted: there is a lack of consensus on the rates of carbon sequestration and the permanence of the carbon storage.

Emissions intensity from cradle to farm gate – not including land use change



Emissions intensity of fish from cradle to farm gate (PoP: place of feed material production)

- Production of feed materials is the biggest source of emissions in all 3 systems.
- Feed emissions are a function of the feed EI and the FCR.

	B'desh tilapia	India carp (pellet)	Viet Nam str. catfish
Fish EI at farm gate ($kgCO_2e/kgLW$)	1.58	1.84	1.37
FCR (kg IN (as fed)/kg fish LW out)	1.59	1.47	1.69
FCR (kg IN (DM)/kg fish LW out)	1.43	1.32	1.52
Feed material production EI (NO LUC) ($kgCO_2e/kgDM$)	0.51	0.68	0.49
Feed material production EI (NO LUC) ($kgCO_2e/kgLW$)	0.68	0.79	0.71

- Carp rations have high amounts of high EI grains.
- Viet Nam catfish rations contain less fish products.
- Viet Nam catfish rations also have more lower EI animal by-products and cassava.

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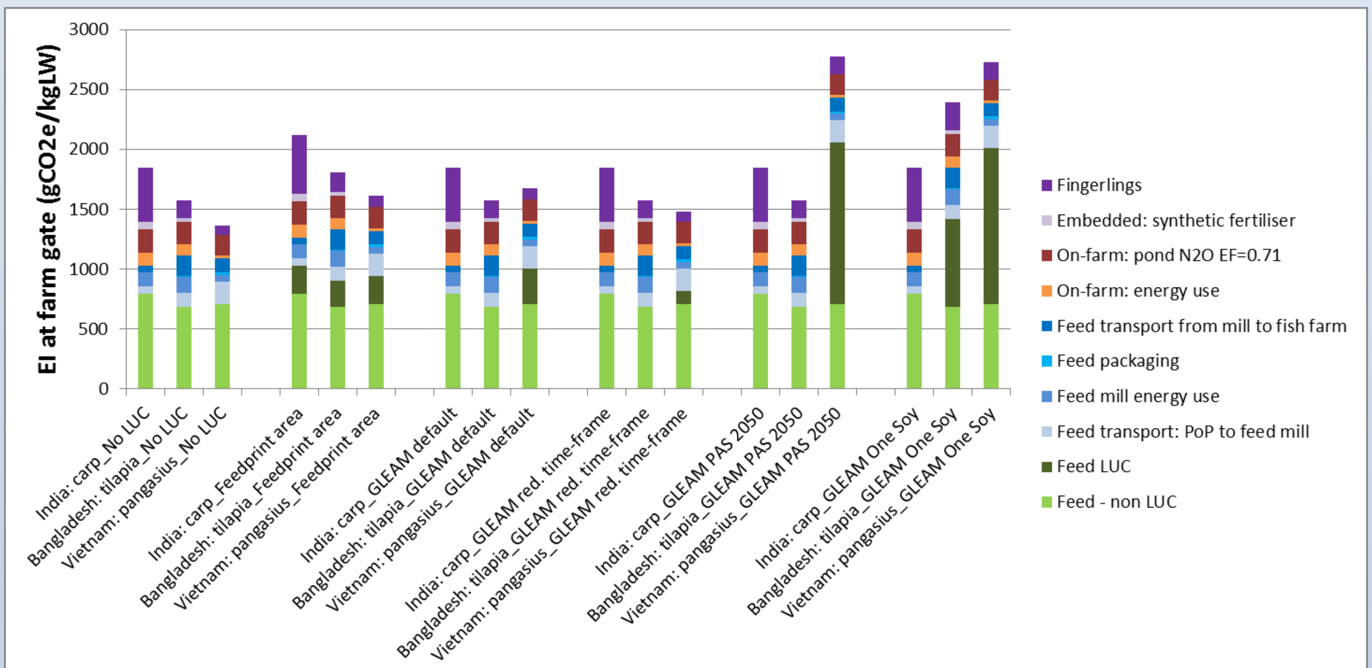
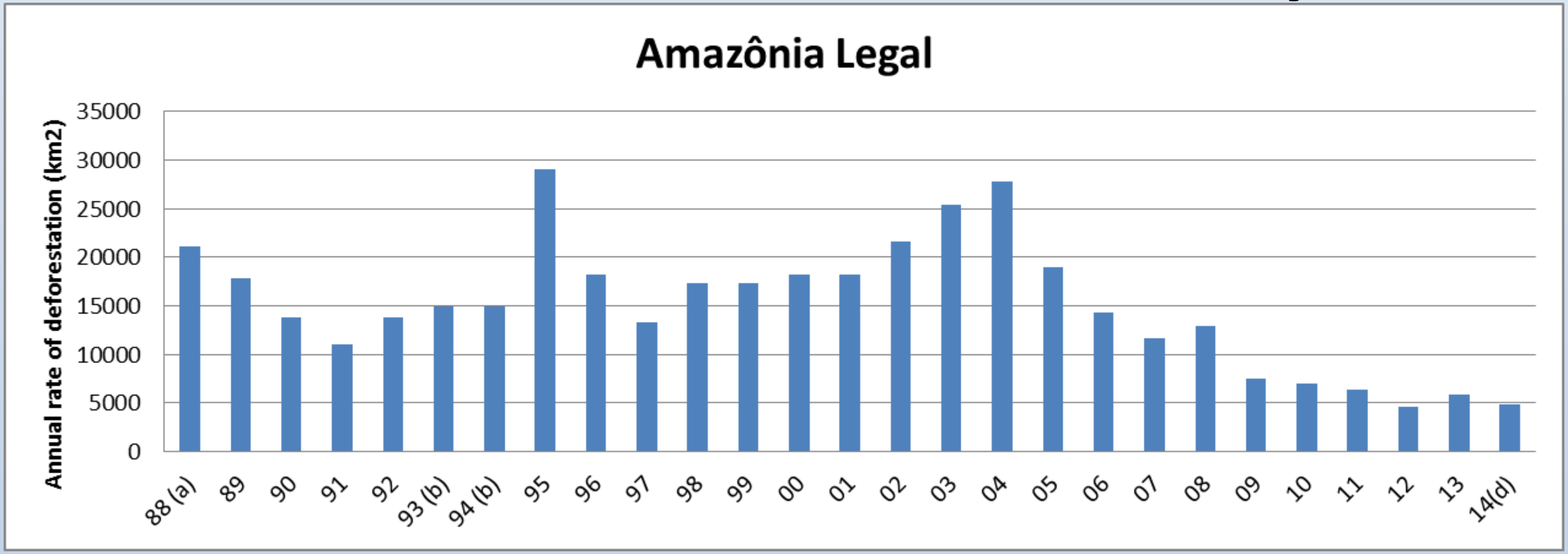
Effect of land use change method on emissions intensity

Method	Summary
1. Feedprint area	Total agricultural LUC emissions are allocated to all crops (not just soy).
2. GLEAM default	LUC emissions in Brazil and Argentina from 1990-2006 allocated to soy imported from Brazil and Argentina.
3. GLEAM reduced time-frame	As above, but for the period 2002-07.
4. GLEAM PAS 2050	As with 1-3, allocates LUC to soy grown within a country, but uses a different approach to determining rates and drivers of LUC.
5. GLEAM One Soy	Allocates all LUC arising from soy to all traded soy.



Effect of land use change method on emissions intensity

- The method used to quantify and allocate LUC emissions can have a strong influence on the EI.
- LUC emissions are time sensitive – rates of deforestation. have decreased over the last 10 years.



Data source for figures: http://www.obt.inpe.br/prodes/index.php

Comparison with other studies

Feed emissions intensity

Study	Species	Feed EI (kgCO$_2$e/kg feed (DM) at fish farm)					
	LUC method:	a	b	c	d	e	f
This study	India carp (pellet fed)	0.89	1.09	0.89	0.89	0.89	0.89
This study	Bangladesh tilapia	0.82	0.99	0.82	0.82	0.82	1.37
This study	Viet Nam striped catfish	0.74	0.90	0.94	0.82	1.66	1.63
Bosma *et al* (2011)	Catfish	0.98 to 2.55					
Pelletier &Tyedmers (2010)	Tilapia	0.79					

Fish emissions intensity

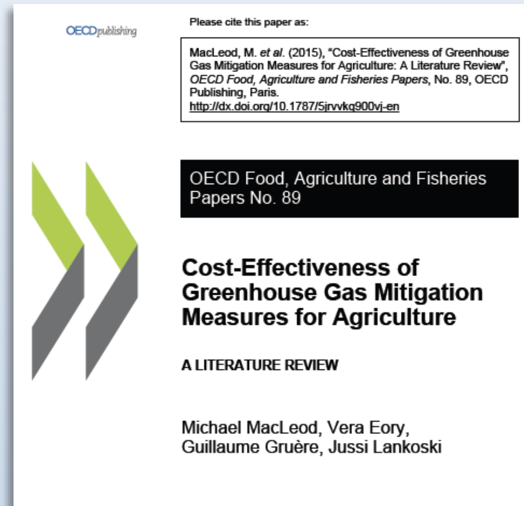
Study	Species	System	Country	EI	Units
This study	IMC	Pond	India	1.84	Note 3
This study	Tilapia	Pond	Bangladesh	1.58	Note 3
This study	Striped catfish	Pond	Viet Nam	1.37	Note 3
Bosma *et al.* (2009) (1)	Striped catfish	Pond	Viet Nam	8.93	Note 3
Bosma *et al.* (2009) (2)	Striped catfish	Pond	Viet Nam	2.85	Note 3
Pelletier and Tyedmers (2010)	Tilapia	Lake	Indonesia	1.52	Note 3
Pelletier and Tyedmers (2010)	Tilapia	Pond	Indonesia	2.10	Note 3
Henriksson *et al.* (2014a)	Tilapia	Pond	Thailand	10.35	Note 4
Henriksson *et al.* (2014a)	Striped catfish	Pond - small	Viet Nam	8.02	Note 4
Henriksson *et al.* (2014a)	Striped catfish	Pond - med	Viet Nam	7.88	Note 4
Henriksson *et al.* (2014a)	Striped catfish	Pond - large	Viet Nam	6.88	Note 4

Notes: 1 average ration; 2 low EI ration; 3 kgCO2e/kgLW at farm gate; 4 kgCO2e/kg frozen fillet at point of import to EU

So, now we know the EI, how do we reduce it?

- The importance of feed emissions means that the EI per t of fish is strongly influenced by:
  - the way in which feed materials are produced
  - the composition of the ration
  - feed conversion efficiency.
- There are many ways in which the EI of crop feed materials can be reduced during and after crop production (reducing storage losses etc.).

OECD report
http://dx.doi.org/10.1787/5jrvvkq900vj-en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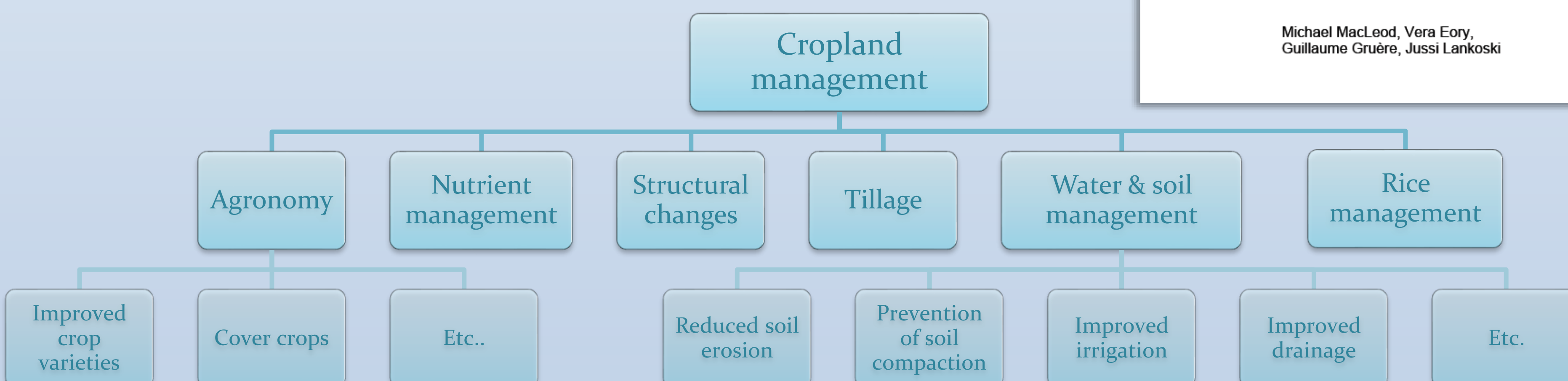
http://dx.doi.org/10.1787/5jrvvkq900vj-en

OECD Food, Agriculture and Fisheries Papers No. 89

Cost-Effectiveness of Greenhouse Gas Mitigation Measures for Agriculture

A LITERATURE REVIEW

Michael MacLeod, Vera Eory, Guillaume Gruère, Jussi Lankoski



Potential mitigation measures

- Reducing feed material EI – plenty of ways of doing this, but not easy for the aquaculture industry to influence?
- Changing ration composition – what might the effects be on fish performance, quality etc.?
- Reducing feed mill emissions – improved equipment and training; use of lower EI fuels?
- Improving feed management and FCR
  - Optimising feed – better matching feed to requirements, reducing waste, use of feed additives.
  - Feed timing, particle type etc.
  - Water quality, e.g. improved oxygenation.
- Improving fish health
- Reducing pond N2O
  - reducing surplus N: improving feed efficiency, alternative systems.
  - reducing the N > N2O conversion rate: achieving optimal pH, T, O_2 etc.

Identifying suitable mitigation measures

Does it work in theory?

- What effect does the measure have on emissions and production?
- How does its effect vary (e.g. between countries, species, farm types)?
- What is the certainty of the effect?
- What might the unintended consequences be?

How much could it reduce emissions by in practice?

- What is the measures applicability?
- What are the barriers to uptake?
- How amenable is it to different policies approaches?

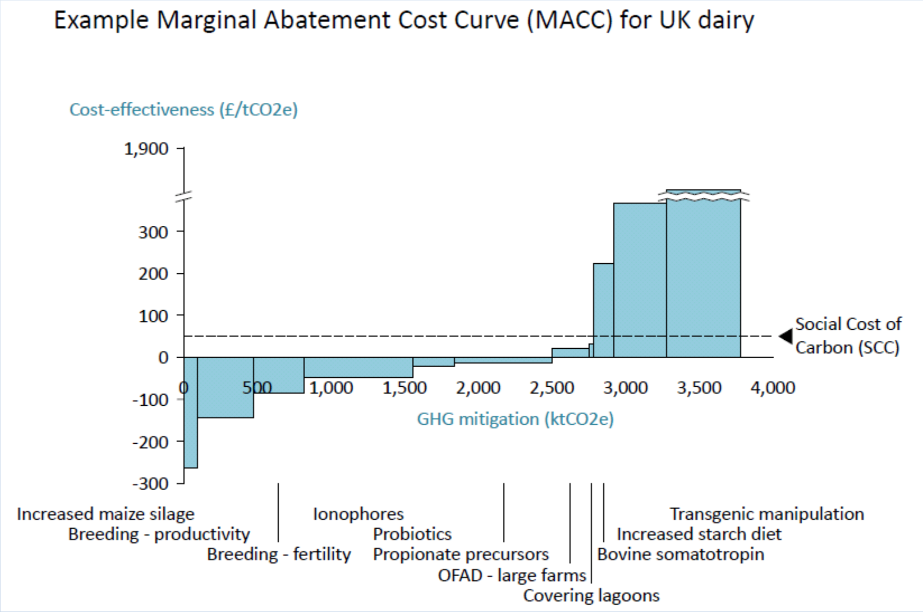
Is it economically efficient?

- Are the total economic (i.e. monetary and non- monetary) benefits of the measure greater than the total economic costs?
- Is the measure cost-effective, i.e. does it achieve reduction at a lower financial cost than the social cost of carbon?

Identifying suitable mitigation measures

Marginal Abatement Cost Curves (MACCs) are a useful way of comparing measures. They tell us something about:

1. The total mitigation possible (width of the bars).
2. Cost-effectiveness (height of the bars).
3. The total cost (area of the bars).



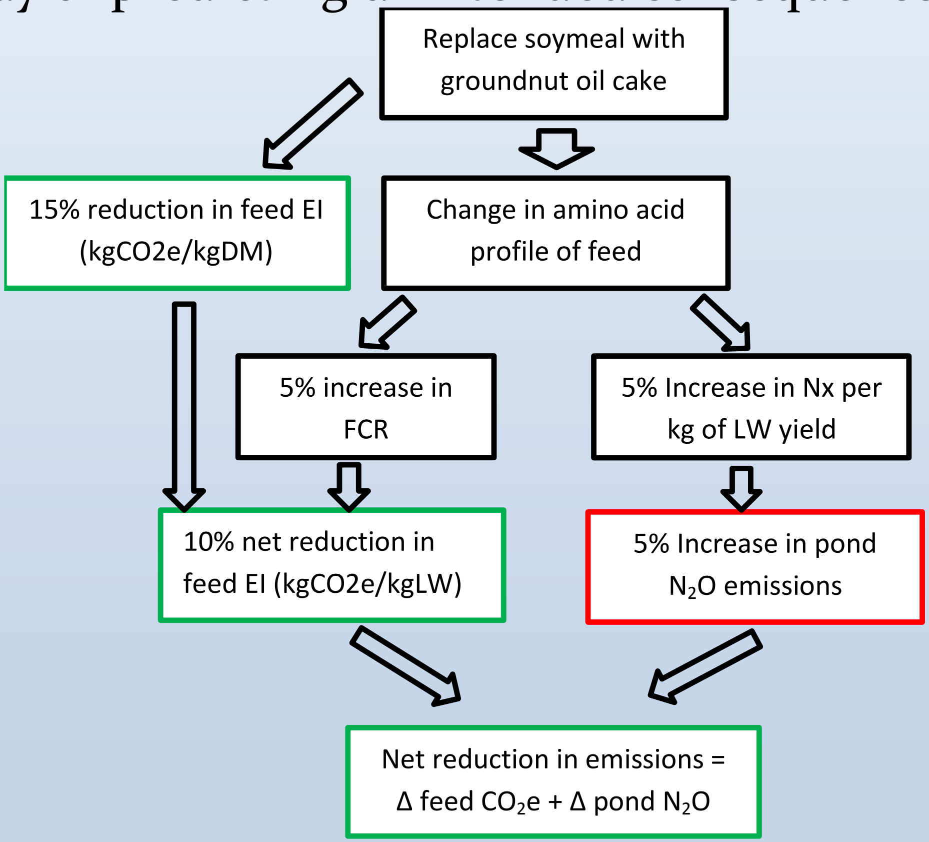
Limitations include

1. Scope: don't include all emissions or costs.
2. Heterogeneity and uncertainty: MACCs are essentially static and tend to provide a high-level snapshot of the average or typical performance.
3. Interactions: risk of double counting.

MACCs don't provide "the answer", but can make a significant contribution over time.

Evaluating mitigation measures

- In order to identify the most cost-effective (CE) mitigation measures, we need to be able to quantify the emission reductions arising from the measures and the costs of implementing them.
- Need some way of predicting unintended consequences



Evaluating mitigation measures

Three examples of the extent to which GHG mitigation measures could be captured with the current version of the model.

Mitigation measure	Could the measure be modelled with the current version of the model?
Fuel switching in feed mill	Yes – by changing the energy EF, though potential (food) displacement effects of bioenergy or induced LUC would need to be accounted for.
Changing ration composition	Potentially – provided a link can be made between ration composition and fish performance. More information on raw material prices and nutritional properties, especially digestibility, is required to optimise this.
Improved aeration	Potentially but challenging – an understanding of the relationship between [DO] and (a) fish health and performance and (b) nitrification/ denitrification processes would be required.

Conclusions

- The LCA model has a sound empirical basis (feed and farm surveys), but room for improvement in some areas.
- Overall results broadly consistent with expectations (and other studies), i.e. the main sources of emissions are:
  - Production of crop feed materials.
  - Transportation of feed materials and compound feed.
  - Energy use in feed mills.
  - N_2O from ponds.
  - Energy use on fish farms.
- Many opportunities exist for reducing the EI of aquaculture, the challenge is to identify the most cost-effective measures for a particular species/system.
- Relatively simple models, such as the one developed in this project, can provide insights into the impact of mitigation measures.

References and acknowledgements

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Priorities for expanding the emission categories included, and for refining the emissions calculation methods

Emission category	Priority for future inclusion or refinement
Feed transport from PoE/PoP to mill	Refinement of domestic road and ship EFs
Feed transport from mill to fish farm	Refinement of domestic road and ship EFs
Hatcheries/nurseries	Potentially significant – refine method
On-farm energy use	Investigate the marked difference between the energy use in this study and other studies.
Fish health and mortalities	These can have a significant influence on EI, so refine the model to reflect different health statuses
Direct and indirect N_2O from surplus N	Pond N_2O EF is important and requires further investigation
N_2O/CO_2 from the addition of (organic and synthetic) fertiliser to ponds	Improved N_2O EF Improved nutrient budgeting
LUC arising from pond construction	Complex, but should be quantified if the pond was constructed within 20 years, see BSI (2012)
C sequestration in pond sediments	Include once there is greater certainty on the net sequestration rates. Is C seq'n consistent with high health status?
Transport of live animals and products to slaughter and processing plant	Not a major source of emissions, but boat transport in Viet Nam requires clarification
Transport of fish and processed products to retail point	Refine EFs, particularly where chilled transport is used.
Retail energy use and coolants	Could make a significant impact on the emissions intensity of the consumed product due to refrigeration
Retail packaging	Packaging unlikely to be a significant source of emissions, but can influence retail and post-retail loss rates.

Thank You

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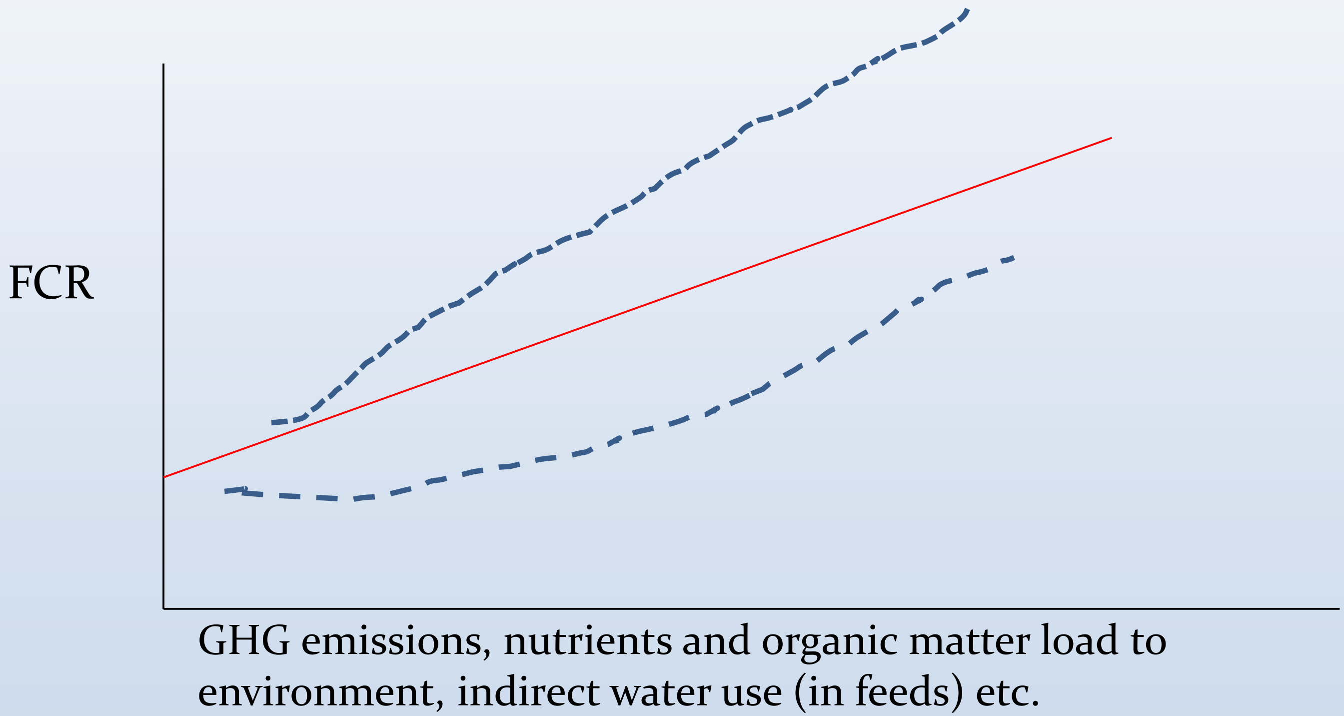
GLOBAL SALMON INITIATIVE

The role of FCR as a performance indicator

Liberia, Costa Rica, 9– 11 November 2015

Doris Soto
Fisheries and Aquaculture Department
FAO, Rome



The economic costs of these impacts are usually not considered in the equations and farm decisions

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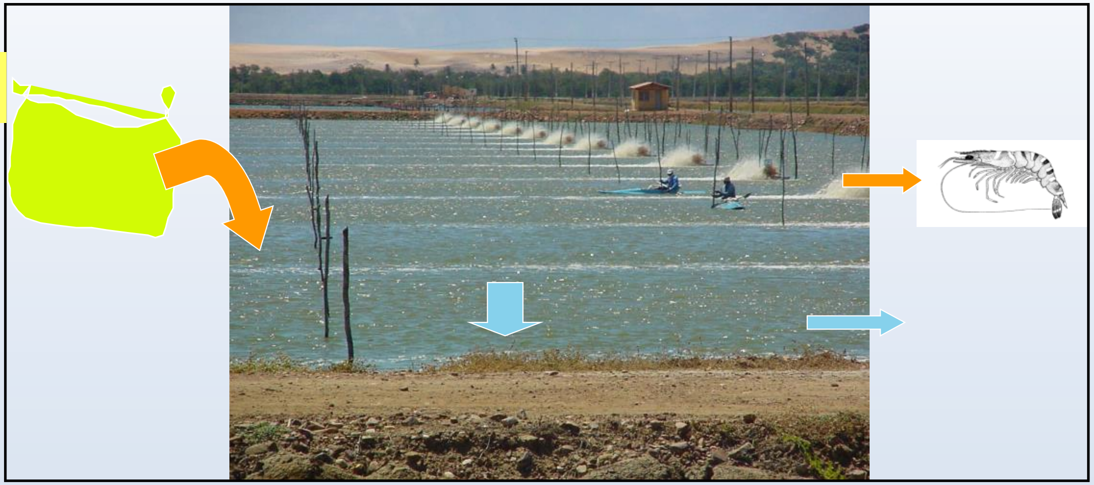
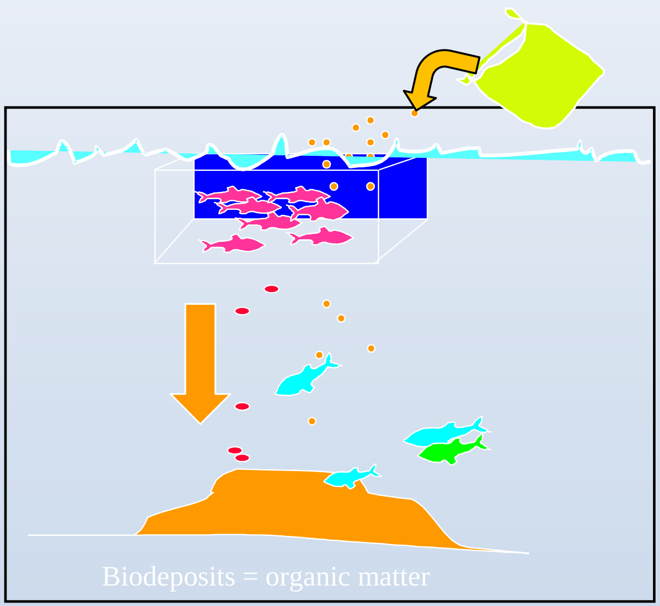
GLOBAL SALMON INITIATIVE

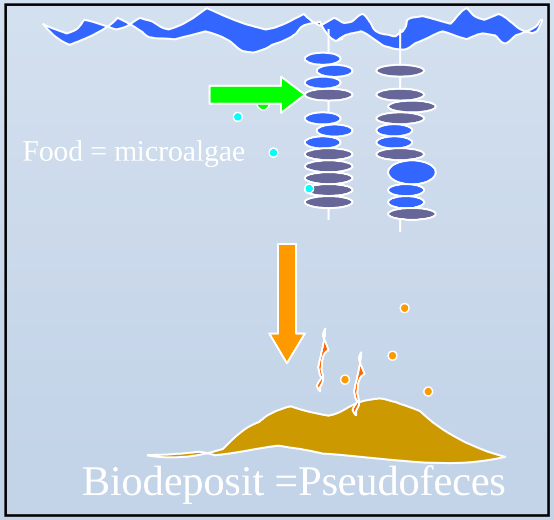
The first law of thermodynamics matters

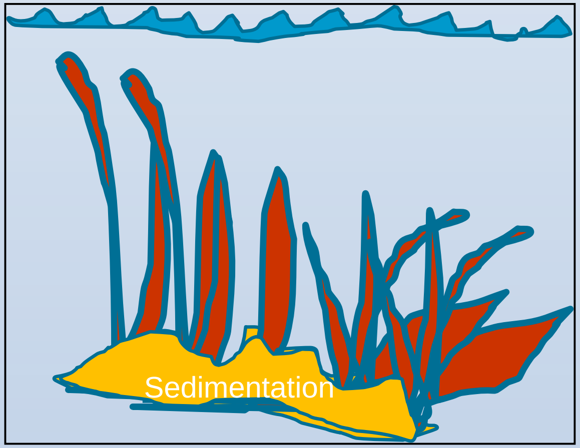
External feeds





No external feeding





Nutrients and organic matter
do not disappear, only transform

Aquaculture as a food production process
(and therefore different from fisheries)

HOW MUCH IS COMING IN (and source)
AND HOW MUCH IS GOING OUT (and where)

Organic matter
and other "wastes"

Fish biomass

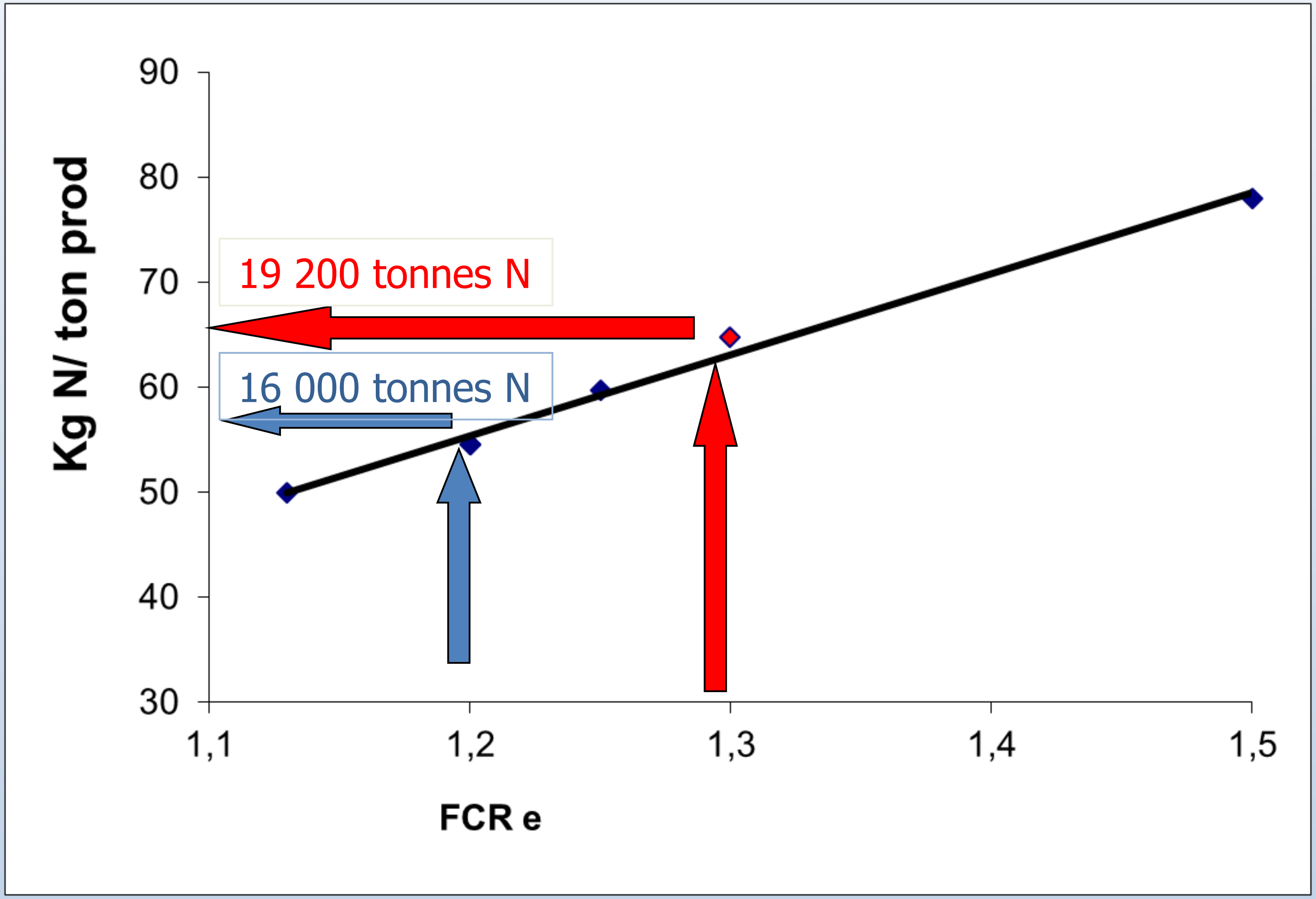
Therefore **<u>ecosystem considerations</u>** are needed from the early planning process

Aquaculture footprints in perspective

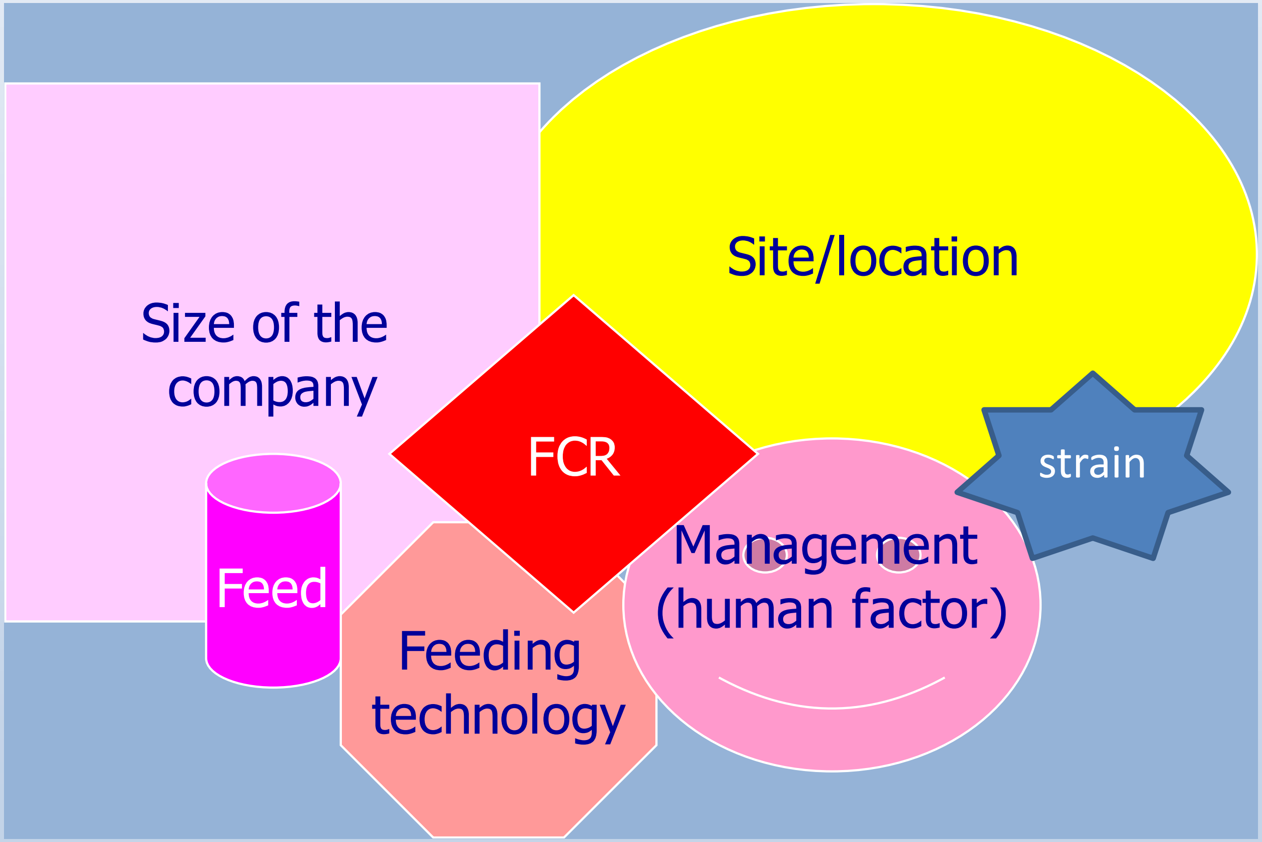
SPECIES GROUP	ECOSYSTEMS			WATER			CLIMATE
	HABITAT[a]	LAND USE (ha / t EDIBLE PROTEIN)[b]	USE OF WILD FISH IN FEED (FISH-IN / FISH-OUT RATIO)	FRESHWATER CONSUMPTION (m^3 / kg EDIBLE PROTEIN)	WATER POLLUTION (kg P / t EDIBLE PROTEIN)	WATER POLLUTION (kg N / t EDIBLE PROTEIN)	GREENHOUSE GAS INTENSITY (t CO2e / t EDIBLE PROTEIN)
Carps	F	12.0	0.2	61.4	97	329	47.2
Mollusks	M	0.0	0.0	0.0	-148	-136	11.1
Shrimps	B, F, M	16.4	0.8	4.4	104	422	161.7
Tilapias	F, B	7.5	0.7	15.9	82	349	40.7
Catfish	F	9.5	0.4	52.2	97	234	134.8
Salmonids	M, F	2.4	1.9	0.0	48	182	9.8
All six species groups							
World aquaculture	**F, M, B**	**9.1**	**0.3**	**40.4**	**76**	**273**	**66.8**
TERRESTRIAL LIVESTOCK							
Pork	T	2.0	N/A[c]	56.5	120	800	57.6
Chicken	T	3.0	N/A[c]	34.3	40	300	42.3
Beef	T	50.0–145.0	N/A[c]	112.5	180	1200	337.2

