Breeding selection in aquaculture fishes, with emphasis on the meagre *Argyrosomus regius*

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SYSAAF references in aquaculture

• **Salmonids**
  
  aqualande

• **Marine and new fish species**
  
  France Turbot
  
  Ferme Marine du Douhet

• **Shellfish and shrimp**
  
  SATMAR
  
  Gènocéan

• **Multi-year international genetic advising + audit**
  
  SyAqua
  
  MOANA
  
  blueGENETICS
  
  CASEMEX VIETNAM

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Genetic selection?

It’s the **cumulative** improvement of profitability by the **reproduction** of the best parents at each **new generation** according to the **market demand**.
Organisation of a breeding program

Genetic data treatment

DNA genotyping:
- Parentage assignment
- QTL markers
- Genomic selection

Reproduction

A. I.

Breeding nucleus

Phenotyping & BLUP-EBV evaluation

Separated for mixed family rearing

Individual tagging, DNA collection

Eyed eggs, fry, PL, semen, broodstock

Multipliers (hatcheries)

Eyed eggs, fry, PL

Farmers

Sib testing

- Quality and reproductive traits
- Disease resistance
- GxE interaction

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1st objective of a breeding program: not lose performance by inbreeding!

Effect of 3 generations of successive full-sib crossing in rainbow trout (Gjerde et al., 1983)

- Effective number of parents participating to the next generation:

\[ Ne = \frac{4 \times N_{Sires} \times N_{Dams}}{N_{Sires} + N_{Dams}} \]

\[ F = \frac{-1}{2Ne} \]

\[ Ne > 100 \Rightarrow F < 0.5 \% \text{ / generation} \]
Technical requirements to invest in selection

- Have a broodstock with minimum genetic variability → Ne > 100
- Define traits to improve according to the market → ?
- Create at least 150-200 families per generation, more being better
- Limit initial non-genetic bias (maternal effects, tanks effects, mortality, cannibalism...)
- Apply a minimum of selection pressure (< 10 %)
- Manage inbreeding by optimized mating → pedigree and artificial fertilization
- Use adapted specialized genetic software (inbreeding, estimation of the breeding value)
- Transfer efficiently the genetic progress to the production
### Which method of selection?

<table>
<thead>
<tr>
<th>Breeding methods</th>
<th>Within-family selection</th>
<th>Family selection</th>
<th>Mass selection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Selection program</strong></td>
<td>8 families / year = 50 / generation</td>
<td>40 families / year = 180-240 / generation</td>
<td>40 families / year = 180-240 / generation</td>
</tr>
<tr>
<td></td>
<td>Separate family rearing</td>
<td>Separate family rearing</td>
<td>Mixed family rearing</td>
</tr>
<tr>
<td></td>
<td>= 8 tanks</td>
<td>= 40 tanks</td>
<td>= 1 tank → 1 cage</td>
</tr>
<tr>
<td></td>
<td>Tagging 100-200 fish / family → 1 cage</td>
<td>Tagging 100-200 fish / family → 1 cage</td>
<td>Selection of 300-1000 fish / year</td>
</tr>
<tr>
<td></td>
<td>Selection of 20 fish / family at 2 years</td>
<td>Selection of 20 fish / family at 2 years of the 10 best families</td>
<td>DNA parentage assignment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expected genetic gain for growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 5-6 % / generation</td>
</tr>
</tbody>
</table>

|                      | Simple, robust | Theoretically the more efficient if > 400 families / generation | Simple |
|                      | Intermediate facility demanding | Multitrait and mutigeneration based on BLUP-EBV | Low facility demanding |
|                      | Good for inbreeding management | Disease resistance | High selection pressure (3-5 %) |

| + Only 50 % of the expected progress of mass selection | + Theoretically the more efficient if > 400 families / generation | + Cost efficient ratio / family selection : 1 : 10 |
| - Only traits measurable on the candidates (growth, morphology) | - Only traits measurable on the candidates (growth, morphology) | - Only traits measurable on the candidates (growth, morphology) |

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Biological and economical factors to consider for the selective breeding of the meagre

Unfavorable factors

• Limited and variable production (3900 T in 2010 and 560 T in 2013 in EU (FEAP); 2,8 M€ at 5 €/kg) → 3% of the turn-over for genetics = 84 K€ investment / year !
• Long generation interval (5-7 years) ⇒ Limited genetic gain / year (+2-3 %) ≈ + 20-25 % in 10 years
• Need of female hormonal stimulation and only 10 % ready to spawn in a tank → 10x the female number
• High body weight of the broodstock (> 8-10 kg) → Difficulty for manipulation and high rearing cost to meet adequate Ne

Favorable factors

• Artificial fertilization → Factorial mating design and high number of families
• DNA parentage assignment available (Soula et al., 2012; Duncan et al., 2012; Bestin et al., 2014)
• Genetic variation of broodstocks? →
• Heritability of growth?
How to split the families production per generation?

Selected line
\( (Ne > 100) \)

\[ \begin{array}{cccccccccccccccc}
0 & \cdot & 0 & \cdot & 0 & \cdot & 0 & \cdot & 0 & \cdot & 0 & \cdot & 0 & \cdot & 0 & \cdot \\
1 & - & 1 & - & 1 & - & 1 & - & 1 & - & 1 & - & 1 & - & 1 & - \\
3 & - & 3 & - & 3 & - & 3 & - & 3 & - & 3 & - & 3 & - & 3 & - \\
5 & - & 5 & - & 5 & - & 5 & - & 5 & - & 5 & - & 5 & - & 5 & - \\
7 & \uparrow & 7 & \uparrow & 7 & \uparrow & 7 & \uparrow & 7 & \uparrow & 7 & \uparrow & 7 & \uparrow & 7 & \uparrow & 7 & \uparrow \\
\end{array} \]

Year Class 1
\( (Ne > 16) \)

Year Class 2
\( (Ne > 16) \)

Year Class 3
\( (Ne > 16) \)

Year Class 4
\( (Ne > 16) \)

Year Class 5
\( (Ne > 16) \)

Year Class 6
\( (Ne > 16) \)

Year Class 7
\( (Ne > 16) \)

7 year classes + rotational mating by males

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Genetic variation of the wild populations of the meagre?

