Selective breeding for better farmed fish: how to be more efficient ?

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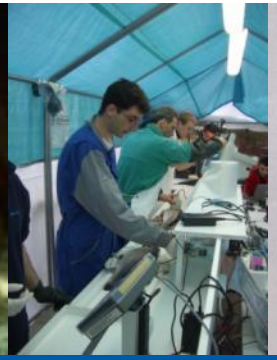
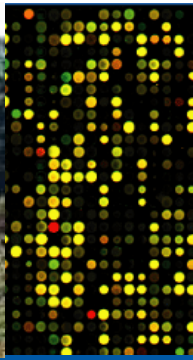
AQUAFARM congress, Pordenone, Italy, 26 January 2017

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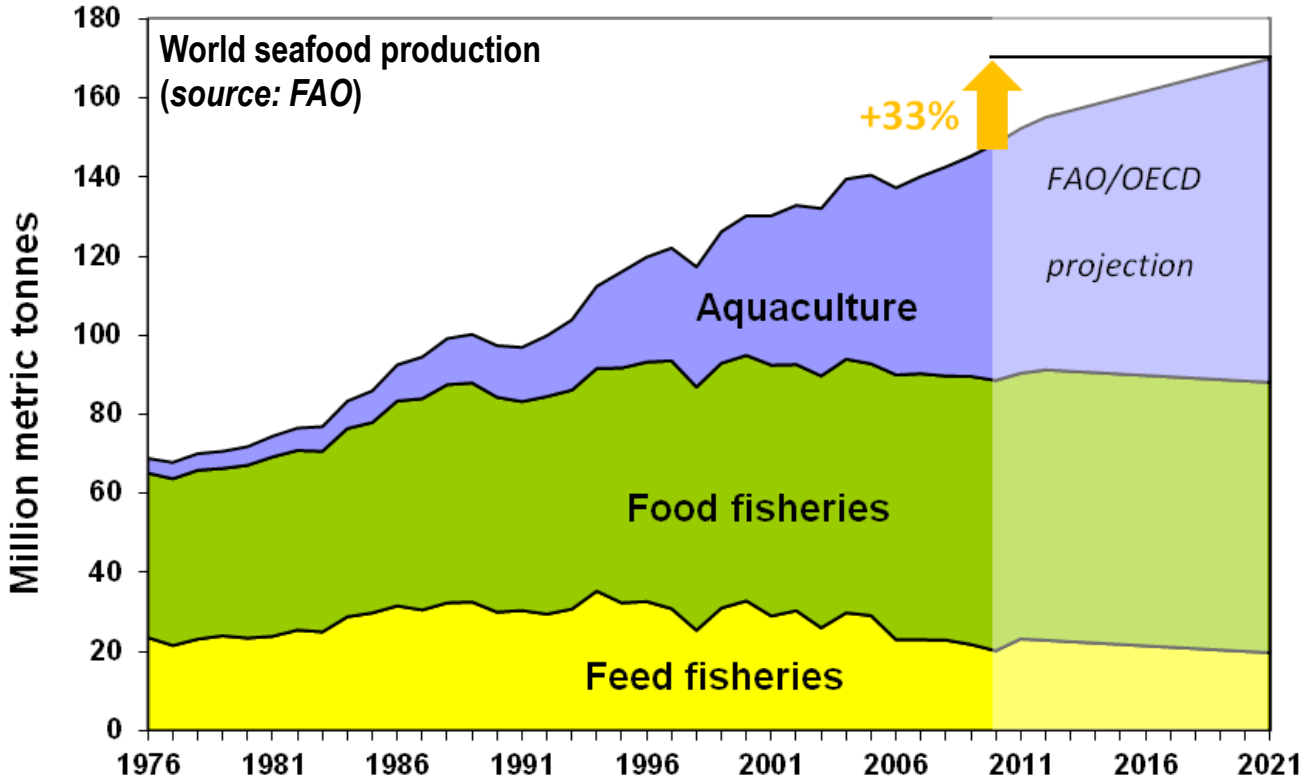
Aquaculture: a growing challenge



- The increase in consumption is and will be met by aquaculture
  ➔pressing need to increase competitiveness and sustainability

Selective breeding: a major productivity enhancer

- **Simultaneous comparison of 1957 and 2001 broiler strains**

1957

Day 43 Day 57 Day 71 Day 85

2001

- Body weight
  810g ➔3950g
- Carcass Yield
  60.8%➔74.4%
- Breast Yield
  11.4%➔ 21.3%

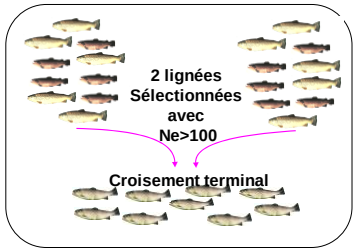
All were fed the same feed

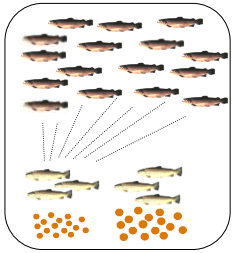
Havenstein, 2006, Lohmann Information 41: 30-37