White *et al.* (2014), WRI

Role of FCR in N release



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.) and the role of management



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GSI GLOBAL SALMON INITIATIVE

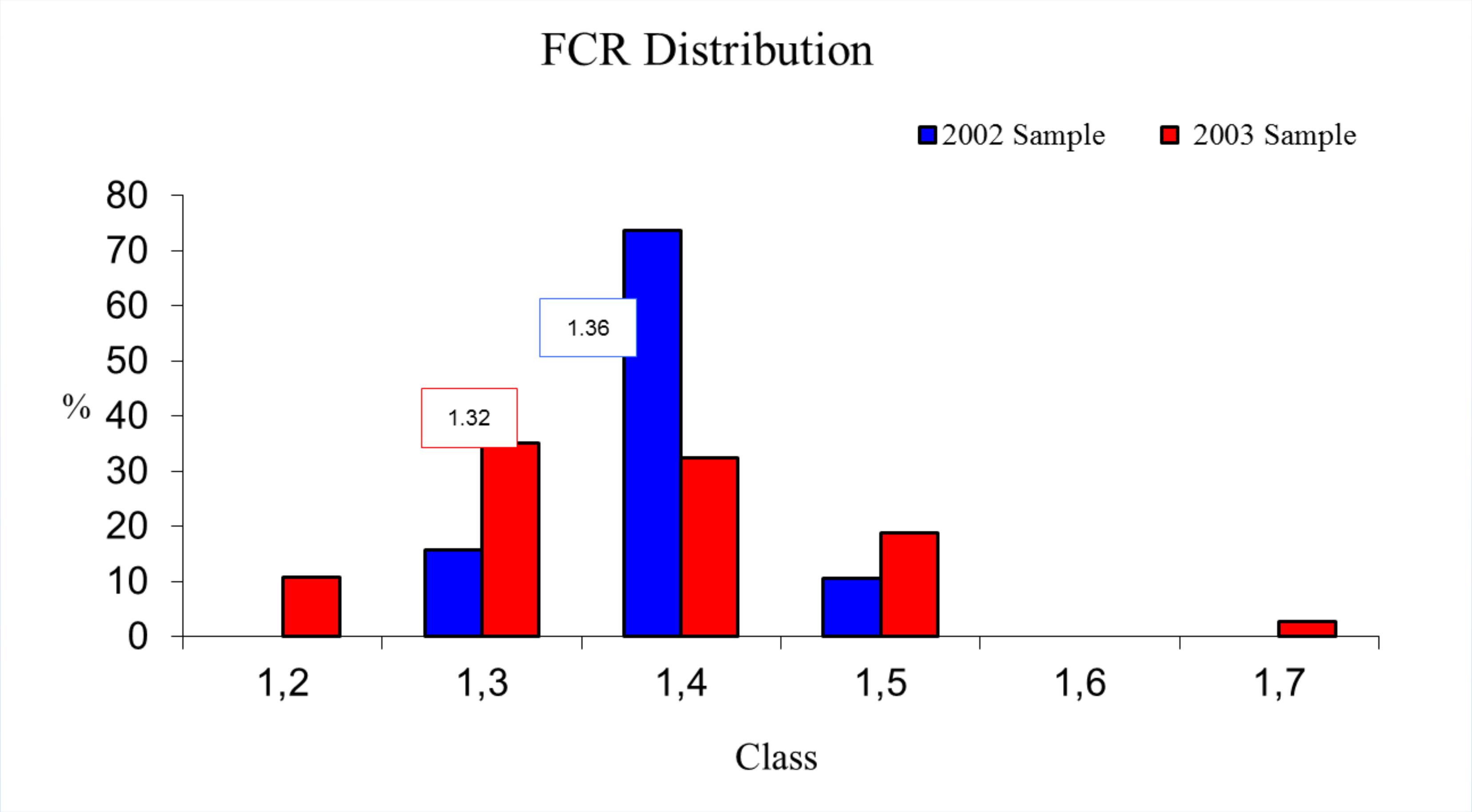
An environmental performance indicator for salmon farming companies in southern Chile

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

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 (g/month)	Culture density (fish/m^3, kg/m^3)
Mortality (%)	Size of the company (%)
Length of the cycle (months)	No of manual feeders (pers.)
Weight at harvest (kg)	Cage volume (m^3)
Net P in sediments (mg/kg)	
Physical variables	**Environmental integrated indicators**
Mean depth (m)	Environmental condition
Qualitative current (1-5)	Image

Annual production per farm in 2002 and 2003 (tonnes)



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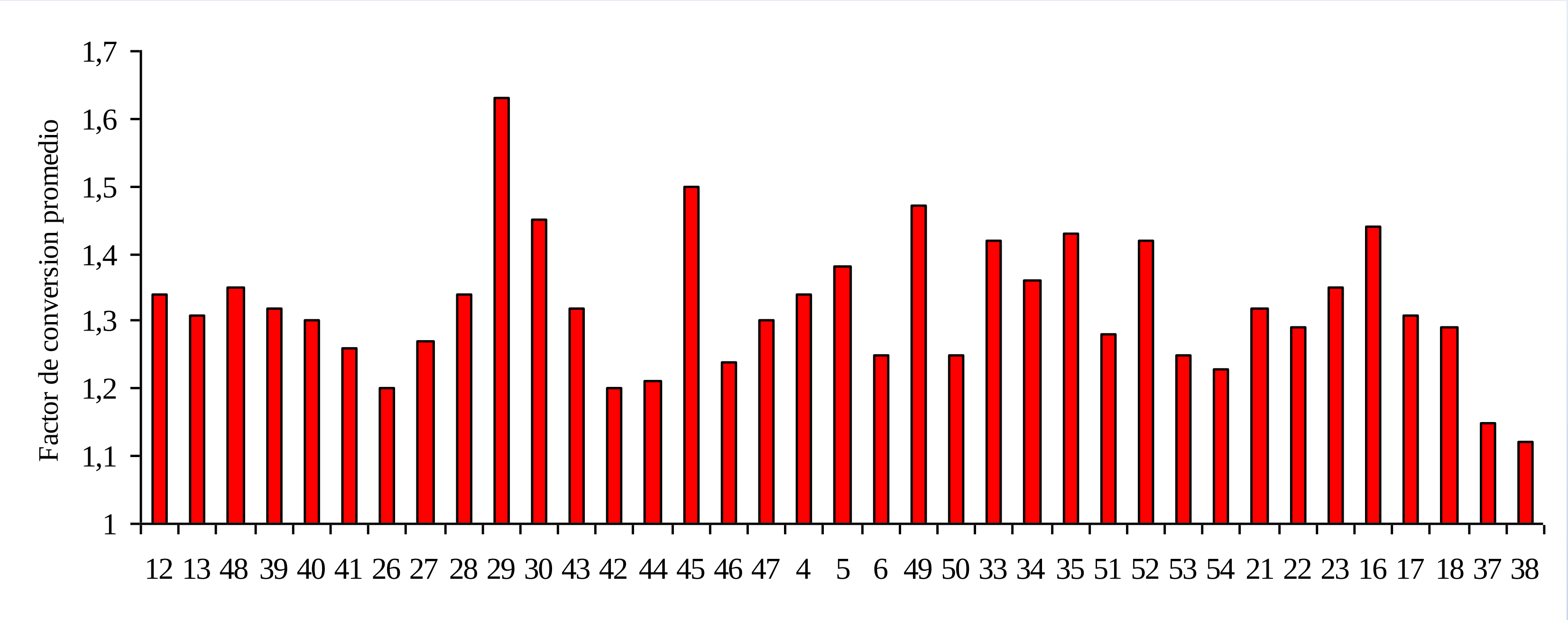
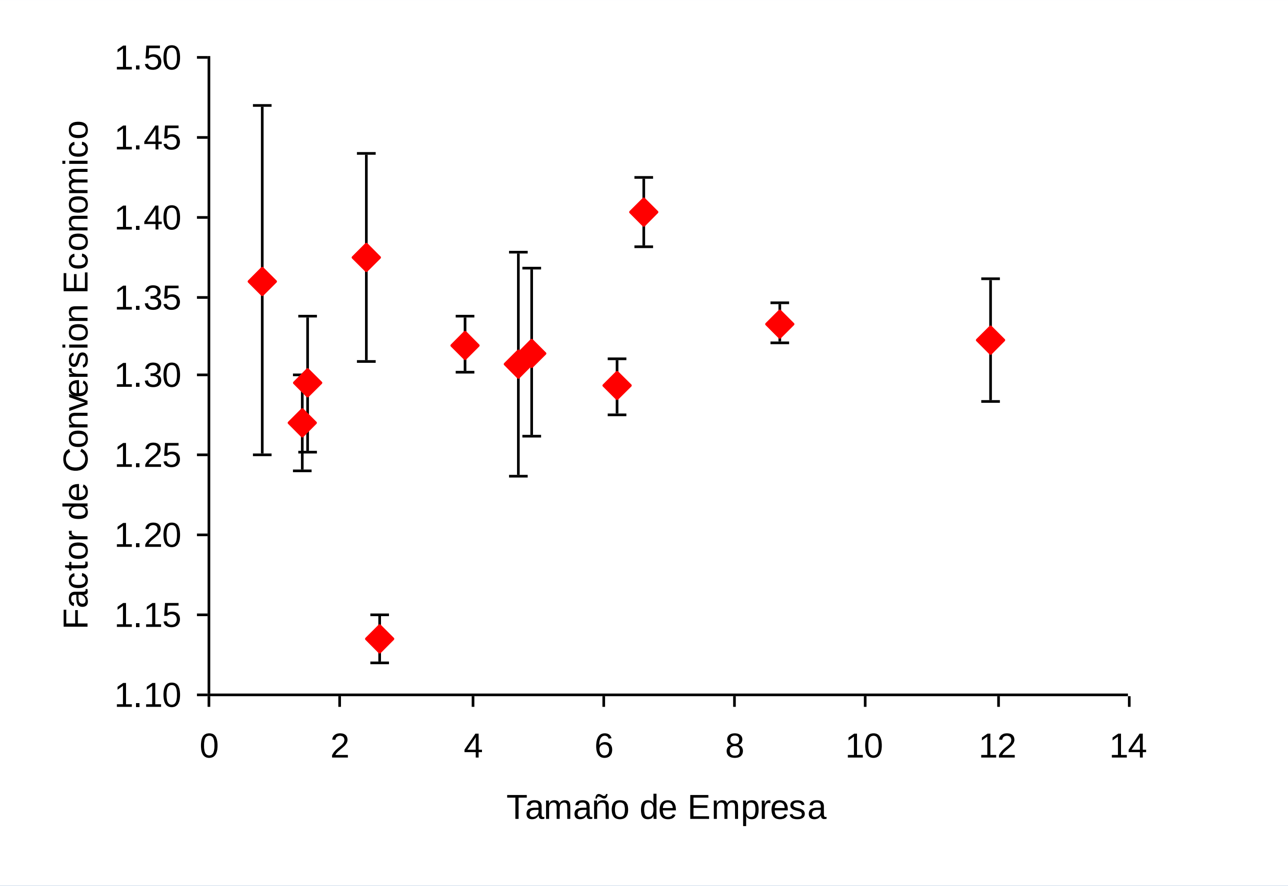
GLOBAL SALMON INITIATIVE

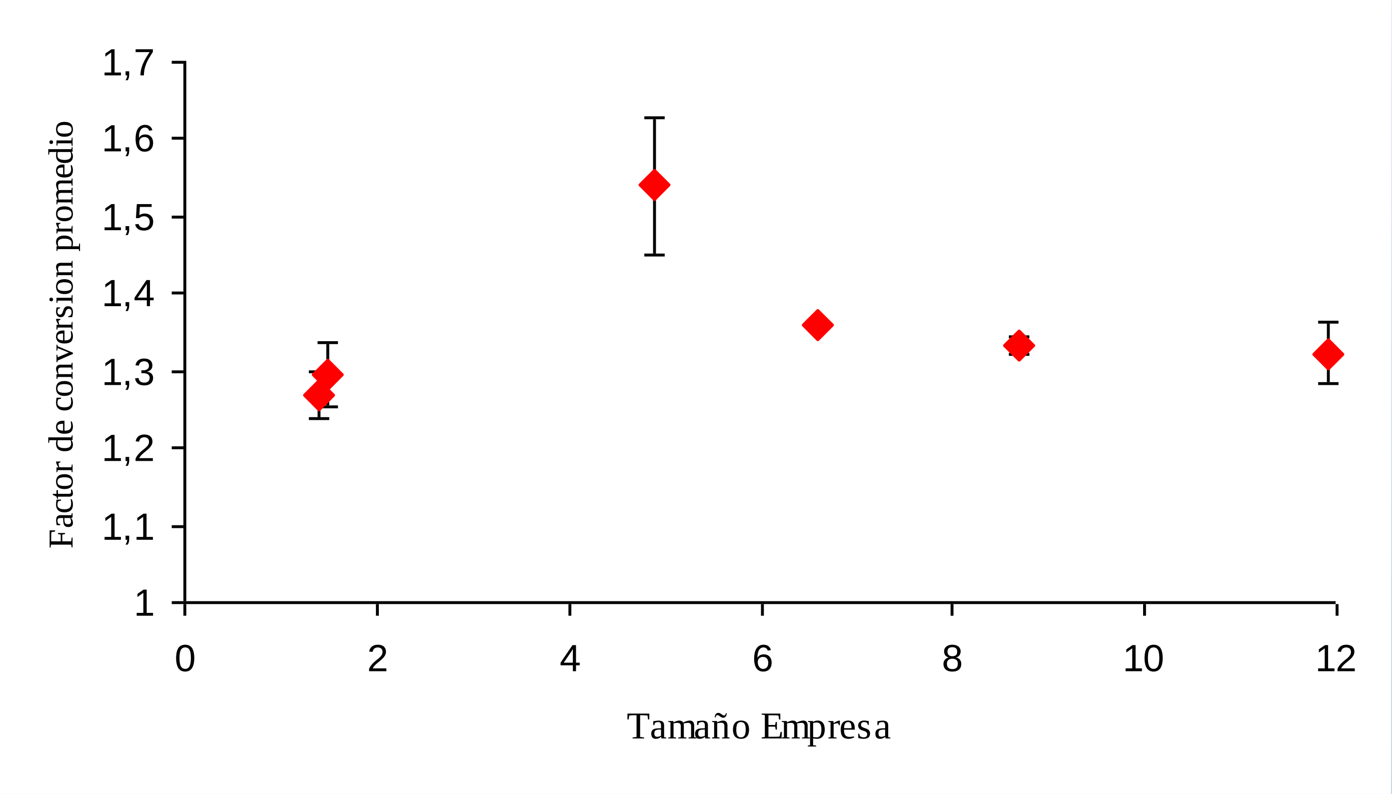
FCR in 38 farms



The size of the companies did not affect the FCR (but the volume of the farm did!)



Average FCR seems higher in medium size companies



Multivariate model to estimate production efficiency of Atlantic salmon

	Slope	Probability	R^2
Dependent variable			
Production efficiency (g/mes)		<0.00057	0.774
Model intercept	3.64408	0.000000	
Independent variable			
Fish density (No fish/m³)	-2.97682	0.001080	
Size of the company (%)	6.6017	0.007580	
Age of the site (years)	-5.3804	0.007783	
Feeding technology	1.5834	0.000155	

Multivariate model to estimate feed conversion ratio

	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	0.056343	
Production volume	0.000053	0.040610	

Conclusions

- The production efficiency can be predicted by several obvious factors, but this indicator mainly points to economic goals.
- The FCR does not seem to be affected by the size of the company but increases with production volume per farm.
- FCR decreases with feeding technologies
- FCR increases with more feeders, (and this is not good from the social perspective)

Thank You

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GSI GLOBAL SALMON INITIATIVE

Improving feeds and FCRs: the perspective from salmon farming

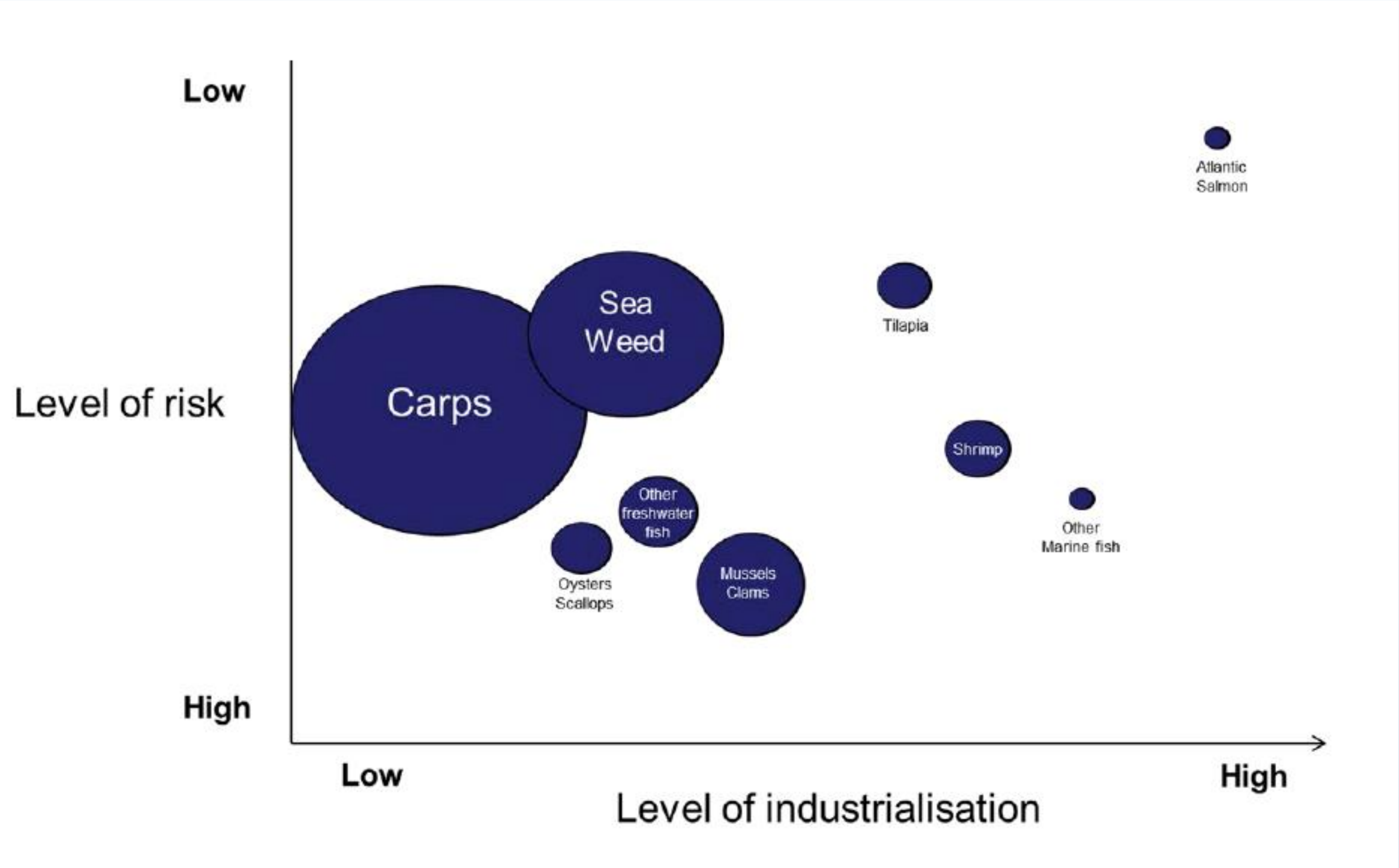
Liberia, Costa Rica, 9– 11 November 2015

Michael Adler
BioMar Americas
Puerto Montt, Chile

Food and Agriculture Organization of the United Nations

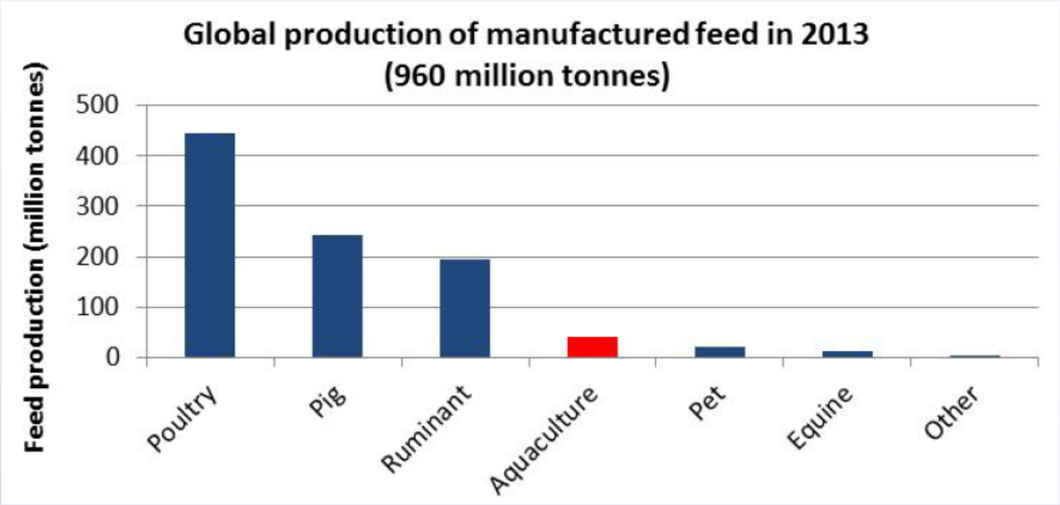
GLOBAL SALMON INITIATIVE

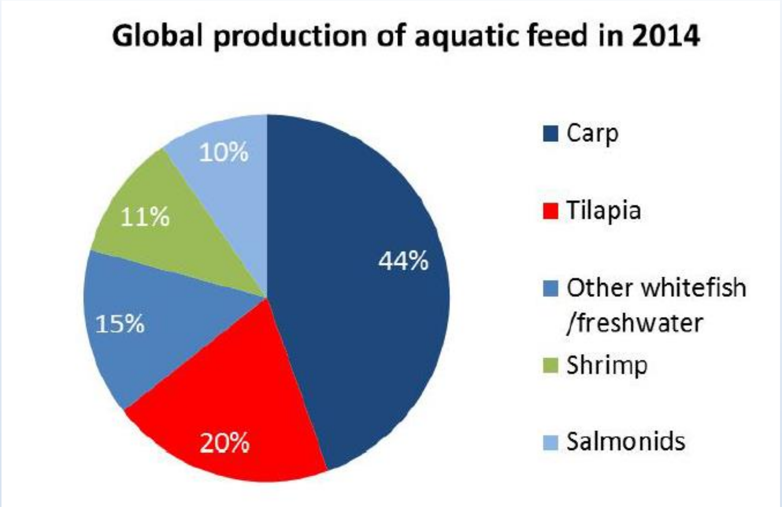
Salmon farming in context

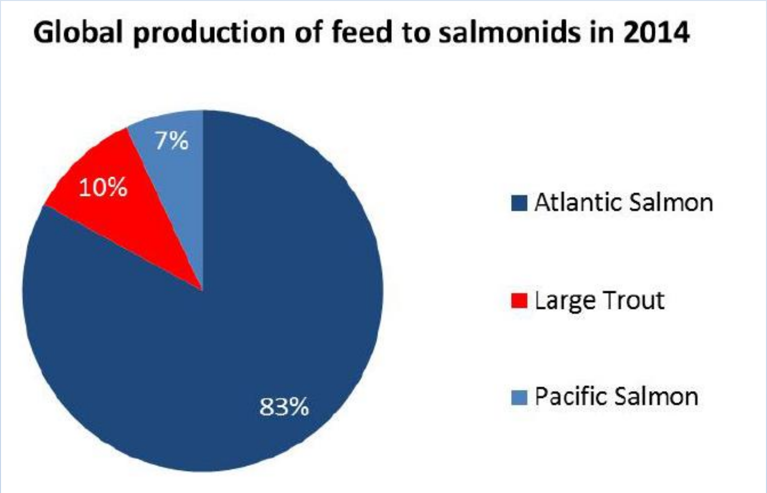


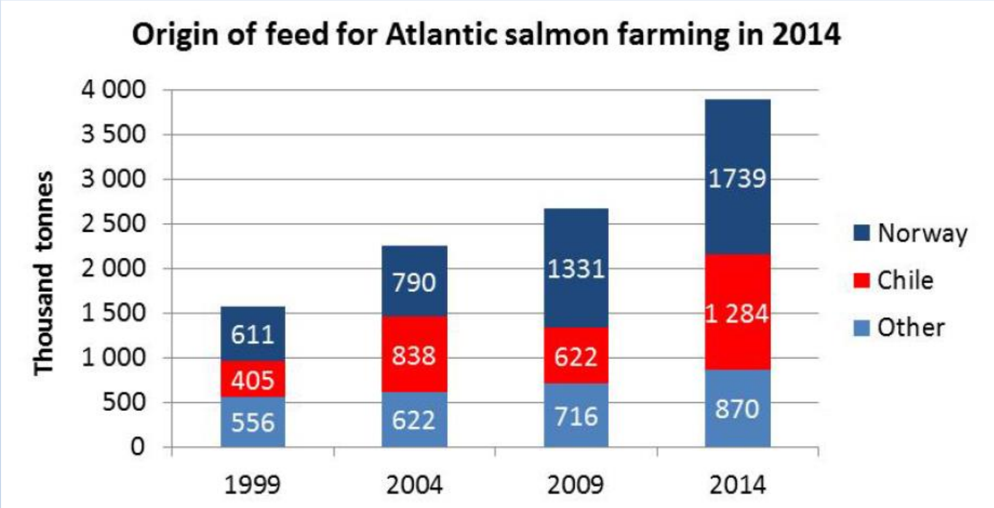
Kontali Analyse; Marine Harvest Salmon Farming Guide 2015

Salmon farming in context



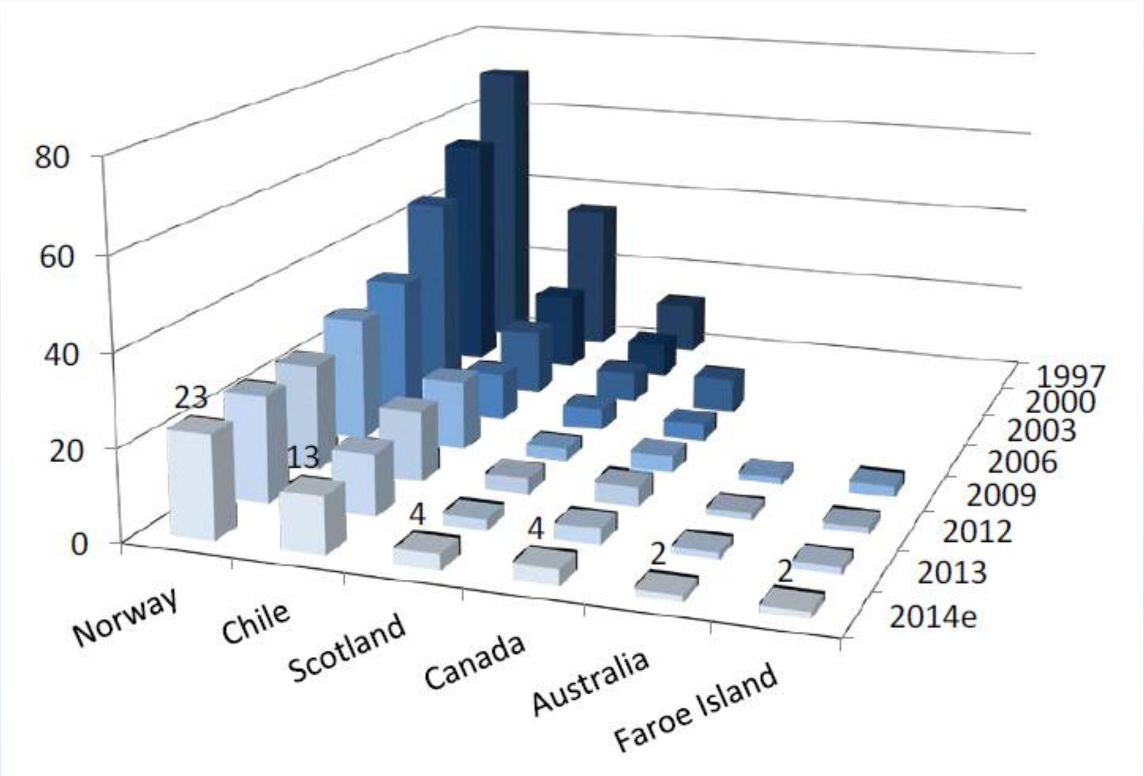






Kontali Analyse; Marine Harvest Salmon Farming Guide 2015

Salmon farming in context



- Industrial activity
- Concentrated
- High level of investment required
- In each country salmon farming is an important contributor to the local economy
- Important efforts in R&D have been made to improve productivity (privately and publicly funded)

An example of R&D capacity to support the sector: Norway

- Universities - 6
- Institutes/aquaculture R&D -17 (industry focus scientifically based research)

Infrastructure;

- Fish trials facilities;
  - Land based; 6 (3 on the institute sector)
  - Sea based; 8 (4 on the institute sector)
- Challenge facilities; 2 land based facilities on the institute sector
- Chemistry laboratories
- Technology: pilot factories.

Strong funding programs

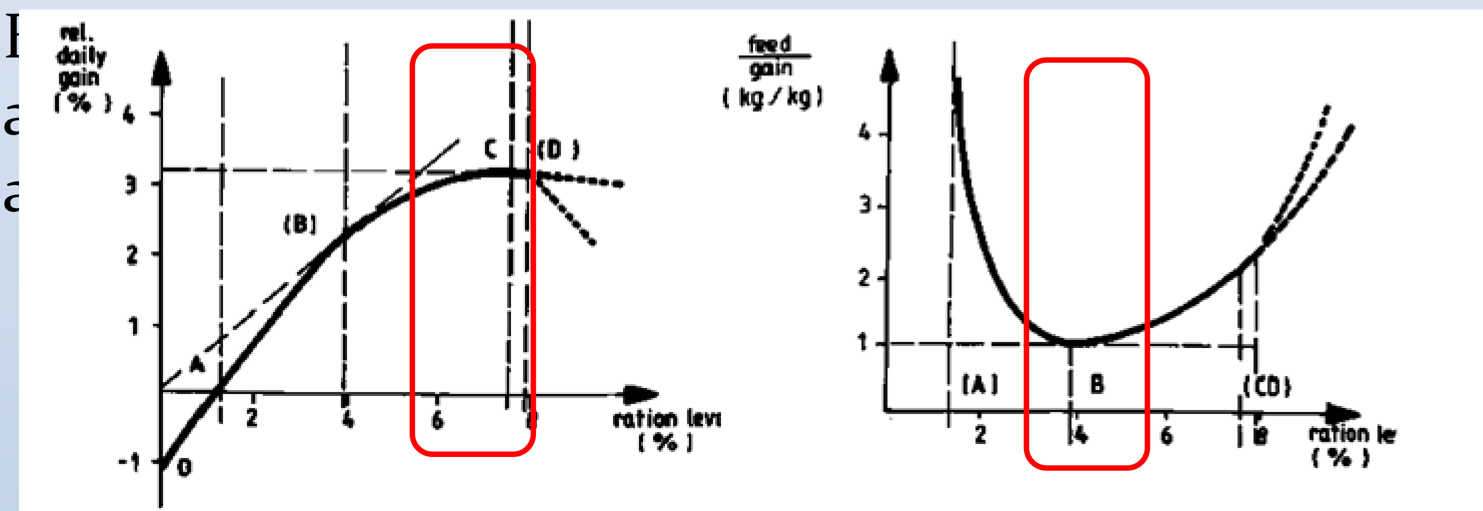
- Innovation programs
- Tax Incentives
- Basic research
- Grants to the industry
- Fishery and aquaculture research fund = 0.3% of seafood export value, industry focus.

Obtaining a low FCR is no easy task

- FCR = Feed intake (kg)/ Biomass Increase (kg).
- Biomass increase (growth) is factor of genetic potential, nutrient intake and environmental conditions.
- At a farm level feed intake = feed delivered, accounting for the wasted feed as well

Main challenge;

- I
  a
  a



Max growth

Best FCR

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GLOBAL SALMON INITIATIVE

Obtaining a low FCR is no easy task

- Genetics → Performance Increment = adjustment
- Environment
  - Oxygen
  - Temperature
  - Light
- Feed
  - Nutritional Quality
    - Nutrient density
    - Stability of its nutritional value
  - Physical Quality
    - Feeding Systems
    - Specie
- Husbandry
  - How
    - Automatic/ Manual
    - Times per day & Speed
    - Waste Control
  - How much
    - Satiation
    - Set Ration

    Satiation / Set Ration → Control
    - Growth
    - Stock

Genetics

Impact of selective breeding programs on the production of different aquaculture species (modified from Neira, 2010 and Rye et al., 2010).

Species	No. of programs[a]	No. of families per program	Average no. of traits selected	World prod. in 2005, (1000 tonnes)
Common carp	8	76	2.0	3044
Rohu carp	1	60–70	2	1196
Silver barb	1	–	1	97
Tilapia Nile	20	229	3.6	1703
Tilapia blue	2	90	2.0	2
Tilapia red	4	125	4.0	–
Tilapia *O. shiranus*	1	51	1.0	–
Channel catfish	1	200	4	380
African catfish	1	70	1	29
Striped catfish	1	182	3	436
Atlantic salmon	13	280	5.4	1236
Chinook salmon	2	100	1.5	24
Coho salmon	4	133	2.7	117
Rainbow trout	13	206	5.2	487
European whitefish	1	70	2.0	1
Turbot	2	60	1.0	7
Atlantic cod	3	110	4.0	8
European seabass	3	100	5	58
Sea bream	4	100	6	111
Freshwater prawn	2	82	1	205
Shrimp, *P. monodon*	3	212	–	723
Shrimp, *P. vannamei*	4	197	2.0	1599
Abalone	3	210	1.7	334
Oysters	3	48	4.3	4615
Mussel	1	60	3.0	1410
Total listed species	101	–	–	17,822
Total all species	–	–	–	48,150[b]

Genetic gain in Atlantic salmon over five generations of selection (Thodesen et al., 1999).

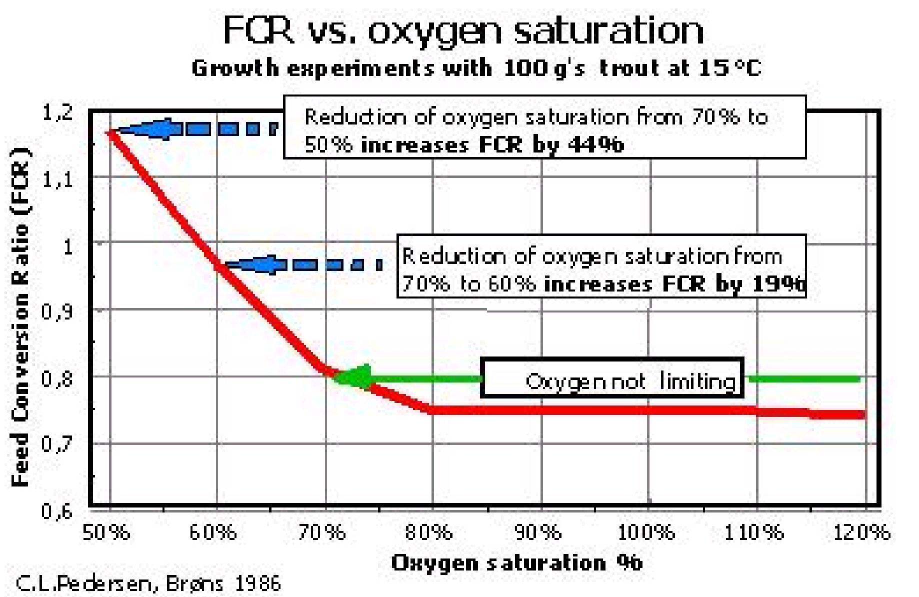
Trait	Improvement selected over wild (%)
Growth rate	+113*
Food consumption	+40*
Protein retention	+9
Energy retention	+14*
FCR[a]	−20*

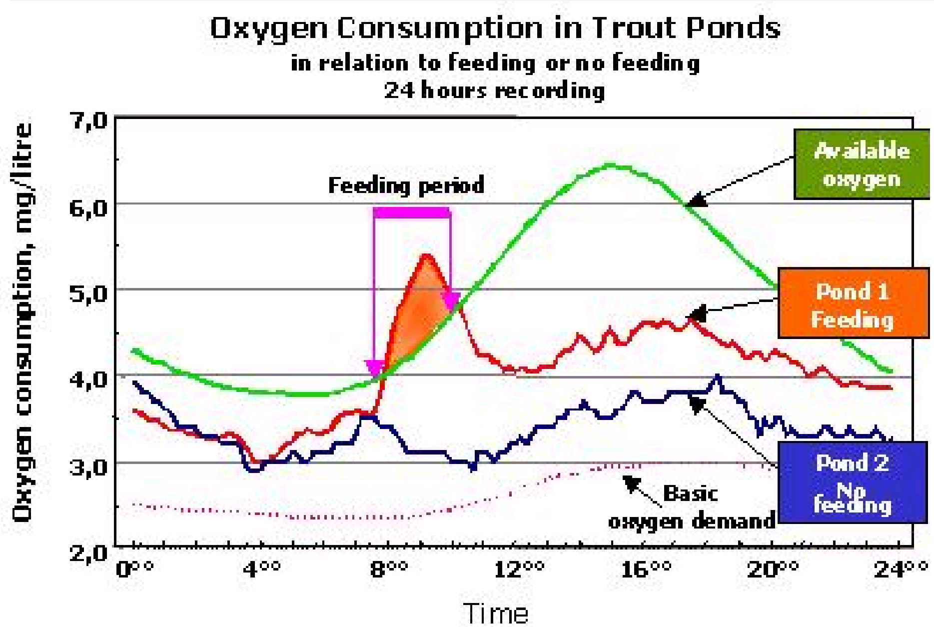
[a] Feed conversion ratio or kg feed per kg body weight produced. (*, $P<0.05$)

Gjerdem, et al 2012.

