Selective breeding: a way to boost the production of fish in Europe

Selective breeding has a very high potential for improving the genetic makeup of fish in aquaculture production. It just takes a few generations to accomplish major improvements in economically important traits. These improvements can be achieved by using selective breeding in better and efficient breeding programmes, adapted to SMEs and/or larger companies and markets.

European aquaculture production is all about bringing a good quality product for a good prize to the ever growing market for fish. There is a huge potential in making European aquaculture more efficient, more profitable and more sustainable. One of the ways to realise this potential and boost aquaculture production is domestication of new species and selective breeding. The European research project FISHBOOST will advance European aquaculture to the next level for six aquaculture finfish species. This brochure will show the benefits of selective breeding for aquaculture producers.

FISHBOOST can bring you one step further in bringing your fish production to the next level by improving:

- the health and welfare of the fish;
- the product characteristics such as fillet yield and flesh quality;
- the impact on the environment by improving feed efficiency;
- the efficiency and profitability of your business.

The six species in FISHBOOST

Atlantic salmon
Common carp
European seabass
Gilthead seabream
Rainbow trout
Turbot
**What is selective breeding?**

Selective breeding is the process where the genetic variation present in desirable traits within a population is used to improve production quality, efficiency and sustainability.

*Selective breeding in aquatic species is very successful.*

Two key reasons for these good results in aquaculture species are:

1. Aquaculture species have very high fecundity allowing for strong selection intensity (see illustration below).
2. Many traits of interest in aquaculture species have high heritabilities, which means that selecting for these traits can deliver substantial genetic improvements.

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**Ranges of heritability estimates (%) for aquaculture species traits**

<table>
<thead>
<tr>
<th>Traits</th>
<th>Heritability (on a scale from 0 – 100%)</th>
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</thead>
<tbody>
<tr>
<td>Growth</td>
<td>30 – 60</td>
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<tr>
<td>Morphology/appearance</td>
<td>10 – 50</td>
</tr>
<tr>
<td>Sexual maturity</td>
<td>10 – 40</td>
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<tr>
<td>Disease resistance</td>
<td>10 – 50</td>
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<tr>
<td>Carcass quality</td>
<td>10 – 30</td>
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<tr>
<td>Processing yield</td>
<td>20 – 50</td>
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</tbody>
</table>

*Based on Allison and Burnell (2013)*

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**How to obtain genetic improvement**

1. Select best parents of generation 1 to cross
2. Cross the selected parents to produce generation 2
3. Obtain genetic improvement with a higher phenotypic mean of the trait after selection

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A good example of the possible benefits of selective breeding is the selection for growth in fish. The genetic improvements that have been obtained for growth in aquaculture species are in general three to five times higher per generation than what is found for terrestrial livestock species in general.
**The need for breeding programmes in aquaculture**

To practice selective breeding in a structured manner, breeding programmes are set up with breeding goals and traits to be measured to achieve those goals. *Major traits of interest for the European fish breeding industry used in breeding programmes are production efficiency, disease resistance, product quality and adaptation to alternative diets.*

However, none of the current aquaculture breeding schemes address all these topics and there is a wide variety in the complexity and advancement of aquaculture breeding programmes. *To boost the European aquaculture sector, more professional and efficient breeding programmes are needed.*

In FISHBOOST the following levels of aquaculture breeding are distinguished:

- **Level 0**  No modern breeding programmes.
- **Level 1**  Basic breeding programmes with few traits that are measured directly on selection candidates.
- **Level 2**  Advanced breeding programmes with several traits and routine sib-testing to improve some traits via family selection.
- **Level 3**  Advanced breeding programmes with several traits and routine use of genomic tools to improve accuracy on sib-tested traits.