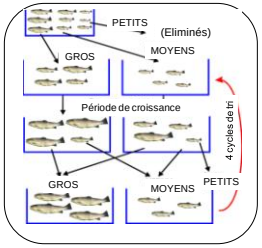
Early fish breeding programs

- **With pedigree: Norway salmon (1972)**

- **Without pedigree: French PROSPER (1986)**

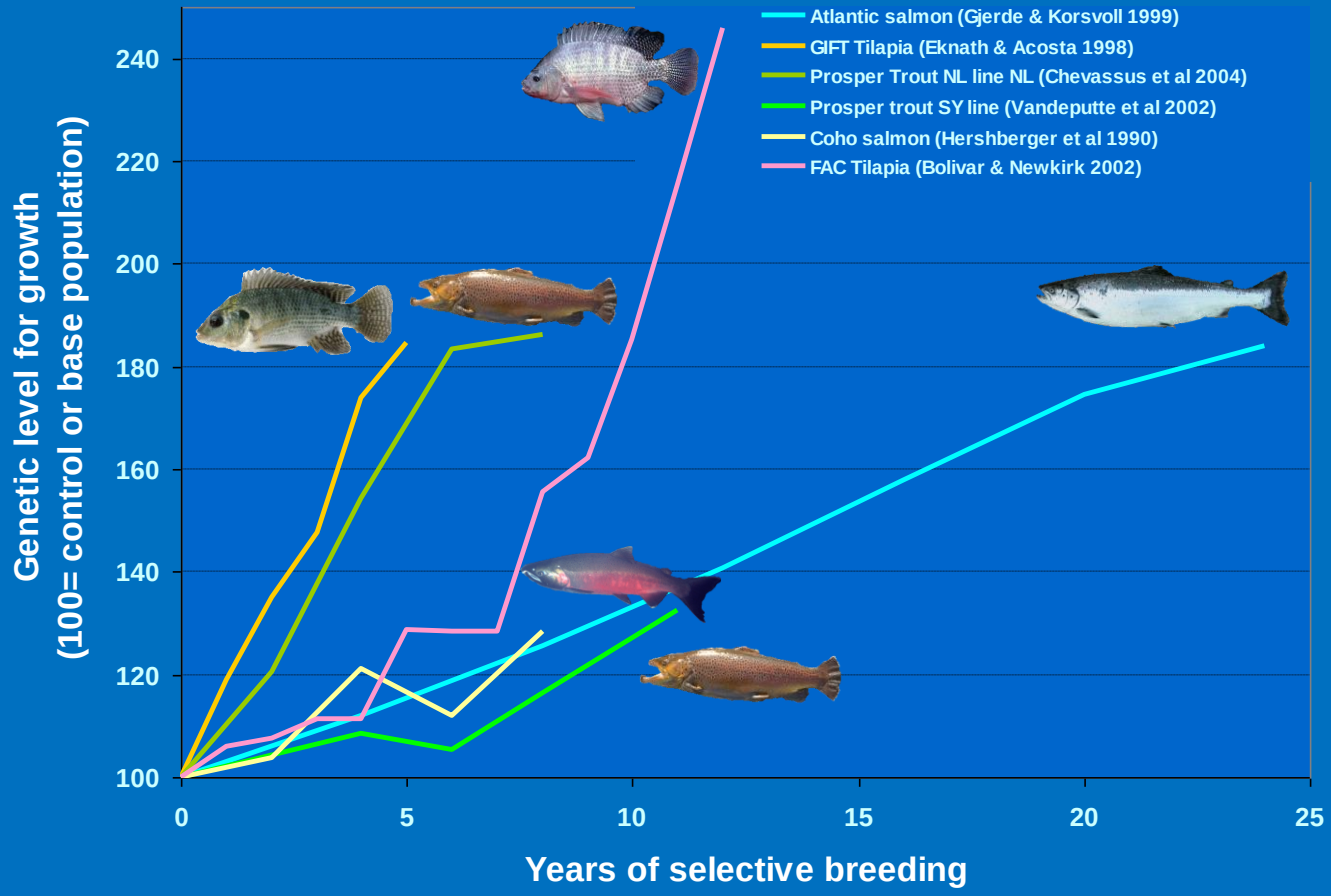






- **One major goal: faster growth**

Increasing growth: it works well!



High potential of fish because:

- Often starts from wild (domestication)
- High selection intensities possible
- Short generations (tropical species)

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Aquaculture breeding in Europe (2016)

