8.5. Aquaculture

Until the 1980s, aquaculture was rather marginal in comparison with fish captures, representing around a 10% of fish consumed, but from 2018 aquaculture has surpassed fish captures, showing a high increase trend. Captures only show a small decline; therefore, fish consumption has notably increased in the last decades, from 9.0 kg per capita in 1961 to 20.5 kg per capita in 2018 (FAO 2020). Fish represents more than 20% of the meat consumed in East Asia, India, Russia, and it has become an important animal production in many European and African countries.

Aquaculture includes a large number of different species of fish, shellfish and crustacean, produced in intensive and extensive conditions. Two thirds of aquaculture production is fish, being around 20% of the production mollusks, 10% crustacea and the rest of species being marginal. Most of the genetic improvement programs are starting, with the noticeable exception of salmon, which has a program similar to other prolific species

8.5.1. Characteristics of fish affecting the organization of genetic improvement

The main characteristic of fish affecting breeding programs is the high reproductive capacity. Salmon female can produce 20,000 eggs, and some marine species hundreds of thousands of eggs. This high full sibs availability allows to do studies that are difficult or impossible in other species.

- ***Genetic per environment interactions*** can be easily estimated by breeding full sib families in different environments and calculating the genetic correlations between full sibs from different environments.
- ***Disease resistance selection*** are feasible by using several tanks with full sibs infected with different diseases.
- ***Carcass quality and some traits of meat quality*** can be also measured in full sibs and can be used in and index for improving the whole economic benefit, as we saw in section 3.2.2.
- ***Sterilization*** is frequently applied not only to not only to prolong growth or improve meat quality, but also for biosecurity, to prevent salmonids from interbreeding with natural populations in case they have escaped from the farm. Inducing triploidy is a common sterilization method in most species.

The high number of descents per mating means that a very small parent stock is needed for fish production. *Inbreeding* should be carefully avoided in the lines of a selection nucleus, so a higher number of males and females than needed for production is used. Due to the high number of full sibs produced, care should be taken when performing selection, otherwise it is likely that most selected animals would be full sibs or have a close relationship. This care for avoiding inbreeding reduces the theoretical high pressure that can be applied in fish breeding.

Another characteristic of fish breeding is the difficulty of identifying the individuals, since tags are more difficult to fix in fish than in other species. Nevertheless, it is common using external tags or implanted electronic tags, and using genetic markers has been proposed (Vandeputte and Haffray, 2014).

8.5.2. Selection objectives

- ***Growth and feed conversion ratio.*** The most immediate character to select for in fish is *growth rat*e because it is easy to measure and it is negatively correlated to *feed conversion ratio*. Several experiments have shown success in selection for growth rate in many species, from oysters to fish, and a negative correlated response to FCR has been observed in Atlantic salmon (see Gjedrem and Rye, 2018, for a review).
- ***Carcass and meat quality:*** With the development of aquaculture, carcass traits were considered, but the genetic response has been rather low for fillet (tilapia), fat content (trout) or meat content (mussel). Fillet traits are currently included in selection programs of Atlantic salmon.

- ***Disease resistance***. This is a main selection objective in aquaculture. It is important in other species, but genetic programs are much more feasible in aquaculture, due to the high number of full sibs available, that allows using several tanks with full sibs infected with different diseases. Most diseases are multifactorial, with some diseases depending on one major gene; the greatest success has been in the later ones (see review in Simm et al., 2021).

8.5.3. Breeding programs

Aquaculture breeding programs are recent, and aquaculture production itself is also recent, so selection programs are generally in their infancy with the exception of Atlantic salmon, which started being selected in the 1970s. Nevertheless, there are several experiments showing that genetic improvement can be possible and efficient in several species (see Gjedrem and Baranski, 2009, and Gjedrem and Rye, 2018).

- ***Atlantic salmon***: Breeding schemes in atlantic salmon are similar to the ones we saw for pigs or poultry in 8.1.1 and 8.2.1 respectively, but here the size of the scheme is not determined by the reproductive capacity of the species. The objectives are feed efficiency (selected by growth rate), disease resistance, carcass traits (fillet yield) and reproductive traits (age at sexual maturation). Genomic selection is currently implemented and G-BLUP is being used (see Gjedrem and Rye, 2018; Lhorente et al, 2019). Cost of genotyping is critical and imputation is a common procedure. At present there are no experimental comparisons for assessing the effectiveness of genomic selection in aquaculture, but some simulation studies have been published showing an increase of precision around 20% when genomic selection was used (Vela-Avitúa et al., 2015).
- ***Tilapia:*** Tilapia is the second species in importance in fish breeding. A genetic program using a synthetic population from several African and Asian origins has been developed selecting for growth rate (Bensten et al., 2017). A similar program took place in Brazil, using an improved strain from Malaysia, in which selection for growth rate was also successful (Yoshida et al., 2022). In both programs, the genetics has been disseminated in both public and private sectors.
- ***Giant freshwater prawn:*** Giant freshwater prawn has been selected for body weight in several Asian countries with variable success. Vietnam and India still have selection programs in an open-nucleus scheme in which migration of prawns is used in order to facilitate inbreeding control. Pillai et al. (2022) review the programs and discuss the practical challenges for implementing them.

References

Bentsen, H.B., Gjerde, B., Eknath, A.E., de Vera, M.S.P., Velasco, R.R., Danting J.C., Dionisio E.E., Longalong, F.M., Reyes, R.A., Abella, T.A., Tayamen, M.M., Ponzoni R. W. (2017) Genetic improvement of farmed tilapias: Response to five generations of selection for increased body weight at harvest in Oreochromis niloticus and the further impact of the project. *Aquaculture* 68: 206–217.

FAO. (2020). *The State of World Fisheries and Aquaculture* 2020. Sustainability in action. FAO. Rome.

Gjedrem, T. and Baranski, M. (2009) *Selective Breeding in Aquaculture: An Introduction*. Springer. New York.

Gjedrem, T., Rye, M. (2012) Selection response in fish and shellfish: a review. *Reviews in Aquaculture* 10, 168-179.

Lhorente J.P., Araneda, M., Neira, R., Yañez J.M. (2019). Advances in genetic improvement for salmon and trout aquaculture: the Chilean situation and prospects. *Reviews in Aquaculture* 11: 340-353.

Pillai, B.R., Ponzoni, R.W., Mahapatra, K.D., Panda, D. (2021). Genetic improvement of giant freshwater prawn Macrobrachium rosenbergii: A review of global status. Reviews in *Aquaculture* 4:1285–1299.

Simm G., Pollott G., Mrode R.A., Houston, R. (2021) *Genetic Improvement of Farmed Animals*. CABI. Wallingford (UK).

Vandeputte, M., Haffray, P. (2014) Parentage assignment with genomic markers: a major advance,for understanding and exploiting genetic variation of quantitative traits in farmed aquatic animals. *Frontiers in Genetics* 5: 432.

Vela-Avitúa, S., Meuwissen, T. H., Luan, T., Odeghd. J. (2015). Accuracy of genomic selection for a sib-evaluated trait using identity-by-state and identity-by-descent relationships. *Genetics, Selection Evolution* 47:9.

Yoshida, G.M., Lopes de Oliveira, C.A., Costa Campos, E., Todesco, H., Araújo, F.C.T., Karin, H.M., Zardin, A.M.S.O., Bezerra, J.S., Filho, L.A., Vargas, L., Pereira Ribeiro, R. (2022). A breeding program for Nile tilapia in Brazil: Results from nine generations of selection to increase the growth rate in cages. *Journal of Animal Breeding and Genetics* 139: 127-135.