### The impact of FISHBOOST: advancing to the next level

<table>
<thead>
<tr>
<th>Fish Type</th>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
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</thead>
<tbody>
<tr>
<td>Atlantic salmon</td>
<td>![Fish Image]</td>
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<td>![Fish Image]</td>
<td>![Fish Image]</td>
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<tr>
<td>Rainbow trout</td>
<td>![Fish Image]</td>
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<tr>
<td>European seabass</td>
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<tr>
<td>Gilthead seabream</td>
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<tr>
<td>Turbot</td>
<td>![Fish Image]</td>
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<td>![Fish Image]</td>
<td>![Fish Image]</td>
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<tr>
<td>Common carp</td>
<td>![Fish Image]</td>
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<td>![Fish Image]</td>
</tr>
</tbody>
</table>
Atlantic salmon

- 40 years of modern breeding
- High sophistication
- Large or highly specialised companies

Main breeding traits
- Growth
- Deformities
- Fillet color
- Disease resistance
  Pedigree tracing by separating families

Important R&D challenges
- Enhance production: *disease resistance, feed efficiency, adaptation to novel diets*
- Enhance breeding: sequencing, turning recording of ’sib traits’ into recording of ’candidate-traits’
- High need for genomics for next level of breeding

Common carp

- 0 years of modern breeding
- Low sophistication
- SMEs and governmental institutes

Main breeding traits
- Scales
  Pedigree tracing by genotyping possible

Important R&D challenges
- Enhance production: *growth, winter survival, fillet yield, disease resistance*
- Enhance breeding: construct efficient programs, inbreeding control
- Low need for genomics for next level of breeding

European seabass

- 20 years of modern breeding
- Moderate sophistication
- SMEs

Main breeding traits
- Growth
- Shape
- Sex ratio
  Pedigree tracing by genotyping

Important R&D challenges
- Enhance production: *disease resistance, feed efficiency, fillet%*
- Enhance breeding: non-lethal ways of recording feed efficiency and fillet%, markers for disease
- Need for genomics for next level of breeding for disease
Gilthead seabream

- 15 years of modern breeding
- Moderate-high sophistication
- Large companies and SMEs

Main breeding traits:
- Growth
- Shape
  Pedigree tracing by genotyping

Important R&D challenges:
- Enhance production: feed efficiency, fillet%, disease resistance
- Enhance breeding: non-lethal ways of recording feed efficiency and fillet%, markers for disease
- Need for genomics for next level of breeding for disease resistance

Rainbow trout

- 30 years of modern breeding
- High sophistication
- Large companies and SMEs

Main breeding traits
- Growth
- Maturity age
- Carcass yield
  Pedigree tracing by separating families or genotyping

Important R&D challenges:
- Enhance production: processing yields, feed efficiency, disease resistance, adaption to novel diets
- Enhance breeding: non-lethal ways of recording feed efficiency and fillet%, SNP chip
- High need for genomics for next level of breeding

Turbot

- 20 years of modern breeding
- High sophistication
- Large companies and SMEs

Main breeding traits:
- Growth
- Shape
  Pedigree tracing by separating families or genotyping

Important R&D challenges:
- Enhance production: fillet yield, disease resistance, adaptation to novel diets
- Enhance breeding: non-lethal ways of recording fillet yield, inbreeding control, SNP chip
- Moderate-high need for genomics for next level of breeding
What does a successful breeding programme need?

The success and efficiency of a breeding programme depends, amongst others, on meeting essential preconditions:

- Variation between animals in the desired traits;
- A genetic basis for at least a part of this variation;
- A known lifecycle which can be controlled to be able to evaluate progeny for the desired traits and subsequently select and cross parents for the next generation;
- Possibilities to identify individuals to keep track of their pedigree.

These preconditions have some practical implications. First of all, the **heritabilities** of the traits one wants to select for have to be known, as well as genetic correlations between traits. Phenotypic information has to be recorded to be able to select the best candidates and follow the response to selection. Furthermore, the reproduction has to be controlled.

