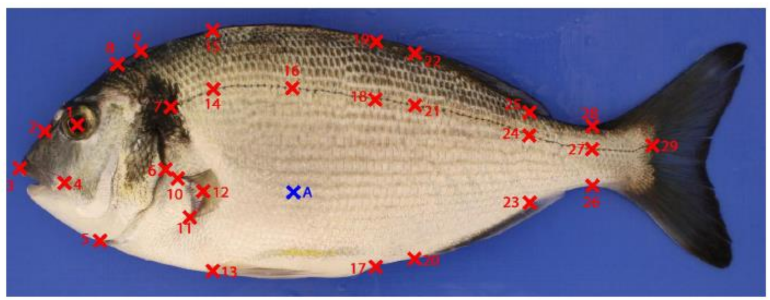
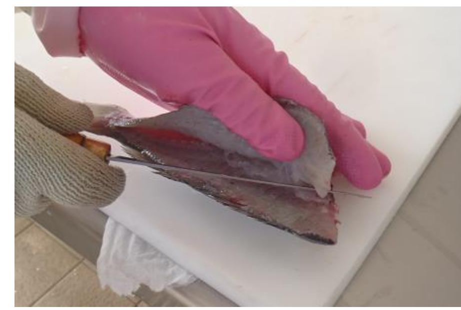
CAN SELECTIVE BREEDING FOR GROWTH OR FILLET YIELD DECREASE ENVIRONMENTAL IMPACT OF FISH FARMING? A GILTHEAD SEA BREAM (*Sparus aurata*) CASE STUDY





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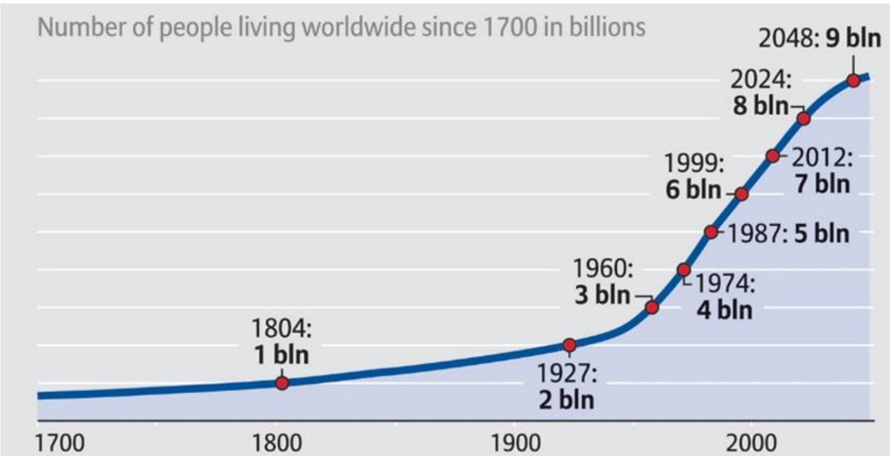
FILD'OR project (2009-2011)

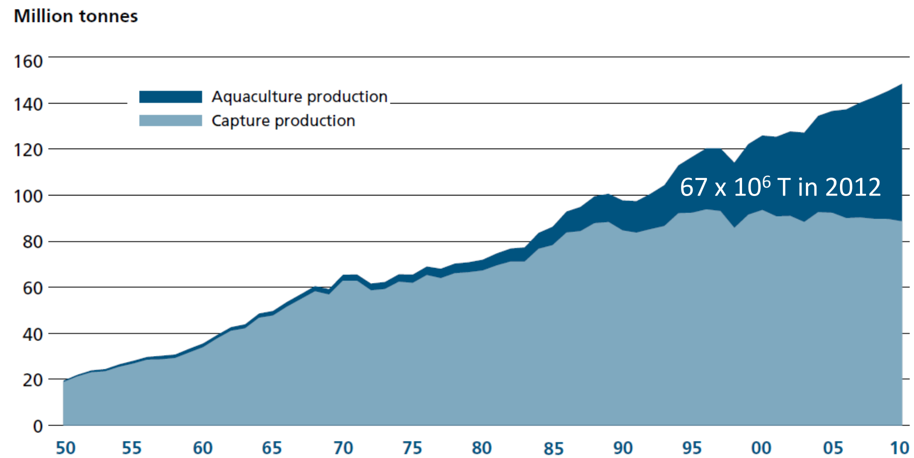
Syndicat des Sélectionneurs Avicoles et Aquacoles Français

An urgent need to adapt development

(Environmental Outlook to 2050, OECD)



(United Nation Population Fund, 2011)



(FAO, 2012; State of the world fishery and aquaculture)

- + 2 billion more people on Earth in 2050 to feed (UNPF, 2011)
- + 0,85 °C (1880-2014) → + 3-6°C in 2100 (IPCC, 2014)
- Need :
  - to limit energy consumption, waters and land use, greenhouse gas emissions
  - to preserve biodiversity
  - to improve Human health and livelihood for socio-economic developments
- Forecast 93.6 billion T of aquaculture production in 2030 (World Bank, 2014)

Does and how genetic selection can increase environmental efficacy of aquaculture?