- Favorable correlation between growth as a selection trait and FCR has been reported.
- In 2010 it was estimated that 10% of aquaculture production would come from breeding programs.

Environment





- Besides enclosed aquaculture systems, aquaculture depends on a variable and not controllable environment, knowing and understanding the farming environment is a key Factor for successful farming.
- Environmental data registration is a must to be able to decide the productive strategy to follow.
- Aeration systems to avoid mortalities.

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Feed in the PAST or the 'good old days'

- Fixed declarations (Crude protein, oil & energy)
- Limited information on nutrient digestibility and utilisation
- Conservative High protein / low energy feeds
- Relatively high levels of fish oil and fishmeal
- High pigment content

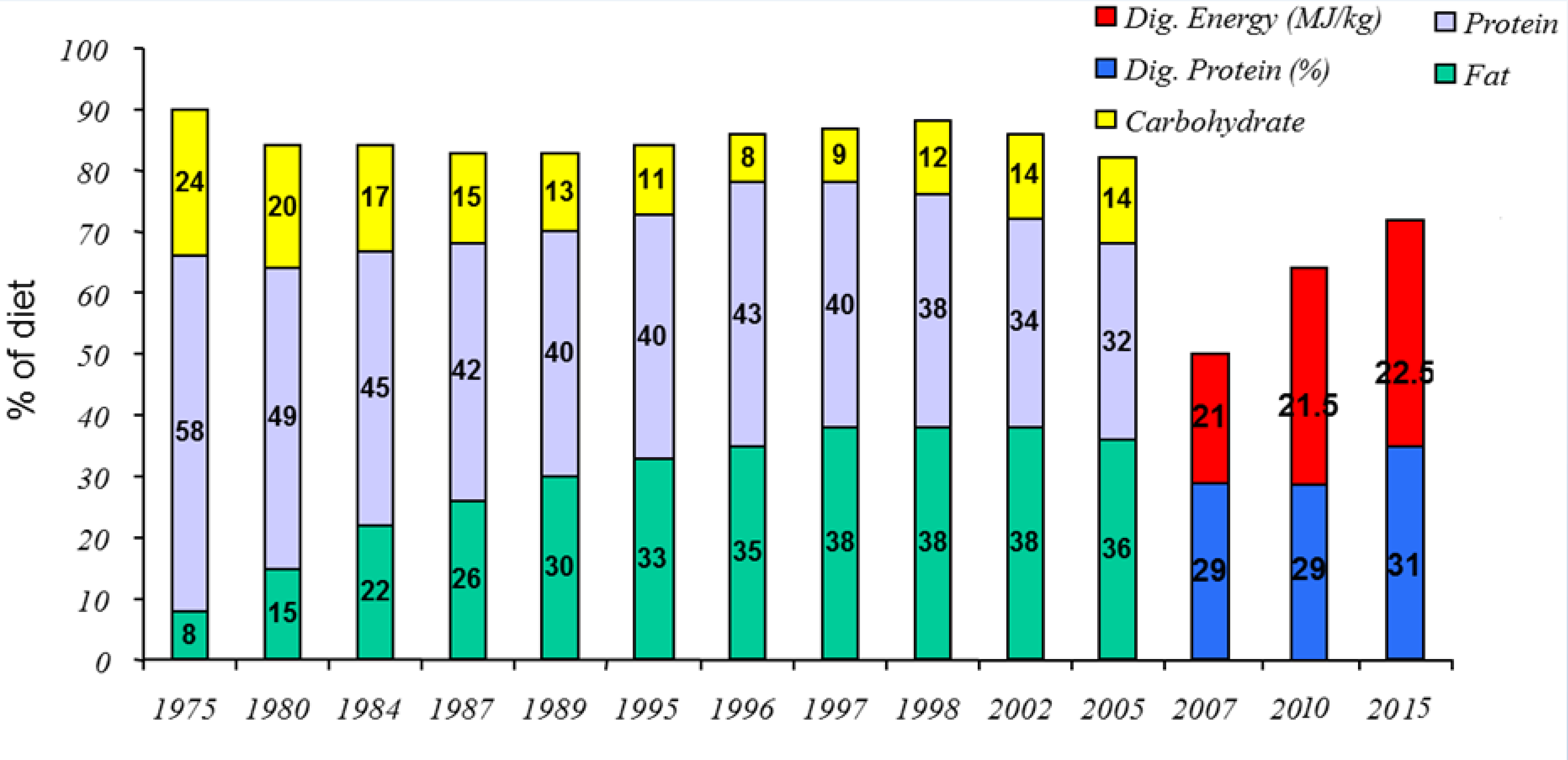
Output:

- Leaner slower growing well pigmented fish
- Longer production cycle / higher FCR
- High relative feed cost and feed cost / kg salmon produced

What changed?

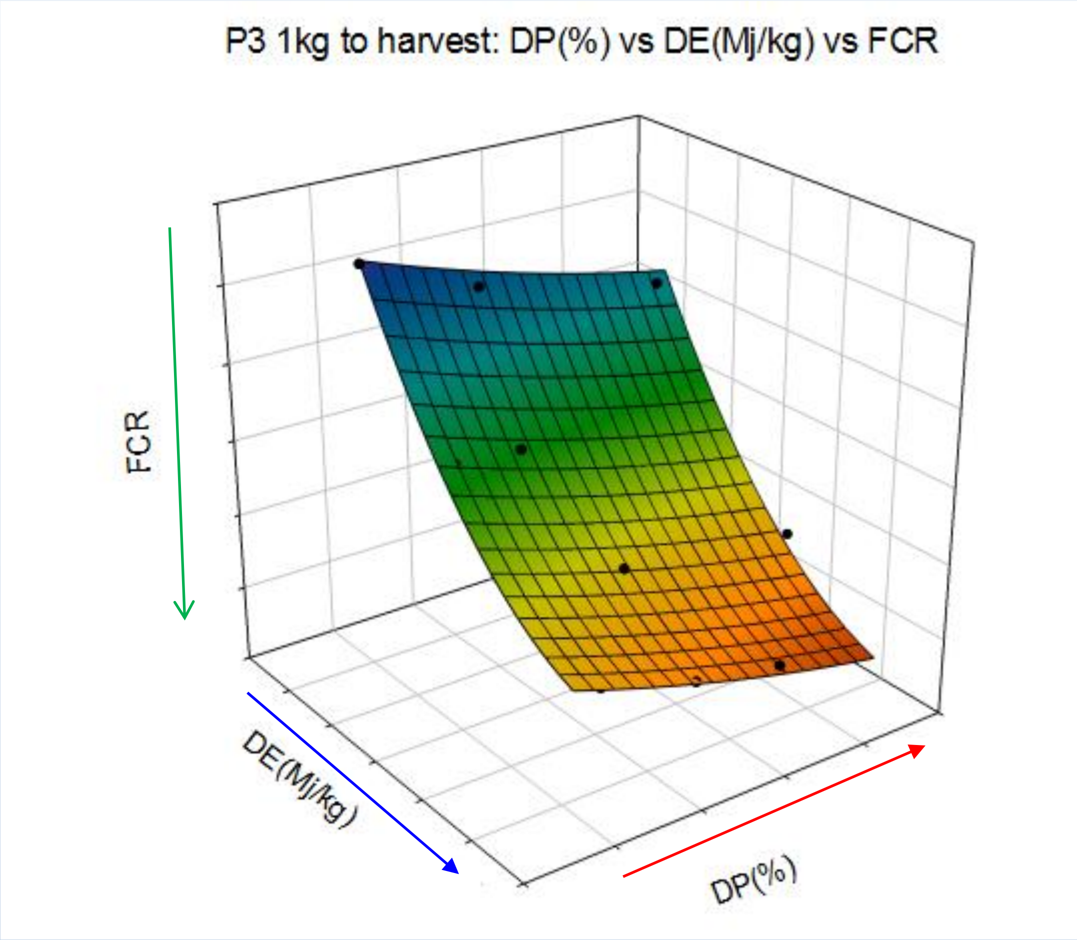
- Key driver was production cost of salmon
- More focus on Digestibility and performance (FCR, growth rate x feed cost)
- Feed manufacturers had to reduce feed cost and improve performance to remain competitive
- What did we do?
  - ↑ Energy
  - ↓ Protein levels
  - Replace fishmeal and oil
  - Introduce a wider number of raw materials into our feeds

Salmon feeds evolution



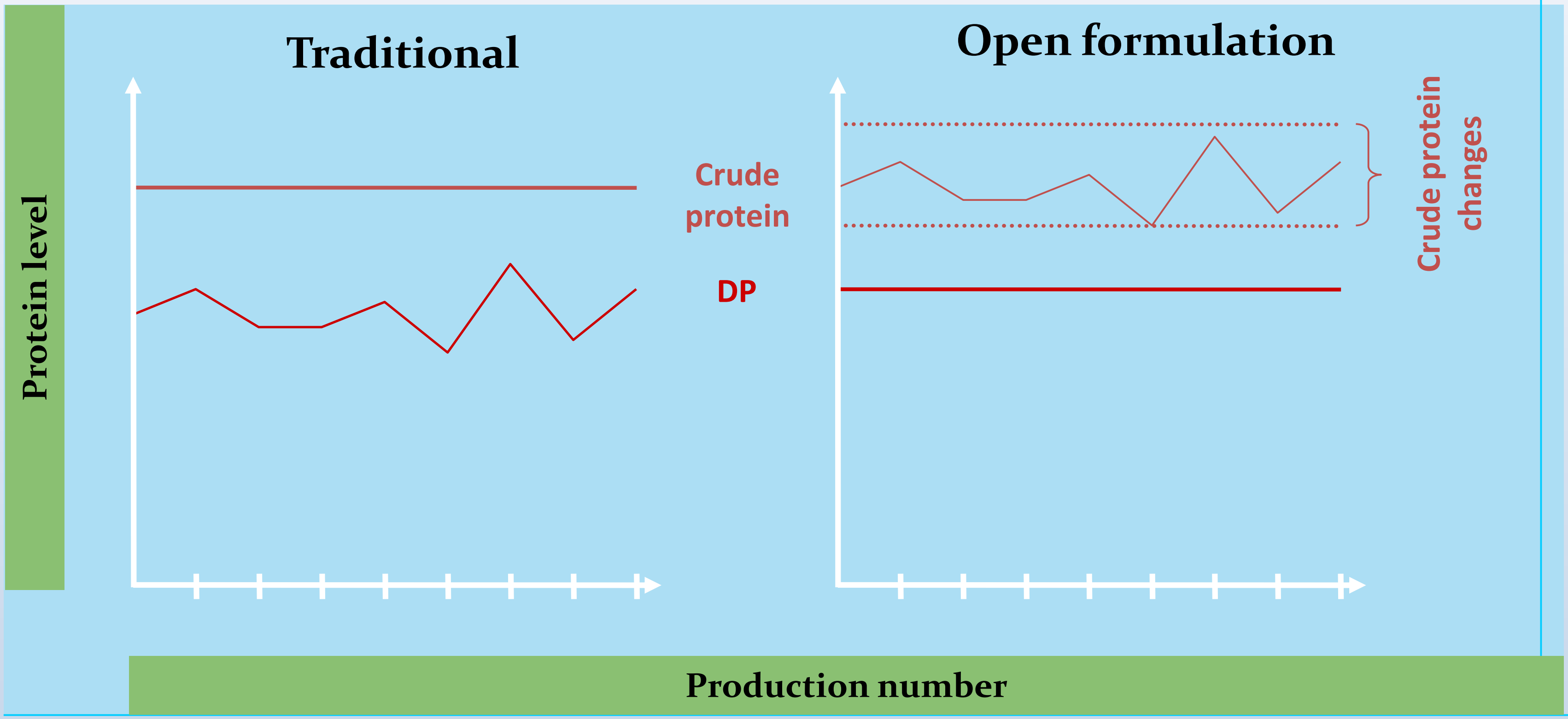
Feed/nutritional quality/nutrient density

DP/DE correlations with FCR (ATS 1-5 kg)



Change in formulation methods

- Fixed crude protein vs. fixed digestible protein (DP)

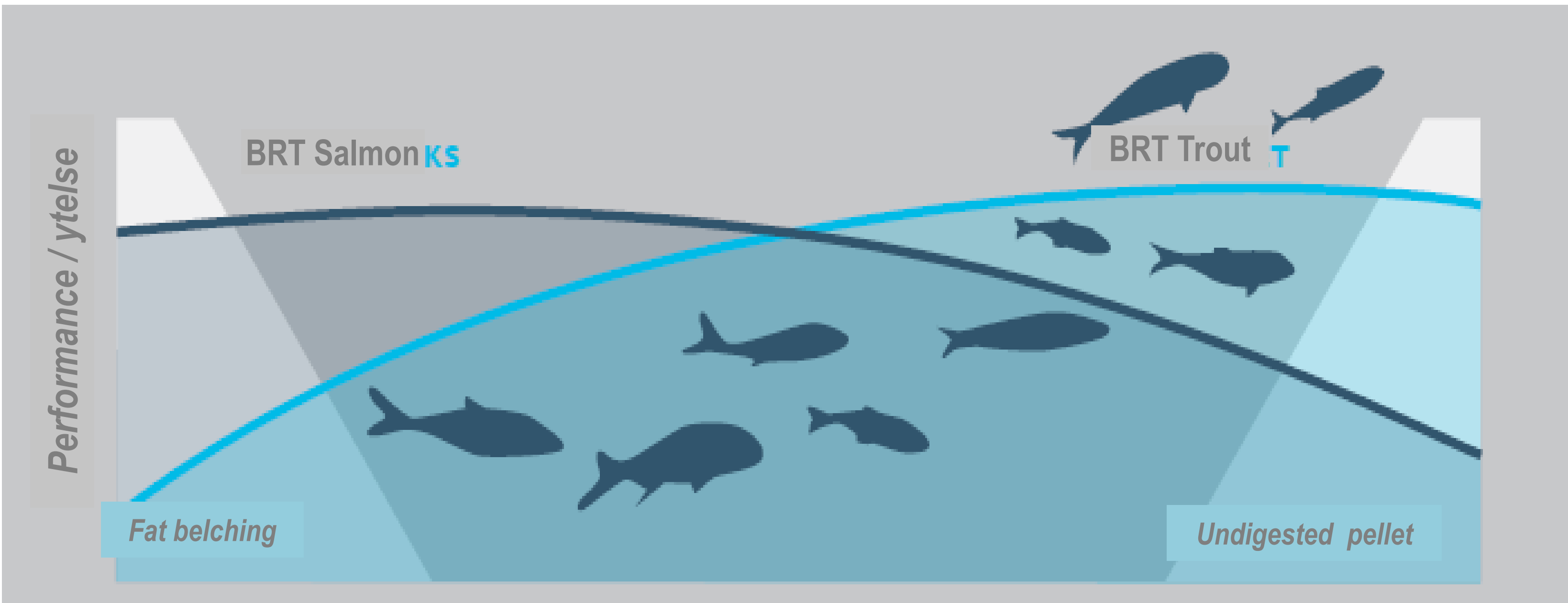


- To achieve an stable performance that digestible nutrients have to be stable.
- Crude protein and energy are not good indicators of the potential of the feed.
- All raw materials nutrients and energy digestibility must be known and controlled

Feed/nutritional quality/nutrient density

- ✓ Physical quality needs to match the specie requirement and the operative conditions.

PROCESS- AND RAW MATERIAL KNOWLEDGE



Process- and raw material knowledge for optimal pellet for the different species
Salmon and trout for example have different needs that can affect the digestibility of nutrients, fat belching in trout and undigested pellet in salmon

Feeding; how?


AkvaControl
FishControl
@
Feed Computer
Remote location
Temperature
Current
Oxygen
Wireless CAP Transmitter
Pipes
Feed Blower
Air Cooler
akvasmart
Feed Doser
IAS
SEEMATE
UNDERWATER CAMERA
Radio Data link
AQ1 Controller & Auto Feeder
Onshore computer
Sensor

Thank You

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GLOBAL SALMON INITIATIVE

A tool to assess GHG contribution in aquaculture: salmon and other species as cases studies

Liberia, Costa Rica, 9– 11 November 2015

Jonathan Moir
AquaGem Inc.
Newfoundland, Canada A1E 1C9

Concept

- The Aquaculture industry has come under increasing scrutiny over GHG emissions.
- The Seafish Authority, with Dalhousie University & Sintef, produced a simple tool to evaluate the impact of fishing practices on GHG emissions in the fishery.
- FAO proposed developing a similar tool for Aquaculture.

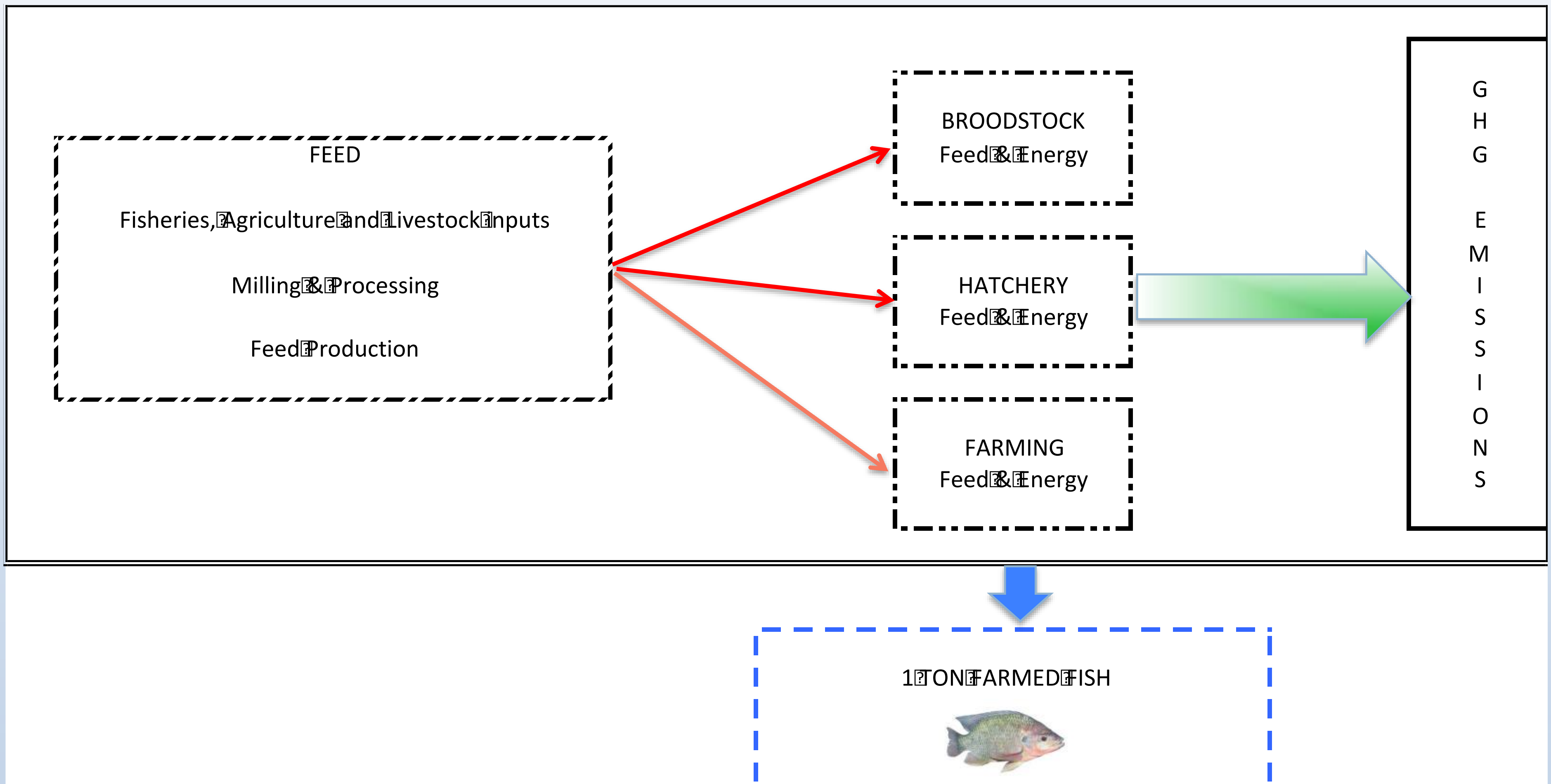
Goal

- Develop a 1st generation aquaculture GHG footprint tool.
- A simple, user friendly spreadsheet model that can be used to evaluate on farm emissions.
- Developed from literature values and publicly accessible data bases.
- Available to the public on line.

Principles

- Use established literature based estimates of GHG emissions for data bases.
- Recognize that:
  - up to 80-90% of all emissions may be due to feed, depending on the production system; and
  - FCR is the most significant variable to impact GHG emissions.

Boundary


FEED
Fisheries, Agriculture and Livestock Inputs
Milling & Processing
Feed Production
BROODSTOCK
Feed & Energy
HATCHERY
Feed & Energy
FARMING
Feed & Energy
GHG EMISSIONS
1 TON FARMED FISH

The focus

Primarily focused on fed systems

- Establish a tool that utilizes sets of data:
  - Published data bases for feed GHG emission;
  - Published data bases for energy generation & energy consumption; and
  - Inputted data from the farm linked to data bases for energy GHG emissions covering things such as transport, processing, and energy, etc.

Constraints

We can make some generalizations about feed & feed companies:

- Use a variety of raw materials sourced world wide and also regionally;
- Precise formulations are a trade secret; and
- Proximate composition supplied with the feed is of no use in calculating GHG carbon footprint.

Sample case: salmon

- Used salmon as there is a considerable body of information available.
- In depth LCA undertaken by Pelletier, Tyedmers *et al.* (2009) provided the basis for the feed GHG for salmon for 4 countries.
- Feed companies supplied exhaustive data on raw material and diet formulations – information not normally available to customers.
- Used this to develop a way to evaluate and update emissions for diets in 2015.

Process

- Tabulated raw material emissions data.
- Took the average of this data for each country.
- Compared the average formulation data with inclusion rates from this study.
- Calculated the change in GHG emissions since 2009 on current 2015 formulation.

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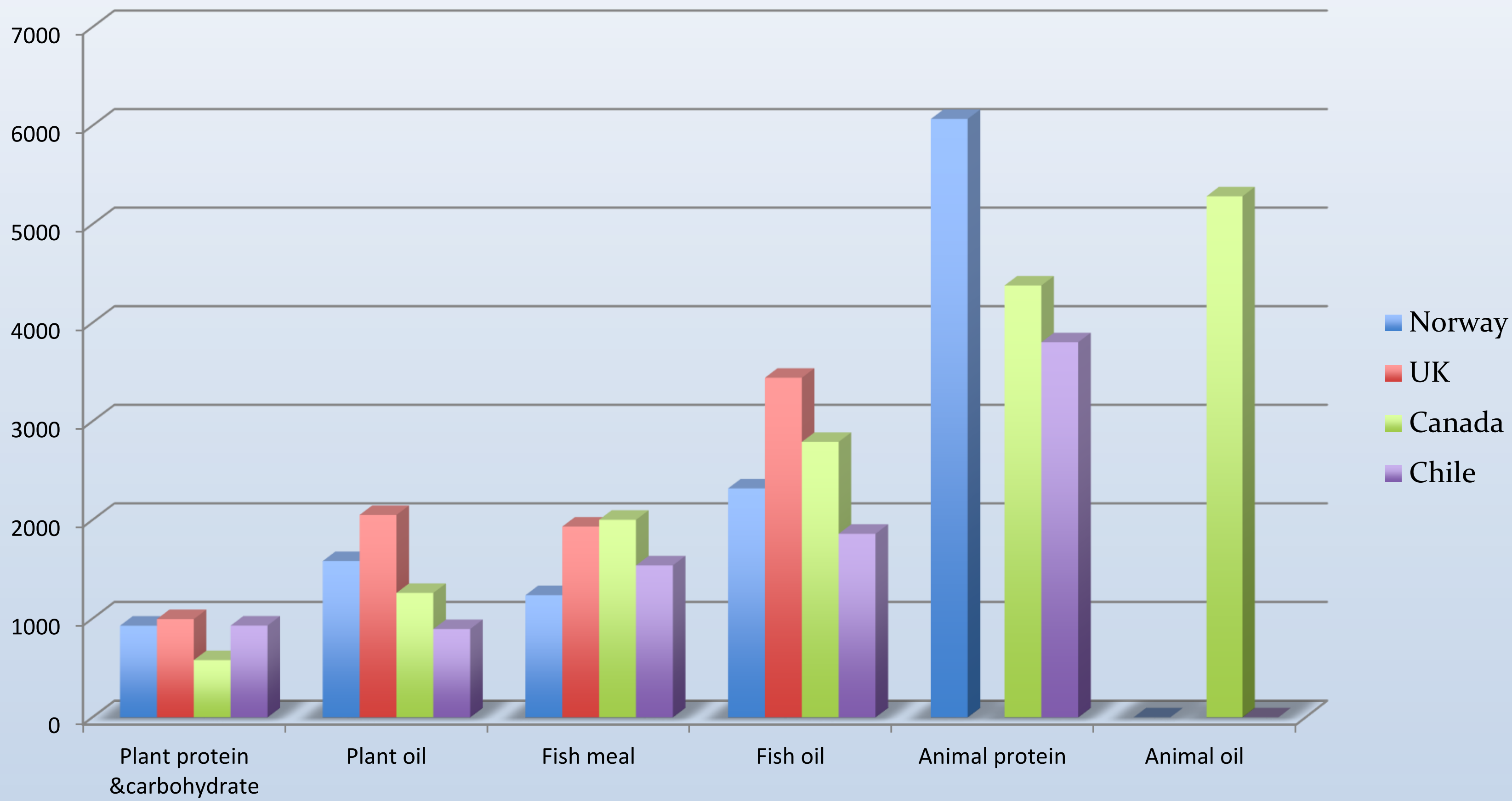
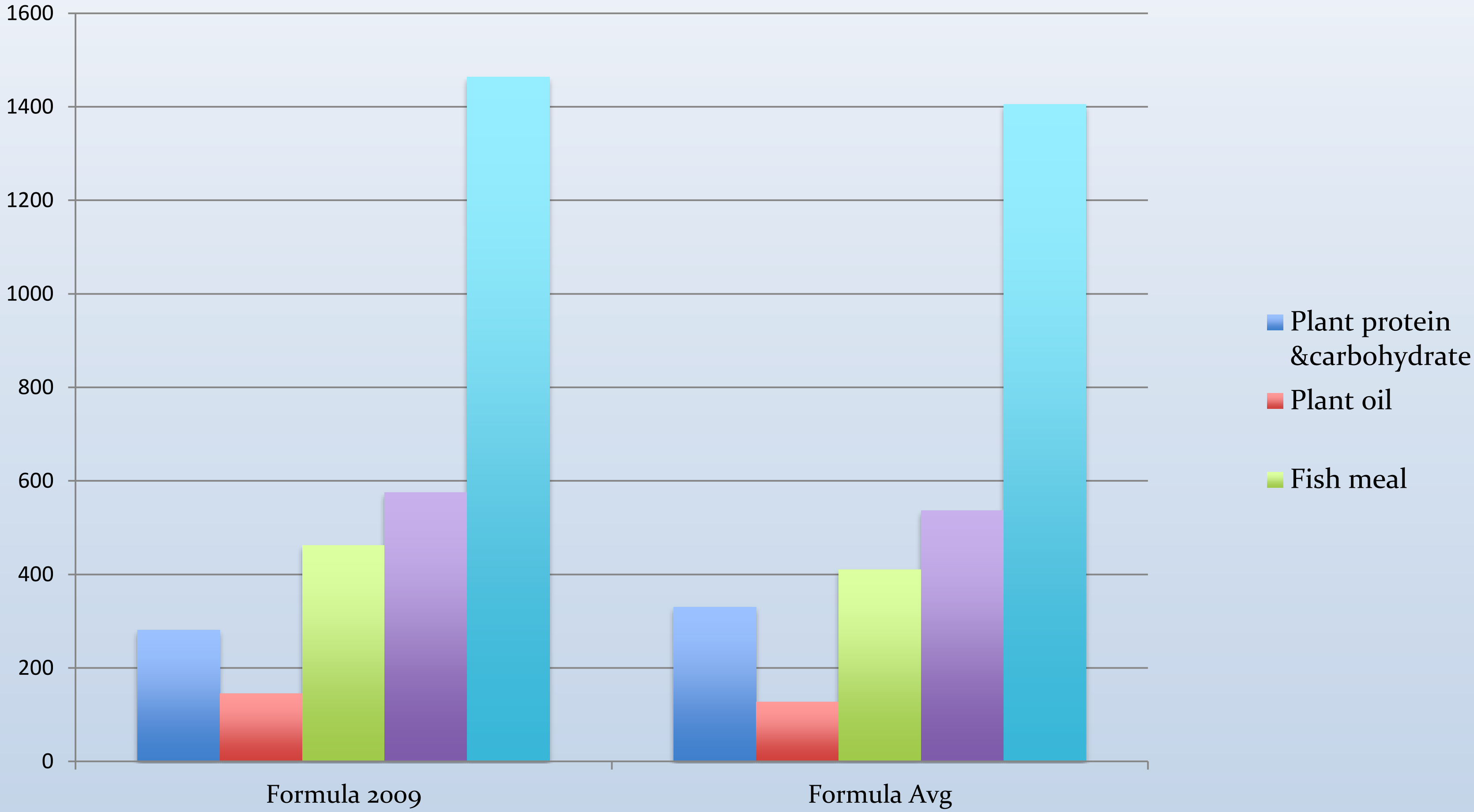
Raw material: GHG emissions by country



GHG (Kg CO_2-eq/tonne of raw material)

(*Source*: Pelletier *et al.* (2009)

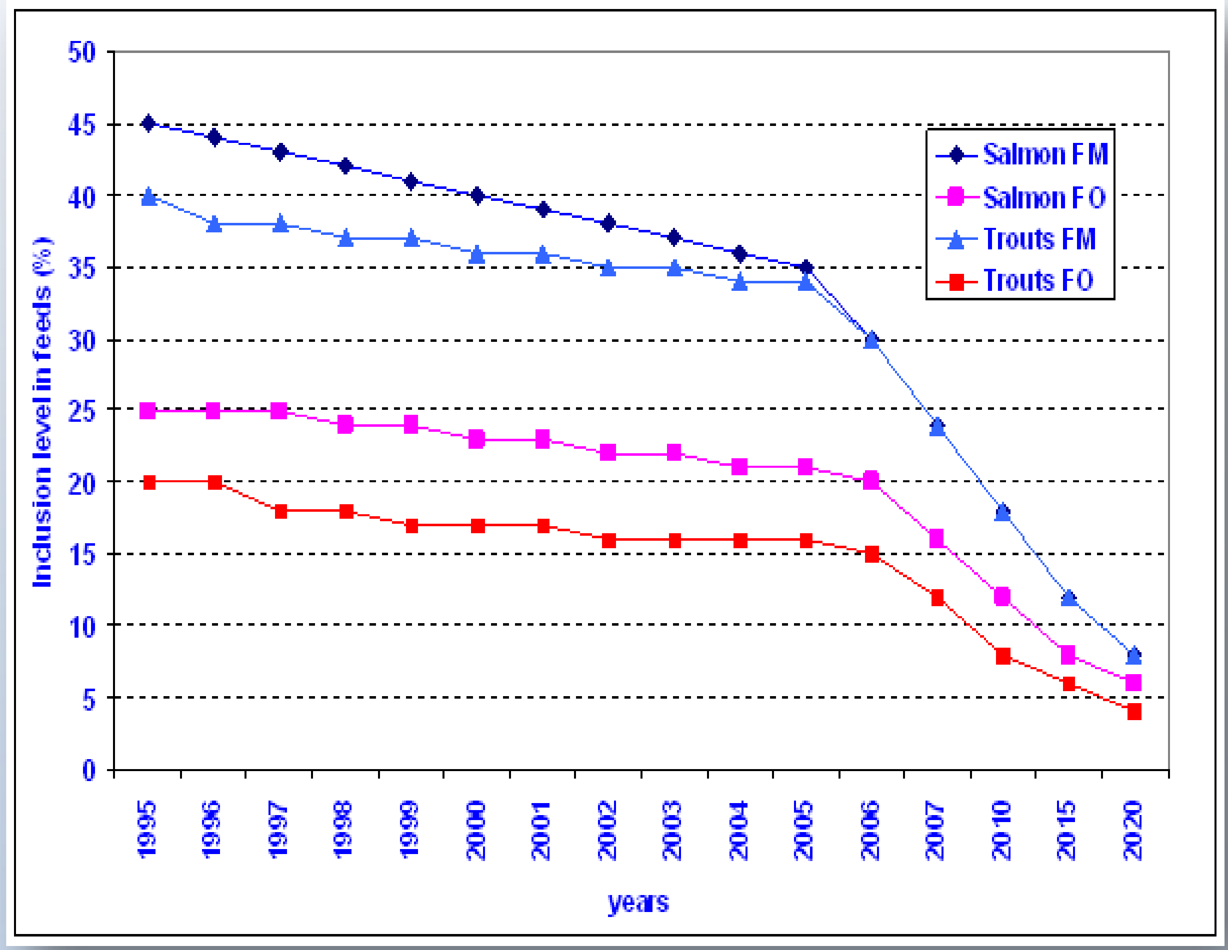
Norway -GHG Emissions



Inclusion rates

- We can see with the change in fishmeal & fish oil use that diets in 2015 will have a different GHG emissions value than in 2009.
- Diets may now contain in excess of 75% of plant based materials, protein, carbohydrate and oil.
- Some may contain as little as 5% or less fish meal or in some cases none.
- All of these changes have an impact on GHG emissions.

Use of fishmeal in salmon diets



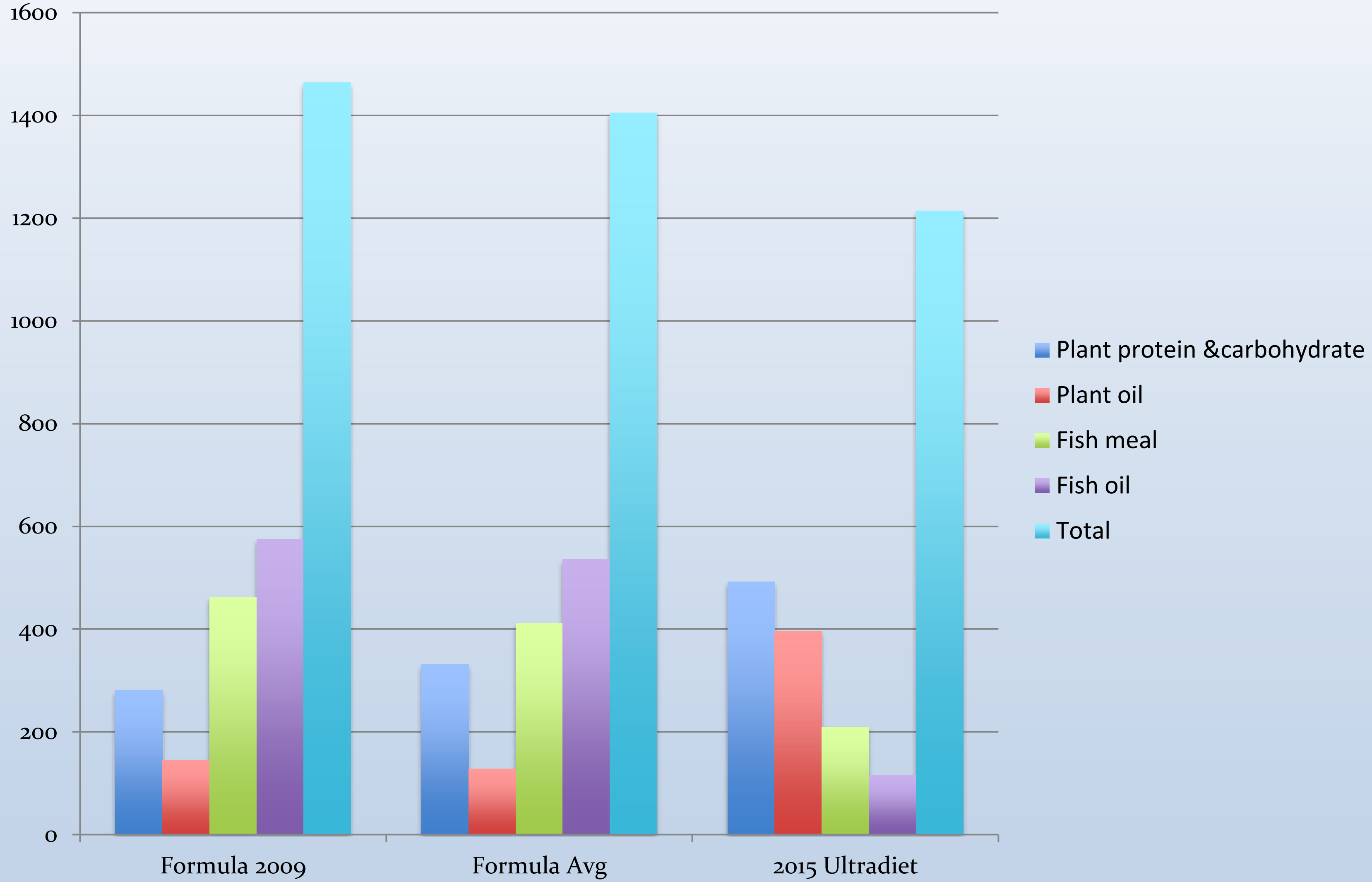
Source: Aquaculture in the Reform of The Common Fisheries Policy, March 2012 Brussels.

