



# LCA of aquaculture systems

## - Review of existing aquaculture LCAs -

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STIRLING



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- The SEAT project
- Review of existing aquaculture LCA studies
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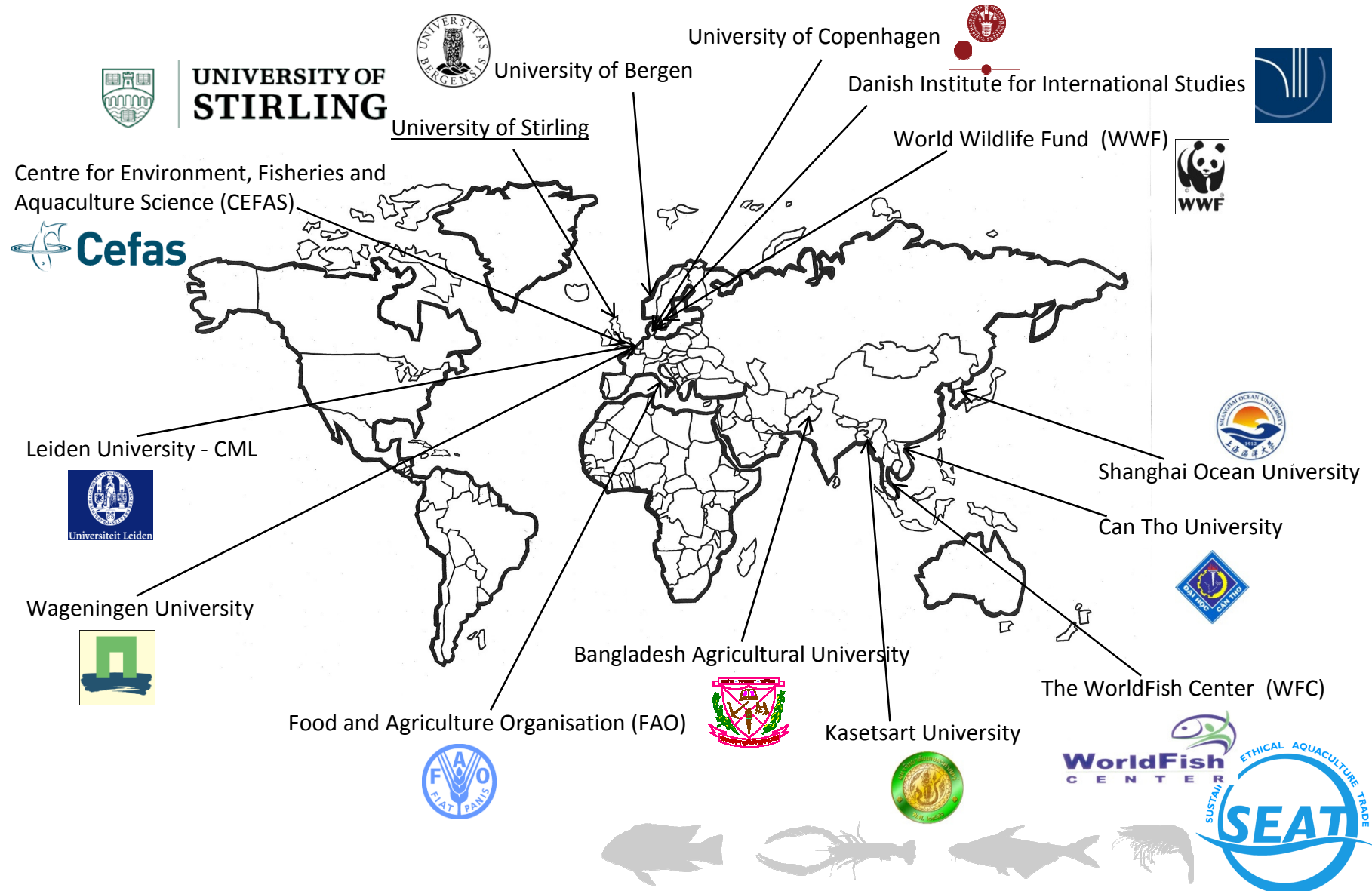
# The SEAT project