Information on the phenotypes is used to estimate the breeding value (EBV), the value of the selection candidates for breeding. A challenge is to estimate these breeding values accurately. There are different methods which vary between using direct phenotypic measures of selection candidates themselves to utilising records from relatives of candidates and/or **genomic data**. Use of records from relatives might limit the structure of the breeding scheme (due to separate rearing of families), and use of genomic data calls for genomic tools.

Avoidance of inbreeding is especially important in aquaculture breeding where few parents can produce large numbers of offspring (large families). Inbreeding restrictions impose limitations on the breeding design, and call for more sophisticated selection methods to manage the inbreeding whilst maximizing the genetic level of the selected parents.

**The benefits of the breeding scheme come through the additional and cumulative improvement of genetics of the offspring that enter the production system.**

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**Heritability:** the fraction of the variation in phenotype in a population that can be explained by variation in genotype.

**Genomics:** the use of information on the genome (DNA).

**Phenotype:** The physical appearance or biochemical characteristics of an organism as a result of the sum of its genotype and the environment.
What will FISHBOOST do for you?

The partners in FISHBOOST recognise the importance of the European aquaculture and the major role selective breeding can play in enhancing the profitability and sustainability of the sector. Within the project particular emphasis is placed on the development and advancement of tools and methods to improve traits such as disease resistance, non-specific mortality, feed efficiency, fillet yield and quality, adaptability to alternative (plant-based) feeds.

For SMEs, such as many producers, key parameters and protocols to realise impacts for these novel traits will be delivered, ready for routine implementation, including:

- recording protocols for defining new traits for the breeding goal;
- heritabilities and genetic correlations for evaluations;
- genomic architecture for disease resistance traits to decide upon optimum selection strategy;
- QTL and Estimated Breeding Values (EBV) for selection.
- tools and procedures for genomic selection

A major challenge and opportunity for the aquaculture breeding industry is to realise the large scope for increased efficiency and profit in the European aquaculture industry by domestication and genetic improvement of farmed finfish.

Interested in selective breeding and FISHBOOST?

Are you an aquaculture producer and do you want to know more about FISHBOOST? Do you want to know what you can do to boost your production by selective breeding?

During the FISHBOOST project our results and tools will become available on our website, so please visit us at www.fishboost.eu!

You can also contact one of our project partners (see backpage) in your field or country.

QTL: Quantitative Trait Loci, stretches of DNA containing or linked to the genes that underlie a quantitative trait.

You can find a full glossary on our website! www.fishboost.eu/glossary
Project information

FISHBOOST is a project funded by the European Commission which aims at improving the efficiency and profitability of European aquaculture by advancing selective breeding to the next level for each of the six main finfish species through collaborative research with industry. In FISHBOOST 14 RTD participants and 7 SMEs, 4 large industry partners and 1 NGO throughout Europe that are in the lead of the development of their species’ breeding programmes or are vectors between industry and RTD are collaborating. The six species are Atlantic salmon, common carp, European seabass, gilthead seabream, rainbow trout and turbot.

Project partners

Industry partners

Andromeda Group
Andromeda Group is a member of Andromeda Group (Greece) www.andromedagroup.eu

Bretagne truite
Bretagne truite is a member of Bretagne truite (France) www.bretagne-truite.fr

Ferme Marine du Douhet
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Klatryb
Klatryb is a member of Klatryb (Czech Republic) www.klatryb.cz

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Les Poissons du Soleil is a member of Les Poissons du Soleil (France) www.poissons-soleil.com

FEAP
FEAP is a member of FEAP (France) www.feap.info

BMR Genomics
BMR Genomics is a member of BMR Genomics (Italy) www.bmr-genomics.com

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Research partners

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Ifremer
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IMARES
IMARES is a member of IMARES (Netherlands) www.imares.nl

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University of Edinburgh
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University of Padova
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University of South Bohemia in České Budějovice
University of South Bohemia in České Budějovice is a member of University of South Bohemia in České Budějovice (Czech Republic) www.jcu.cz

VUVEL
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Wageningen UR
Wageningen UR is a member of Wageningen UR (The Netherlands) www.abg.wur.nl

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