2015 inclusion rates

Ingredient	Inclusion %	Typical diet %	Low fishmeal diet %
Fishmeal	5-50	5	2
Fish Oil	0-30	5	5
Wheat	3-30	15	8
Soybean meal	0-15	15	15
Plant proteins	0-40	10	25
Animal by products	0-15	18	18
Brewers yeast	0-5	5	0
Amino acid	0-2	2	2
Distillers grain	0-10	5	0
Other oils	0-30	20	25
		100	100
Total plant origin material		70	73

Source: Pers. Com, Canadian Feed mill

Low fishmeal diet 2015



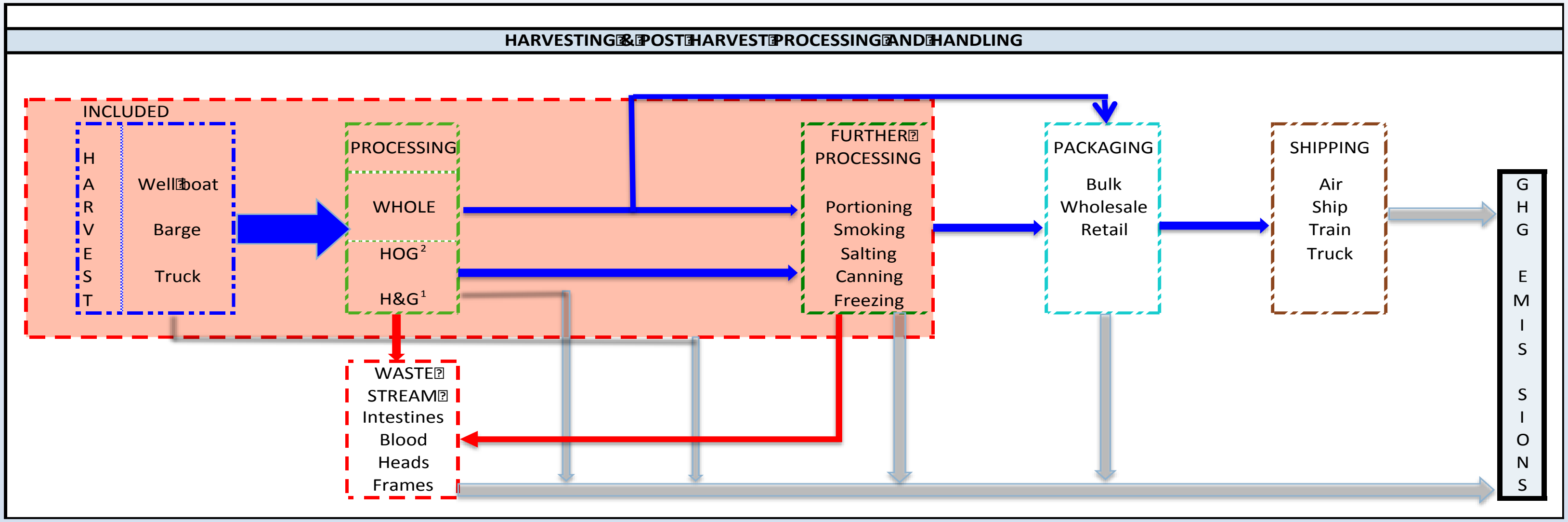
FCR

- Varies
  - Low: Norway ≈ 1.103
  - High: Chile ≈ 1.5 (study completed during ISA outbreak in Chile).
- Affects the absolute value of GHG emissions on a farm.
- Not a lot room to reduce FCR in salmon culture.

Farm energy consumption

- Depending on the system may reach up to 50% of total emissions
- Covers everything from:
  - Energy generation;
  - Fish & Feed transport;
  - Harvesting; and
  - Crew movements etc.

Harvesting & post harvest handling



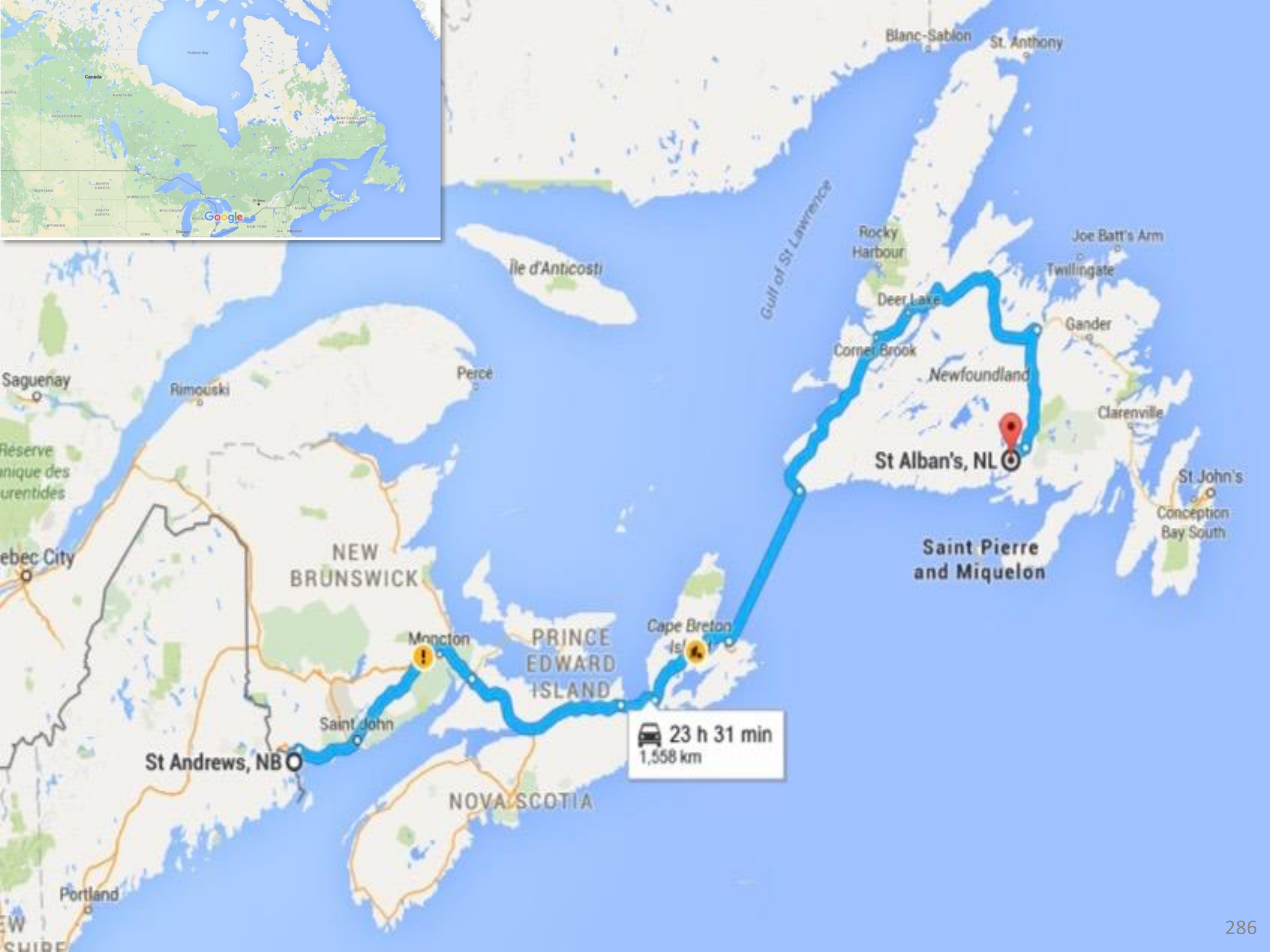
- Only included up to some primary processed product such as gutting/fileting/freezing.
- Shipping and handling are very complicated and not within the scope of this exercise.
- Similarly with packaging.
- Waste stream handling information is not available at present though could be a significant contributor.

The model

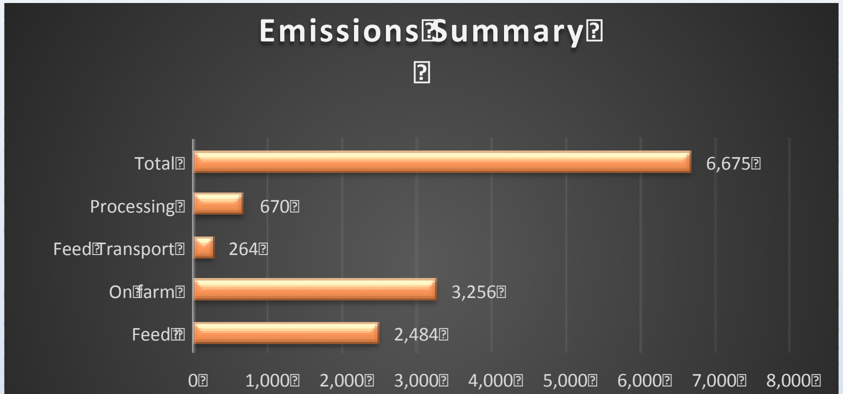
- Interface page linked through menus to a series of data tables covering:
  - Geographic location;
  - Species;
  - System type; ponds & cages; intensive, semi intensive, extensive, etc.;
  - Production volume;
  - Mortality;
  - # fish/tonne wet weight;
  - Feed formulation/proximate analysis: non-feed inputs, e.g., fertilizer/manure;
  - FCR, as a consequence of feed quality, mortality and efficiency of operation;
  - On farm energy consumption; and
  - Processing and product form.

Example

- Salmon farm – Canada
- Production 1 000 tonnes of whole fish
- Output 850 tonnes of headed and gutted fish.

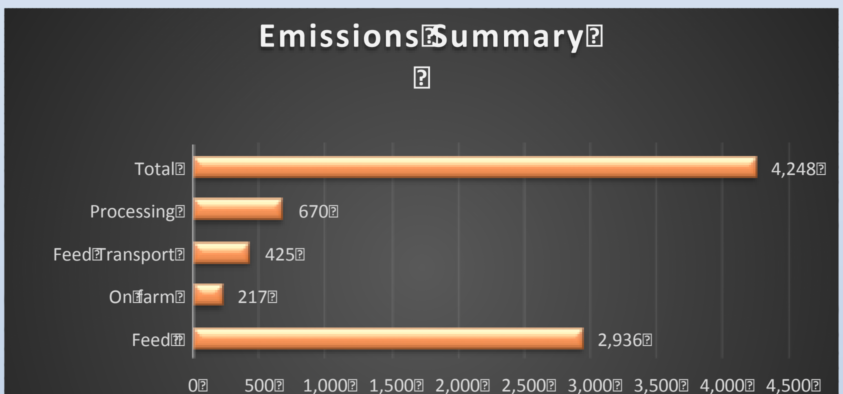

Google
Blanc-Sablon
St. Anthony
Île d'Anticosti
Gulf of St Lawrence
Rocky Harbour
Joe Batt's Arm
Twillingate
Deer Lake
Gander
Corner Brook
Newfoundland
Clarenville
St Alban's, NL
St John's
Conception Bay South
Saint Pierre and Miquelon
Saguenay
Rimouski
Percé
NEW BRUNSWICK
Moncton
PRINCE EDWARD ISLAND
Cape Breton Island
Saint John
St Andrews, NB
23 h 31 min
1,558 km
NOVA SCOTIA
Portland

Emissions summary RAS – cage salmon-Canada



	Feed	On farm	Feed Transport	Processing	Total
Emission Source	2,484	3,256	264	670	6,675

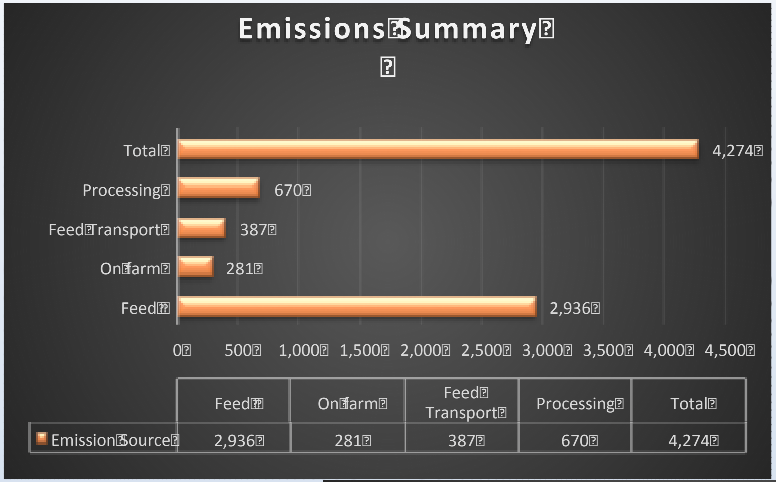
- RAS System
- Energy is the most important emitter



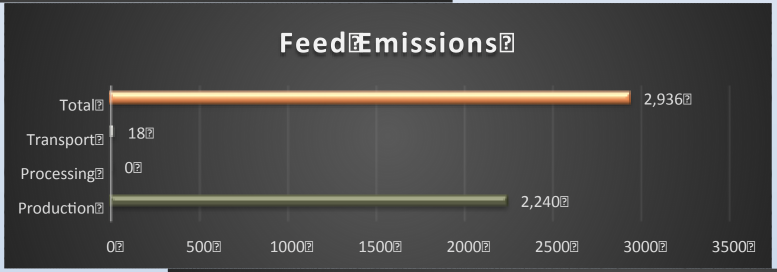
	Feed	On farm	Feed Transport	Processing	Total
Emission Source	2,936	217	425	670	4,248

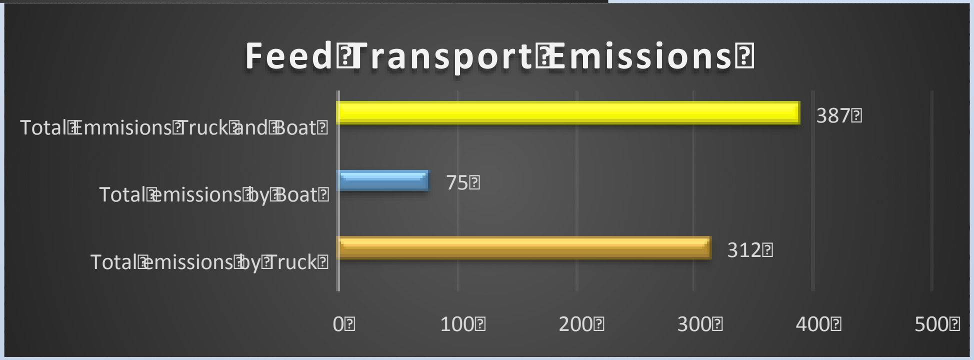
- Cage system
- Feed is the most significant

Presentation of results

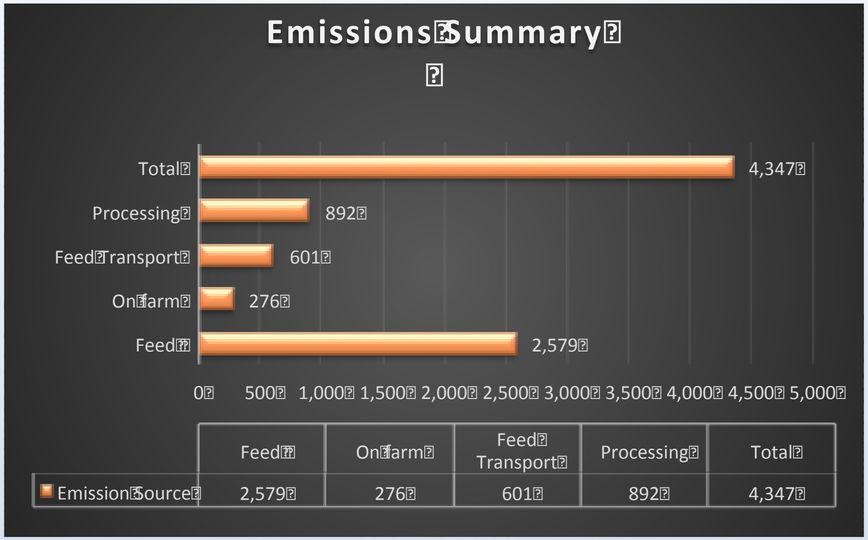


	Feed	On farm	Feed Transport	Processing	Total
Emission Source	2,936	281	387	670	4,274

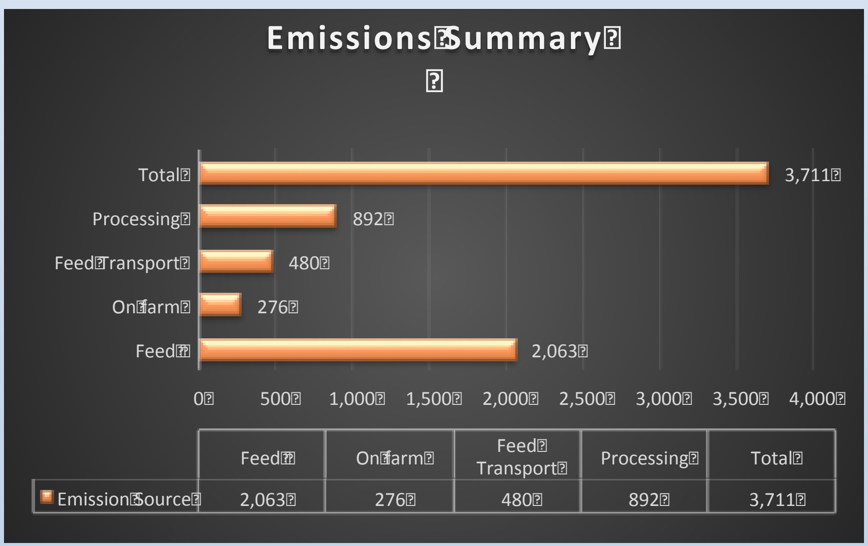




Tilapia emissions summary



- FCR = 2.5



- FCR = 2.0

Conclusion

- Tool is simple to use.
- Accuracy, particularly with respect to feed emissions, will depend on buy-in from feed companies.
- Data bases can be expanded to cover other methods of production particularly for impacts of pond sediments.
- The model can be modified to attempt to evaluate national production impacts.

References

Pelletier, N., Tyedmers, P., Sonesson, U., Scholz, A., Kruse, S., Cancino, B. and Silverman, H. Not all salmon are created equal: Life cycle assessment (LCA) of global salmon farming systems. Environ. Sci. Technol. 2009 *43* 8730-8736

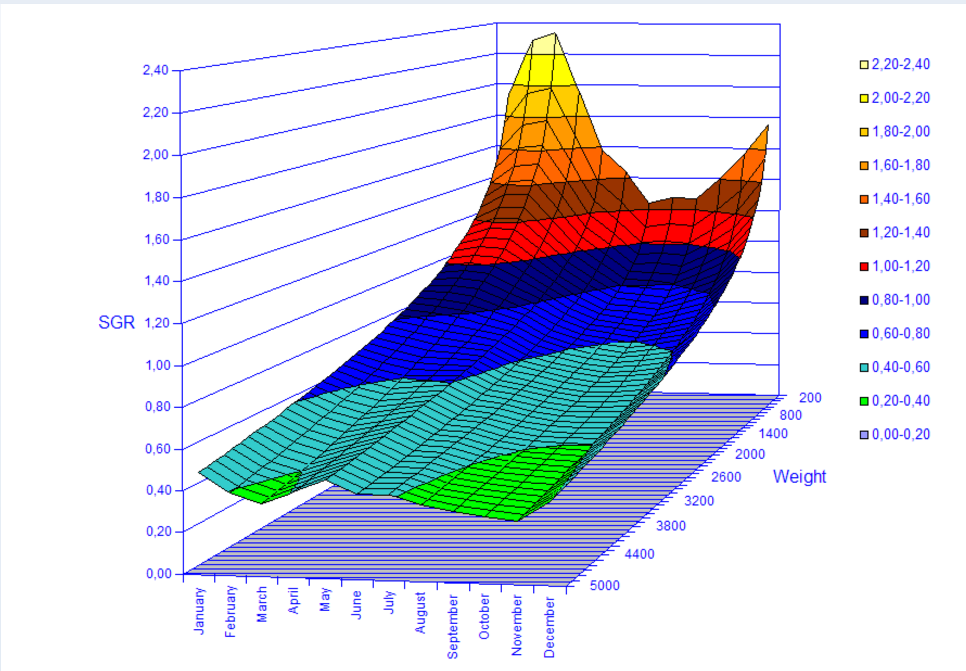
This work was funded by Aquaculture Branch (FIAA), Fisheries and Aquaculture Policy and Resources Division, Fisheries and Aquaculture Department, FAO, Rome, Italy.

Feeding; how?

- Motivated
- Committed
- Skilled
- Trained
- Experienced

Feeding; how much?

SGR/ Month/ Weight, Atlantic Salmon Chile



- Target is to feed to satiation
- Close control is necessary to ensure that no feed is waste.
- Control measures
  - Surface activity (visual)
  - Sensors (underwater cameras, IR sensors, dopplers)
  - Daily estimation of feed intake vs real
- Periodic weight measurements;
  - Samplings
  - Weight estimators

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Husbandry

- Stock management;
  - All in all out; farming sites are no longer mixing year classes.
  - Segregated stocks; fish of similar background are kept together.
  - Well establish initial conditions;
    - Known number of fish
    - Known fish weight
    - Close follow up on mortalities/samples along the production cycle.
  - Detailed registration of environmental conditions
  - Detailed registration of feed delivery = daily estimation of growth and biomass

Closing remarks

- In aquaculture control over the production is made on a set of different indicators based on partial observation, that helps understanding what is going on in each farming unit . The indicators have to be correctly interpreted;
  - Data registration & analysis
  - Education and training
- Focus on efficiency; high performance feeds (high energy)
- Use of proper raw materials and feed digestibility analysis
- Potential Feed performance correlated to DP and DE
- Physical quality needs to match the specie requirement and the operative conditions.
- Genetic selection is a necessary tool for improving production efficiency; gains obtained in genetic programs are eternal and cumulative (Weller, 2006).
- R&D with focus on production applications, clusters of Universities/Institutes.

Thank You

Return to content

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On reducing ‘FCR’ in semi-intensive Indian major carp culture in Andhra Pradesh, India

Liberia, Costa Rica, 9– 11 November 2015

Ramakrishna Ravi
Managing Trustee
FISHNEST-The Indian Fish Family
Eluru 534007, Andhra Pradesh, India

On reducing 'FCR' in semi-intensive indian major carp culture

- Farmed aqua food production – India
- Semi-intensive Indian major carp culture – Andhra Pradesh
- Natural food and supplementary feeds
- Supplementary feeds - feeding management
- Farmers' strategies to reduce 'FCR'
- Key areas for further research
- 'FCR' related aquaculture footprints
- Conclusions

Farmed aquafood production of India in 2012 (in tonnes)

• Inland culture	:	3 812 420
• Mariculture	:	84 164
• Crustaceans	:	299 926
• Molluscs	:	12 905
• **Total**	**:**	**4 209 415**

Source: FAO (2014)

RELIES HEAVILY ON INLAND AQUACULTURE OF FINFISH

Andhra Pradesh farmed aquafood production (2013-2014) (in tonnes)

- Total freshwater fish production : 1 140 000
- Pond production of Indian major carps : 900 000
- Projected total fish production by 2019 : 1 393 000

ANDHRA PRADESH AIMS TO DOUBLE DIGIT GROWTH (2014-19)

MAIN STAY OF ANDHRA PRADESH AQUACULTURE SEMI-INTENSIVE INDIAN MAJOR CARP CULTURE

Fresh water fish culture in Andhra Pradesh, India

- SEMI-INTENSIVE INDIAN MAJOR CARP CULTURE
  - 100 000 ha
  - YEARLING BASED
  - ZEROPOINT BASED

- STRIPED CATFISH CULTURE
  - 15 000 ha

- PIRAPATINGA CULTURE
  - 2 000 ha

Source: FAO (2013)

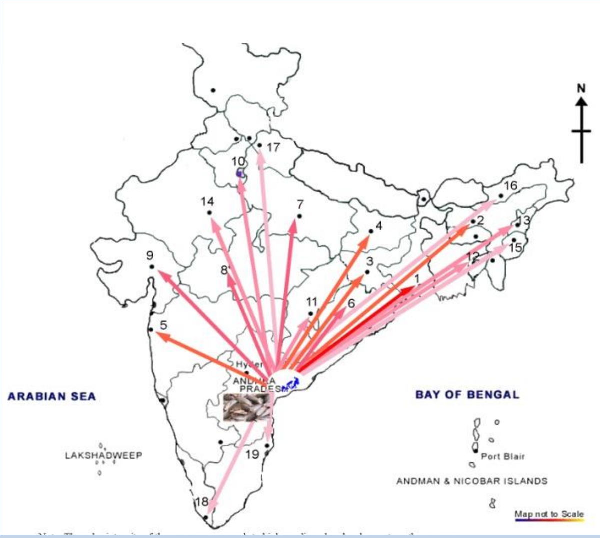
Semi-intensive indian major carp culture in Andhra Pradesh, India

- Culture area : 100 000 ha (2015)
- Average production : 9 tonnes/ha
- Total production : 900 000 tonnes
- Major species : rohu *Labeo rohita* (Rohu)
  catla *Catla catla* (Catla)
  mrigal *Cirrhinus cirrhosus*

MRIGAL ALMOST ELIMINATED

Semi-intensive Indian major carp culture
Some key features

- 85-90% rohu
- Price – catla dependent
- Standard market size: rohu 1 kg; catla 2 kg
- Fed and fertilized
- Still water culture
- Farmers: 20 000
- Dependent people: 2 000 000
- Fish exported to 21 Indian states



Semi-intensive Indian major carp culture: fertilization for natural food production

- Organic fertilizers
- Inorganic fertilizers
- Phytoplankton
- Zooplankton
- Bacterial floc
- Benthic food

***Source*: FAO (2013)**

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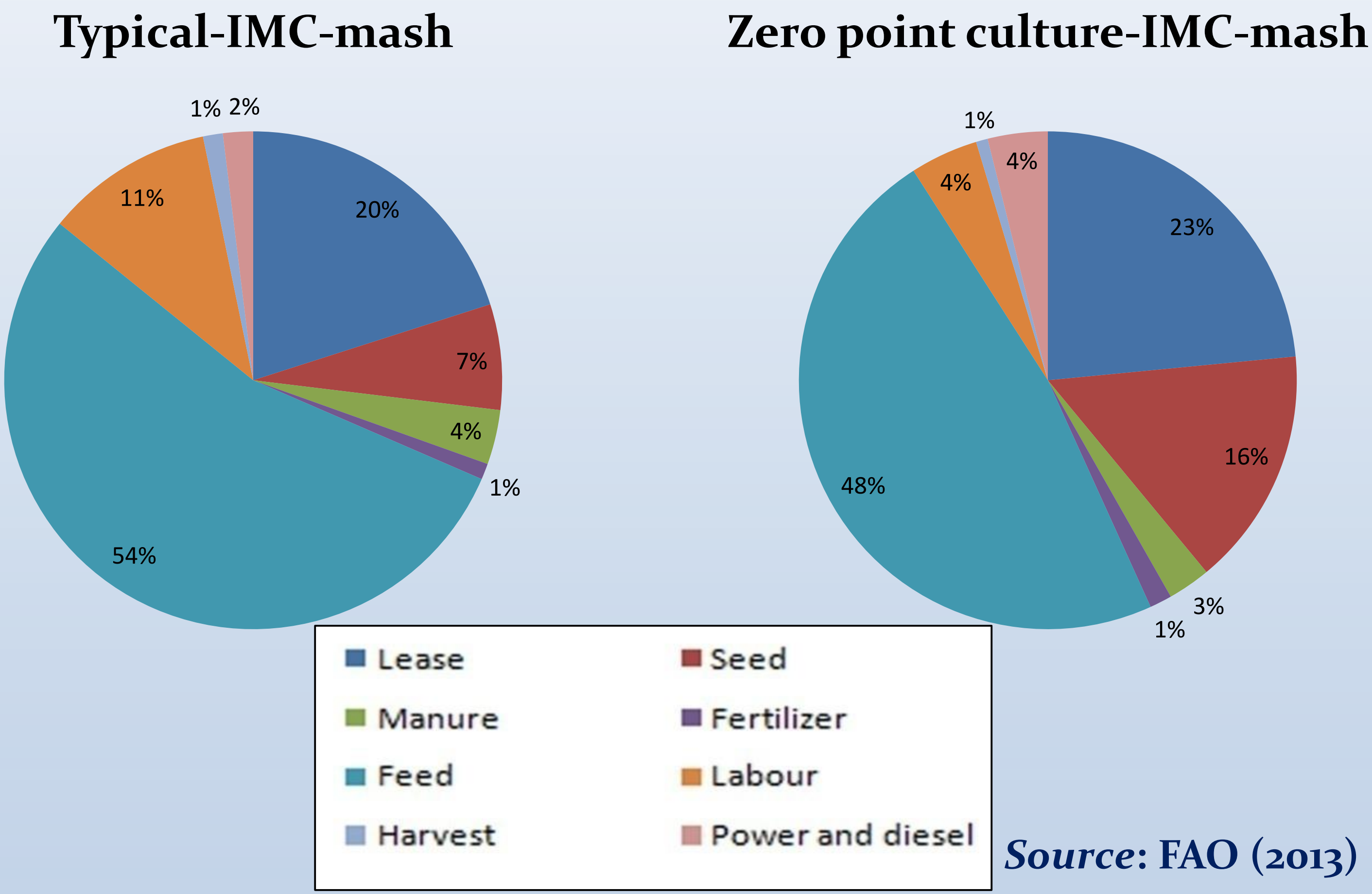
Semi-intensive Indian major carp culture: percentage of feed cost in production cost



***Source*: FAO (2013)**

Semi-intensive Indian major carp culture: feeds and feeding rates

Suggested feeding rate* for Indian major carps
(Sinking pellet**+ de-oiled rice bran and floating pellet*** feeds)

- **Feeding rates are back calculated.**

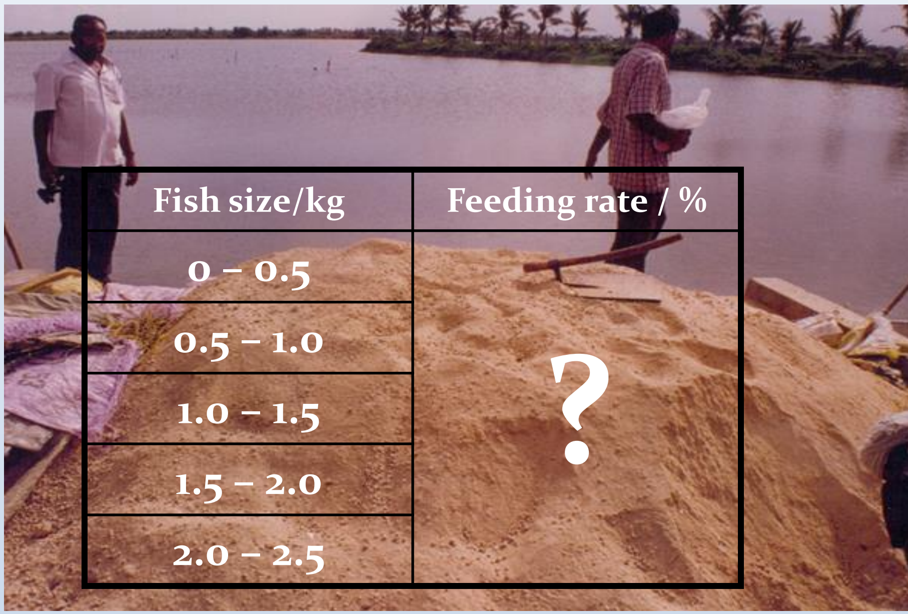
Initial weight (kg)	Anticipated monthly growth (kg/month)	Sinking feed	De-oiled rice bran	Total feeding rate	Floating feed
0.100	0.10	2.64	4.00	6.64	3.30
0.200	0.12	1.60	2.40	4.00	2.00
0.320	0.12	1.00	1.50	2.50	1.40
0.440	0.12	0.72	1.10	1.80	1.00
0.560	0.15	0.70	1.10	1.80	1.00
0.710	0.15	0.70	1.10	1.80	1.00
0.860	0.18	0.55	0.80	1.35	0.75
1.040	0.18	0.46	0.70	1.16	0.75

* Percent fish body weight per day
** 20% protein feed; *** 22% protein feed

Source: FAO (2013)

Semi-intensive Indian major carp culture

Feeds and feeding rates: high degree of variability



Fish size/kg	Feeding rate / %
0 – 0.5	?
0.5 – 1.0	
1.0 – 1.5	
1.5 – 2.0	
2.0 – 2.5	

- Farmers follow different feeding rates.
- Correct feeding rates - to be determined experimentally.

Semi-intensive Indian major carp culture

Feeding methods

'Rope-bag' feeding

'Pole-bag' feeding

Open distribution

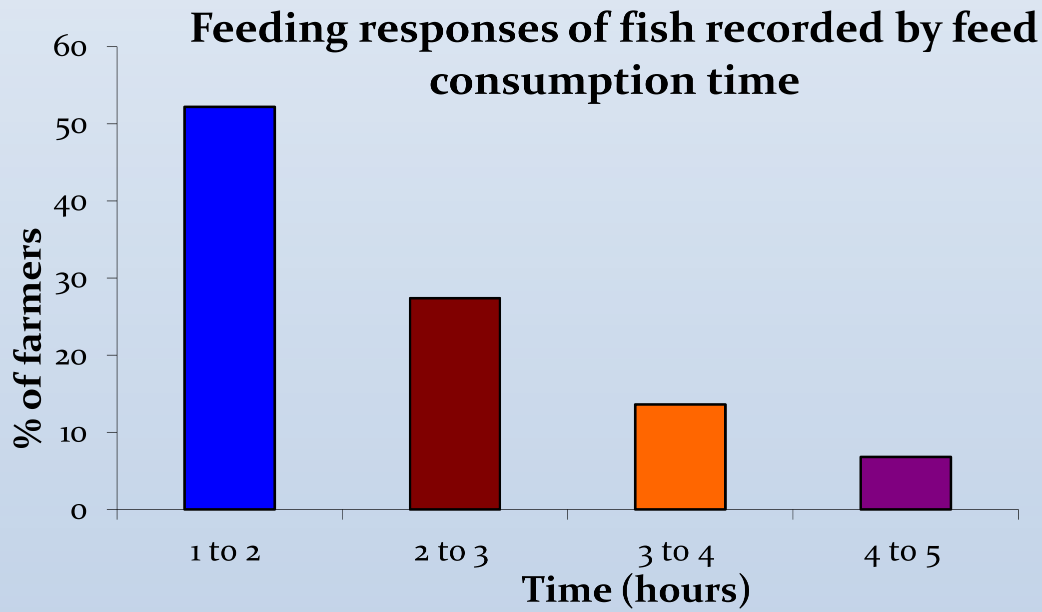
Source: FAO (2013)

Semi-intensive Indian major carp culture

Feed consumption and ration adjustment

- □ Farmers usually report feed consumption time for entire pond
- □ bigger the pond longer the feed consumption period reported
- □ Next day ration adjustment

- Same/adjusted
  - Plankton density
  - Weather
  - Other reasons



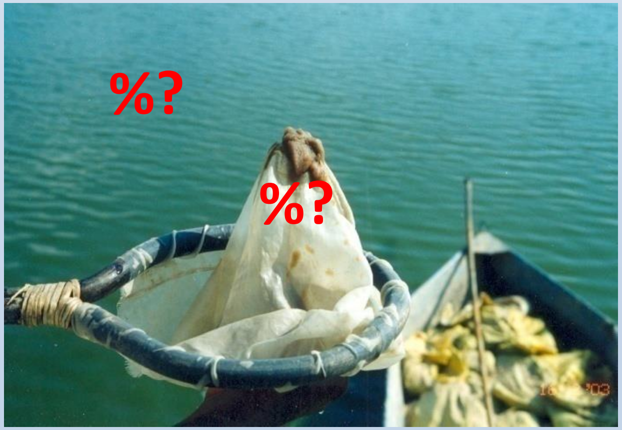
***Source*: FAO (2013)**

Semi-intensive Indian major carp culture
Feed conversion ratio (FCR)

□ Typical culture-IMC-mash	: 3.05 (±0.85)
□ Zero point culture-IMC-mash	: 3.57 (±0.92)
□ Zero point culture-IMC-mash + pellet	: 1.78 (±0.61)

Source: FAO Fisheries and Aquaculture Technical Paper No. 578, (2013)

- **Pond 'FCR'**
- **Contribution of natural food?**
- **Supplementary feed 'FCR' alone – probably higher**



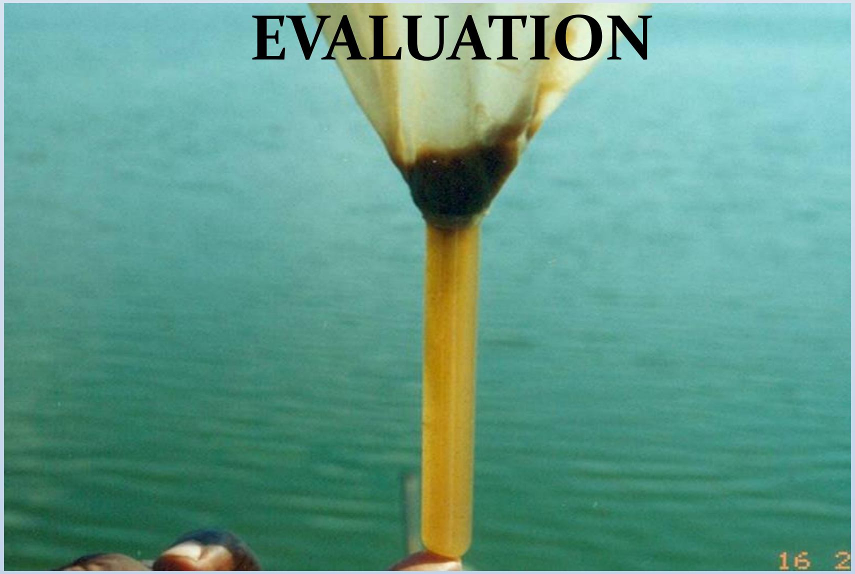
Farmers strategies to reduce 'FCR'

Based on zooplankton density on sunny days

- **DESIRED DENSITY: 2 ml**

Low : increase 20%
Medium : no change
High : reduce 20%

SUBJECTIVE EVALUATION



Source: FAO (2013)

Farmers strategies to reduce ‘FCR’