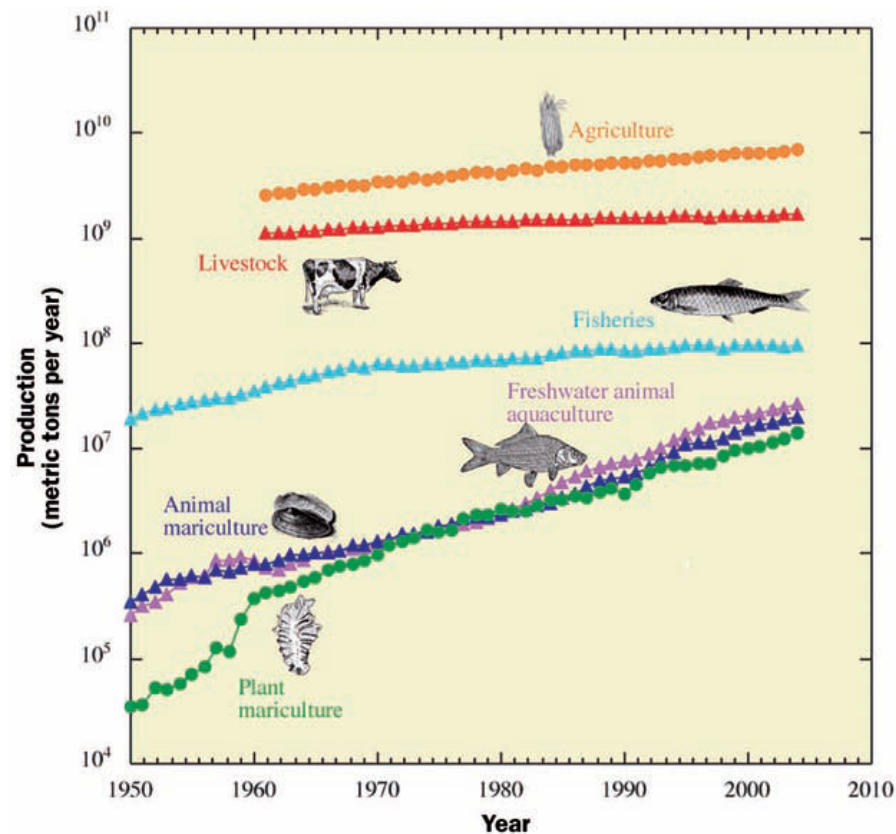
- Sustaining Ethical Aquaculture Trade
  - EU, 7<sup>th</sup> Framework Programme
  - Large collaborative project
  - “Food, Agriculture and Fisheries, and Biotechnology”
- Coordinator:
  - Institute of Aquaculture, The University of Stirling, UK
- Period:
  - 2009-2013
- Project website: <http://seatglobal.eu/>



# 14 Partners over Europe and Asia



# SEAT motives



Duarte *et al.* 2009

- Global fisheries levelled off in the early 1990s
- Growing global demand for seafood
- Growing seafood imports in the EU from Asia



# SEAT aims

- To gain and disseminate an in depth understanding of emergent Asian aquatic food production/ market chains from a holistic systems perspective through an interdisciplinary effort
- To develop improved and transparent measures of sustainability for target aquatic food production systems
- To enhance the sustainability and ethical 'values' of four major aquatic food commodities
- To enhance farmed aquatic food, scientific, business and policy linkages between Asia and Europe
- Dissemination of LCA: training of partners 2 weeks ago