12 species
54 programs
>31 with pedigree

Sources: Chavanne et al., 2016
Aquacult. Int. **24**: 1287-1305

AQUA BREEDING
FP6-2005-SSP-044424

SYSAAF

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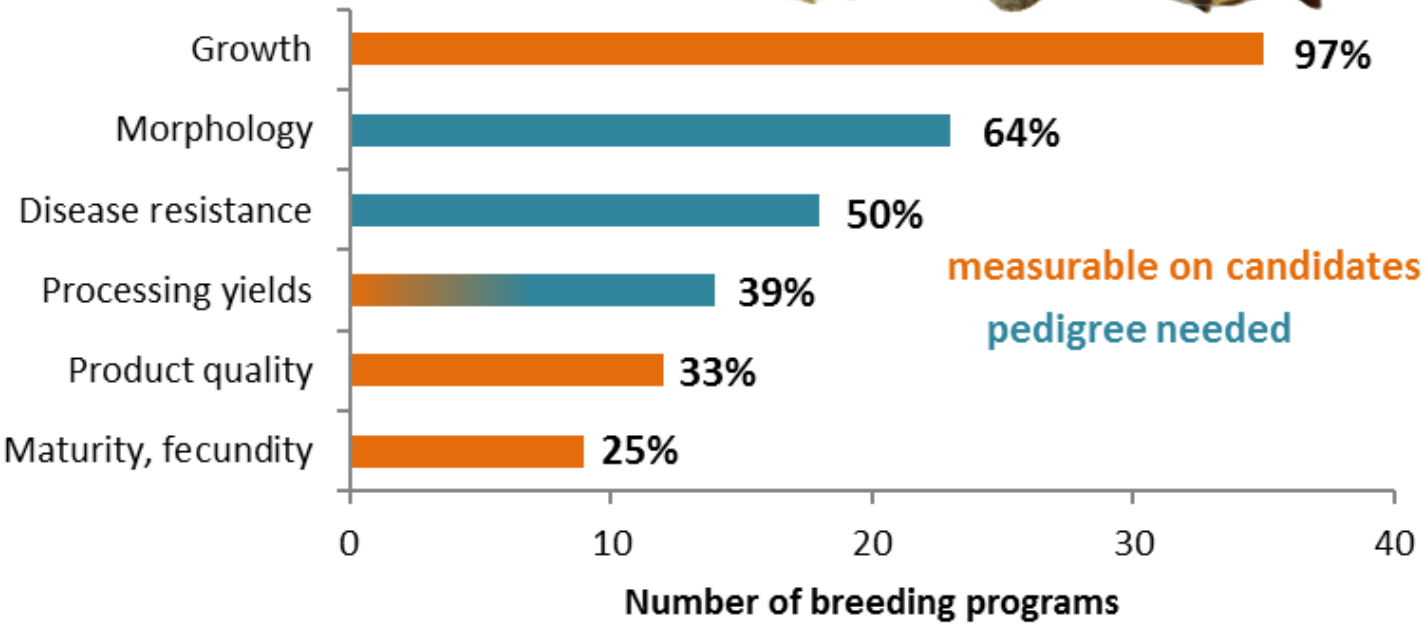
Traits selected



Chavanne et al., 2016, Aquacult. Int. 24:1287-1307

FISHBOOST
The next level of aquaculture breeding

Growth remains the #1 trait

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Aquaculture 350–353 (2012) 117–129

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Review

The importance of selective breeding in aquaculture to meet future demands for animal protein: A review

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ABSTRACT

Aquaculture is the fastest growing food production industry, and the vast majority of aquaculture products are derived from Asia. The quantity of aquaculture products directly consumed is now greater than that resulting from conventional fisheries. The nutritional value of aquatic products compares favourably with meat from farm animals because they are rich in micronutrients and contain high levels of healthy omega-3 fatty acids. Compared with farm animals, fish are more efficient converters of energy and protein. If the aquaculture sector continues to expand at its current rate, production will reach 132 million tonnes of fish and shellfish and 43 million tonnes of seaweed in 2020. Future potential for marine aquaculture production can be estimated based on the length of coastline, and for freshwater aquaculture from available land area in different countries. The average marine production in 2005 was 103 tonnes per km coastline, varying from 0 to 1721 (China). Freshwater aquaculture production in 2005 averaged 0.17 tonnes/ha, varying from 0 to close to 6 tonnes per ha (Bangladesh), also indicating potential to dramatically increase freshwater aquaculture output. Simple estimations indicate potential for a 20-fold increase in world aquaculture production. Limits imposed by the availability of feed resources would be lessened by growing more herbivorous species and by using more of genetically improved stocks.

Aquaculture generally trails far behind plant and farm animal industries in utilizing selective breeding as a tool to improve the biological efficiency of production. It is estimated that at present less than 10% of aquaculture production is based on genetically improved stocks, despite the fact that annual genetic gains reported for aquatic species are substantially higher than that of farm animals. With an average genetic gain in growth rate of 12.5% per generation, production may be dramatically increased if genetically improved animals are used. Importantly, animals selected for faster growth have also been shown to have improved feed conversion and higher survival, implying that increased use of selectively bred stocks leads to better utilization of limited resources such as feed, labour, water, and available land and sea areas.

Contents

But is it growth that we really need to improve?

With an average genetic gain in growth rate of 12.5% per generation, production may be dramatically increased if genetically improved animals are used