Stocking bigger seed

□ **To ensure correct estimation of:**

- Survival
- Standing fish biomass
- Daily feed ration
- Fish biomass at harvest

Zero-point size

Fry

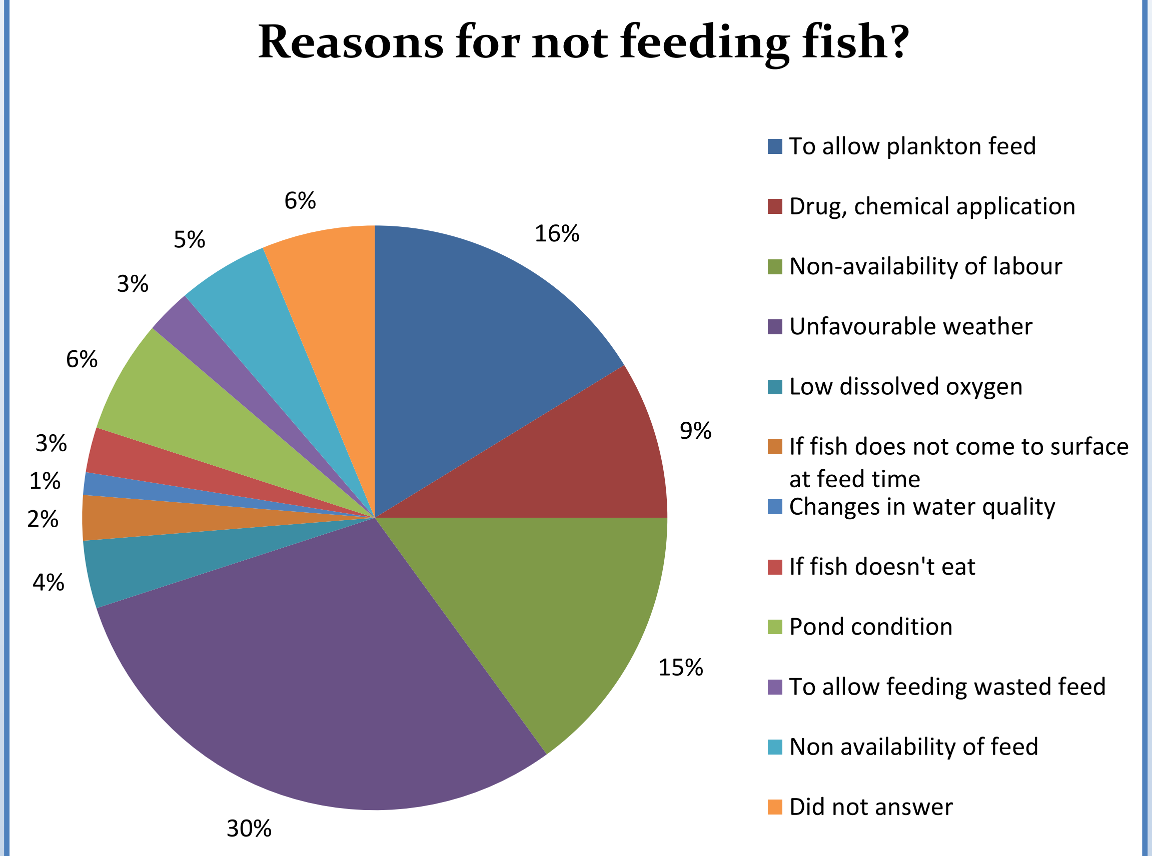
Yearlings

Source: FAO (2013)

Farmers strategies to reduce 'FCR'
Mixed feeding schedules

- □ Skip feeding
- □ Add sinking pellets
- □ Up to 300 g/yearlings only rice-bran
- □ Add raw rice-bran

***Source*: Field Survey (2015)**



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Farmers strategies to reduce 'FCR'

Daily ration-on anticipatory fish growth increase

- Pond : 16 ha

(An example)

- Stocking details

Species	No	Weight (g)	Biomass (kg)
Rohu	75 000	200	15 000
Catla	7 500	350	2 625
Mrigal	3 000	25	75

- Anticipatory growth increment/month

Species	Individual (g)	Biomass (kg)	Feed (kg/day) at FCR '3'
Rohu	100	7 500	
Catla	250	2 625	
Mrigal	50	150	
Rohu + catla		10 125	1 012

Month	Feeding rate
1	5.7
2.	3.6
3.	2.6
4.	2.1
5.	1.7
6.	1.48
7.	1.29
8.	1.14
9.	1.02
10.	0.93

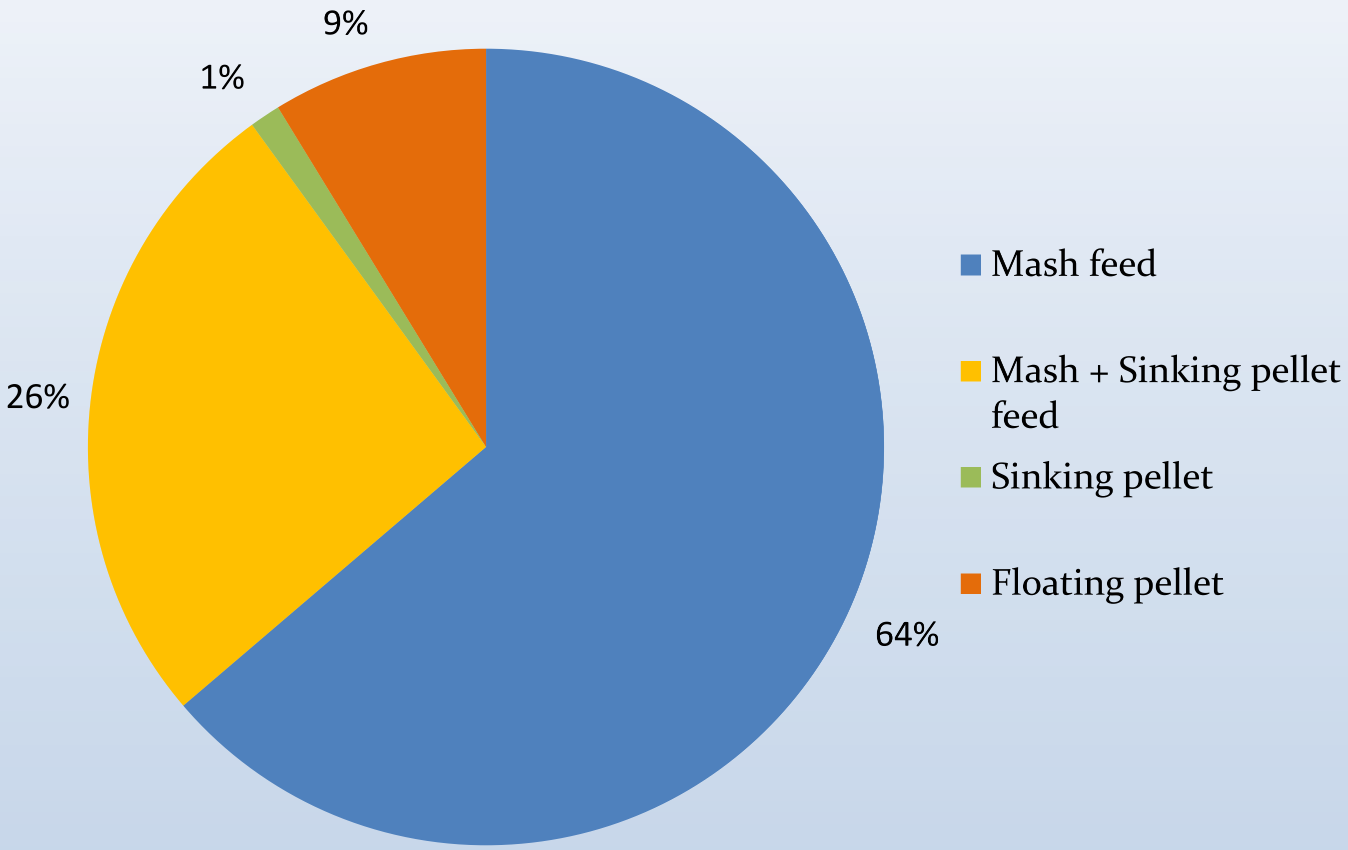
Key areas for further research

Relative contribution of natural and supplementary feed

Source: FAO (2013)

- □ Stable carbon isotopes study
  - To estimate relative contribution to growth
    - Natural food
    - Supplementary feed

Feeds used by farmers

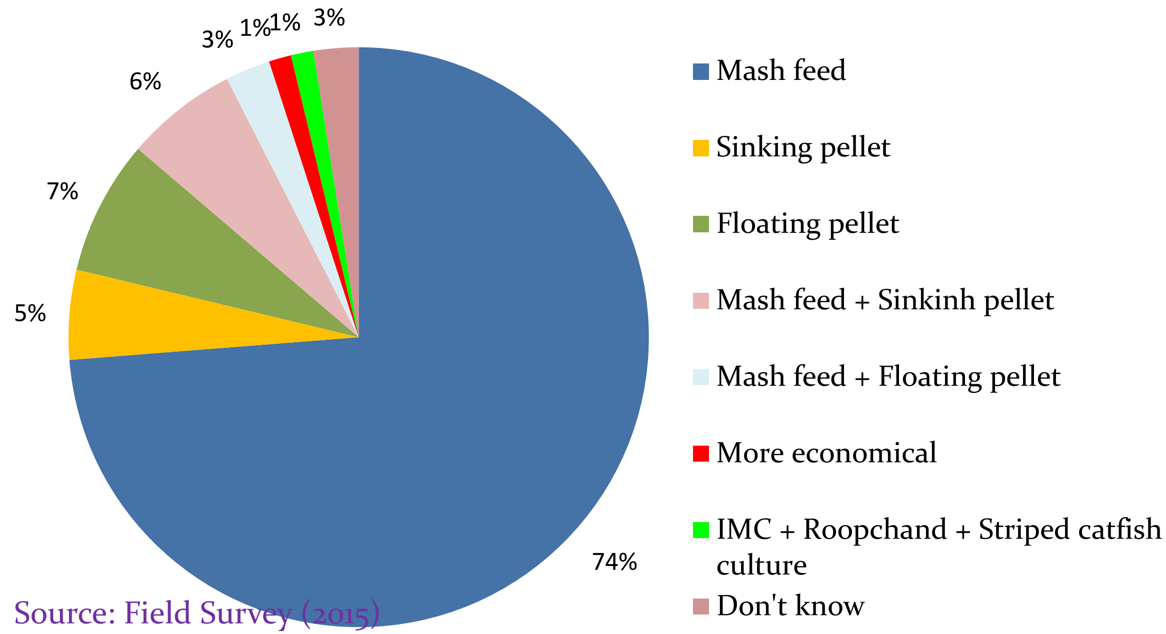


Source: **Field Survey (2015)**

Key areas for further research

Mash feed? Pellet feed? Which is more efficient?

Source: FAO (2013)

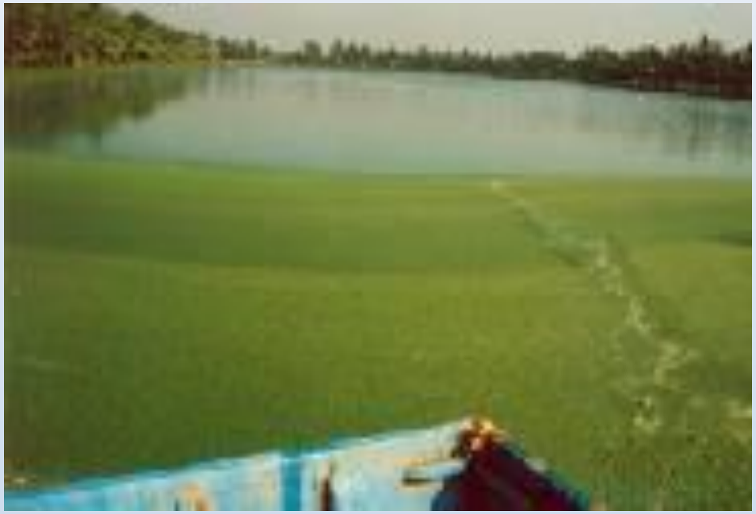


Source: Field Survey (2015)

- Farmers not yet convinced of better performance *of* pellet feed
- Research on relative efficiency (in farmers ponds) is needed

Key areas for further research

Toxic phytoplankton – *Microcystis*



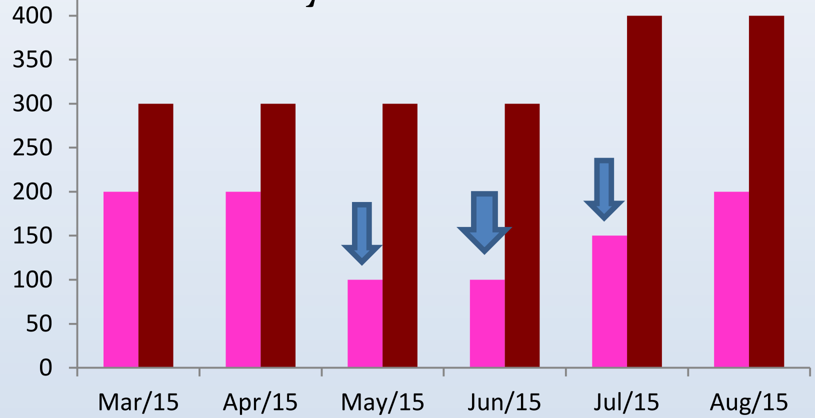
- In recent years – *Microcystis* zones instead of *Microcystis* ponds

Key areas for further research

Negative effect of *Microcystis* on 'FCR'

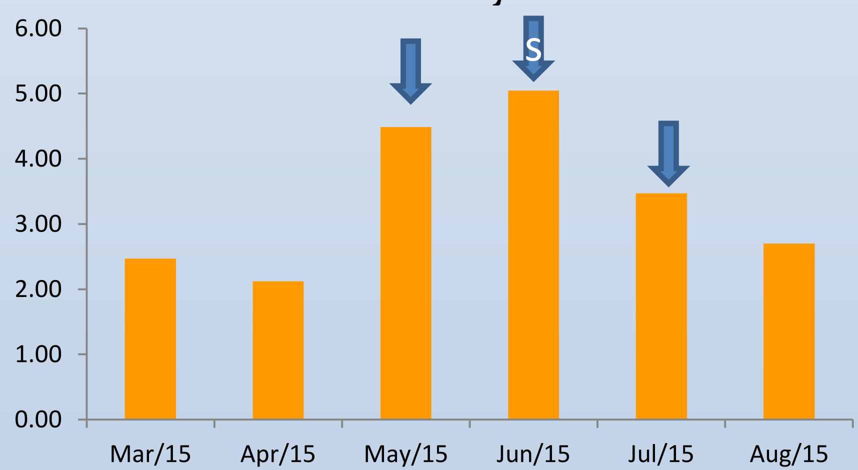
(An example: farmer Mr. D. Subba Raju, West Godavari)

Monthly Growth of rohu and catla



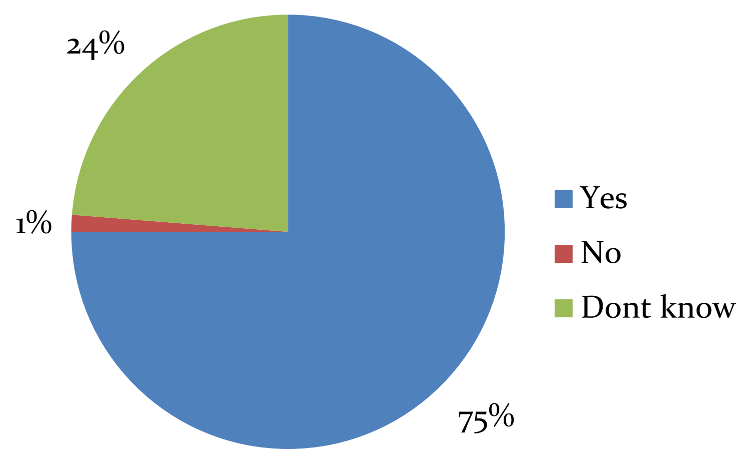
- Pond area : 16 ha.
- Rohu (nos.): 69 000 (250 g avg.)
- Catla (nos.) : 7 000 (350 g avg.)
- Feed : Only DOB (80%) + sinking pellet (20%)

Monthly 'FCR'



Source: Field Survey (2015)

Does microcystis reduce fish growth?



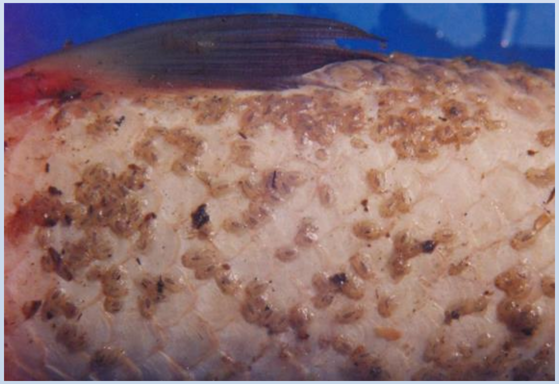
Source: Field Survey (2015)

Key areas for further research

Negative impact of infectious diseases on 'FCR'

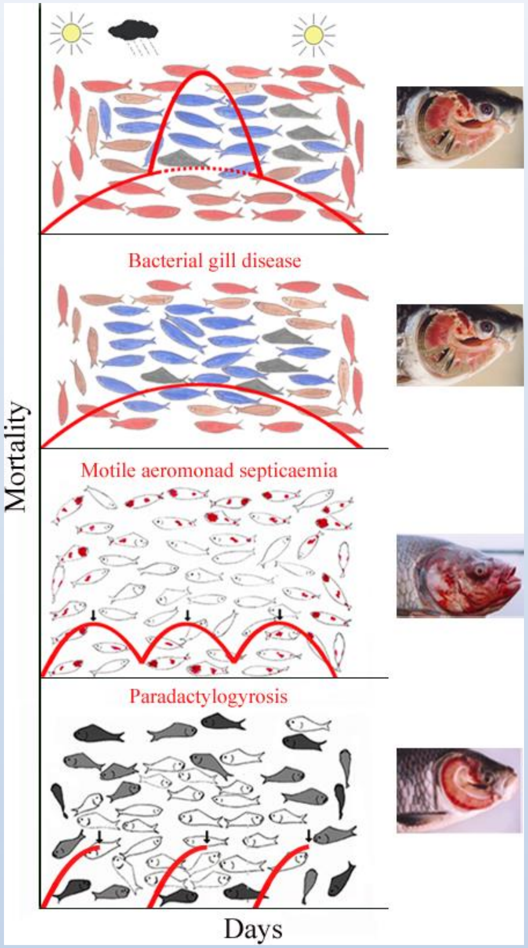
Bacterial gill disease (rohu)

Bacterial red disease (catla)



Argulosis (rohu)

Paradactylogyrosis (catla)



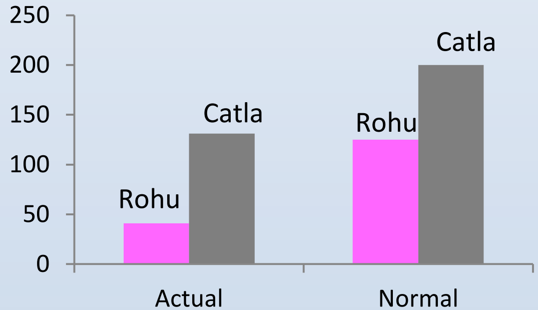
Mortality pattern

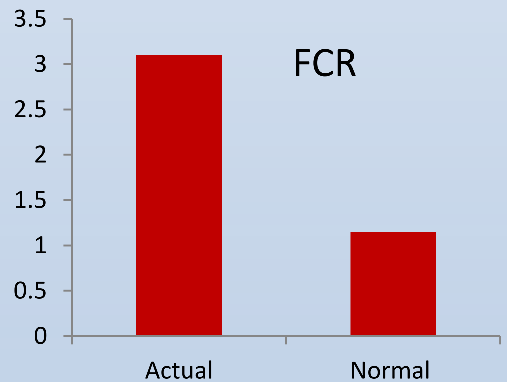
Key areas for further research

Negative effect of argulosis on 'FCR'

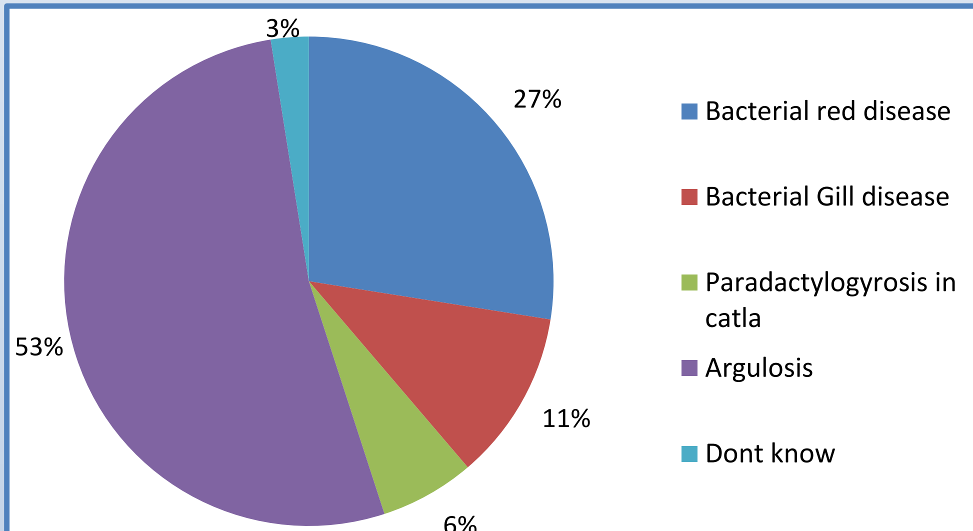
(An example farmer: Mr. M. Rajgopal, Krishna District)

- Pond area: 17.64 ha
- Rohu: 105 220 (193 g)
- Catla: 8 850 (261 g)
- Culture days: 362
- Floating pellet feed
- 28% protein





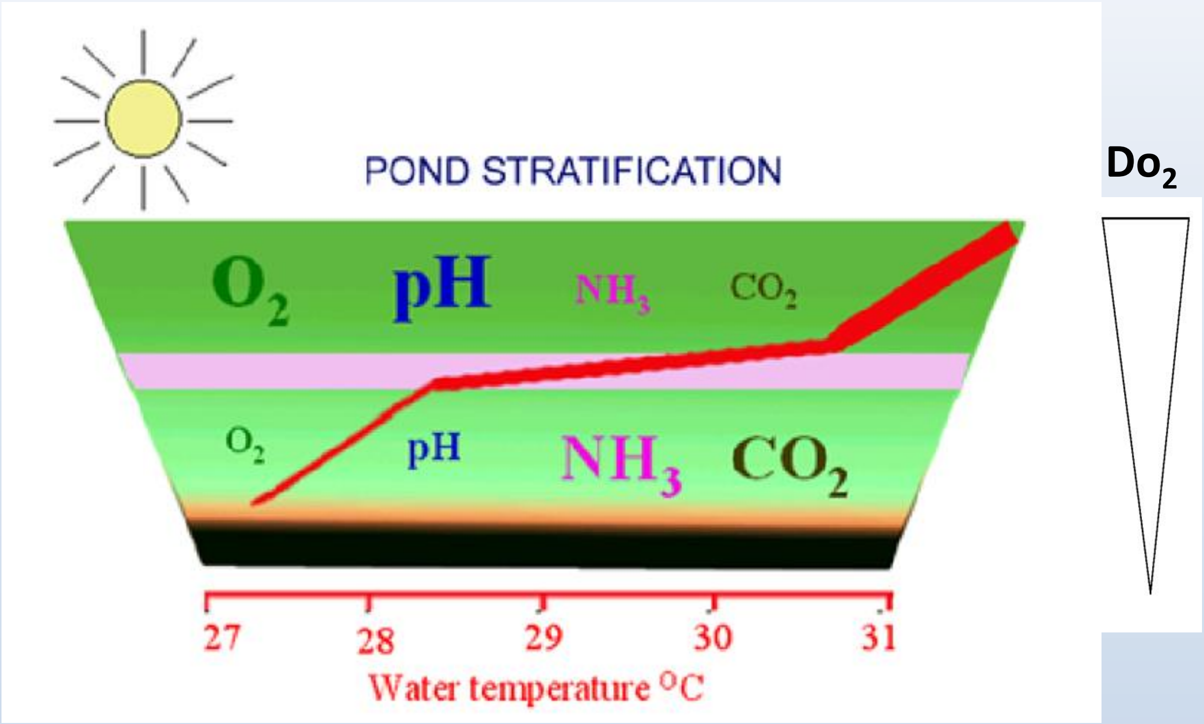
Source: Field Survey (2015)



Source: Field Survey (2015)

Key areas for further research

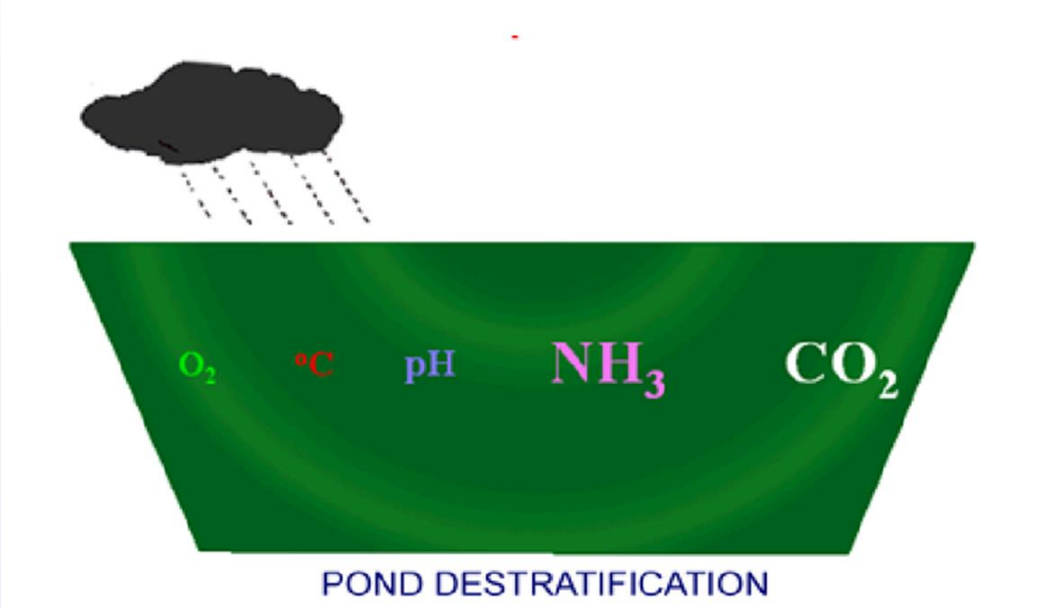
Negative impact of strong stratification on ‘FCR’

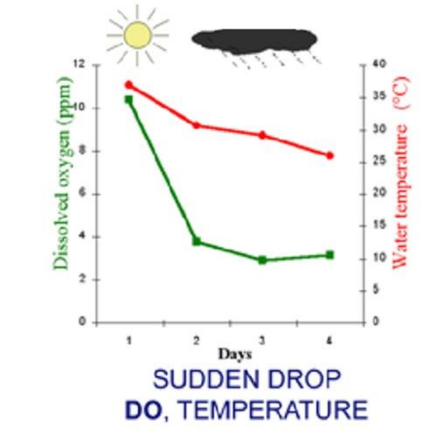


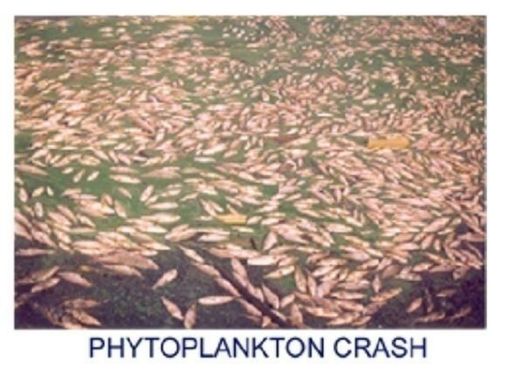
- Upper half is usually optimally productive
- Lower half significantly less productive
- ‘FCR’ improves if whole pond made optimally productive

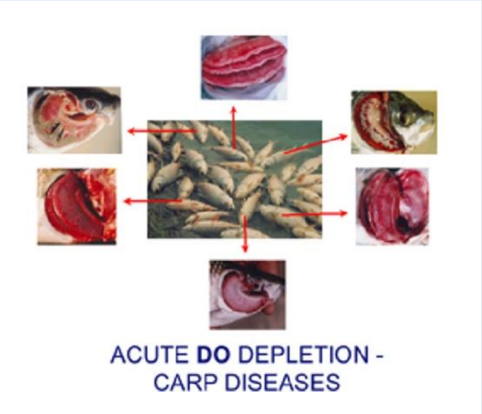
Key areas for further research

Negative impact of de-stratification on 'FCR'





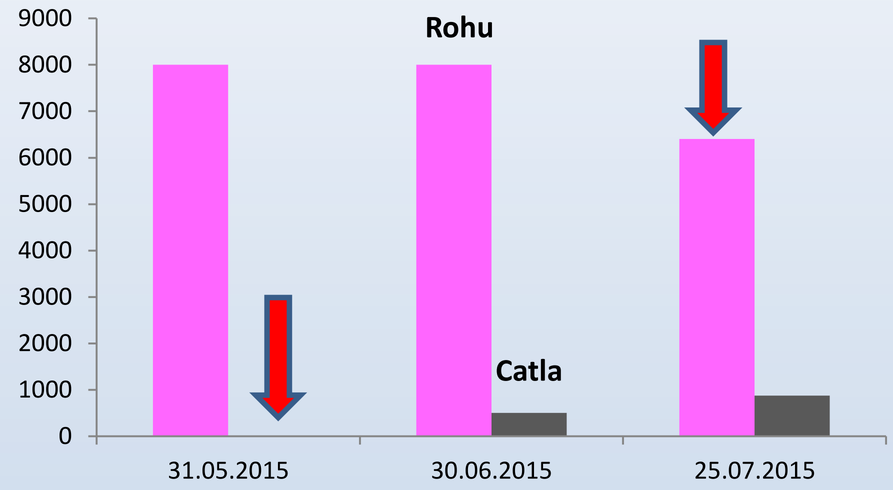




Key areas for further research

Negative effect of diseases and de-stratification on ‘FCR’

(An example: Mr. I. Hari Raju, West Godavari)

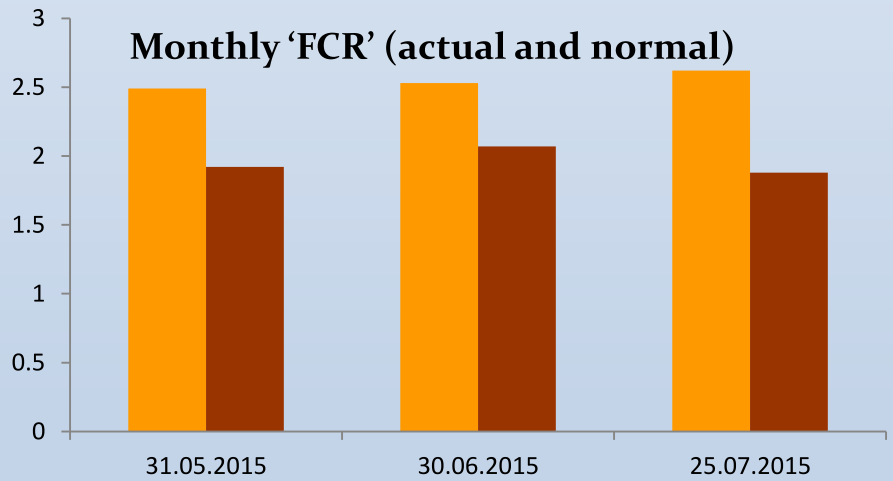


May 28 : Sudden de-Stratification

- 4,200 catla died (1.7 kg avg.)
- 2,500 smaller catla restocked in June

July 28: Bacterial gill disease break-out

- 1 500 rohu died (1.2 kg avg.)



Source: Field Survey (2015)

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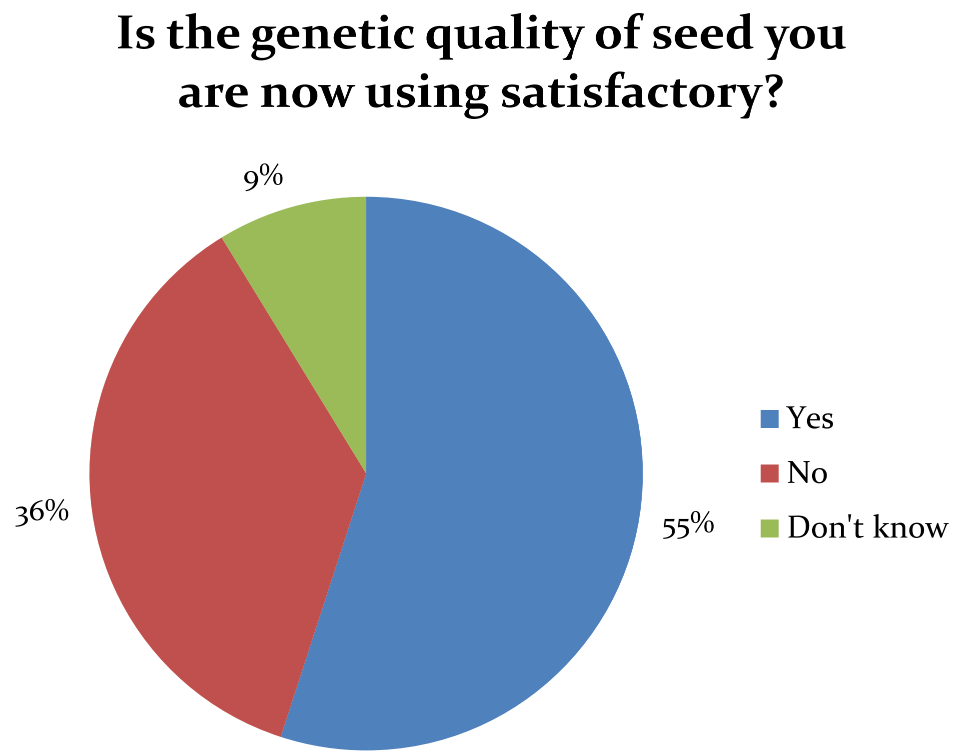
Key areas for further research
Compromised genetic quality

Brood Stock seperately managed (1985-1990)

Pond cultured fish used as brood fish (1990 onwards)



Source: Field Survey (2015)

BIASED BROODSTOCK SELECTION

Key areas for further research

Recording monthly/fortnightly 'FCR'

S. NO.	Month	FCR / Month	Pond FCR
1.	March	---	
2.	April	---	
3.	May	---	
4.	June	---	
5.	July	---	
6.	August	---	
7.	September	---	
8.	October	---	
9.	November	---	
10.	December	---	
			3

- **Pond 'FCR' recorded as 3**
- **FCR during each month of culture unknown**

Key areas for further research Freshwater scarcity and use

- Fish farmers mostly use drain water
  - Water quality already deteriorated
- Demanding right on freshwater supply
- Abnormal seasons of weather
  - Natural availability reduced
  - In many areas water depth becomes half
  - Feeding reduced
  - Growth negatively affected

Krishna district (2015)

(March, April, May, June, July)

- Severe scarcity
- Water depth almost half (1m)
- Increasing water salinity

‘FCR’ Increased : 1.3 –1.8 (floating pellet feed: 24% protein)

***Source*: Field Survey (2015)**

'FCR' related aquaculture footprints - water

- Global water footprint: 1 243 m^3/cap/year
- India water footprint: 980 m^3/cap/year
  - Domestic: 38 $m^{3/}$cap/year
  - Agriculture: 921 m^3/cap/year
  - Industrial: 21 m^3/cap/year
- AFR (Aquaculture to Freshwater Ration)
  - World average: 721 tonnes/km^3
  - Asia average: 2409 tonnes/km^3
  - China: 7344 tonne/km^3
- World aquaculture consumptive water use : 111.4 km^3 /year

Andhra Pradesh (India) carp culture?

To be estimated

Ref : Aquaculture, Resource use and Environment, C.E.Boyd & A.A. Mc. Nevin, 2015

'FCR' related aquaculture foot prints – land use

- Major land uses for India (1000 km²)
- Total : 3 287
- Inland water area : 314
- Forest : 678
- Agriculture : 1 800
- Other : 495

Land required to produce plant meals for 1 000 kg of selected species		
Species	**Land area/plant meal (ha)**	**Live fish or fishmeal (kg)**
Atlantic salmon	0.074	1 350
Trout	0.081	1 350
Shrimp	0.220	1 750
Tilapia	0.402	486

Ref : Aquaculture, Resource use and Environment C.E.Boyd & A.A. Mc. Nevin, 2015

TO BE ESTIMATED FOR INDIAN MAJOR CARP PRODUCTION, ANDHRA PRADESH

Conclusions

1. Semi-intensive culture of Indian major carps – main stay of Andhra Pradesh aquaculture.
2. Proved sustainable for the last 35 years.
3. However, many economically important problems emerged.
4. Natural food i.e. phytoplankton, zooplankton etc. significantly contributes for fish growth and 'FCR'.
5. Increased feed cost and higher 'FCR'.
6. Evaluation of the contribution of natural food for fish nutrition.
7. Fish farmers adopt several feeding management strategies for reducing 'FCR'.
8. Key areas and negative impact factors in 'FCR' related areas identified for further research.
9. 'FCR' related aquaculture foot prints – an emerging area of research

Thank You

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History of FCR reduction in marine shrimp and its impact in shrimp farming in Ecuador

Liberia, Costa Rica, 9– 11 November 2015

Laurence Massaut
Cámara Nacional de Acuacultura
Guayaquil, ECUADOR

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National Chamber of Aquaculture

- Private non-profit organization, founded in 1993
- Represents the shrimp industry of Ecuador
  - **Maturation facilities - Hatcheries - Farms - Processing plants - Feed mills - Providers of goods and services - Shrimp farmers associations**
- Link between the private sector, governmental and non-governmental organizations, in order to promote sustainable business models where aquaculture boosts the development and welfare of the Ecuadorian community

National Chamber of Aquaculture

Ecuador says industry must do more for farmed shrimp's reputation

Country's aquaculture association calls on shrimp producing nations to promote product as a safe, sustainable food source for consumers.