# Objects of SEAT



**Tilapia**



**Pangasius Catfish**



**Penaeid Shrimp**



**Macrobrachium Prawns**



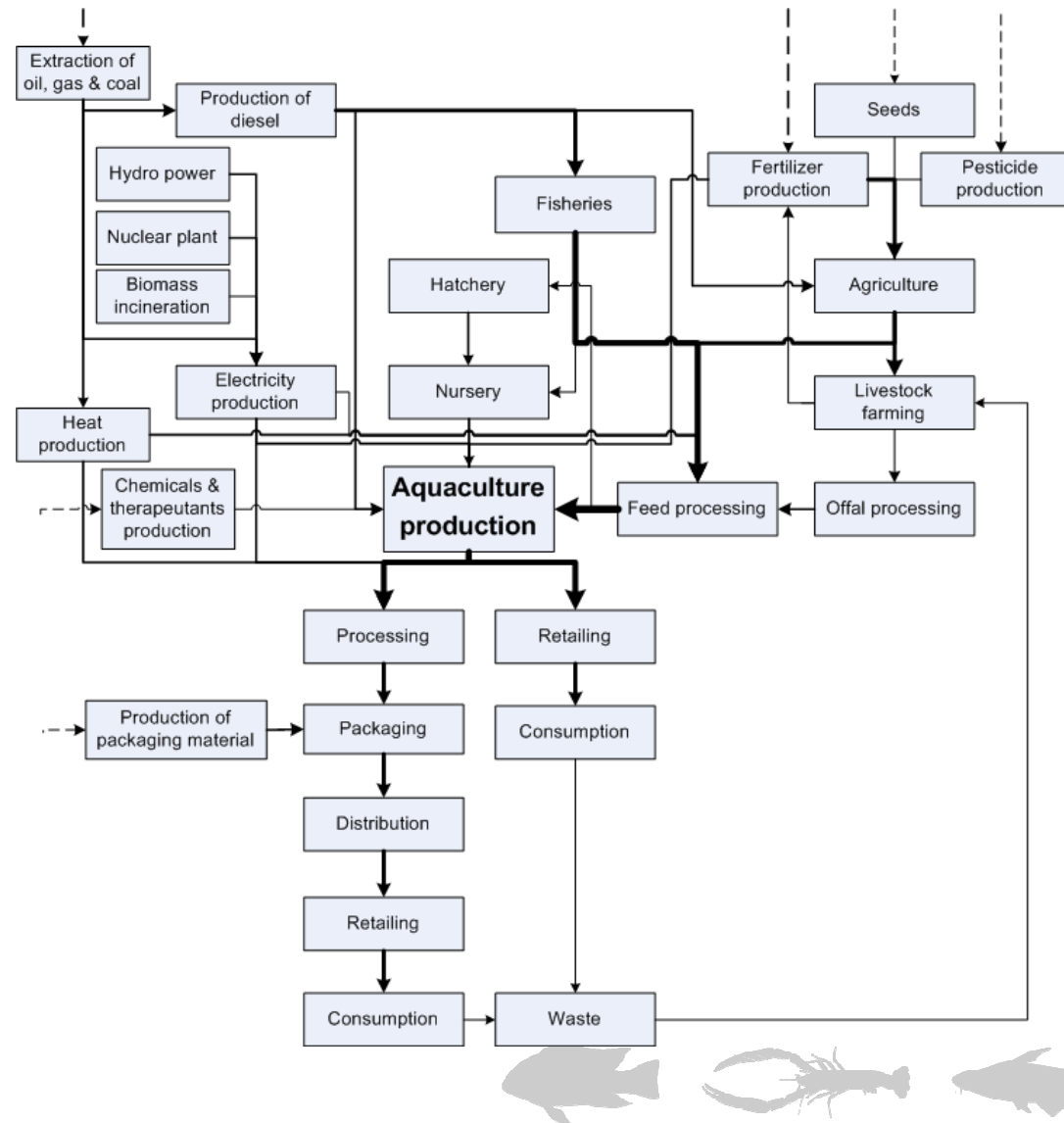
# Role of LCA

- One tool among others
  - Risk Assessment, Global Value Chain, social, antibiotic and ethical assessments etc.
- Focusing on a holistic environmental assessment, hot spot identification and problem shifting
  - no “silver bullet”
  - focus on whole life cycle, cradle-to-grave (kitchen?) and broad range of impacts (but not all impacts; no “silver bullet”)





# Example flow chart



# Review of existing aquaculture LCAs

Author	Title	Journal
Papatryphon et al. 2004	Environmental impact assessment of salmonid feeds using Life Cycle Assessment (LCA)	Ambio
Mungkung 2005	Shrimp aquaculture in Thailand: application of life cycle assessment to support sustainable development	PhD thesis
Aubin et al. 2006	Characterisation of the environmental impact of a turbot ( <i>Scophthalmus maximus</i> ) re-circulating production systems using Life Cycle Assessment	Aquaculture
Ellingsen & Aanondsen 2006	Environmental Impacts of Wild Caught Cod and Farmed Salmon – A Comparison with Chicken	Int. Journal of LCA
Grönroos et al. 2006	Life cycle assessment of Finnish cultivated rainbow trout	Boreal Environ. Research
Pelletier & Tyedmers 2007	Feeding farmed salmon: Is organic better?	Aquaculture
Aubin et al. 2009	Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment	J. of cleaner production
Ayer & Tyedmers 2009	Assessing alternative aquaculture technologies: life cycle assessment of salmonid culture systems in Canada	J. of cleaner production
d'Orbcastel et al. 2009	Towards environmentally sustainable aquaculture: Comparison between two trout farming systems using Life Cycle Assessment	Aquacultural Engineering
Pelletier et al. 2009	Not all salmon are create equal: Life cycle assessment (LCA) of global salmon farming systems	Environ. Sci. and Technol.
Iribarren et al. 2010	Revisiting the Life Cycle Assessment of mussels from a sectorial perspective	J. of cleaner production
Pelletier & Tyedmers 2010	A life cycle assessment of frozen Indonesian tilapia fillets from lake and pond-based production systems	J. of Industrial Ecology
Phoung et al. 2010	Life Cycle Assessment of food production in Integrated Agriculture-Aquaculture Systems of the Mekong Delta	PhD thesis

# *Preliminary* results with respect to:

- Species
- Regions
- Functional unit
- System boundaries
- Data(bases)
- (Allocation)
- Impact assessment
- etc.