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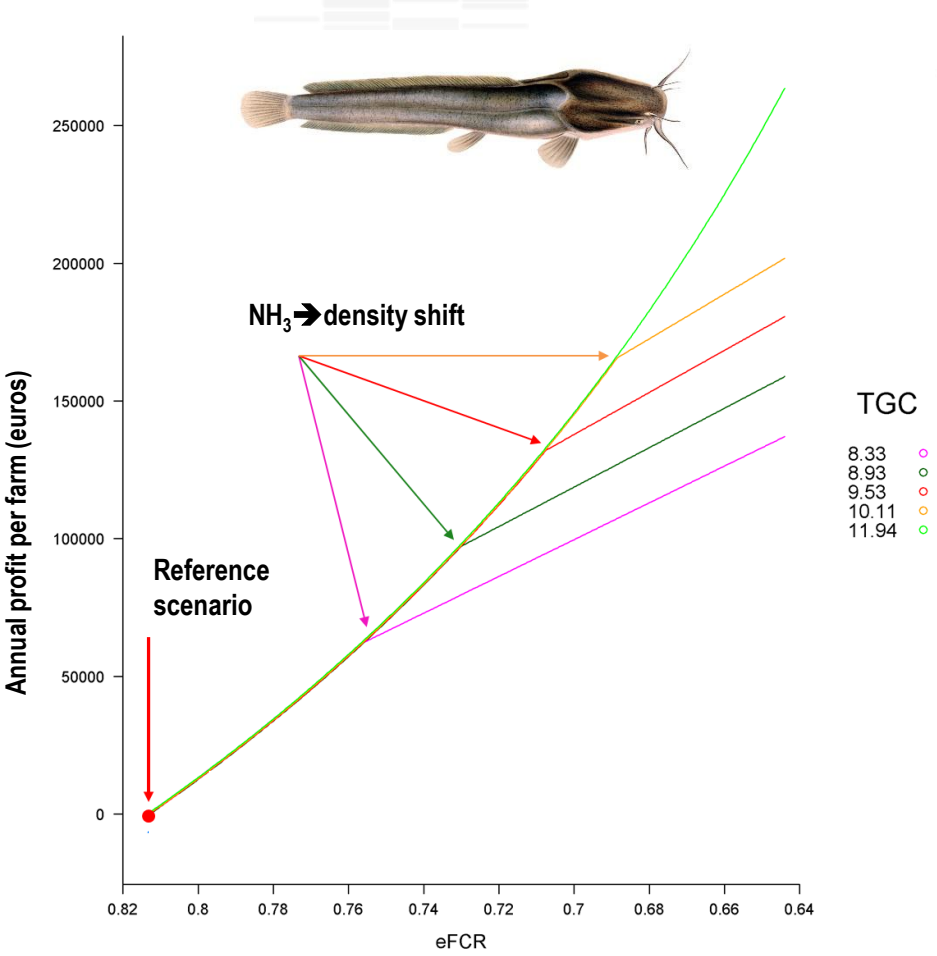
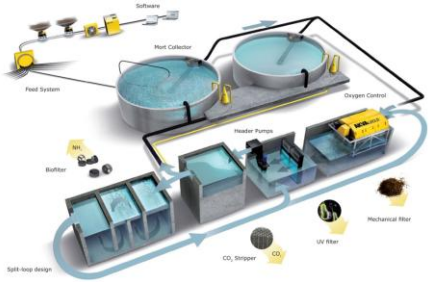
The problem…

The solution?

Economic value of TGC et FCR





500t/yr, 1.35€/kg

- Variable traits

FCR: 0.81 (Δ=0.06/generation)

TGC: 8.33 (Δ=+0.6/generation)

- Limiting factors
  - Density 230 kg/m^3
  - N-NH$_3$: 40 kg/day

- FCR is always profitable
- TGC is profitable only if density is the limiting factor
- Extension to other systems show similar results

Besson et al. 2014, J Anim. Sci. 92:5394-5405.

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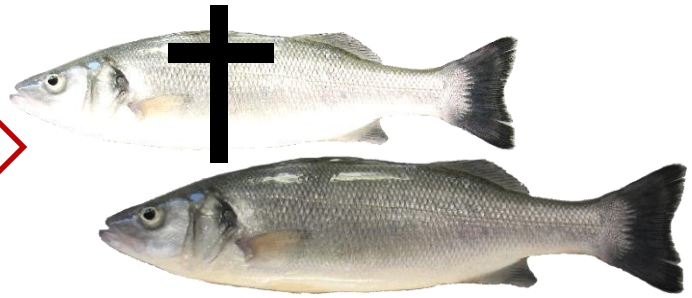
Changing perspective: towards efficiency



Adaptation to PB Diets

Feed Efficiency

Survival/ Disease resistance

Fillet yield

5.8 kg ⇐ 2.9 kg ⇐ 2.6 kg ⇐ 1.0 kg

1.9 kg ⇐ 1.7 kg ⇐ 1.6 kg ⇐ 1.0 kg

How can we improve those traits by selective breeding ?
Will faster growing fish also be better for efficiency ?

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Fillet yield: indirect selection

➢ Carp

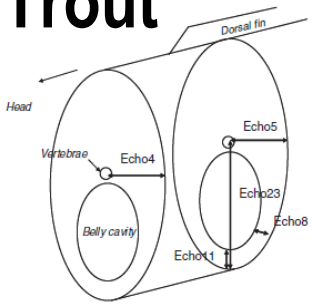
- Head size

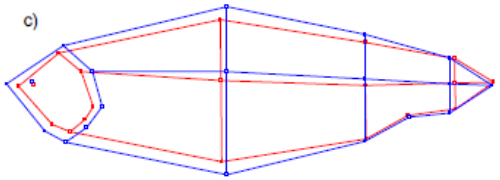
+fillet **-fillet** **r_A=-0.86**

Selection for smaller head:
+1.4% filet/gen. (avg 31,2%)

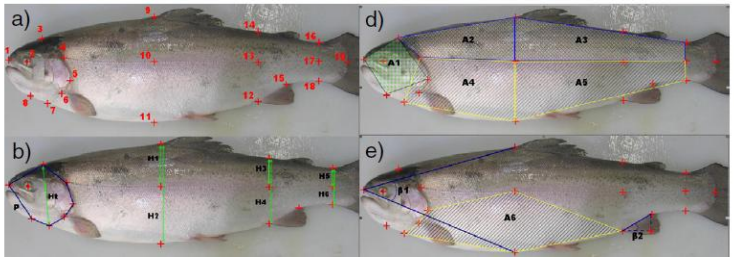
Kocour et al, 2007. Aquaculture 270: 43-50