Dominic Welling

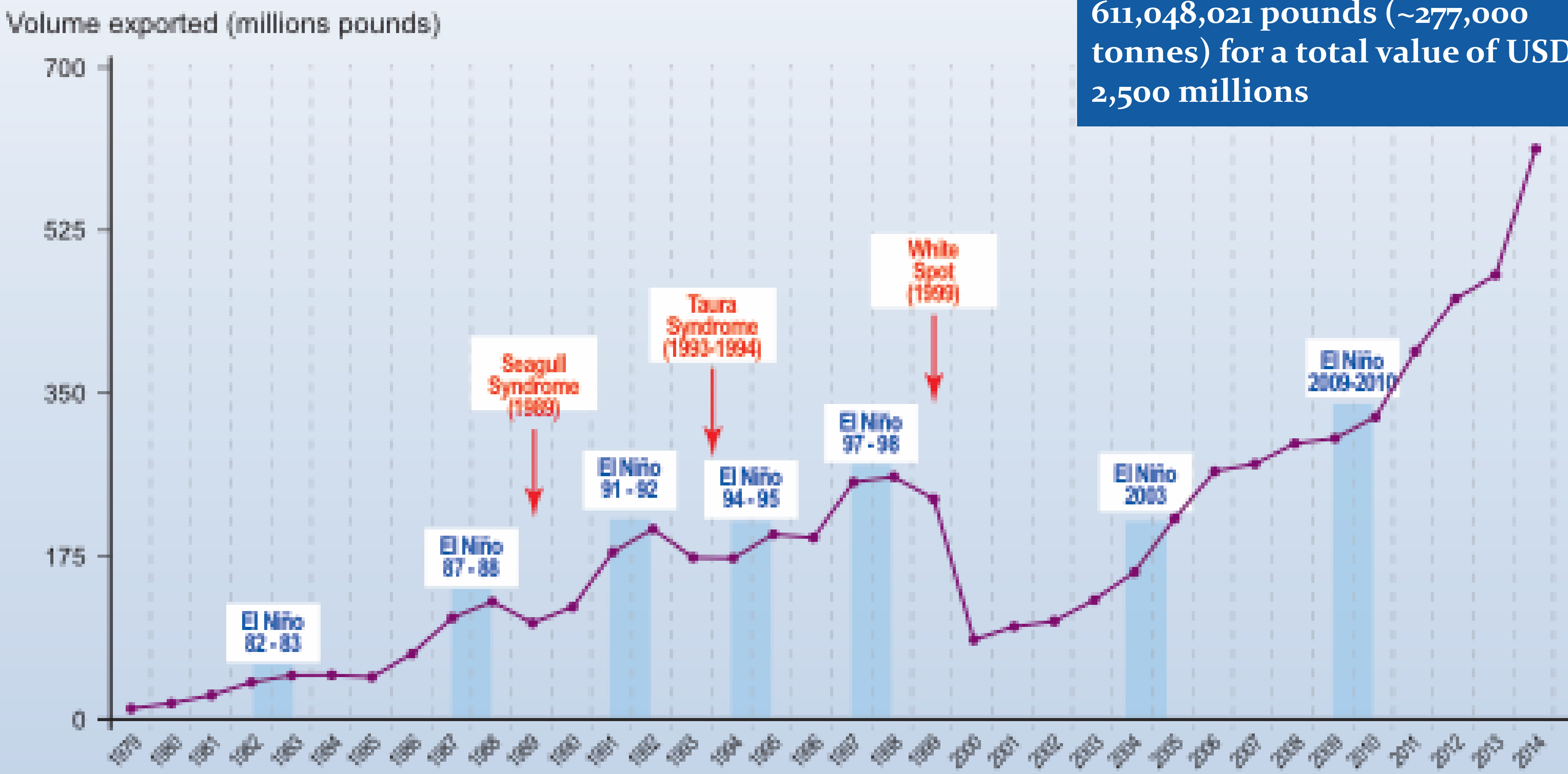
Published: 09.11.2015 15:10 Updated: 09.11.2015 14:28

Shrimp farming in Ecuador

- Shrimp farming started in 1969 in Santa Rosa (El Oro province)
- Shrimp farms: 3,070 farms spread over 213,032.16 hectares
- Water surface for production: ±175,000 hectares
- Production areas in the 5 coastal provinces: Guayas (66%), El Oro (18%), Manabí (9%), Esmeraldas (6%), Santa Elena (1%)
- Two-thirds of shrimp farmers are small (0-50 ha) and medium (50-250) producers
- Shrimp is the second non-oil export product for Ecuador (13%)
- In 2011, the shrimp industry generated 177,276 direct and indirect jobs (5% of the employed population)

Shrimp production in Ecuador

In 2014, Ecuador exported 611,048,021 pounds (~277,000 tonnes) for a total value of USD 2,500 millions



Shrimp farming in Ecuador

Semi-intensive low-density production system in equilibrium with nature:

Production parameter	1998-1999	2000-2002	2003-2004	2005-2007	2014
Stocking density (PL/m²)	12 - 16	12 - 10	8 - 10	8 - 10	6 - 12
Survival rates (%)	45%	15% - 30%	30% - 45%	40% - 55%	60% - 70%
Yield (kg/ha/year)	850	250 - 500	750 - 1,000	1,200 - 1,400	1,600 - 1,800
Growth rate (g/week)	0.7-0.9	-	-	-	1.2-1.6

- **Low density reduces the spread of diseases and helps maintain good water quality**
- **Maturation with breeding programs - No use of wild postlarvae or broodstocks**
- **Widespread use of good quality feed, probiotics, immunostimulants and organic acids**
- **Adoption of a multi-phases system**

Facts on feeding shrimp (Ecuador)

Feed represents between 30 and 45% of shrimp production costs in Ecuador (Global Consult, 2010):

- Higher cost item
- Followed by: workforce, other inputs, larvae, energy, maintenance, and Security

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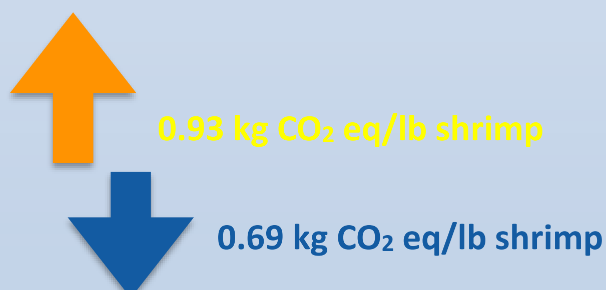
Facts on feeding shrimp (Ecuador)

Feed is the first contributor to GHG emissions during shrimp production of small shrimp farmers in two provinces of Ecuador (CNA-CENAIM-GIZ, 2013):

- **Surveys of 77 small farmers (90% were <20 hectares) in Manabi and Esmeraldas (Ecuador)**
- **Energy (electricity, diesel, LPG); Inputs (feed); Transport; Larvae**

- **GHG emissions: 0.77 - 1.22 kg CO_2 eq/lb. shrimp produced**
  - **Feed represented 48% of GHG emissions (FCR: 0.7 - 1.2)**
  - **Diesel - 40% / Larvae - 6% / LPG, electricity and transport - 2% each**

- **Shrimp pond sediments act as carbon sinks (Boyd *et al*., 2010)**
  - **158 samples analysed from 77 shrimp farms**
  - **On average 0.69 kg CO_2 eq/lb. shrimp produced is retained in shrimp pond sediments**



Factors influencing shrimp feeding

Feed characteristics

- Attractability (shrimp sensing - fishmeal); palatability; texture; water stability

Shrimp physiology

- Between 1 and 3 hours to evacuate digestive tract; Circadian rhythm (enzymes activity); molting (lower during molting); body size (size of pellets)

Environmental conditions

- Dissolved oxygen (>4 mg/L); temperature (29-31°C); presence of natural food

Feeding shrimp

Feeding management:

- Broadcasting (manually - mechanically)
- Feed trays (as control - to fully feed)
- Checking stomach content
- New technology - automatic feeders controlled by sounds

Feeding shrimp

Broadcasting according to feeding table

Normally twice per day (40% am/noon - 60% pm)

Shrimp average weight (g)	Feeding rate (% biomass)
1,0	6,00
1,5	5,33
2,0	4,83
3,0	4,23
4,0	3,80
5,0	4,00
6,0	3,80
7,0	3,43
8,0	3,20
9,0	2,66
10,0	2,57
11,0	2,43
12,0	2,33
13,0	2,23
14,0	2,10
15,0	2,00
16,0	1,93
17,0	1,87
18,0	1,80

Feeding shrimp

Use of feed trays

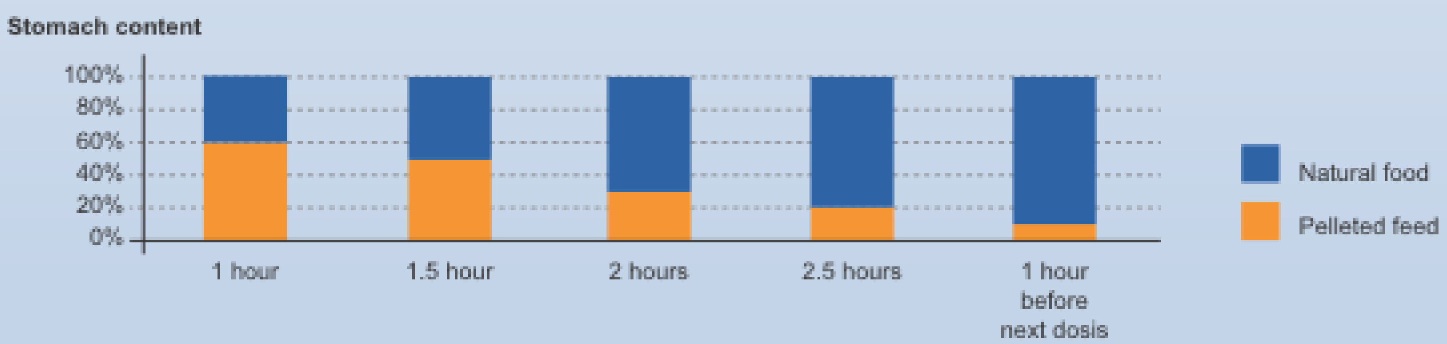
As control to adjust broadcasting rations (3-6/ha)

To fully feed (maximum 1.0 - 1.5 kg/tray)

Feeding shrimp

Checking stomach content

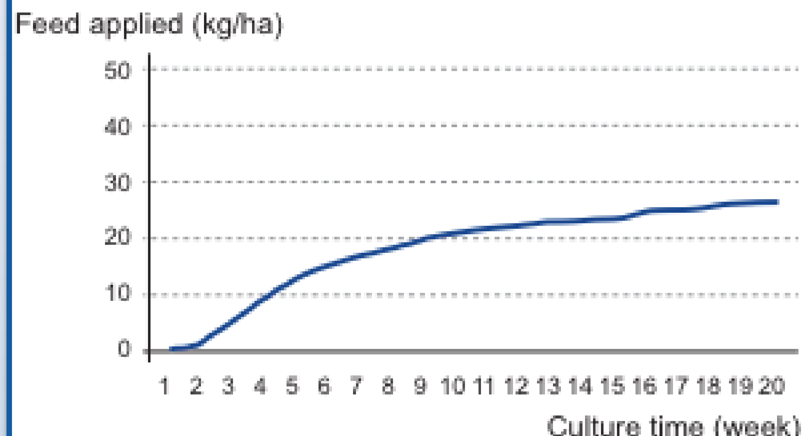
(Data Dr. Carlos Ching, Alicorp Nicovita, Peru)



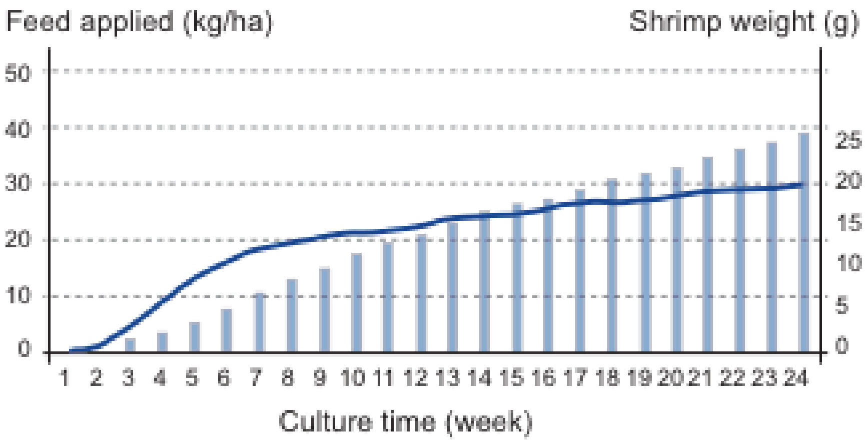
Feeding shrimp

Jorge Córdova, M.Sc. - Naturisa, Ecuador

Average 7 ponds harvested in April 2015



Average 2 ponds harvested in July 2015



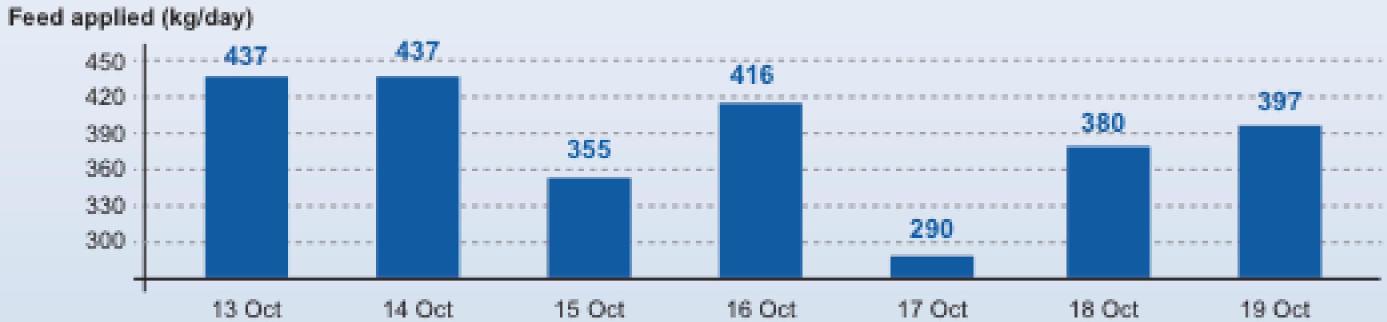
Production parameter	1998-1999	2000-2002	2003-2004	2005-2007	2014
Feed conversion ratio	2.0 - 2.4	-	-	-	0.8 - 1.6

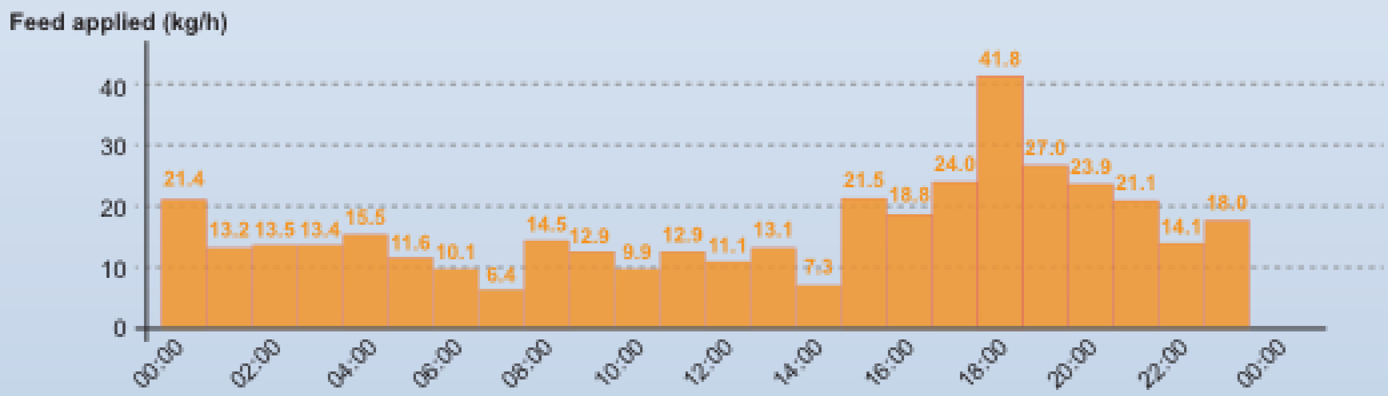
New feeding paradigm

New feeding paradigm

Jorge Córdova, M.Sc. - Naturisa, Ecuador

Shrimp feeding behaviour





New feeding paradigm

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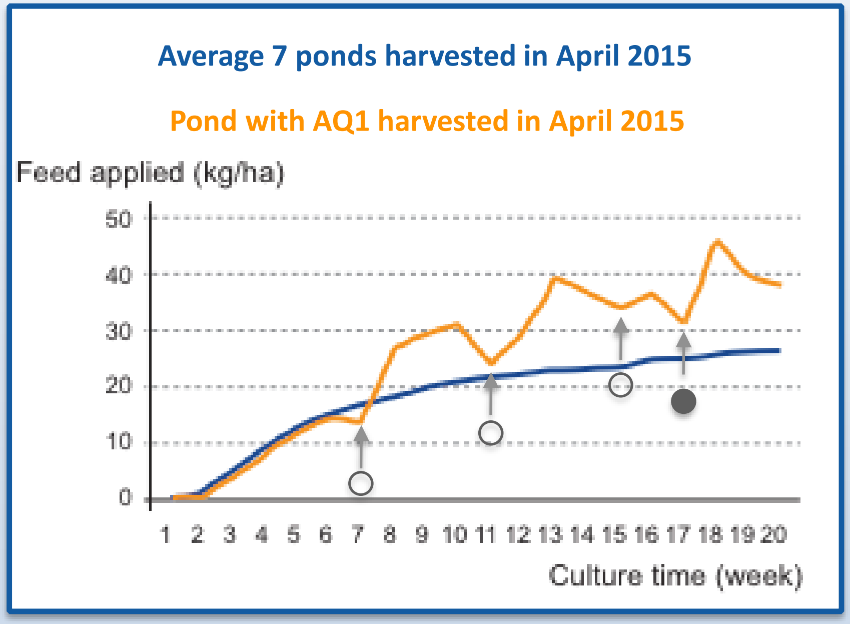
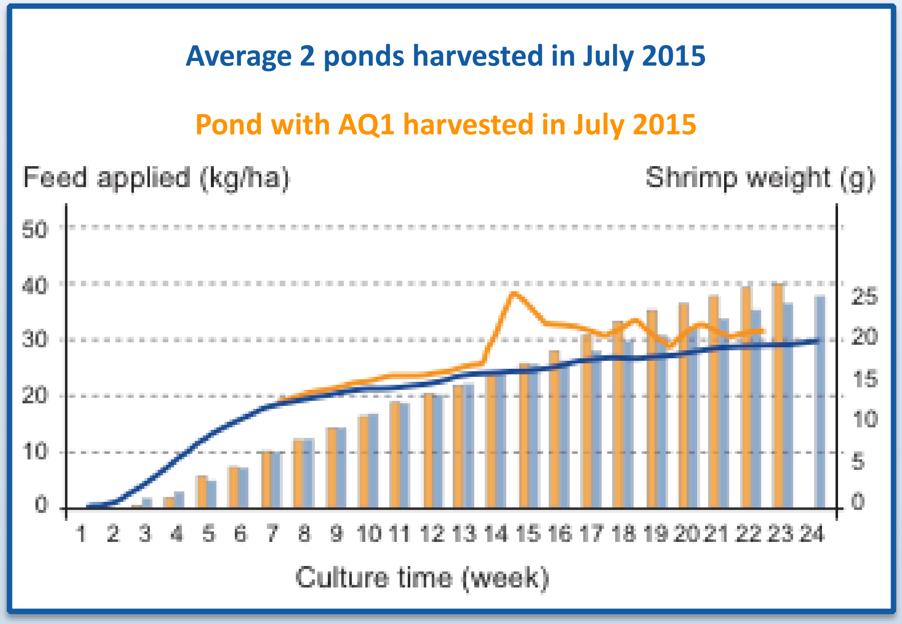
Jorge Córdova, M.Sc. - Naturisa, Ecuador





Applied feed only on an area equivalent to 1.2% of total pond surface

Improvements observed in Ecuador:

FCR: 1.83 versus 2.41 (-24%)
Yield: 4 280 lbs/ha versus 3 320 lbs/ha (+29%)
Survival rate: +10% / DOC: - 20 days for 25-30 grams shrimp / Growth rate: +10%

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Thank you

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Management of FCR: the perspective from the shrimp Industry

Liberia, Costa Rica, 9– 11 November 2015

Roberto Lopez-Ibanez
NovaGuatemala, Pescanova, Ecuador

…So, why the difficulty?

Poor pond-side metrics

- Biomass
- Mortality
- Animal health
- Consumption
- Level of education of laborer

Lack of visual feedback

- Sinking feed
- No behavior observation
- Poor understanding of husbandry behavior

Lack of proper standards or benchmarks

- Feeding tables/regimen
- Unknown genetic performance
- Feed quality and control
- No credible or formal publications on the standards

Animal health

- Poor diagnosis
- Primitive immune system
- New unknown diseases
- Difficult to manage biosecurity

Economic stressors

- Lack of funds
- High risk and low profitability
- Affected by up–down cycles typical of agroindustry

Environmental stressors

- Temperature
- Salinity
- Moon cycle
- Water conditions
- Water quality
- Neighbours
- Rain

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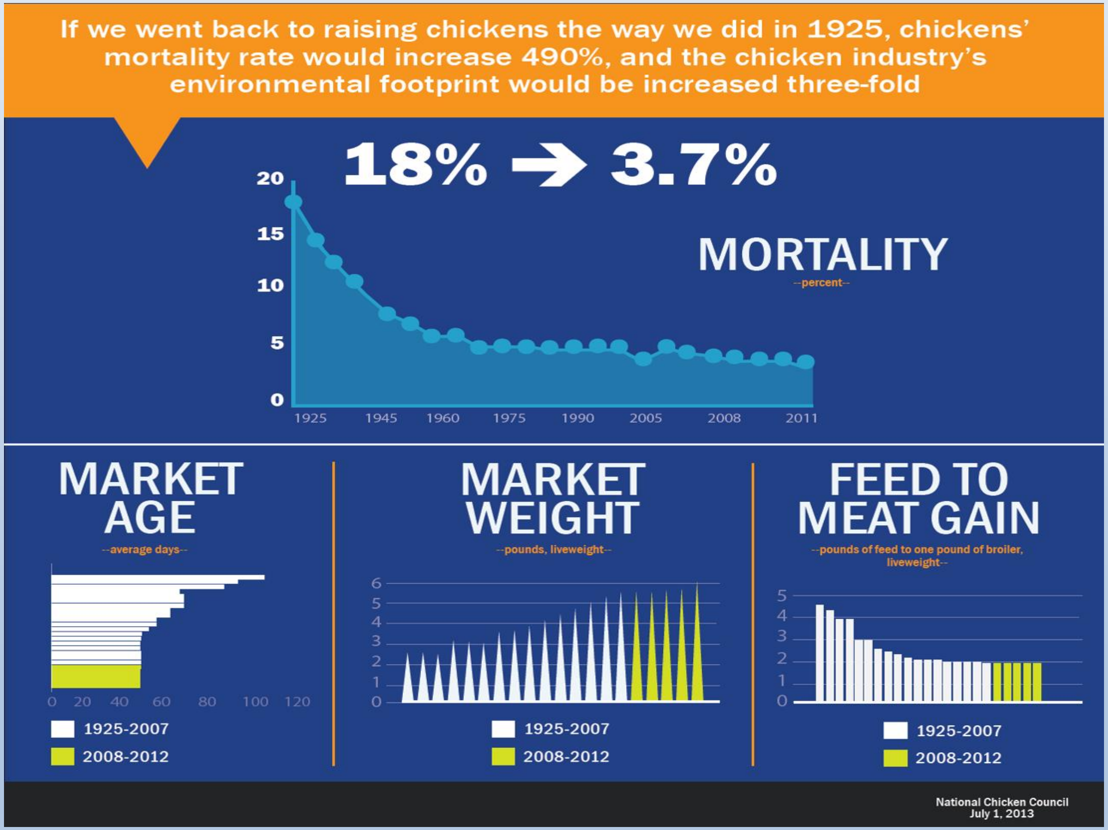
… Let’s look at poultry

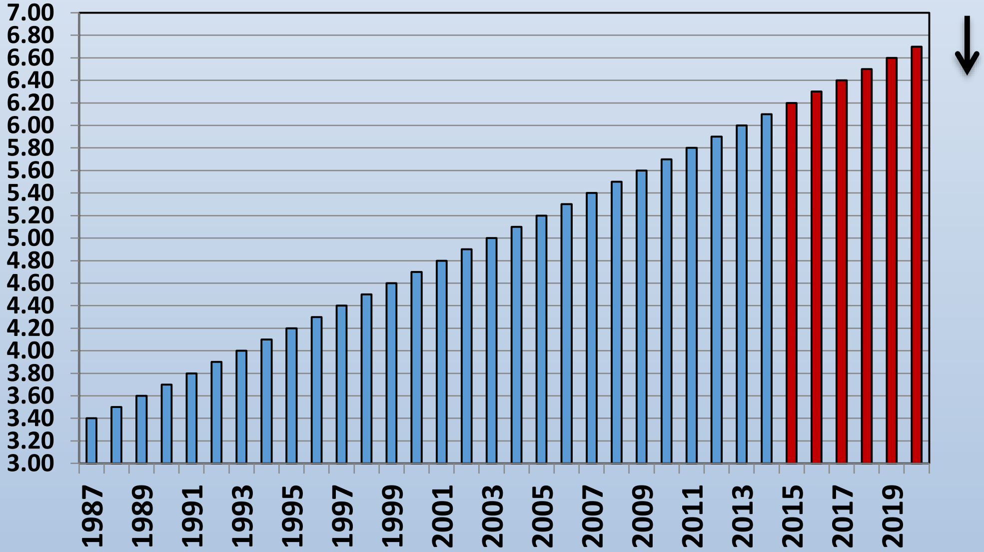
Advancements in the poultry industry



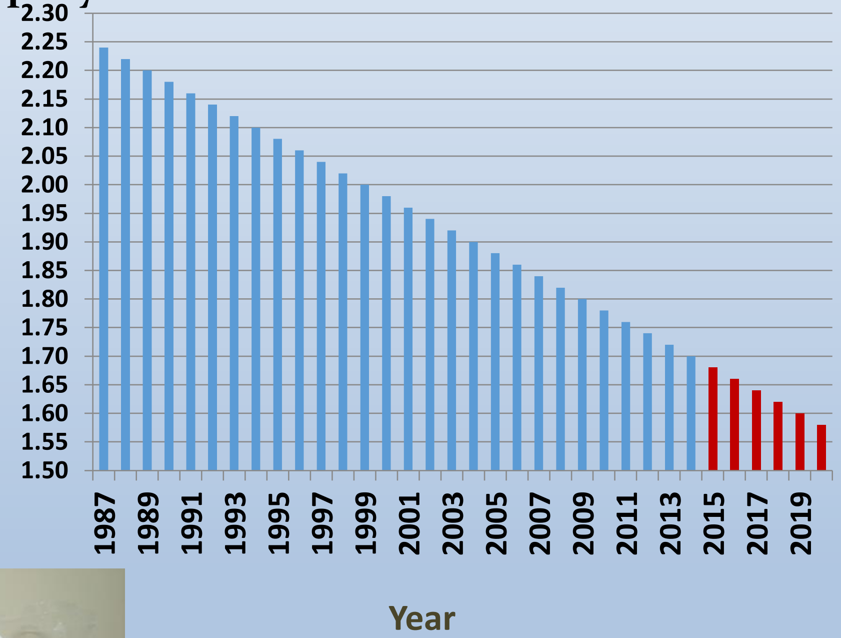
Cobb*500*™ ***Pedigree*** *Improvements*

FCR & weight at 42 days of age

Genetic improvement: 40-45 g per year



Broiler FCR Genetic improvement: -.02 to -.025 per year



Its genetics…

- Double the weight with 50% less feed vs. 1953;
- Changes attributable to genetic selection: 85.3% of growth rate, 91.3% yield & 62.5% FCR;
- THE REST IS NUTRITION AND HANDLING.

When performance is predicted and replicated with certainty under varied conditions it becomes a truly managed exercise

Shrimp husbandry remains a technical ART

What we know / the human factor: our weakest link in good FCR

- Invest in an educated workforce… OR NOT;
- Insist on protocol adherence and discipline: have a good feeding table/plan, protocol and follow the program;
- Standardize infrastructure;
- It's all about metrics: consistency, historical, diagnosis, water condition and environmental condition;
- Develop production benchmarks and review results consistently;
- Establish a good relationship with the feed supplier and demand standard.

What is new / technology advancements

- Feed performance
- Meeting dietary requirements
- Feed delivery
- Communication
- Automation
- Standardize infrastructure

Where we are going

Let's focus on the quality of the larvae

- Select an environmentally adapted animal;
- Let's make sure its clean from specific known pathogens;
- Let's produce seed of prime quality with proper feed and care.

Establish a genetic selection program

- Even if shrimp history does NOT support this;
- Manage expected genetic performance.

Where we are going

Control the environment

- Closed systems
- Biosecurity
- Self cleaning
- Dynamically optimized
- Maximum productivity focused

Optimize the feed

- Ideal protein composition
- Sustainable ingredients
- Accepts multiple ingredient / least cost substitution
- Optimal format and particle size
- Optimal manufacturing
- Delivery
- Highest FCR performance and lowest risk

Let's not forget what it's all about…

$ Cost /kg

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Potential for reducing FCRs in the production of native tilapias in Malawi

Liberia, Costa Rica, 9– 11 November 2015

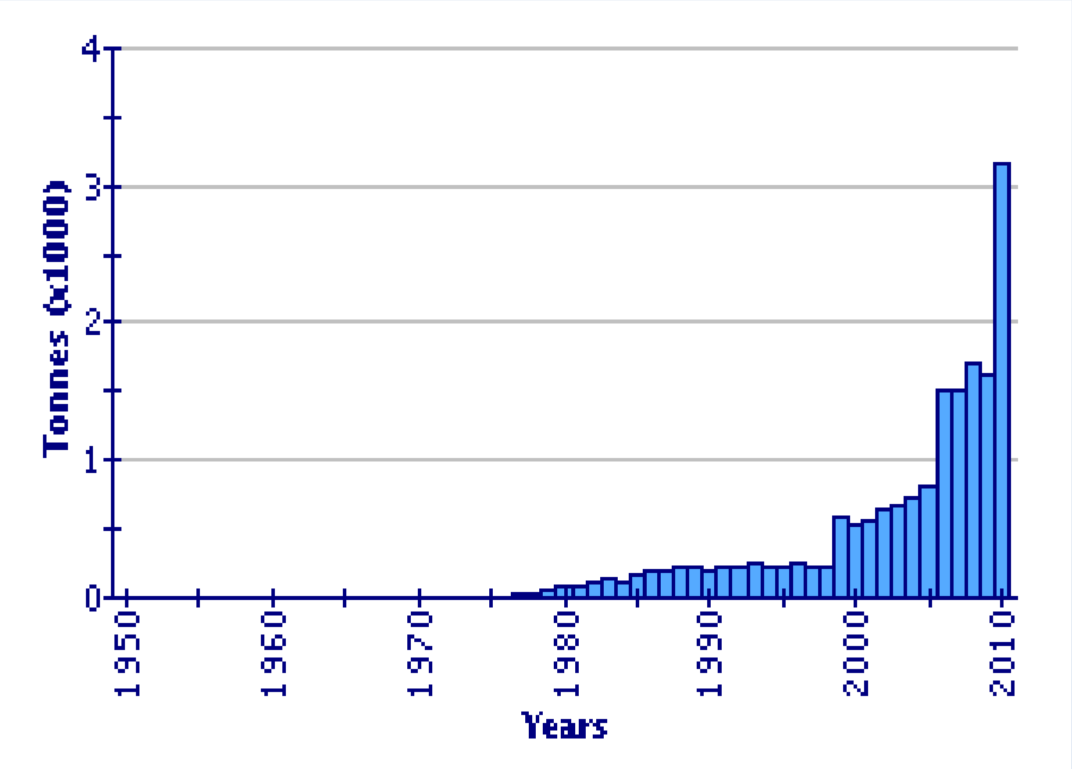
Daniel M. Jamu

Fisheries Integration of Society and Habitats Project

Mangochi, Malawi

Drivers of aquaculture production

- Growing demand



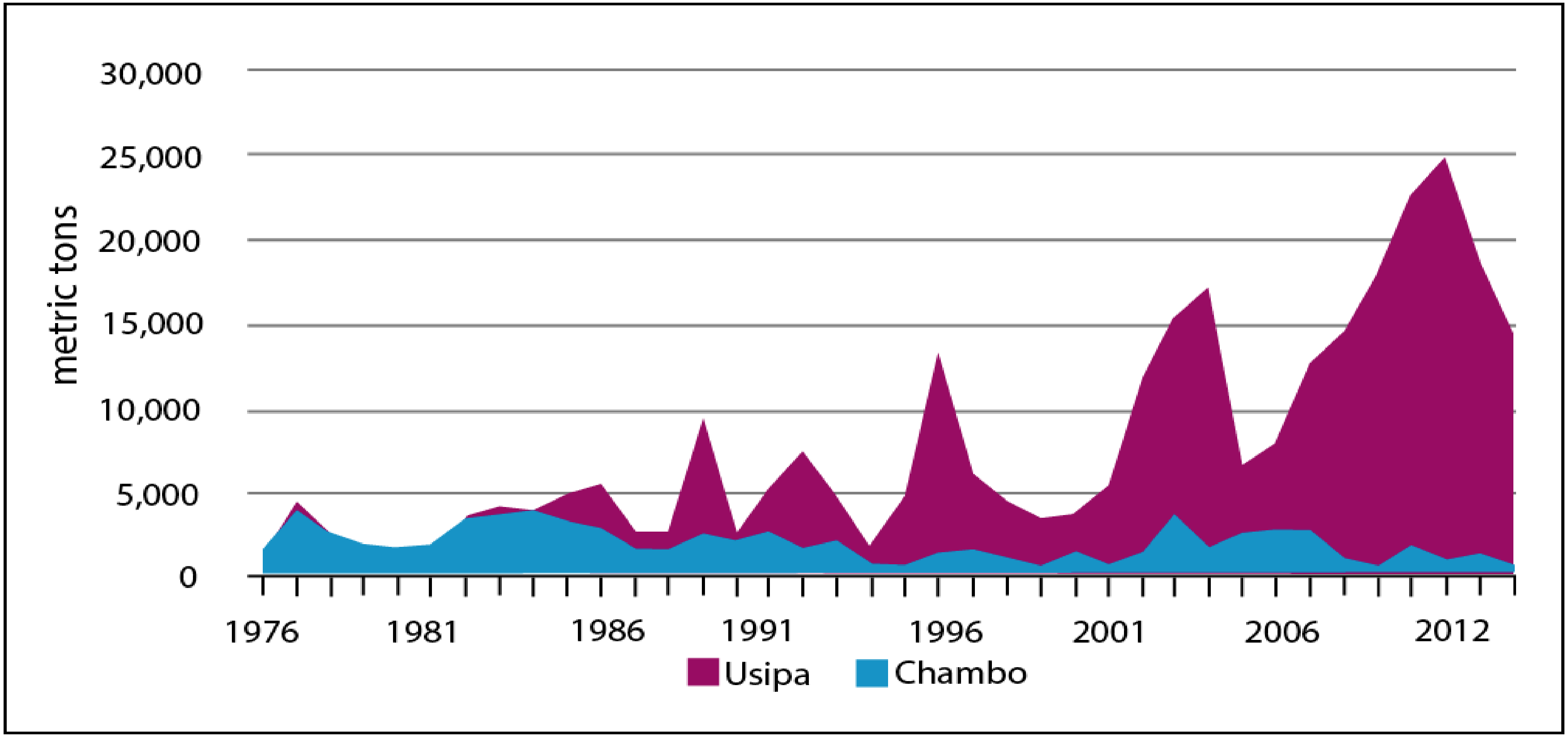
Source: FAO (2015)

Tilapia supply gap: **>30 000 tonnes** vs. total annual production of **9 000 tonnes**

All species gap: **approx. 120 000 tonnes**

Drivers of aquaculture production

Collapse of tilapia Fishery



Tilapia production in the South-East Arm of Lake Malawi. Source: Malawi Government

Closing the tilapia supply gap

- Regional import of farmed Nile tilapia from Zimbabwe
- Increased aquaculture investment

Tilapia imported from China in Zambia

Pond raised tilapia from Maldeco

Production systems: ponds

- **Extensive and Semi-intensive**

Small ponds(<1000 m^2; 1.5 tonnes/ha Large ponds(<100,00 m^2; 6-9 tonnes/ha

Production systems: tanks

- Semi-intensive and Intensive RAS

Maldeco Aquaculture,
Mangochi, MALAWI

Chambo Fisheries,
Blantyre, MALAWI

Production systems: cages

- **Formulated sinking feed (32% crude proten); 500 tonnes/year fish production capacity**

Maldeco Cage Farm, Mangochi, MALAWI

Formulated feed use

Estimated at 6 000 tonnes (2 000 tonnes formulated feed)

- Farm produced feed: Maize and rice bran with occasional soya bean meal
- Formulated feed from maize, defatted soya, fish meal imported from Namibia

FCR

- 2 to 4 in small-scale manured ponds
- 1.8 to 2.5 in cages and semi-intensive ponds

Improving FCRs in native tilapia production in Malawi

- Increase adoption of formulated fish feed http://mwnation.com/fish-farmers-cry-for-feed-subsidy/
- Improve genetics of native tilapias (variable growth leading to high FCRs)

Improving FCRs in native tilapia production in Malawi

- Improve feed management
  - Reduce feed waste
  - Report_Fri_Sep_11_8-32-01_CAT_2015.pdf
  - FCR in semi-intensive ponds reduced from 3 to 1.3
  - Reduce fish theft and pr

MONTH		1	2	3	4
JAN	TARGET	1.43	6.17	3130.14	878.64
	ACTUAL	0	10	72	280
FEB	TARGET	3	8.85	2578	1948.84
	ACTUAL	68	181	270	550

Future prospects and recommendations

- Projected 3 to 4 increased use of formulated feeds in next 5 years
  - Increased aquaculture investment to meet growing local demand
  - increased awareness of cost – effectiveness of formulated feeds by SME farmers
- Use of mobile apps as a feed management advisory service for small-scale fish farmers
- Improved feed formulation to suit native tilapia requirements will reduce FCRs in Malawi

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Application, interpretation and reduction of FCRs and consequences for major feed ingredients

Liberia, Costa Rica, 9– 11 November 2015

Krishen J. Rana

Bridge of Allan, Stirling FK9 4AX,

United Kingdom

Road map: back to basics

- **Current FCR performance of major species**
- **Concept of FCR** - application and interpretation
- **Approach : disaggregation of the FCR**
- **Implications for fishmeal and fish oil**
- **Summary**

Major species referenced

- Salmonids
- Carps
- Catfishes
- Tilapia

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Overall performance/outcome

On-farm feed management practices in tropical aquaculture

Tilapia	China	Thailand	Philippines	Egypt		Ghana	
System	Pond	Pond	Cage/pond	Cage	Pond	Cage	Pond
Commercial feed	1.69	1.4-1.6	1.5 -1.7	1.5-2.5 Sinking	1-1.2 Floating	1.2-1.4 Coppens	1.8-2.3 others
Farm-made feed	NA	<1 (2.5?)	NA	Not used		NA	

Fish	Viet Nam	Bangladesh	India
	Striped catfish	Major carps	Major carps
Commercial feed	1.6	?	1.8-3.4
Farm-made feed	2.9	1.3:1-2:1	2.3-4.1

Salmon	Cages
Commercial feed	1.2-1.4

Shrimp	Bangladesh	India	Viet Nam
Species	Freshwater prawn	Tiger shrimp	Whiteleg shrimp
Commercial feed	2.3	1.27-1.38	1 -1.2
Farm-made feed	2-4	?	?