Genetic tool box
breeding programs, genetic parameters, genomes

→ How to use them to feed the World sustainably?

→ **Life Cycle Analysis ?**

- LCA = International methodology (ISO 14040) to assess environmental impact of Human related activities
- Genetic improvement was never addressed in LCA in 2009
- Pioneering application to aquaculture (Aubin et al. 2006)
- Choice to target :
  - **Gilthead sea bream** (even if not filleted) as low feed efficacy (IC > 1.7-2)
  - **Fillet yield** = final objective of the aquaculture,
  - **Whole chain from fry to the waste incineration** (original in aquaculture)

Phase 1: Estimation of genetic parameters of growth and fillet yield

Ferme Marine du Douhet

25 dams x 86 sires
241 families (AI)

28 g

FMD – Genetic Nucleus (Oléron Island)
19-23 °C (4294 progenies)

FMC - Commercial Environment (Corsica Island)
12.5-25°C (2644 progenies)

- **Phenotyping of 2000 sibs / site (350 g)**:
  - BW, BL, Lipid % in the fillet (Fat Meter),
  - 2D photo, body thickness by ultrasound measures (FMC),
  - gutted W, filet W, head W, viscera W
  - vertebral malformations
- **DNA parentage assignment** (Labogena DNA): 95 % assignment
- **Estimation of genetic parameters** under multi trait animal model with VCE software

Phase 1: Phenotype performances and genetic parameters of growth and processing yields

- **Phenotypic performances**

	Body weight (BW, g)	K	Muscle Fat (%)	Gutted yield (%)	De-headed yield %	De-headed and gutted yield (%)	Fillet yield (%)
FMD - Genetic Nucleus (day 421)	**324.4 ± 44.6**	2.25 ± 0.18	12.5 ± 3.6	94.1 ± 0.9	77.8 ± 1.4	71.9 ± 1.5	**57.8 ± 2.1**
FMC – Commercial Environment (day 660)	**384.2 ± 65.3**	2.20 ± 0.22	10.0 ± 3.0	94.1 ± 1.0	77.2 ± 1.7	71.2 ± 1.7	**59.8 ± 2.3**

- **Genetic parameters**

	Body weight (BW, g)	K	Muscle Fat (%)	Gutted yield (%)	De-headed yield %	De-headed and gutted yield (%)	Fillet yield (%)
h^2 FMD - Genetic Nucleus	**0.51 ± 0.08**	0.39 ± 0.07	0.49 ± 0.08	0.73 ± 0.9	0.40 ± 0.07	0.58 ± 0.08	**0.35 ± 0.06**
h^2 FMC – Commercial Environment	**0.39 ± 0.08**	0.48 ± 0.08	0.35 ± 0.07	0.79 ± 0.09	0.39 ± 0.07	0.46 ± 0.07	**0.30 ± 0.06**
Genetic correlation (rg) between sites	**0.56 ± 0.11**	0.64 ± 0.10	0.58 ± 0.11	**0.89 ± 0.04**	**0.84 ± 0.07**	**0.94 ± 0.3**	**0.93 ± 0.05**

- High r_g between de-headed and gutted % and fillet % : 0.94 ± 0.02 and 0.97 ± 0.02
- Choice to consider only the genetic parameters from the Genetic Nucleus