➢ Trout





High fillet yield
Low fillet yield



Haffray et al., 2012. Aquaculture 368: 145-152

FISHBOOST The next level of aquaculture breeding *ongoing work:*

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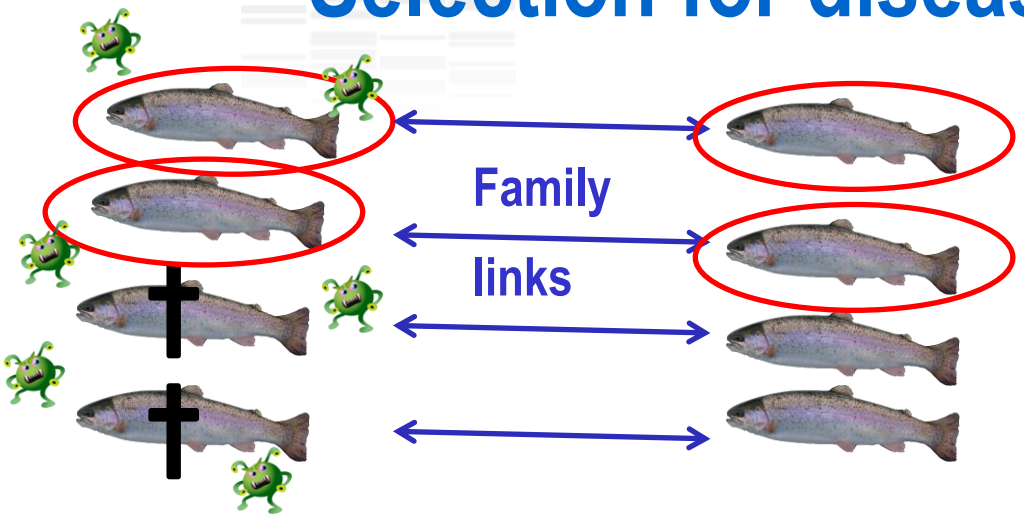
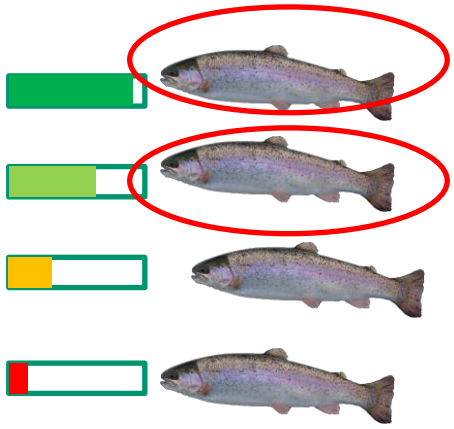
Selection for disease resistance





Selection of survivors

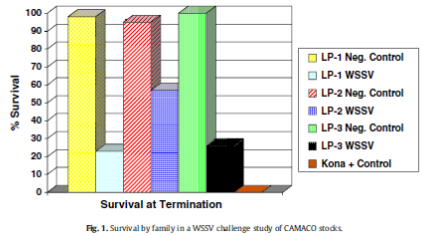


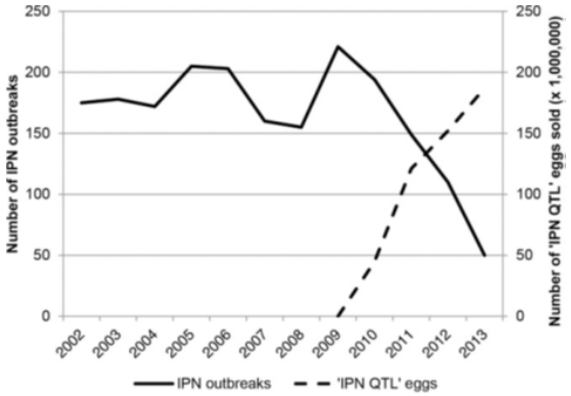
Fig. 1. Survival by family in a WSSV challenge study of CAMACO stocks.

Cuellar-Angel et al, 2012 Aquaculture 368: 36-39
IPN: *Okamoto et al 1993 Aquaculture 117 71-76:*

Sib selection

2-18% gain/generation in multitrait
Gjedrem, 2015, JMSE 3: 146-153:

Indirect (QTL / genomic)