Haffray et al., 2012, Aquat. Living Resour., 25, 173-183

(Argyrosat research project, 2008-2010)
Only 3 reproductive areas previously described
Quéro and Vayne 1987

Reproduction areas

Other spawning areas
(Turkey? Morocco?, Guadalquivir? Portugal, Croatia?…)

Same species?

If yes, how many populations?

Genetic distances?

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Sample collection

Cemagref
Sciences, eaux & territoires

Gironde

West Portugal

South West Iberia

Mauritania

M1
M2
M3
M4

G1
G2

P1
P2
S1

T1
Egypt

EEAA
Egyptian Environmental Affairs Agency

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### Genetic distances between populations

<table>
<thead>
<tr>
<th></th>
<th>Gironde</th>
<th>West Portugal</th>
<th>Mauritania</th>
<th>South Spain</th>
<th>Egypte</th>
<th>Turkey</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gironde</strong></td>
<td>0,026***</td>
<td>0,026***</td>
<td>0,025***</td>
<td>0,099***</td>
<td>0,140***</td>
<td></td>
</tr>
<tr>
<td><strong>West Portugal</strong></td>
<td>0,026</td>
<td>0,041***</td>
<td>0,012***</td>
<td>0,107***</td>
<td>0,168***</td>
<td></td>
</tr>
<tr>
<td><strong>Mauritania</strong></td>
<td>0,026</td>
<td>0,041</td>
<td>0,024***</td>
<td>0,061***</td>
<td>0,098***</td>
<td></td>
</tr>
<tr>
<td><strong>South Iberia</strong></td>
<td>0,026</td>
<td>0,012</td>
<td>0,024</td>
<td>0,073***</td>
<td>0,126***</td>
<td></td>
</tr>
<tr>
<td><strong>Egypt</strong></td>
<td>0,104</td>
<td>0,113</td>
<td>0,063</td>
<td>0,076</td>
<td></td>
<td>0,081***</td>
</tr>
<tr>
<td><strong>Turkey</strong></td>
<td>0,151</td>
<td>0,184</td>
<td>0,104</td>
<td>0,134</td>
<td>0,085</td>
<td></td>
</tr>
</tbody>
</table>

*Genetic distance (Reynolds et al., 1983) in bold and $F_{ST}$ (Weir et Cockerham, 1984)*

*Very high genetic fragmentation rarely reported in marine fishes (~intercontinental level!)*

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Evolutionary relationship between the 6 populations

Genetic distances between the 6 populations based on the neighbor-joining algorithm (MEGA 4; Tamura et al., 2007)

- Subdivision of the meagre in at least 2 different genetic units:
  - Atlantic unit
  - Mediterranean unit
- Limited suitable areas and environments for reproduction and nursery and growing?
Genetic variation of the French broodstocks of the meagre

Haffray et al., 2014, EAS Aquaculture Conference. San Sebastian

(Argyrosat research project, 2008-2010)
Genetic variation of French broodstocks in 2009?

- A high number of alleles

Same range of within-population heterogeneity

- French broodstock collected in 2009 were variable and non-inbred
What do we know about traits that can be selected in the meagre?

Bestin et al., 2014, 10th World Congress on Genetics Applied to Livestock

(VEGEAQUA FUI French research project, 2009-2012)
Genetic parameters for growth and winter survival and GxE interaction with feed substitution

• **Protocole**
  - 3 ♀ x 14 ♂ males (Ne = 10)
  - 42 families
  - 2 feeds from 33 g (D150)
    - Normal diet
    - Substituted diet (2% FM and 2 % FO)
  - DNA-Parentage assignment

![Graph of body weight and heritability](image)

- **Unwanted sudden drop of temperature to 10°C**
  - Survival = 8,6 % ± 13.8 % (0%-57%)
  - $h^2 = 0.38 \pm 0.05$
Potential genetic risks associated with escapement?

- Early domestication and no proof of impact

- Different situations:
  - Threatened wild population in Turkey and Egypt
  - No known wild population in Western Mediterranean
  - Major wild stocks in Atlantic (Mauritania, Morocco, Spain)

- Unknown interaction between escapement and homing (to where and with what success?)

- Solutions, if needed?
  - Local stocks? More advanced selection?
  - Sterilisation (triploids or hybrids)?

(Karahan et al., 2014, EAS, San Sebastian)
Summary for the meagre selective breeding

• Genetic basis for the initiation of meagre breeding programs are there
  • Characterization of wild and domesticated broodstocks
  • Panels of microsatellites for DNA parentage assignment
  • Heritability for body weight $\rightarrow h^2 > 0.30$

• Major difficulties
  • Long generation interval and very big size of the broodstock $\rightarrow$ High cost of the post-growing phase (between 2 and 7 years) and reproduction for a limited gain/year
  • Limited and variable production $\rightarrow$ Size of breeding program to be adapted to the lower tide of market capacity

• Needs?
  • Characterize remaining wild population and farmed broodstock with other markers mtDNA, SNP
  • Heritability of new traits for disease resistance?
Thank you for your attention and thanks to Costas, Dinos, Neil et Pascal for their invitation