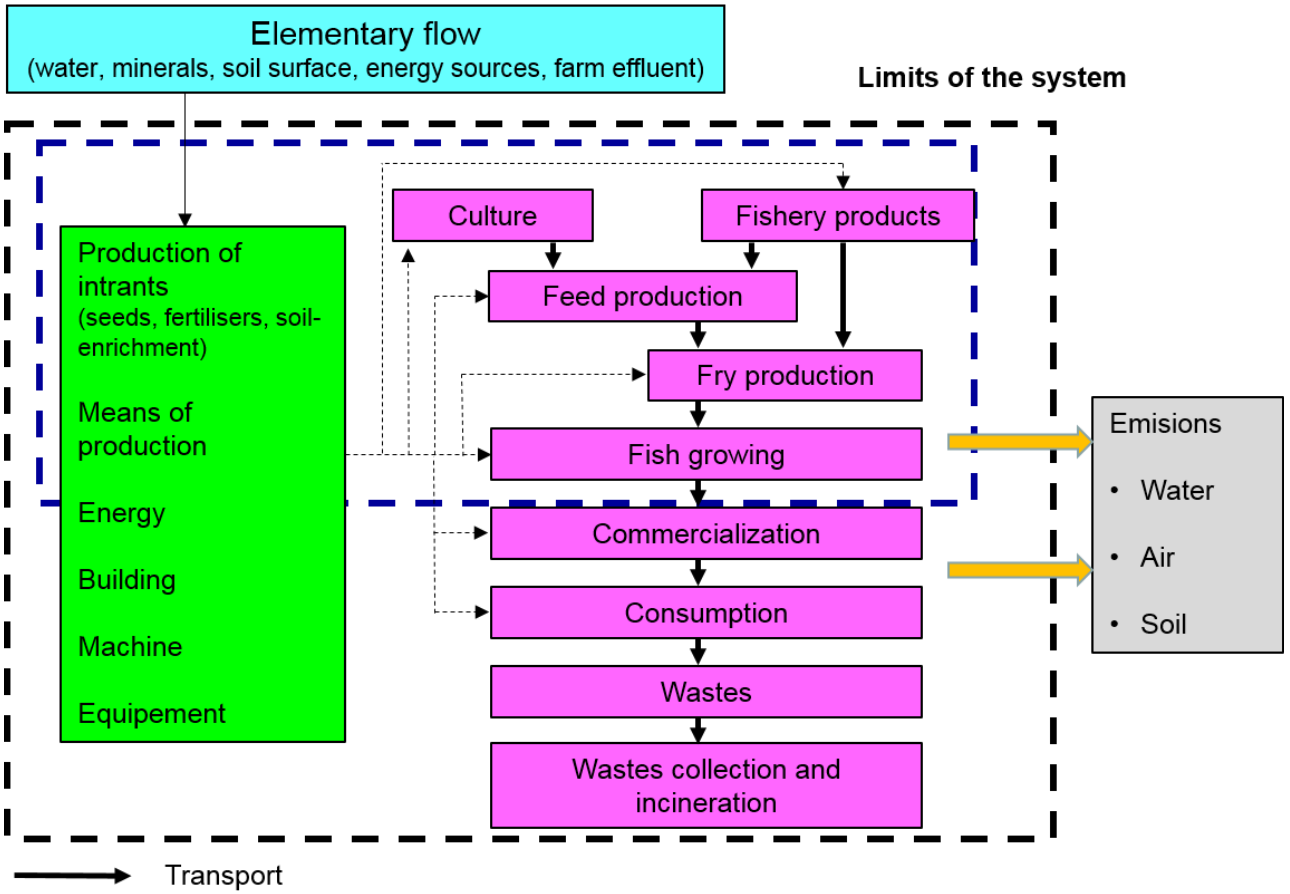
Phase 2 : Life Cycle Analysis scenarios

- **5 scenarios to estimate environmental efficacy after 5 generations of selection (gain estimated according to Falconer, 1976; $G = i\ h^2\ \sigma_p$)**

Scénario	Selection pressure	Performance	Genetic progress
Control (C)	No	324.5 g and 57.8 % fillet	**0 %**
Selection on growth (p% = 10 %)	10 % (i = 1.755)	519.6 g	**+ 60.0 %**
Selection on growth (p% = 3 %)	3 % (i = 2.269)	576.8 g	**+ 77.7 %**
Selection on fillet yield (p% = 20 %)	20% (i = 1.4)	63.0 %	**+ 8.9 %**
Selection on fillet yield (p% =10 %)	10% (i = 1.755)	64.3 %	**+ 11.2 %**