Moen et al, 2015, Genetics

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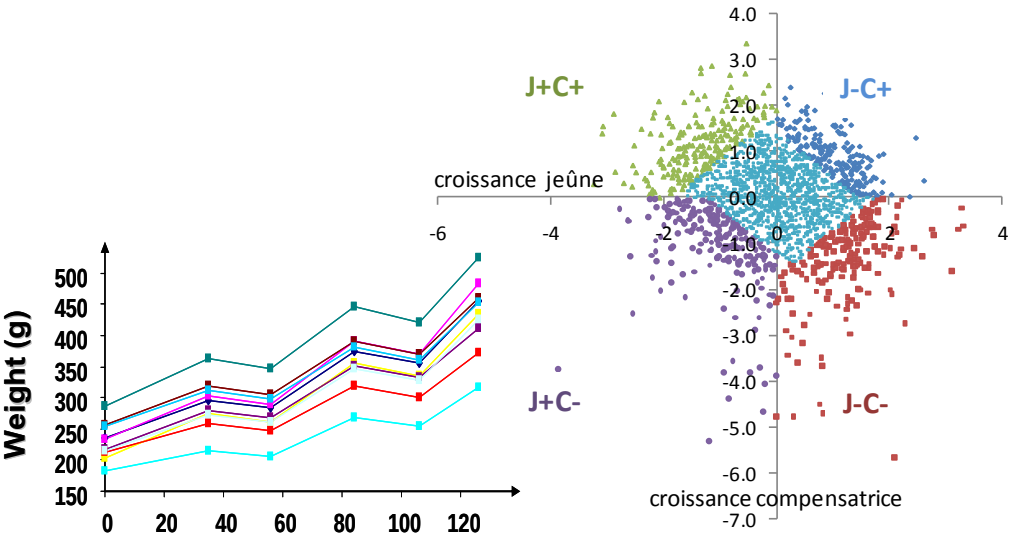
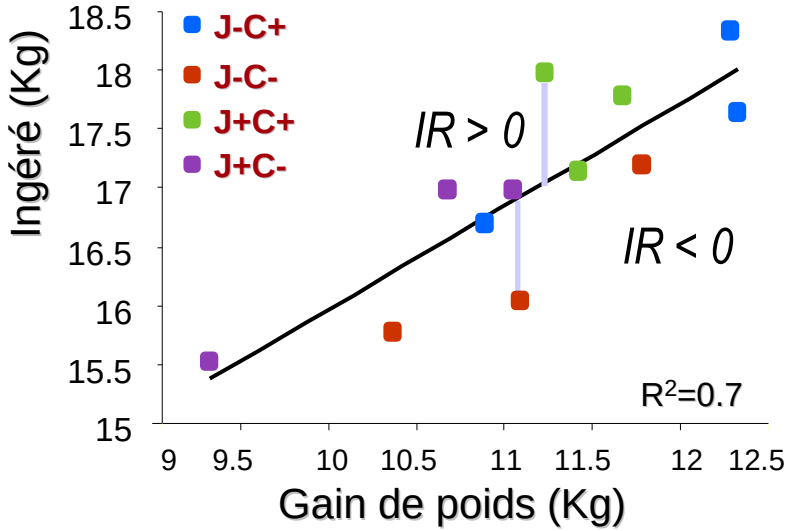
Selecting for feed efficiency ?

- **Highly profitable but not selected for**
- **Individual feed intake on long periods not measurable**
  ➔ candidate FE not measurable
- **Indirect criteria:**
  - FE of individually housed fish
  - **X-ray point FI measurements**
  - **Weight loss at fasting**
  - **Growth ??**

Weight loss at fasting





Grima et al, 2010a. Aquaculture 300: 50-58

Grima et al, 2010b. Aquaculture 302: 169-174

Validation by experimental selection in sea bass ongoing

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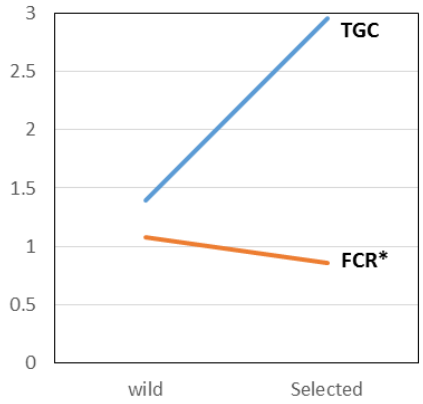
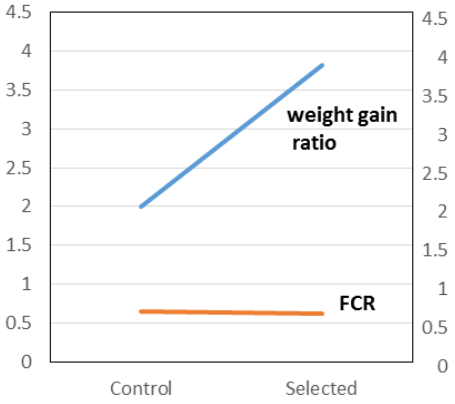
Does selection for faster growth imply better FE ?

Atlantic salmon



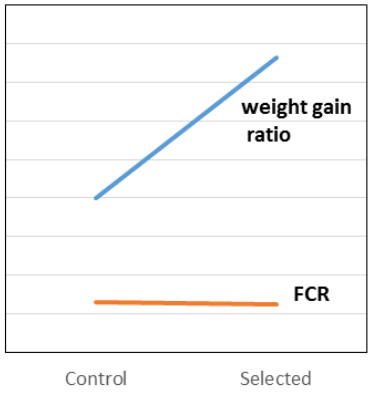
Thodesen et al 1999
Aquaculture 180: 237-246

Japanese flounder



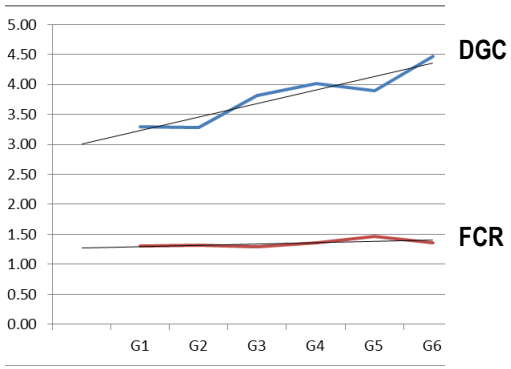
Ogata et al 2002
Aquaculture 211: 183-193