# Species & regions

Species	Region	Author	Institution
Salmonoid	France	Papatryphon <i>et al.</i> 2004	INRA/ IFREMER
Turbot	France	Aubin <i>et al.</i> 2006	
Rainbow trout, sea-bass and turbot	France	Aubin <i>et al.</i> 2009	
Trout	France	d'Orbcastel <i>et al.</i> 2009	
Atlantic salmon	Canada	Pelletier & Tyedmers 2007	Dalhousie University
Salmon & Arctic char	Canada	Ayer & Tyedmers 2009	
Atlantic salmon	Global	Pelletier <i>et al.</i> 2009	
Tilapia	Indonesia	Pelletier & Tyedmers 2010	
Shrimps	Thailand	Mungkung 2005	Other
Rainbow trout	Finland	Grönroos <i>et al.</i> 2006	
Atlantic salmon	Norway	Ellingsen & Aanondsen 2006	
Blue mussels	Spain	Iribarren <i>et al.</i> 2010	
Tilapia, kissing gourami, giant gourami, Viet Nam silver barb, common carp, silver carp and Pangasius catfish		Phoung 2010	

# Functional unit

Functional unit	Author	Institution
1 tonne of feed	Papatriphon <i>et al.</i> 2004	INRA/ IFREMER
1 tonne live weight at farmgate	Aubin <i>et al.</i> 2006	
1 tonne live weight at farmgate	Aubin <i>et al.</i> 2009	
1 tonne live weight at farmgate	d'Orbcastel <i>et al.</i> 2009	
1 tonne live weight at farmgate	Pelletier & Tyedmers 2007	Dalhousie University
1 tonne live weight at farmgate	Ayer & Tyedmers 2009	
1 tonne live weight at farmgate	Pelletier <i>et al.</i> 2009	
1 tonne frozen fillets at market port	Pelletier & Tyedmers 2010	
1.8 kg consumed block of frozen shrimp	Mungkung 2005	Other
1 tonne ungutted fish post-mortem	Grönroos <i>et al.</i> 2006	
200 gram processed fillets	Ellingsen & Aanondsen 2006	
1 kg of dry consumed mussels	Iribarren <i>et al.</i> 2010	
1 kg of live fish and 1 kcal of produce	Phoung 2010	



# System boundaries

Focus on	Author
Salmonoid: <i>feeds</i>	Papatriphon <i>et al.</i> 2004
Turbot: <i>farmgate</i>	Aubin <i>et al.</i> 2006
Rainbow trout, sea-bass and turbot: <i>farmgate</i>	Aubin <i>et al.</i> 2009
Trout: <i>farmgate comparing different farming (flow through/ re-circulating ) systems</i>	d'Orbcastel <i>et al.</i> 2009
Atlantic salmon: <i>farmgate comparing different (organic and conventional ) feeds</i>	Pelletier & Tyedmers 2007
Salmon & Arctic char: <i>farmgate comparing different farming systems</i>	Ayer & Tyedmers 2009
Atlantic salmon: <i>farmgate</i>	Pelletier <i>et al.</i> 2009
Tilapia: <i>European wholesaler</i>	Pelletier & Tyedmers 2010
Shrimps: <i>cradle-to-grave (including consumption)</i>	Mungkung 2005
Rainbow trout: <i>farmgate</i>	Grönroos <i>et al.</i> 2006
Atlantic salmon: <i>European wholesaler</i>	Ellingsen & Aanondsen 2006
Blue mussels: <i>cradle-to-grave (including consumption)</i>	Iribarren <i>et al.</i> 2010
Tilapia, ..., Pangasius catfish: <i>farmgate</i>	Phoung 2010



# Process data

- Almost all authors model - to different extents - relevant agricultural processes and fisheries
- Details of this modelling efforts are, however, not or incompletely published:
  - not published at all
  - inventories are reported but merely in terms of economic inputs and outputs
  - unclear whether background database are used as estimations or real foreground data have been collected