FCR: what are we measuring?

Biological FCR :

- efficiency with which fish converts ingested feed into biomass

- Economic FCR (eFCR)
  - Extent to which a farm can account for feed used/procured in terms of harvested fish

Economic FCR (eFCR)

eFCR = total feed used or procured to produce harvest/total net weight gain at harvest

- Total net harvest = harvest weight * harvesting efficiency
- Excludes total mortality
- Total mortality (weight) = total biomass loss from disease + handling+ grading + escapes + predation etc. over production cycle

Implications

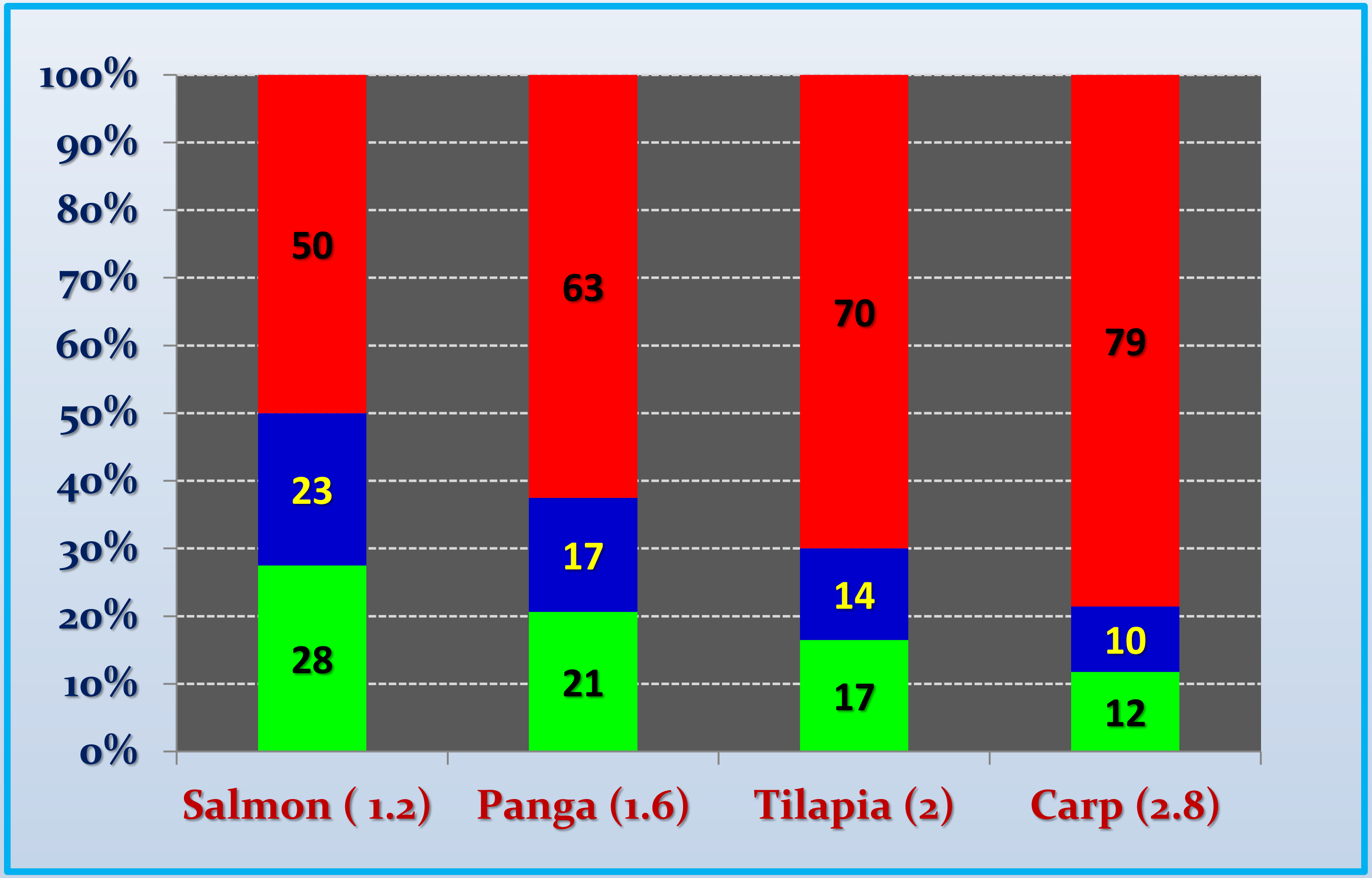
Biological FCR:

- Theoretical FCR of around 0.33. ALL diet biomass transformed to fish (assuming diets have 8% moisture and fish 70% moisture : 92/30=0.33).
- Best nutritional experimental data suggest FCR of 0.6-0.7 due to metabolic costs, inefficiencies etc.

Economic FCR (eFCR) using commercial feed

- Salmonids 1.2 (cages)
- Catfish (pangasius) 1.6 (small deep ponds)
- Tilapia 1.7 (ponds/cage) 1.8-2.7
- Carps 1.8 - 3.4 (ponds)

Window of opportunity to improve



Scope to improve function of the typology of aquaculture system

- Dichotomy of production systems
  - industrialized fish farming , particularly of relatively high valued, mostly cold water cultured species such as the salmonids.
  - small scale, rural, often clustered together, and semi-intensive
- Emphasis has been to concentrate on finding suitable alternatives for fishmeal.
- Needless to say these efforts have had much impact on the sector, but primarily on salmonids and higher trophic fish
- What can not be ignored is that in Asia, the cradle of aquaculture development, by and large the practices remain relatively small-scale

Total mortality (weight) = total biomass loss from disease + handling+ grading + escapes + predation over production cycle.

Total net harvest = harvest weight * harvesting efficiency

$$\text{eFCR} = \frac{\text{Total net weight gain at harvest}}{\text{Total feed used or procured}}$$

Assumptions in feed loss model:

Simulated mortality pattern shown table

Based on expectations on data in case studies.

Where should we target to improve efficiencies?

Case reviews/studies suggest:

- Promote nutritionally balanced feeds
- Increase digestibility
- Choice of pellet type
- Timing of feeding
- Alternate higher and lower protein diets
- Mixed feeding schedules
- Timing of feeding
- Delay onset of external feeding
- Feed administration

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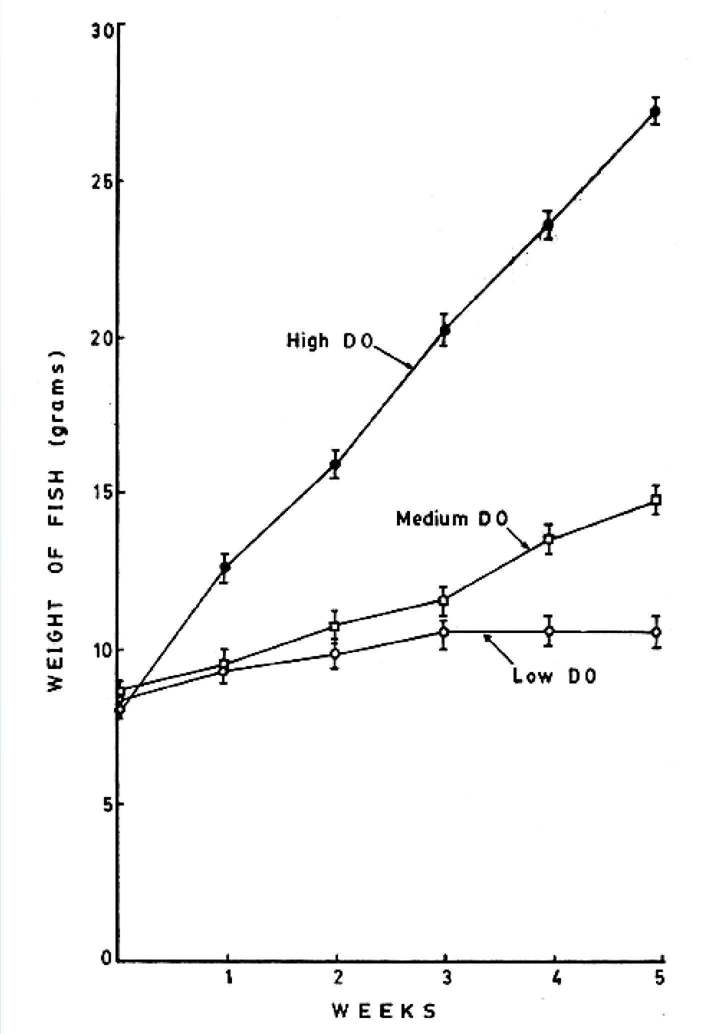
Potential impact of aeration on FCR



FCR @ DO
High - 1.5 @ 7-7.5 mg/l
Med.- 2.35 @ 3-4 mg/l
Low - 5.64 @ 1-1.5 mg/l

nim Sci

Protein (%)	Lipid (%)	Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)
20	9	72.7±0.08[b]	14.6±0.57 [ns]	8.2±0.30[ab]	2.5±0.06 [ns]
20	17	70.8±0.38[a]	14.0±0.11	11.4±1.11[b]	2.2±0.01
30	9	74.6±0.62[c]	14.6±0.44	5.5±0.41[a]	2.3±0.26
30	17	72.0±0.43[ab]	14.4±0.09	9.4±0.62[b]	2.2±0.14
40	9	74.7±0.92[c]	15.0±0.06	6.1±0.92[a]	2.3±0.05
40	17	71.3±0.53[ab]	15.2±0.09	10.0±1.70[b]	2.3±0.11

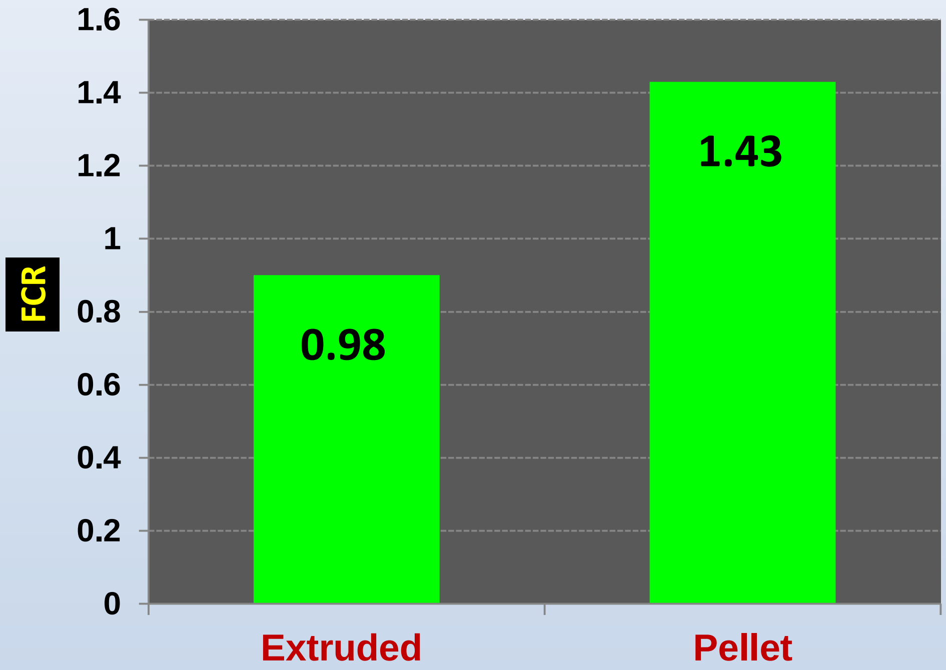
AJAS, 25(3): 369–374

Table 4. Moisture and total lipid content (% wet weight) of liver, viscera and muscle in brown trout at the end of the two growth periods [1]

	Experimental diets		
Period 1	LF (11)	MF (20)	HF (26)
Liver			
Moisture	68.0±0.6	69.9±0.7	68.8±0.5
Total lipid	9.9±0.7	8.7±0.6	8.8±0.7
Viscera			
Moisture	44.0±1.5[a]	39.5±1.7[a]	32.6±2.8[b]
Total lipid	37.9±1.8[a]	41.8±2.2[ab]	47.2±1.8[b]
Muscle			
Moisture	69.0±0.4	67.3±0.8	67.5±0.5
Total lipid	8.3±0.3[a]	10.4±0.8[b]	11.0±0.6[b]
Period 2	LF	Unfed (HF)	LF' (HF)
Liver			
Moisture	71.7±0.7	72.5±0.7	71.4±0.8
Total lipid	6.2±0.6	6.3±0.5	6.3±0.7
Viscera			
Moisture	45.3±2.5[a]	33.1±2.1[b]	36.3±1.9[b]
Total lipid	38.2±3.3[a]	50.4±2.7[b]	47.9±1.5[b]
Muscle			
Moisture	67.9±0.4[a]	69.4±0.3[b]	67.5±0.7[a]
Total lipid	8.8±0.4	8.5±0.5	9.4±0.8

Aquaculture, 2001; 193 (3-4) : 325-345

Feed presentation – pellet type



Source: Iranian Journal of Fisheries Sciences, 2014: 13(1)

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Feed type vs. FCR

Feed type	FCR		Country
Mash	2.3-4.1 (major carps)	Pond	India
Mash + pellet	1.9 (major carps)	Pond	India
Sinking pellets	1.6-2.0	Pond	China
Moist pellets	2.9	Pond	Viet Nam
Manufactured pellets	1.6 (catfish)	Pond	Viet Nam
sinking	1.5	Cage	Egypt
Extruded feeds	1.2-1.5	Cage	China
Extruded feeds	1	Cage	Egypt

Key consideration ponds *vs.* cages

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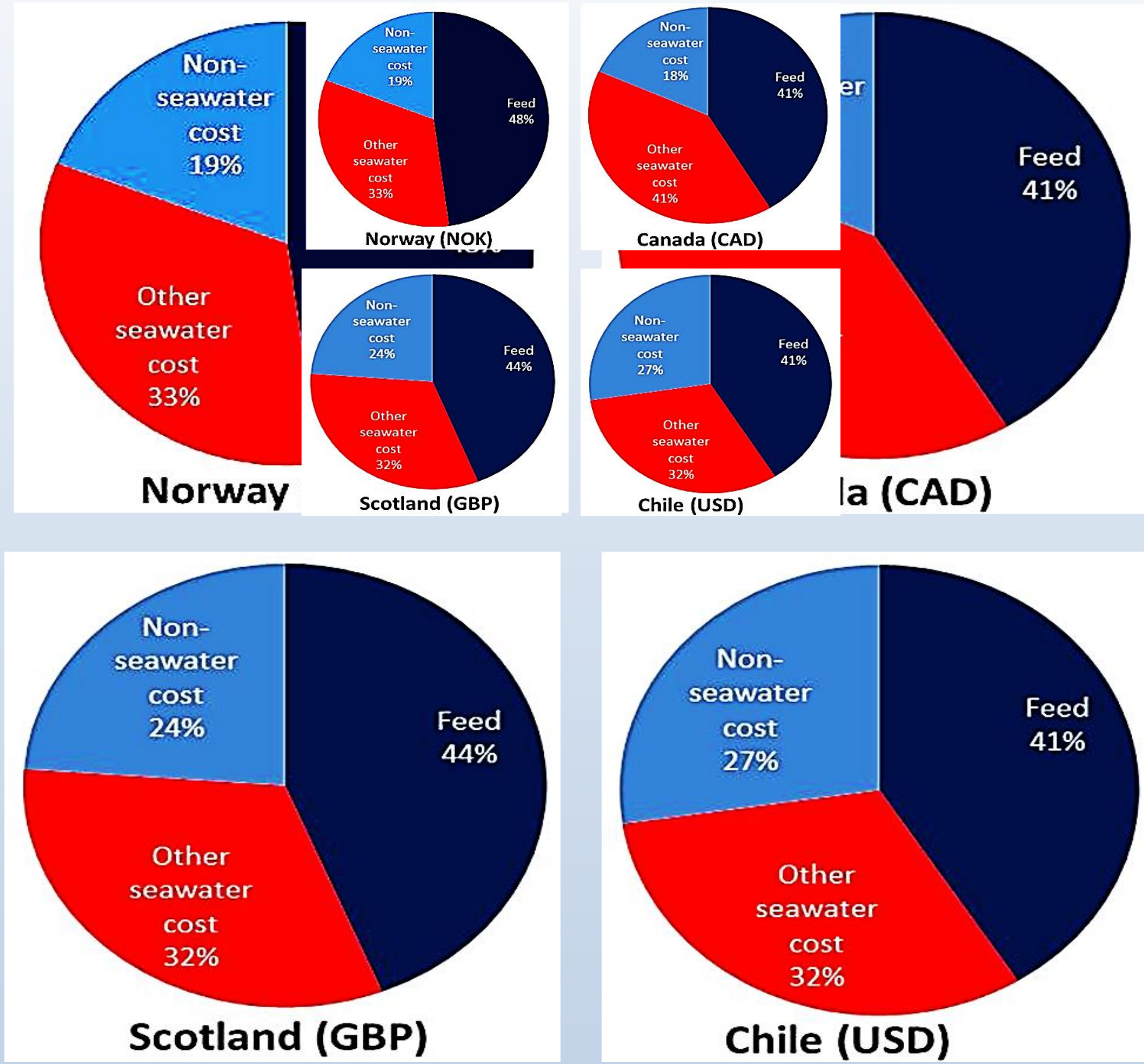
Influence of technology on production costs



Influence of technology on production costs

	Norway (NOK)	Canada (CAD)	Scotland (GBP)	Chile (USD)
Feed	12.35	2.26	1.62	2.08
Primary processing	2.62	0.55	0.31	0.41
Smolt	2.28	0.54	0.31	0.48
Salary	1.49	0.56	0.18	0.15
Maintenance	0.89	0.22	0.09	0.19
Well boat	0.98	0.21	0.21	0.28
Depreciation	0.76	0.20	0.13	0.13
Sales & Marketing	0.62	0.02	0.04	0.01
Mortality	0.34	0.04	0.15	0.02
Other	3.34	1.14	0.25	0.77
Total*	25.69	5.73	3.29	4.53

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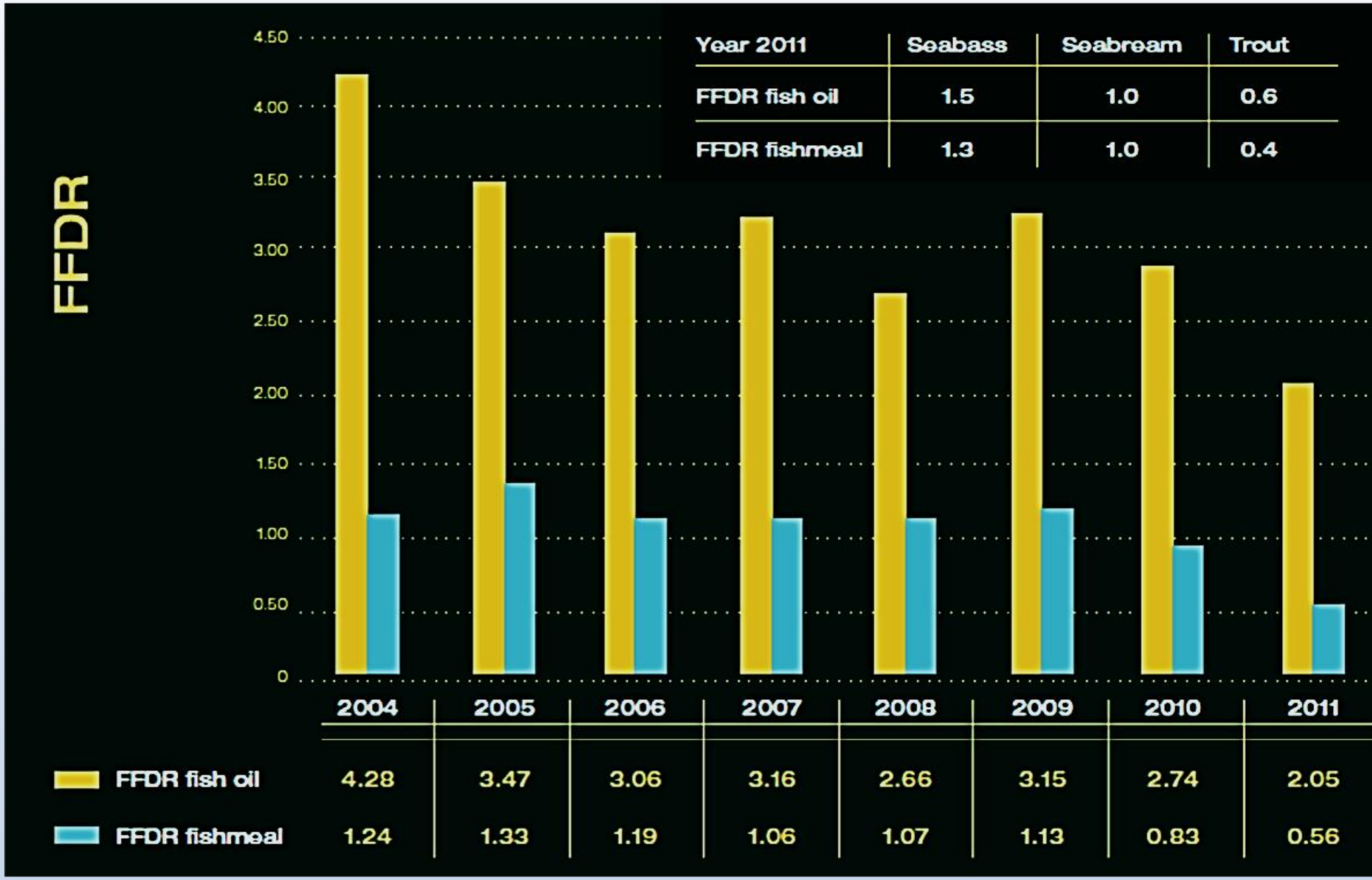
Resource utilization



Recent trends in global average feed fish dependency ratio (FFDR) for fishmeal and fish oil for farmed salmon using Skretting feeds. http://www.skretting.com/

Species groups	ASC Compliance FFDR upper limit	eFCR for varying % protein from fishmeal in diet							
		5	7	8	10	15	20	25	30
Salmon	1.35				3.2	2.2	1.6	1.3	1.1
Trout	1.5				3.4	2.3	1.7	1.4	1.1
Tilapia	0.8				1.8	1.2	0.9	0.7	0.6
Striped catfish	0.5	2.3	1.6	1.4	1.1	0.8	0.6	0.5	0.4
Whiteleg shrimp	1.35				3.0	2.0	1.5	1.2	1.0
Tiger shrimp	1.8				4.1	2.7	2.0	1.6	1.4

Global loses to forage fisheries

Monetary implications of salmonid mortality for Cermaq group in 2014

Location	Fish production (tonnes)	Total mortality (%)	Loss (tonnes)	Monetary loss (million USD)
Atlantic salmon				
Norway	59 094	4.1	2 526	13
Chile	50 027	9.7	5 374	27
Canada	21 431	7.1	1 638	8
Total	130 552	6.8	9 525	48
Rainbow trout				
Chile	5 500	10.8	666	2
Coho salmon				
Chile	30 275	6.8	2 209	11

Total sales revenue loss to group = $61 million-NOT whole story

Company cost to foraging fisheries

	Tonnes	Diet inclusion -tonnes		Forage fish cost (tonnes)
		Fishmeal (%)	Fish oil (%)	
		20	11	
50% biomass	6 200			
Feed loss (FCR 1.3)	8 060	1 934	887	14 777

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Monetary implications of salmonid mortality for Cermaq group in 2014

Tonnage and cost of feed loss

Total biomass loss (tonnes)	12 400
50% biomass (tonnes)	6 200
FCR	1.3
Feed loss (tonnes)	8 060
Cost/tonne	1 200
Total feed loss (USD million)	10

Revenue loss+ lost feed = $61 + $10 = USD71 million

Manual feeding, farm-made wet feed

SINTEF Fisheries and Aquaculture

Salmons

Implication of mortality rates for global reduction fisheries: assumptions/calculations

- Based on 2013 FAO data
- Species group focus: salmonids, carps, catfishes, and tilapias
- Mortality related fish feed loss based on 50% of final biomass
- FM and FO yield set at 24 and 5%, respectively
- Fish oil levels for salmon based on inclusion levels (@11% in 2013)
- Fishmeal in carp tilapia and catfish diets set at 5, 10 and 10%
- eFCR for salmon, carps, catfish and tilapia set at 1.3, 2, 1.5 and 1.8
- Tonnes of fish for reduction lost at global mortalities between 5-30% estimated warm water species.
- Tonnes of fish for reduction lost during salmonid production in 2013 based on industry data.

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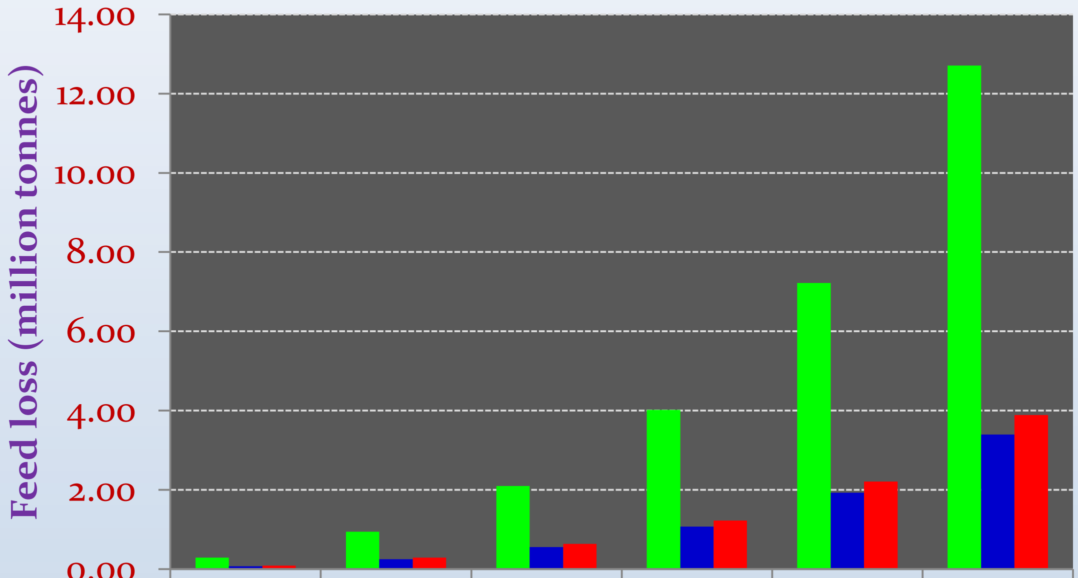
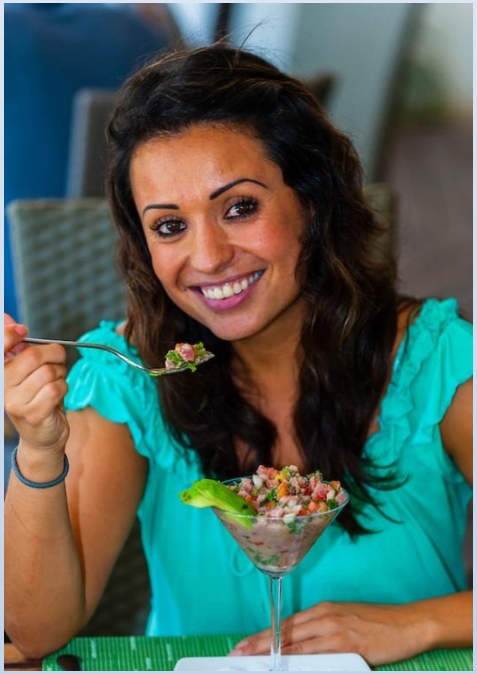
Predicted global loss of foraging fish due to mortality

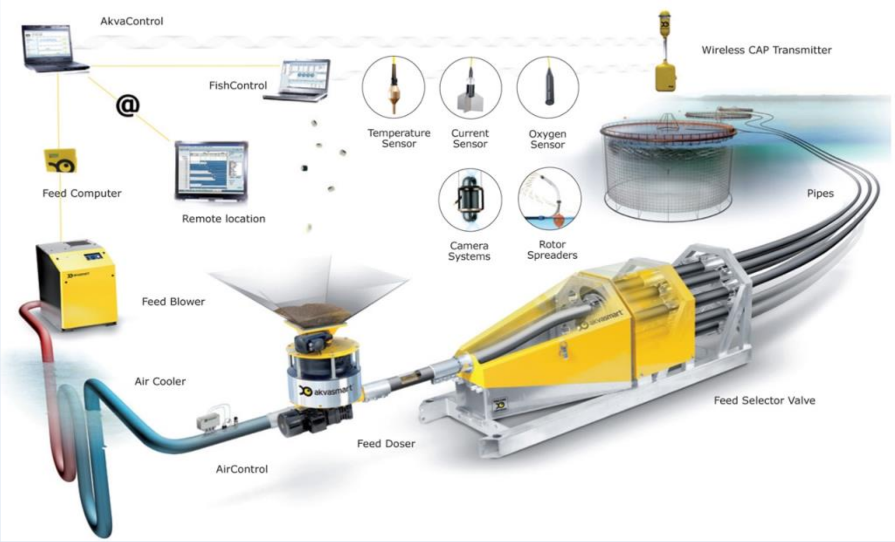


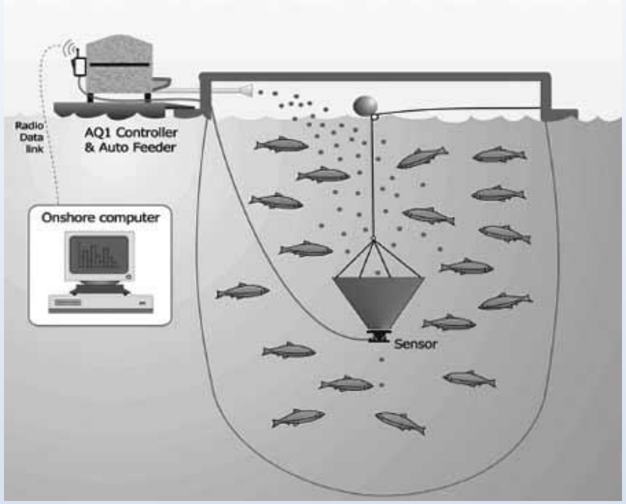
	5.00	10.00	15.00	20.00	25.00	30.00
Carps	0.29	0.95	2.10	4.02	7.22	12.70
Catfishes	0.08	0.25	0.56	1.08	1.93	3.40
Tilapias	0.09	0.29	0.64	1.23	2.21	3.89

Global mortality level (%)

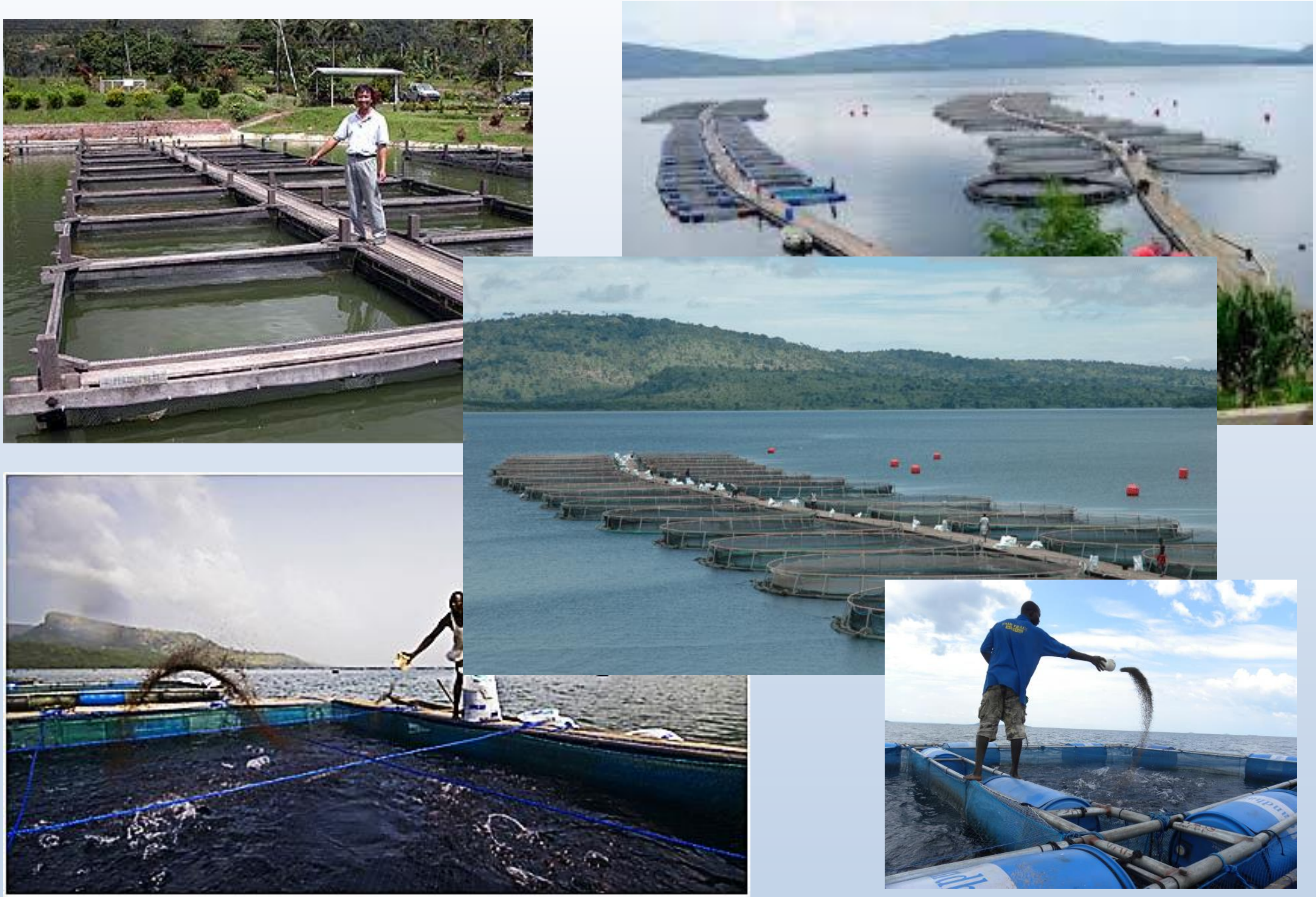
Feed presentation: fundamental problem?