- **250 g of fillets (= portion by two consumers)**

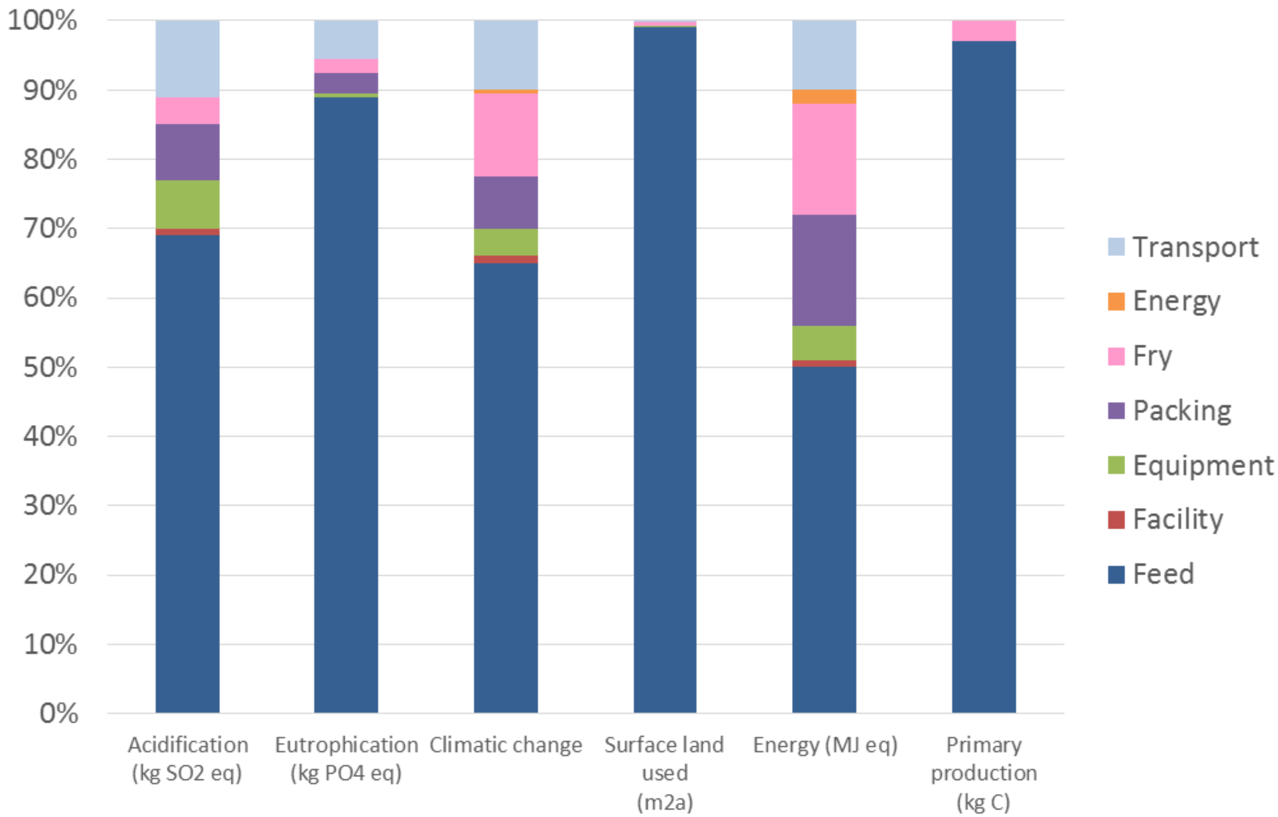
Phase 2: Definition of the system evaluated



- **Production in sea cage** in Corsica Island
- **Previously modeled** rearing performances and feed composition (Ecoinvent v. 2.2 database)
- **Transportation to Paris** : truck, boat, truck (FranceAgrimer 2011)
- **Supermarket and fishmonger** supply by regrigerated truck at 68.6 km/h (ADEME, 2007; UNTF, 2009)