# Background data(bases)

Reference	Software	Database
Papatriphon <i>et al.</i> 2003	SimaPro 2	ECETOC 1994; Buwal 1996; Gaillard <i>et al.</i> 1997
Mungkung 2005	SimaPro 5.1	Included databases of BUWAL 250 & Thai data for el
Aubin <i>et al.</i> 2006	Simapro 6.0	(All?) includ
Ellingsen and Aanondsen 2006	SimaPro	ETH-ESU 9
Grönroos <i>et al.</i> 2006	KCL-ECO 2003	Silvenius
Pelletier & Tyedmers 2007	Simapro 7.0	(All?) i
Aubin <i>et al.</i> 2009	Simapro 6.0	(All?) in
d'Orbcastel <i>et al.</i> 2009	SimaPro 6	EDF, 2004
Ayer & Tyedmers 2009	Simapro 7.0	Ecoinvent 1 LCA Food
Pelletier <i>et al.</i> 2009	Simapro 7.1	ecoinvent v2
Iribarren <i>et al.</i> 2010	SimaPro 6	ecoinvent v2
Pelletier & Tyedmers 2010	Simapro 7.0	ecoinvent v2
Phoung <i>et al.</i> 2010	Not stated	Not stated

Which one(s)?

- ecoinvent v2
- US LCI data
- US IO db
- Danish
- Dut
- base
- data
- se IO dbase
- base



# Foreground data

- Foreground data focus on farm
- Economic inputs:
  - specified in detail (feed and energy inputs)
  - but their process data sourced from (non-specific) background databases (see previous slide)
- Farm environmental outputs added:
  - focus on N/P balances
  - usually quite detailed balances as most practitioners come from aquaculture backgrounds
  - little/no detail on acidifying agents, toxic agents etc.



# Impact assessment

Impact category	$\Sigma$	Impact Assessment method
Global warming potential	12	Houghton <i>et al.</i> 2001 <sup>1,2,3,4,5,6,7,8,9,10,11,12</sup>
Acidification	12	Huijbregts 1999a <sup>1,2,5,6,7,8,9,10,11,12</sup> ; Goedkoop & Spriensma 2001 <sup>3</sup> ; Seppälä <i>et al.</i> 2006 <sup>4--</sup> ; Heijungs <i>et al.</i> 1992 <sup>12</sup>
Eutrophication	12	Heijungs <i>et al.</i> 1992 <sup>1,2,4,5,6,7,8,9,10</sup> ; Goedkoop & Spriensma 2001 <sup>3</sup> ; Seppälä <i>et al.</i> 2004 <sup>4</sup> ; Weidema <i>et al.</i> 1996 <sup>12</sup>
Energy use	8	VDI 1997 <sup>2,5,6,7,8,9,11</sup> ; Goedkoop & Spriensma 2001 <sup>3</sup> ; Article specific <sup>12</sup>
Biotic resource use	6	Papatryphon <i>et al.</i> 2004 <sup>2,6,8</sup> ; Pelletier & Tyedmers 2007 <sup>5,9,11</sup>
Marine aquatic ecotoxicity	4	Huijbregts 1999b <sup>5,7,10</sup> ; Meent & Klepper 1997 <sup>3*</sup>
Human toxicity	3	Huijbregts 1999b <sup>1,7,10</sup>
Freshwater aquatic & terr. ecotoxicity	2	Meent & Klepper 1997 <sup>3*</sup> ; Huijbregts 1999b <sup>10</sup>
Surface use	2	Article specific <sup>8, 12</sup>
Water dependence	2	Article specific <sup>6,8</sup>
Etc.		

\*Ecotoxicity is summarized under one category



# Conclusions (from review)

- Aquaculture LCAs are upcoming
- LCAs mainly origin from aquaculture community
- Main differences between studies:
  - species and regions
  - system boundaries
  - data, data sources, gaps and level of detail
  - impact categories and LCIA methods
  - ... more ...



# SEAT LCA plans



- Improvement/adaptation of LCA data and methodology to specific aquaculture requirements:
  - Inventory analysis:
    - cradle-to-grave
    - feed data, Asian specific processes
  - Impact assessment, broadening impacts & developing
    - water use
    - biotic resource use
    - land use
    - LCC
  - Standardization
    - Combining knowledge of the aquaculture and the LCA community







# Thank you

<http://seatglobal.eu/>