Brown trout



Sanchez et al 2004
J.Anim.Sci. 82: 2865-2875

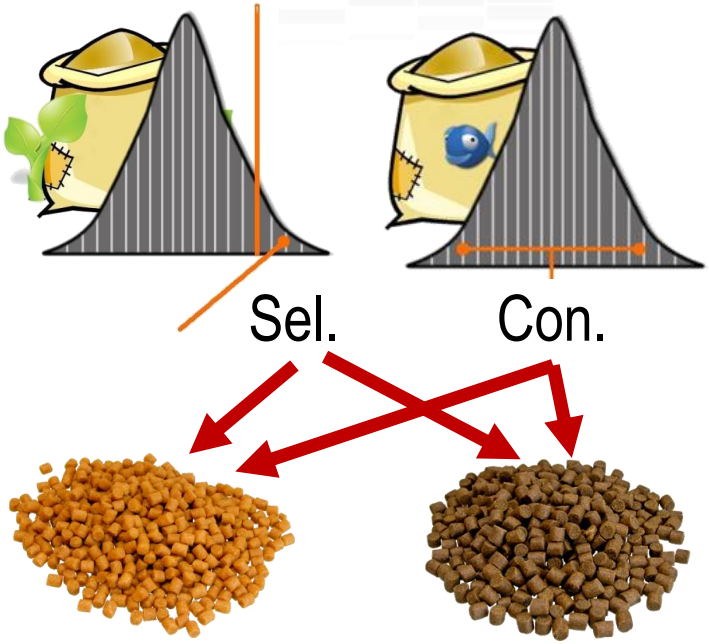
Nile tilapia in RAS



Hans Komen, ABGC, WUR

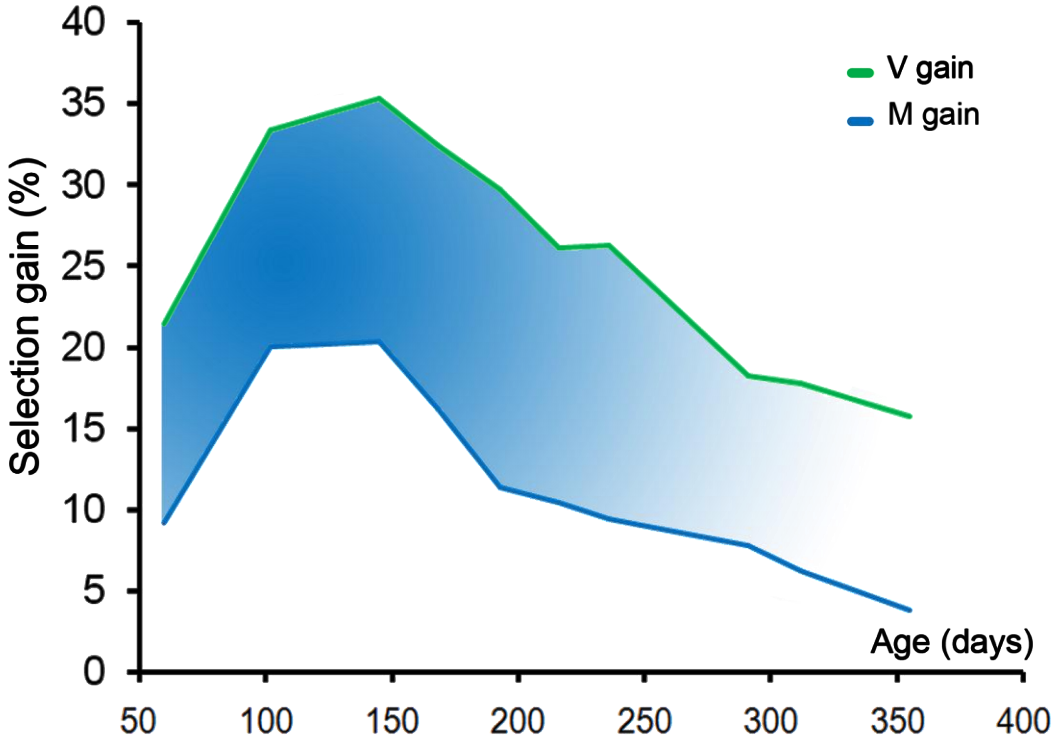
➔ **Growth may contribute but we need more data on FE genetics**