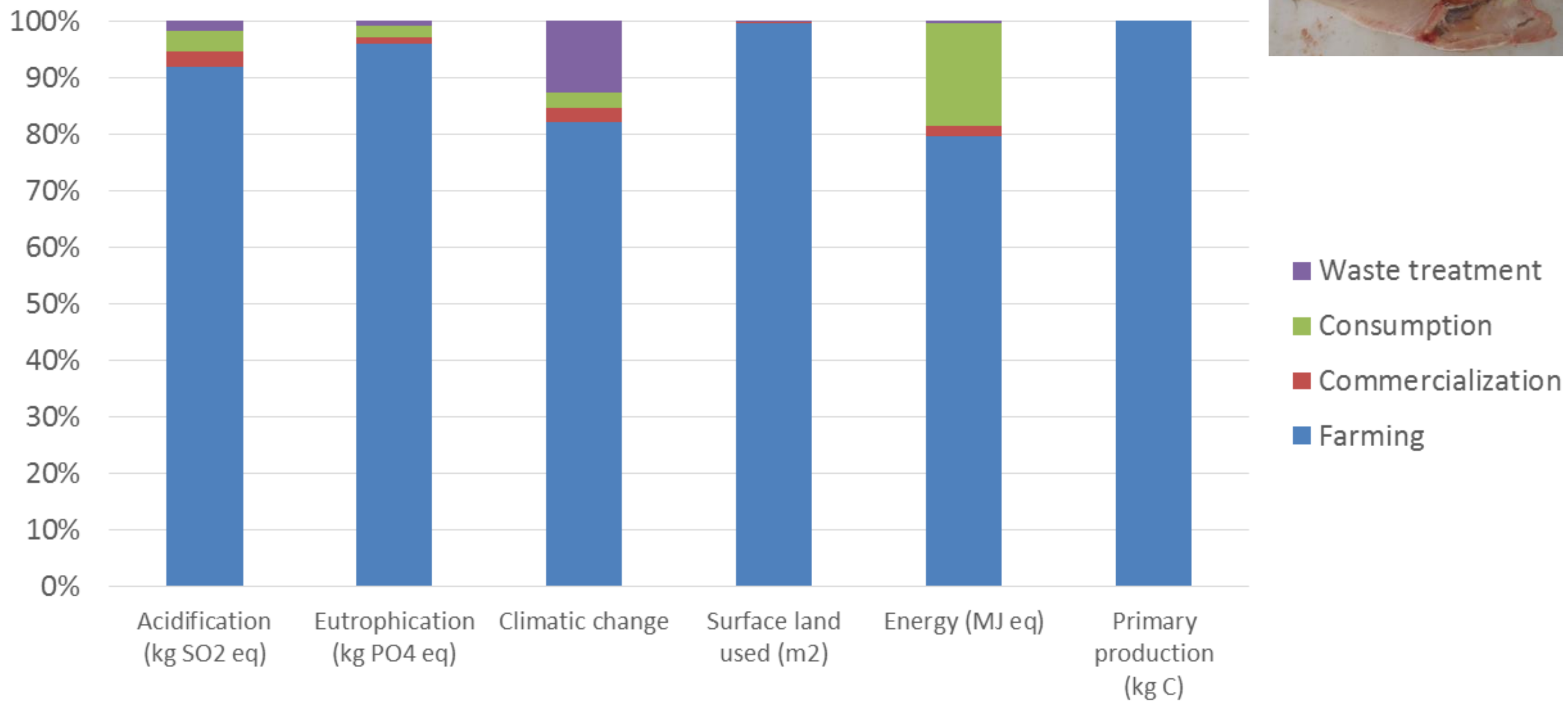
- **Consumer modeling**, middle class and 50 years old (ADEME, 2007), transportation by car (9 km) for 30 kg shopping basket once a week, 3 kg of fish consumed /year
- **2 cooking process,** cooking plate (15'; 906 W/h) and oven (25', 1226W/h)
- **100 % wastes incineration** 27kg/hab/year (ORDIF, 2010), distance 45 km, truck 3.5 T

Impact of the different rearing activities on the LCA impact categories per T of sea bream produced (Control)



- Major impact of feed, fry and transport activities on environmental impact

Relative impact of the different steps on LCA impact categories for 250 g of fillet consumed