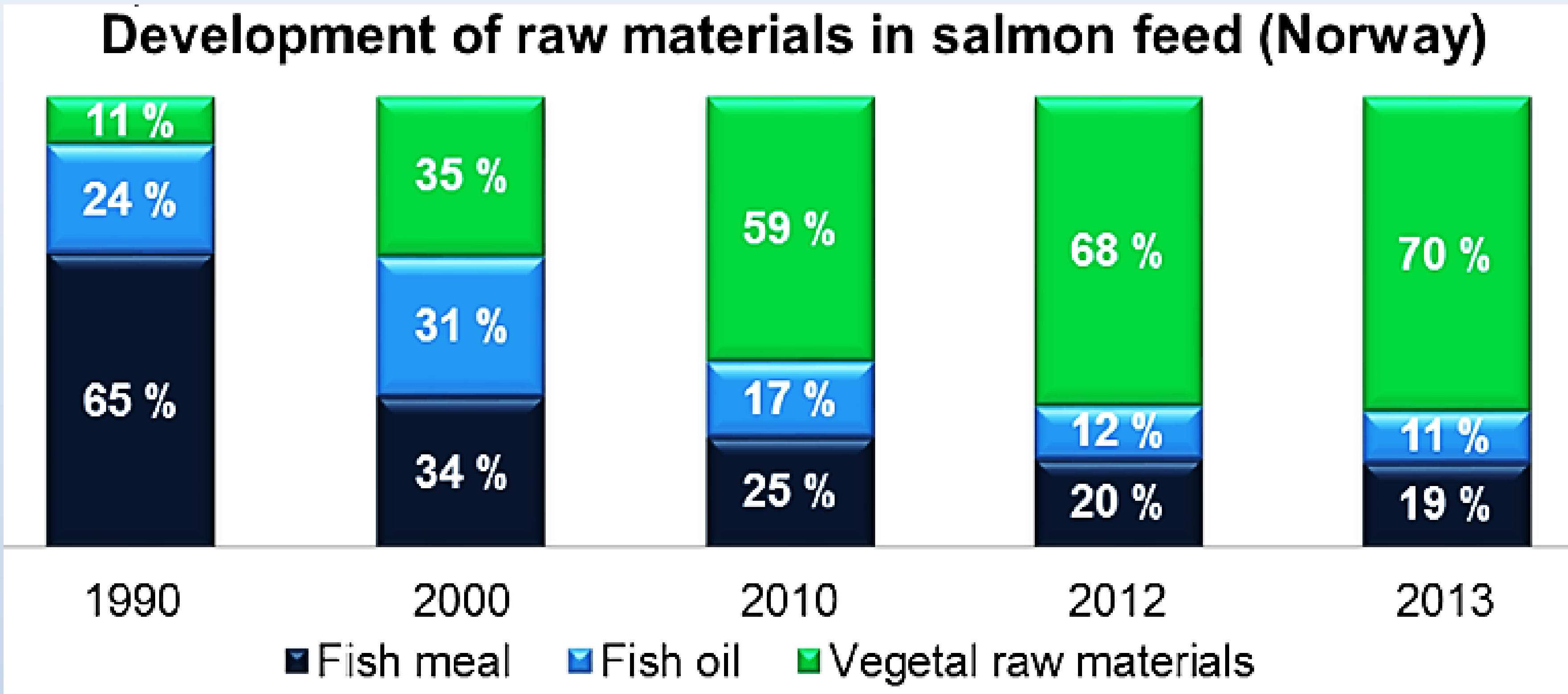




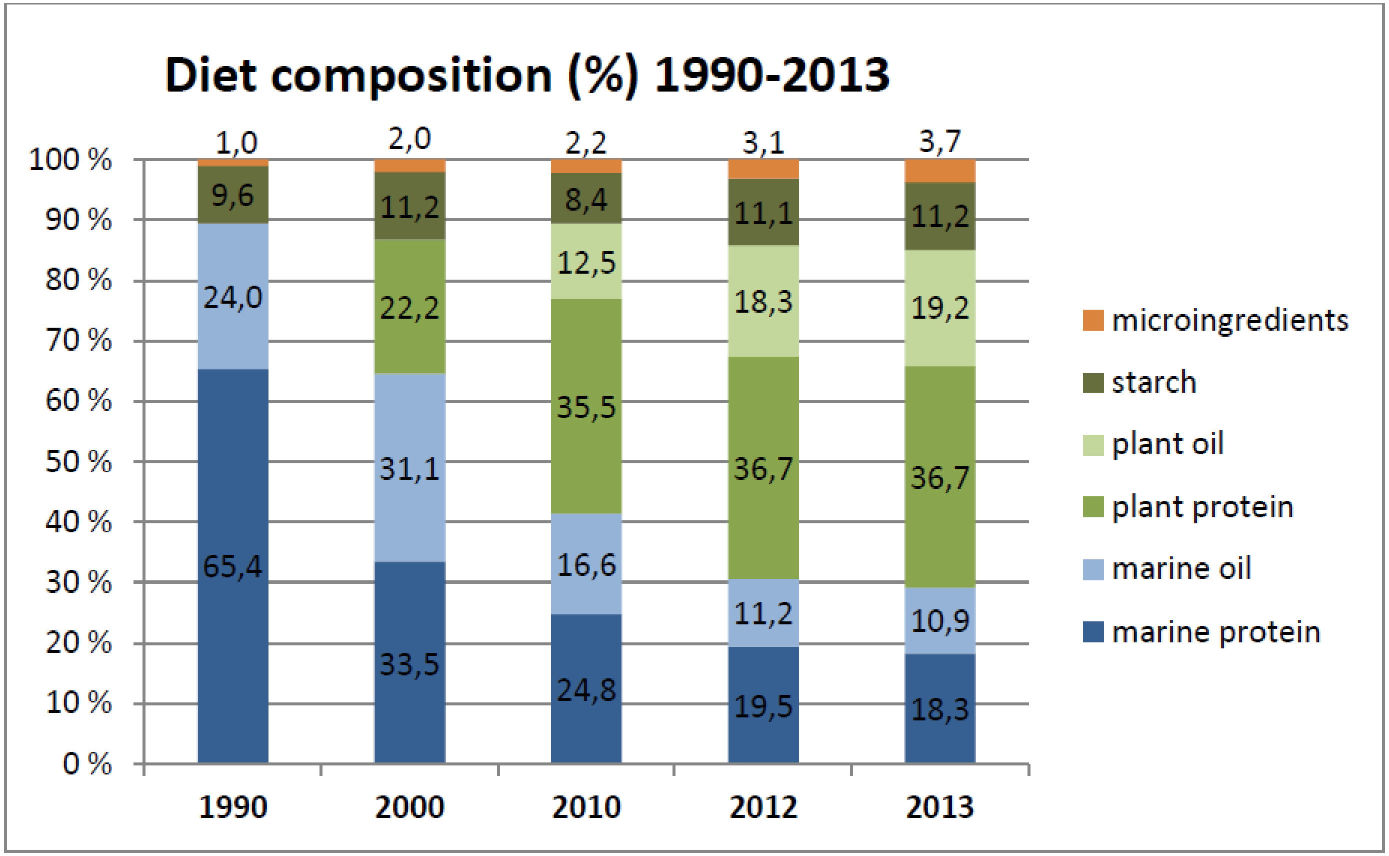
Sea cage automated response monitored feeding system (Akvasmart)



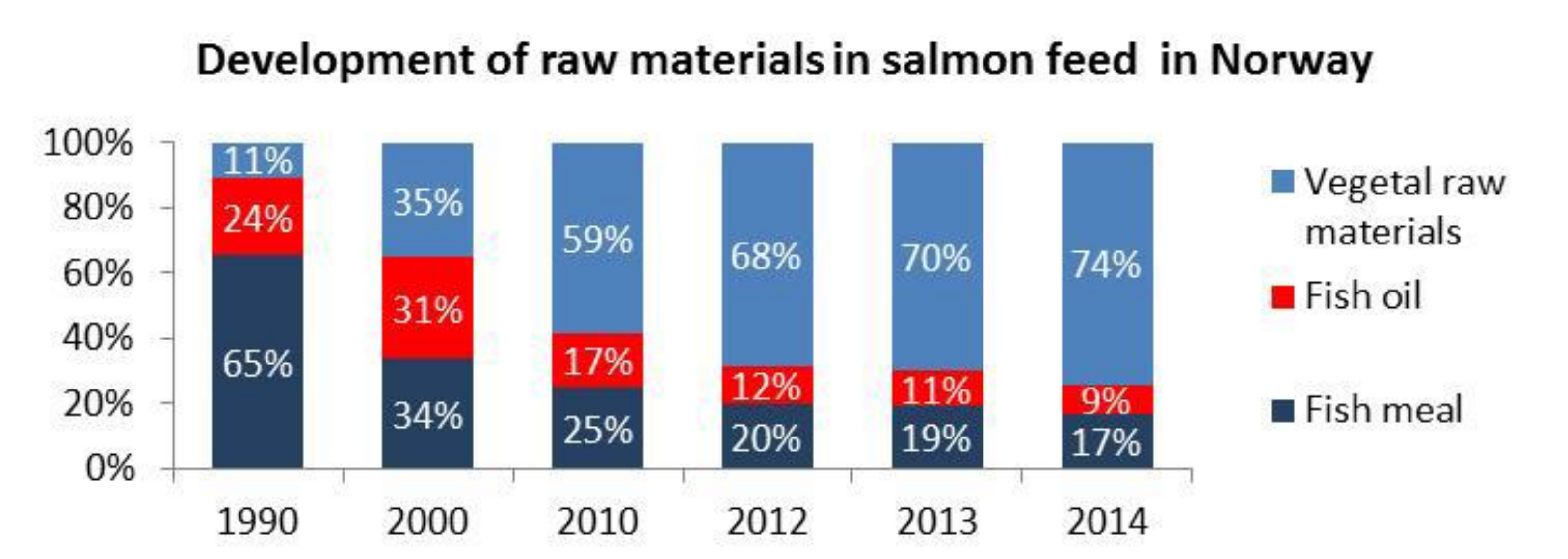
Fishmeal and fish oil in salmon feeds



Ytrestøyl et al (2014), FAO (2012) *World Fisheries and Aquaculture*, UN (2010), FAO (2014) *World Fisheries and Aquaculture*



e 7 Development of salmon feed in Norwegian salmon farming from 1990 to 2013.



Marine harvest Ytrestøyl *et al.* (2014), NOFIMA, FAO (2010), FAO (2012), FAO (2014)

Implications for foraging fisheries and marine ingredients

- **Assumptions**:

i. Based on data reported by CERMAQ, 2014 and used for salmonid sector.

  - Mortality rate 8%/year

i. Calculations based on ASC-Salmon Standard

  - Fish oil: average yield 6%
  - Fishmeal 22.4%

ii. Feed loss based on 50% total biomass loss

iii. FCR 1.3

	ASC compliance FFDR upper limit	eFCR for varying % protein from fishmeal in diet							
		5	7	8	10	15	20	25	30
Salmon	1.35				3.2	2.2	1.6	1.3	1.1
Trout	1.5				3.4	2.3	1.7	1.4	1.1
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Striped catfish	0.5	2.3	1.6	1.4	1.1	0.8	0.6	0.5	0.4
Shrimp									
Whiteleg shrimp					3.0	2.0	1.5	1.2	1.0
Tiger shrimp	1.8				4.1	2.7	2.0	1.6	1.4

What is FCR?

Where can we improve?

Where should we target to improve efficiencies?

Capacity to improve productivity form diets

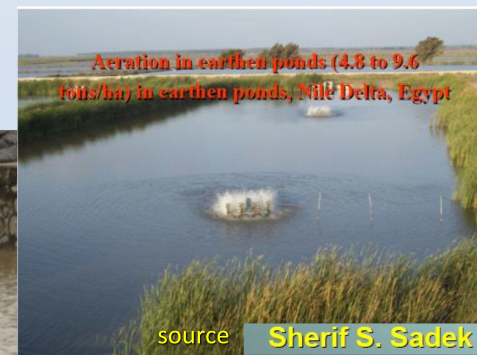
How is this achieved? NB <u>ponds</u> predominate

Egypt: <u>Aerator</u> and commercial feeds (FCR 1-1.2:1)

China: <u>Aerators</u> and commercial feeds (FCR 1.6:1)

Philippines: <u>Aerators</u> and commercial feeds

India : <u>Aerators</u> and commercial feeds



Concentrated diets = Aerators=energy = infrastructure= reliability

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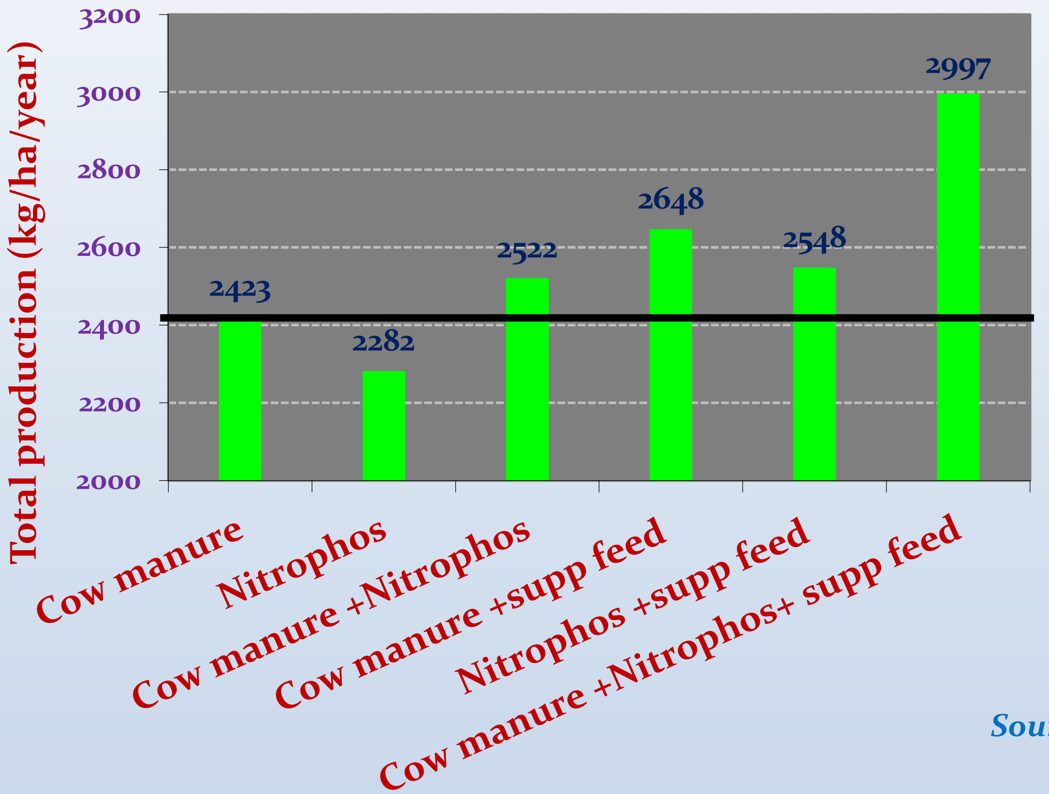
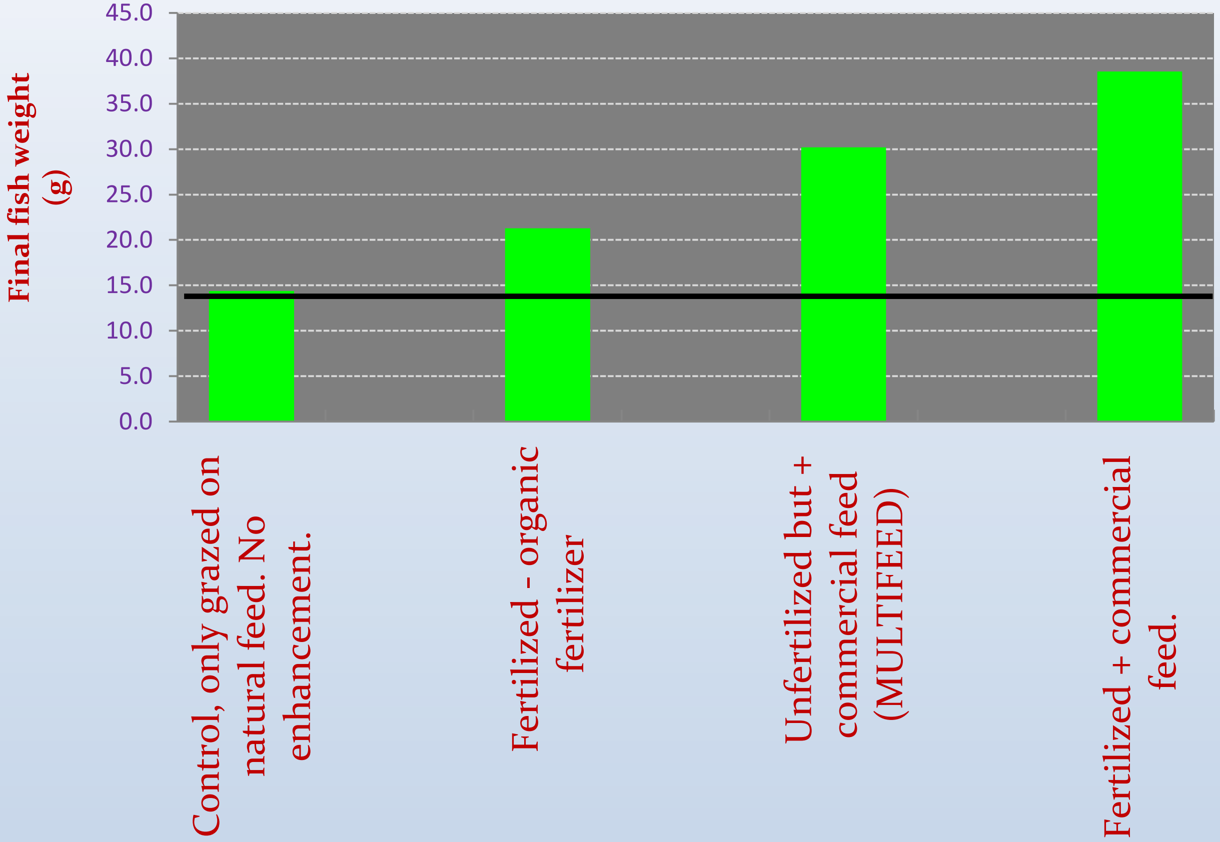
Relative contribution of natural feed to growth: carps



Source: Int. J. Agric. Biol., 12: 276–280

- Three species cultured as polyculture : rohu, catla and common carp
- Supplementary feed only increased total yield by 24%.

Relative contribution of natural feed to growth: catfish



40% of catfish growth can be accounted for from natural feed

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Feeding technologies in salmon

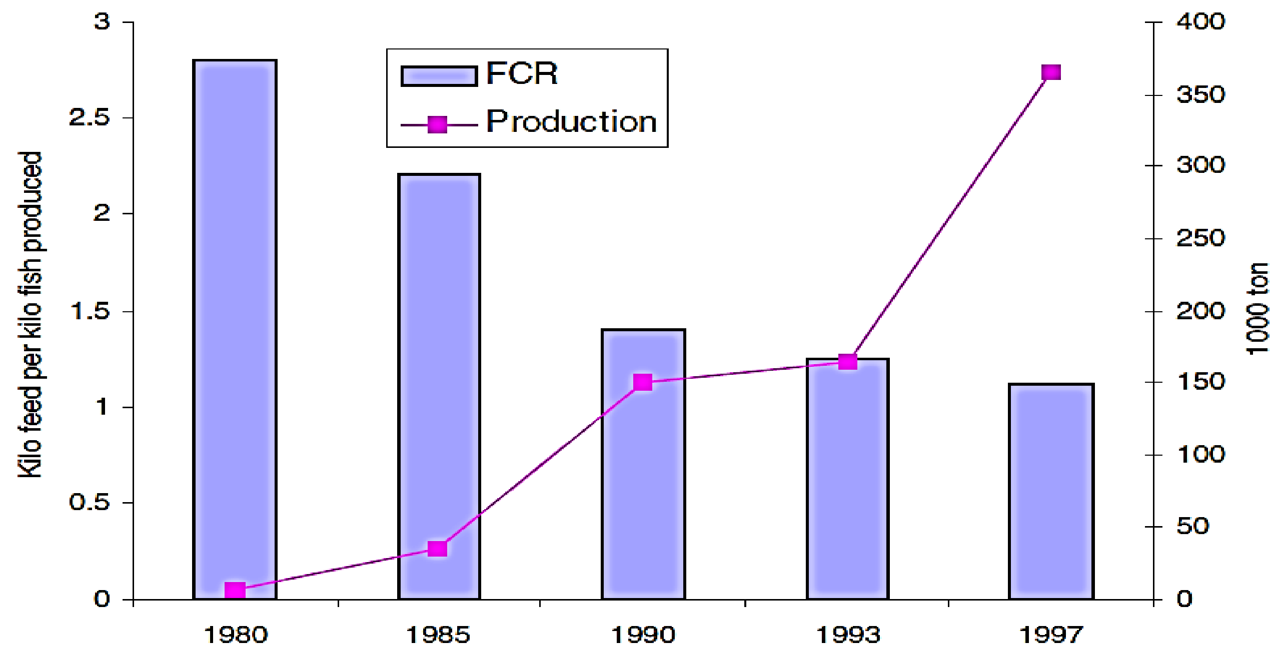


Figure 1. Feed conversion rate 1980-1997.
Source: Directorate of Fisheries

Decline in FCR attributed to

- Externally driven sophisticated feed and feeding technology and feeding systems

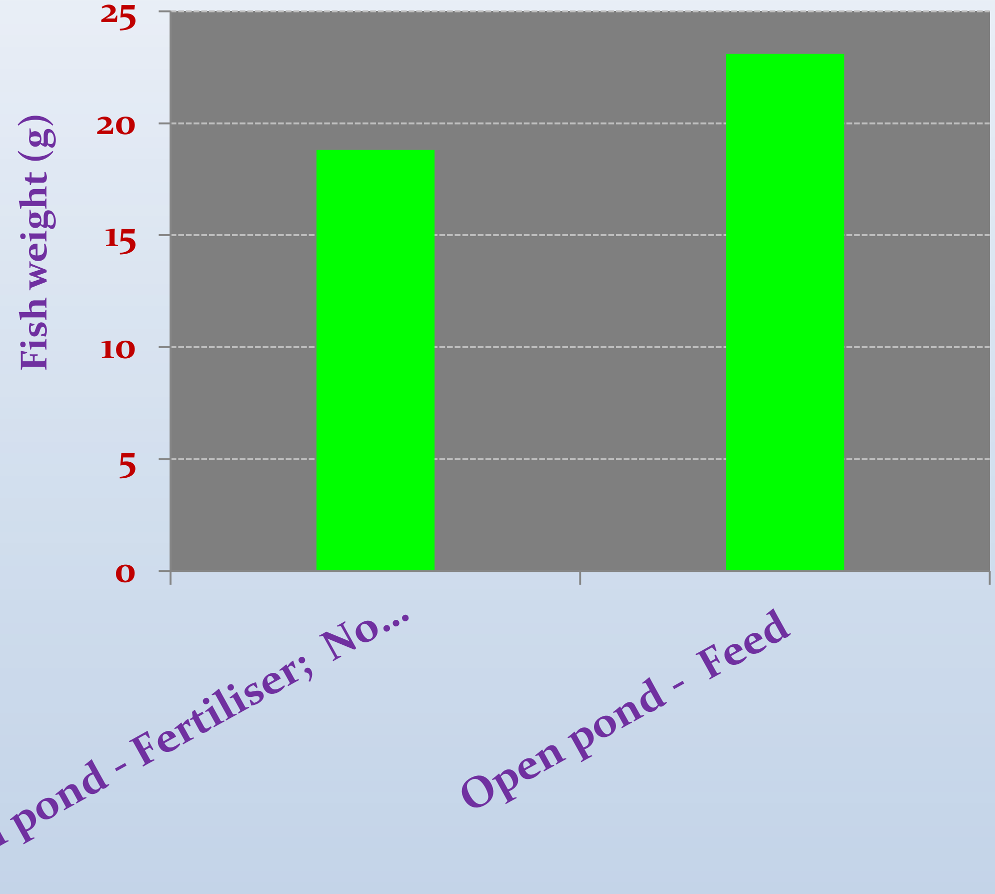
Baseline challenges

- **Water use = water quality**

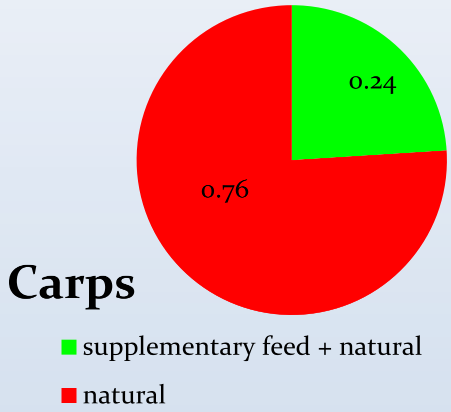
Other factors driving down salmon FCR

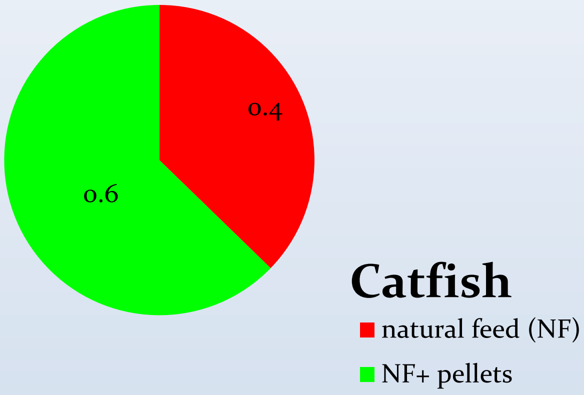
- Greater accountability for fish inventory = accountability and disaggregating the causes of mortality
  - Reduction in salmon escapees
  - Dramatic use of vaccines
  - Control of parasites

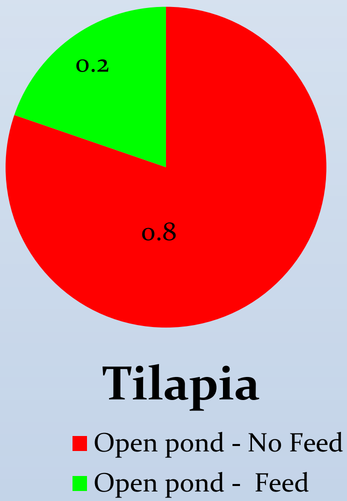
Relative contribution of natural feed to growth: tilapia in hapas



System-specific diets: what we are actually measuring….?







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Reduce protein levels? Are diets over prescribed?

	BD	China	India	Viet Nam	Thailand	Philippines	Egypt	Ghana
Protein (%)	25-32	27-29	15-16	15-18	20-35	23-40	25	30

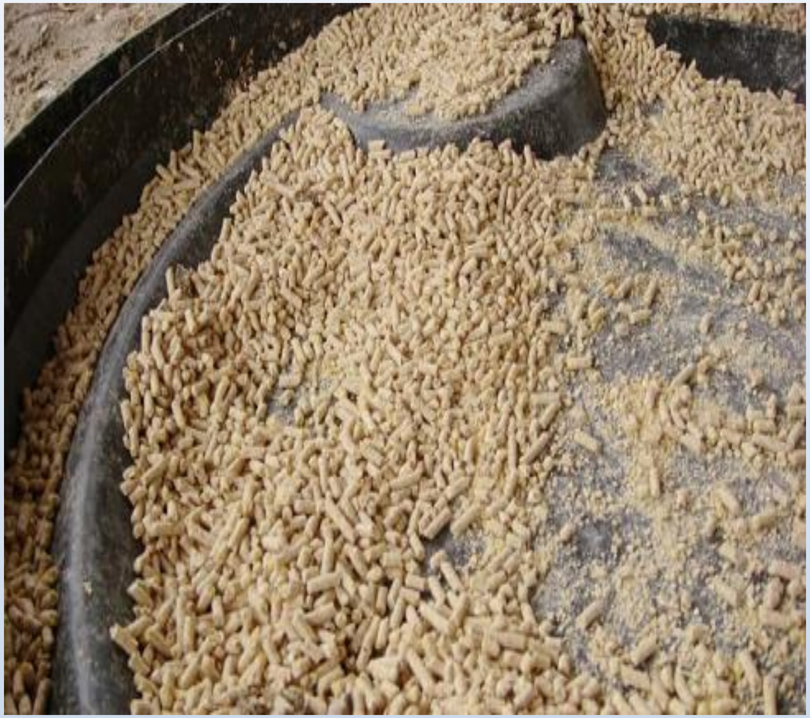
- Fishmeal 5-10%

" A reduction in the protein level will result in a slightly delayed harvest but overall it will result in the best economic gain; that is in effect we are feeding our stock feeds with too much protein in the diets"

Q. 1. What further gains can be had from current reductions?

2. What criteria should we use to prioritise research?

Pellet quality



Target small-scale feed producers

Feed distribution

Feed processing technology	Pelleted	Extruded	Pelleted	Extruded
Sinking rate, cm/sec	8	6.2	9.7	4

1.5 minutes to sink to bottom of pond of 1 m deep

Need to consider feeding behaviour

Impact of mortality on feed efficiency and impact on reduction fisheries

Estimated mortalities (%) from case studies

Egypt	Tilapia	55-60
Thailand		
Ponds	Tilapia	40-50
Cages	Tilapia	35-40
Bangladesh	Tilapia	30%
Bangladesh	Major carps	35%
Philippines	Tilapia	40

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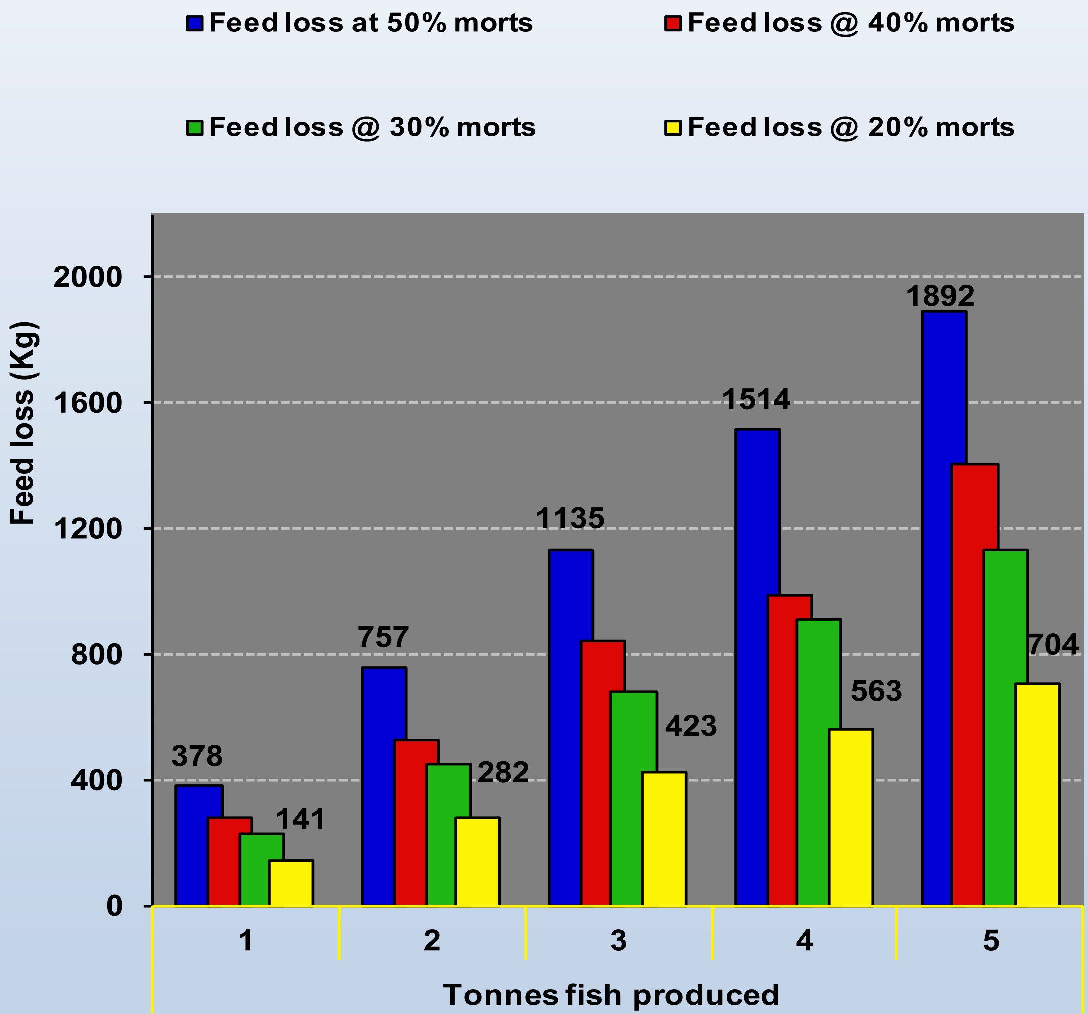
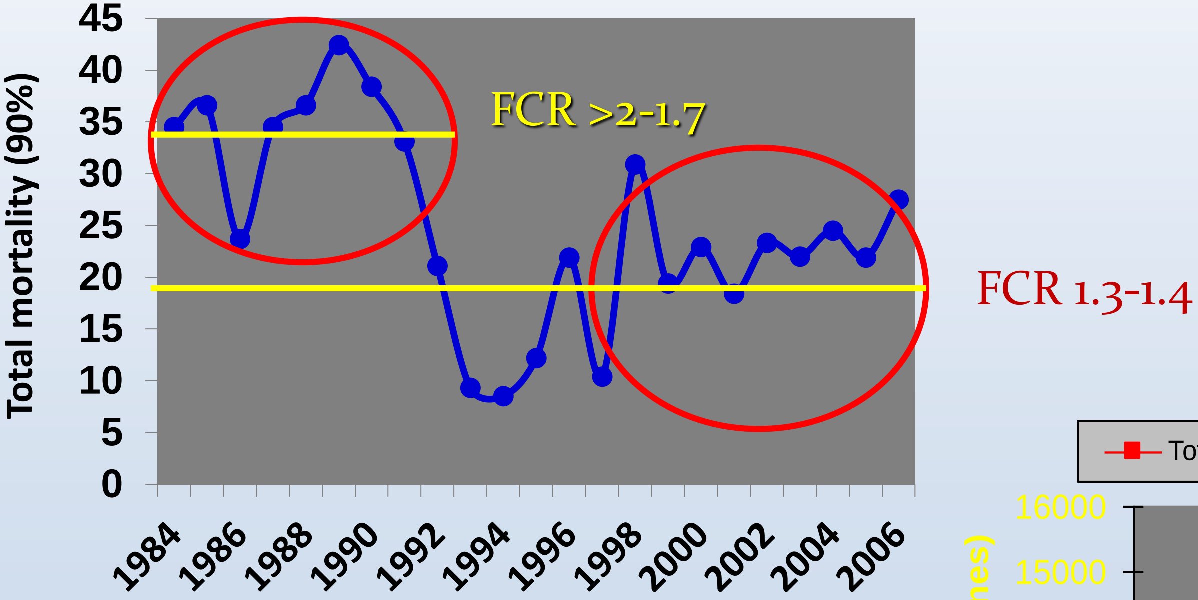
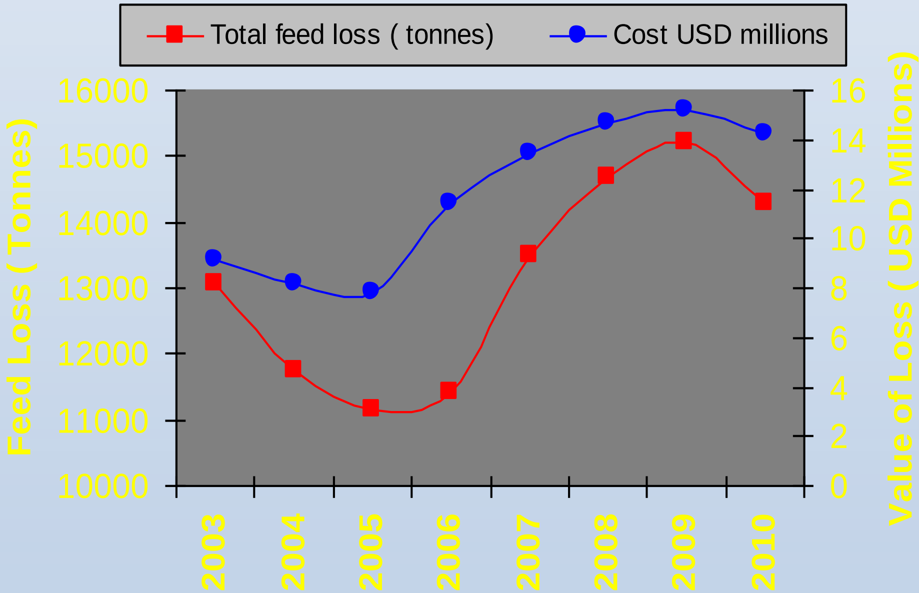
Modelled feed loss due to mortality



40	30	50	20
1	1	0	0
0.8	0.9	0.8	0.95
0.75	0.85	0.7	0.9
0.75	0.85	0.65	0.9
0.7	0.8	0.6	0.85
0.65	0.75	0.55	0.85
0.6	0.7	0.5	0.8

Salmon mortality trends vs FCR- Scotland - SEERAD model





- 15 000 tonnes lost in production 130 000 tonnes
- For every tonne produced 0.110 tonne lost

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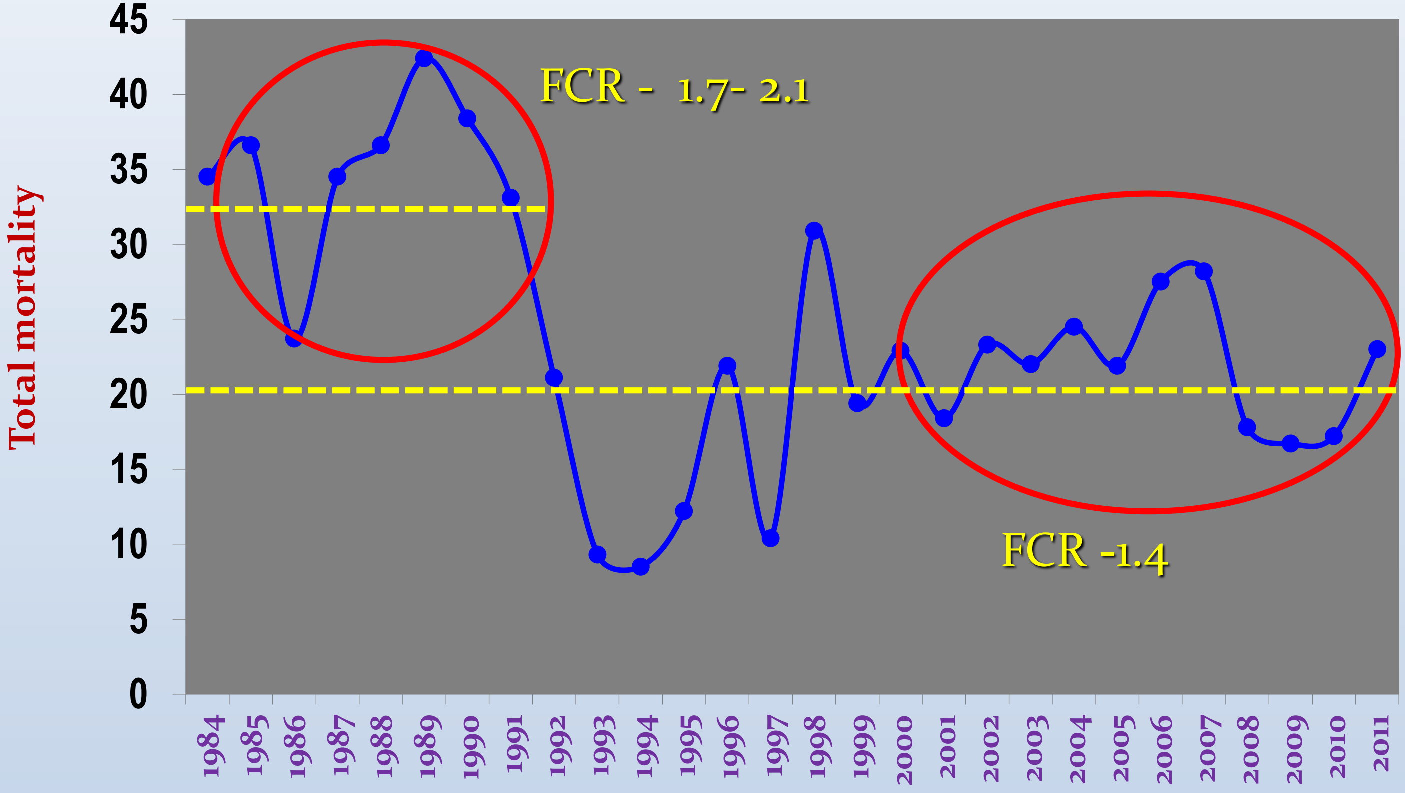
Salmon mortality trends vs FCR- Scotland- SEERAD model



Priority areas

- Maximising oxygen levels
- Immediate shift from individual ingredients to mixed ingredients
- Stable pellet production of these ingredients
- Increase natural feed management with other feed forms
- Reduce feed by accounting for natural micro ingredients
- Interrogate mortally and develop mortality reduction strategies

Summary

- Better clarity on what we want to achieve
- Transfer of technology from salmon to warm water species will be limited
- Production system highly heterogeneous and challenges eFCR
- Mortality is key for short- and medium-term eFCR impact
- Feed presentation, feeding regimes and feed management are key
- ASC standards compromises warm water species
- Loss to reduction fisheries is significant

Thank You

Return to content