Selecting « vegetarian » rainbow trout



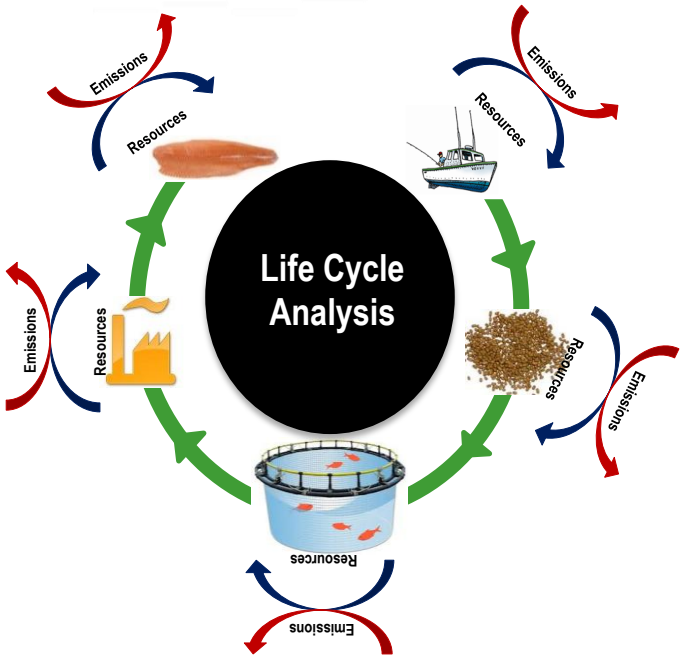
V-gain=
(S-T)/T

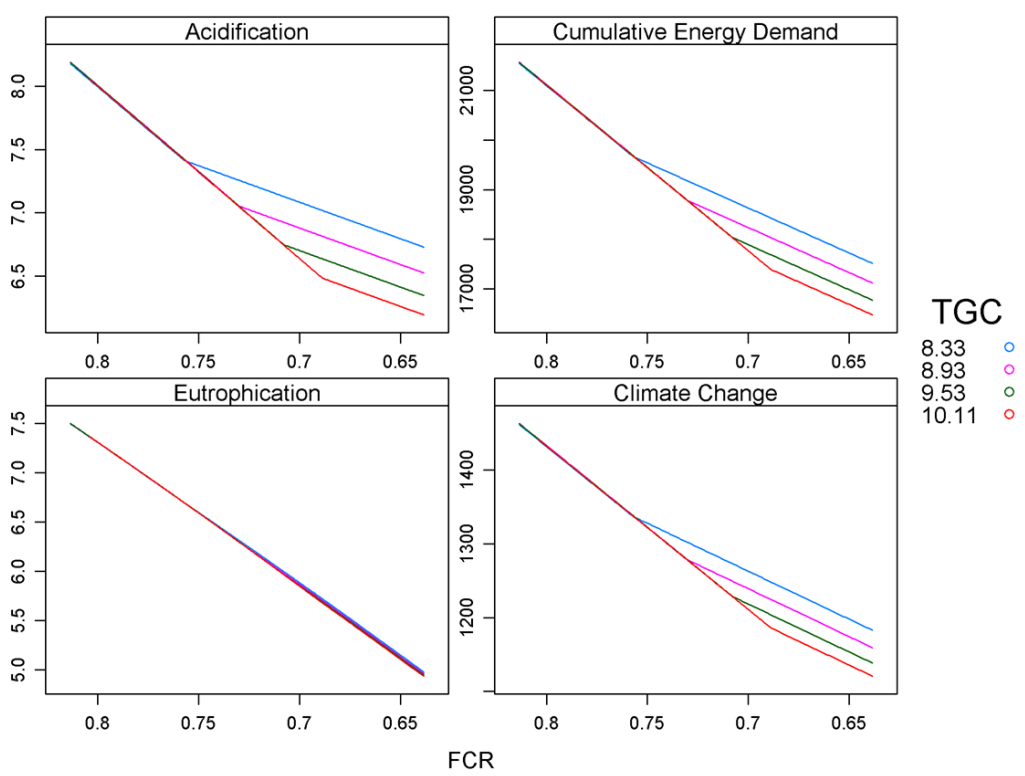
M-gain=
(S-T)/T



Le Boucher et al., 2012, PLoS ONE 7: e44898

Efficiency also reduces environmental impact

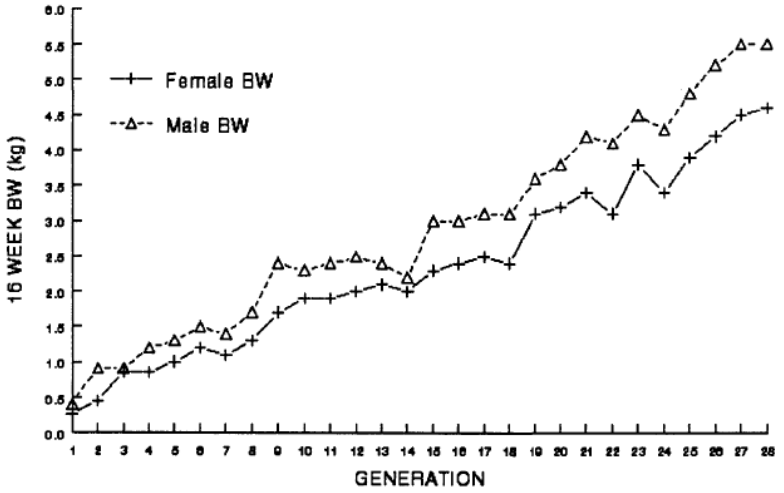




Besson et al., 2016, J. Cleaner Prod. 116: 100-109

What are the limits to selection for efficiency ?

- Ever faster growing fish is (probably) possible
- But an immortal fillet block growing without feed will not be possible…
- What are the limits ?
- Will efficient fish be less robust ?



Nestor et al.1996 Poult Sci 75: 1180-1191

28 gen: 400g➔5500g (♂16 wks BW)

Conclusion

- Efficiency is both economically and environmentally beneficial
- Major traits: feed efficiency, processing yields, disease resistance, adaptation to alternative diets
- Some (little ?) progress may be expected by correlated response to selection for growth
- Specific research needed on phenotyping, genetic and genomic bases of efficiency traits

- A major key for sustained growth of aquaculture production in a finite world