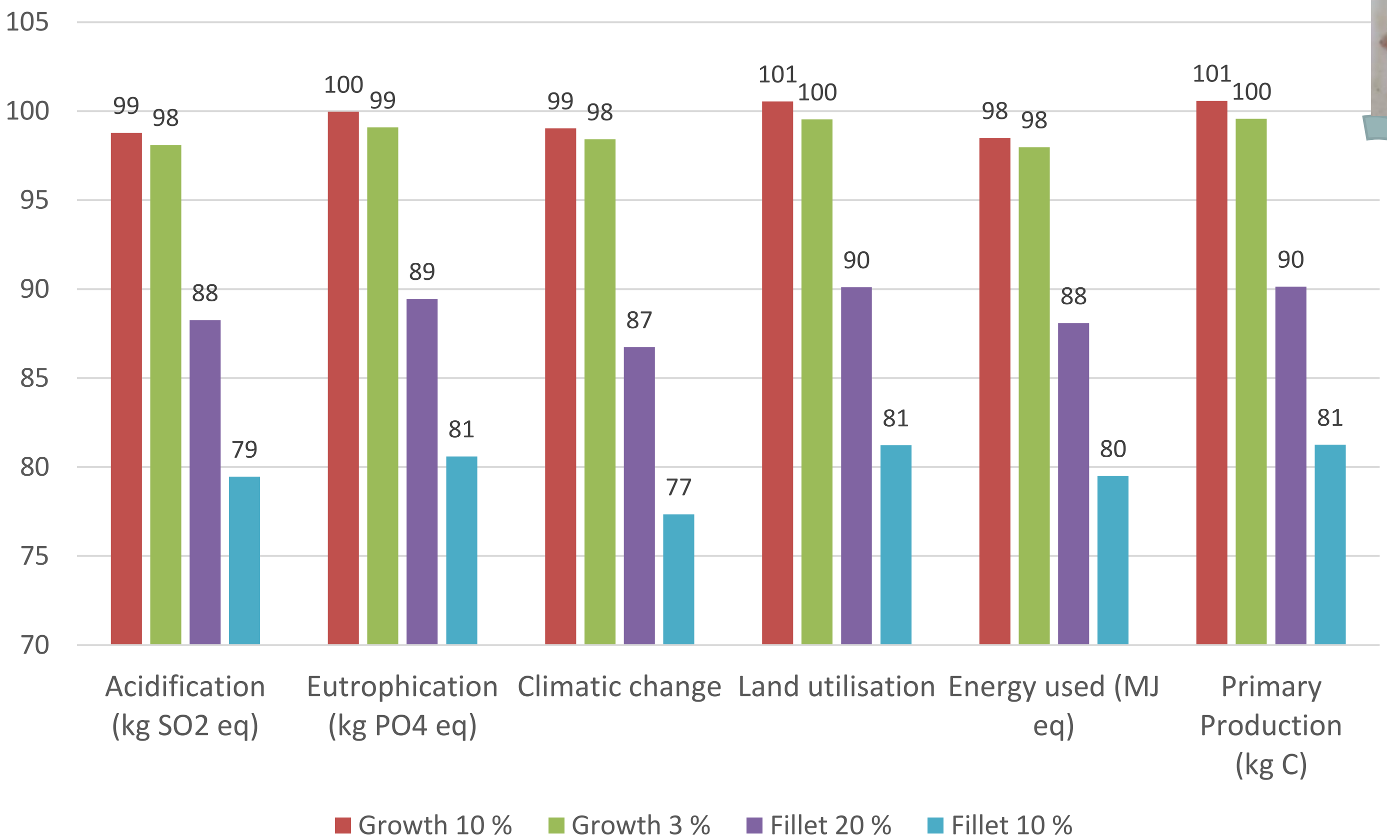
- Major impact of the farming step !
- Other significant impacts:
  - Cooking / energy used
  - Waste treatment / Climatic change farm

Impact of the different selection scenarios on the LCA impact categories per T of sea bream produced

Category of impact	Control	Growth 20 %	Growth 10 %	Fillet 20 %	Fillet 10 %
Acidification (kg SO2 eq)	21,4	21,1	21,0	21,4	21,2
Eutrophication (kg PO4- eq)	13,1	13,1	13,0	13,2	13,1
Climatic change (t CO2 eq)	4,55	4,49	4,46	4,55	4,50
Land surface utilisation (m^2a)	2856	2871	2842	2905	2879
Energy used (GJ eq)	80,7	79,2	78,6	80,2	79,4
Net Primary Production (t C)	141	141	140	143	142
Labor (day)	12,7	12,1	12,0	12,2	12,1

- Very limited gain in environmental efficacy at farm output
- No difference between scenario
- 5 generations of selection will not improve (or deteriorate !) the environmental efficiency the farming process

Relative impact of the different selection scenarios on LCA impact categories per 250 g of fillet consumed



-19 to -23 % !

- Major impact of the selection on fillet yield ! Why ?
  - Decrease of kg of feed (IC = 1.93) / kg of fillet produced and consumed
  - Limitation of environmental impact at all stages

Conclusions

• New estimations of environmental impacts for some new steps (transportation, supply chain in supermarket, waste treatments) in the LCA data bases

• Original approach never reported before in aquaculture or even in livestock that should be extended to other potential traits (feed efficacy, survival, disease resistance

• Improvement of fillet yield can contribute to improve environmental efficacy of aquaculture production by a mostly indirectly feed utilization

• Selection on fillet % = sib selection (- 50 % of efficacy) → Interest to develop indirect predictors of fillet yield on breeding candidates (ultrasound, artificial vision, genomic markers) to improve selection efficacy

Thank you for your attention…