Management options to reduce genetic impacts of aquaculture activities

[1] University of Thessaloniki, Thessaloniki, Greece
[2] UM2-IFREMER-CNRS, Montpellier, France
[3] University of Padova, Padova, Italy
[4] ICRAM, Central Institute for Marine Research, Rome, Italy
[5] University of Oviedo, Oviedo, Spain
[6] FRS Marine Laboratory, Scotland, UK
[7] Institute of Marine Research, Bergen, Norway

A. Triantafyllidis[1], N. Karaiskou[1], F. Bonhomme[2], L. Colombo[3], D. Crosetti[4], D. Danancher[5], E. García-Vázquez[6], J. Gilbey[6], T. Svåsand[7], E. Verspoor[6], C. Triantaphyllidis[1]

Introduction

The potential genetic effects of aquaculture activities have aroused a great deal of concern, and the perceived risks are often associated with interbreeding with natural populations and the adverse effects of ecological interactions. The EU-funded project Genimpact (http://genimpact.imr.no) reviews specific aspects of potential risks and concerns about interbreeding and aquaculture-ecosystem interactions. In workshop 4, the Genimpact scientific team presented results and outputs from previous workshops in various forms, including posters and Power-Point presentations. Discussions followed with aquaculture, breeding, environmental and animal welfare organisations and important points were noted. At the end of the workshop scientists and stakeholders produced consensus statements on the main points discussed, as regards the state of aquaculture of the main species under consideration by Genimpact: Atlantic salmon, Atlantic cod, European sea bass, gilthead sea bream, turbot, common carp, Atlantic halibut, scallops, mussels, oysters (Pacific oyster and European flat oyster) and European lobster.

Aquaculture is currently confronting a set of critical choices that could substantially influence its future development. This is due to the fact that the domestication of aquatic species may benefit from technological advances that were not available at the time of the domestication of terrestrial plants and animals. The number of aquatic animal species entering domestication, already 430, is ten times as great as all domesticated terrestrial animal species, now plateauing at 44. In the past, animal domestication involved two successive stages: first rearing, that is providing shelter, food, care and protected reproduction, and later on selective breeding to rearrange natural genetic variability into phenotypes with better performance. Most aquatic domestication has spread horizontally during the first stage, but only a handful of species have been subjected to improvement programmes according to the protocols of quantitative genetics.

The following are the points of consensus among stakeholders and scientists: 1) on the genetic impact of farming activities and its implications for aquaculture management, stock conservation and environment safety and 2) for the establishment of scientifically based preventive measures for some selected species of importance to European marine aquaculture. The following points should be taken into consideration, not only for these species but for the sustainable development of aquaculture in general.

Main consensus issues

1. Each species should be managed separately

With respect to the level of concern about aquaculture species and their interaction with wild populations, it is not always possible to extrapolate from one species model to others. Every species should be examined independently. No generalised ideas can emerge, since single species/group of species have their own particular life history traits, genetic structure, etc. Much has still to be learnt about the majority of the species under scrutiny, particularly those that are not target species of important commercial capture fisheries, and those from the Mediterranean, because of the high degree of fragmentation of this region. Indeed, basic knowledge is still lacking for most species and appropriate studies are necessary prerequisites for the applied research that would be useful to the industry. One of the most important research priorities would be basic population demographic studies, essential to an understanding of the biology and ecology of the species in the wild and therefore to evaluations of the potential impact of aquaculture. The validity of using Atlantic salmon as a general model for other species, based on the fact that it has been the most studied species so far is questionable, because of the specific biology of salmonids in general that does not resemble that of other groups of species. The potential effect of escapees on wild populations should therefore be assessed on a per species basis.

2. Efforts should be made to avoid escapes

As a sound application of the precautionary principle, it is wise to limit escapes as far as possible, whether or not documented data on their potential impact are already available. Instead of trying to protect wild populations from escapees, the best logical solution would be to try to prevent escapes. This will rely on technical improvements from the industry that have little to do with genetics. There appears to be a growing concern over this problem and a better appreciation of the new challenges that the industry faces as regards more effective confinement techniques. However, realistically, it is almost impossible to completely prevent escapees.

The logical continuation of the debate is therefore: what level of escapes should be regarded as a threat to wild populations? How many individuals can escape before their negative effects on natural stocks are noticeable? This question is another topic that should be dealt on a species basis: for example, Atlantic salmon, mussels and common carp are three extremes managed in completely different ways, which means that the impact of escapees on their respective native populations is unlikely to be the same. The frequency and extent of escapes, the stock structure and the size of the wild populations, as well as the escapees' life stage, are key issues in answering the question posed above. In the case of the common carp, for instance, the definition of what is a wild population is itself a problem, since ferality is commonplace in this species since Roman times. Resilience to the negative impacts of escapes also depends on the relative proportion of gene flow from farmed to wild stocks. Large populations are probably better able to resist the impact of escapes than small ones. Therefore, it is important to stress the fact that wild stocks should be protected to increase their potential to face unwelcome gene flow. Since we still lack a great deal of information on wild populations, such as what is a local population and to what extent these populations have been altered, additional efforts for improving this knowledge are recommended.

As regards the perception of the magnitude of the problem, this may depend on the observer's point of view. Conservationists, environmentalists and non-profit

associations are concerned about aquaculture escapes, but consumers are generally not well informed about the potential environmental or biological impact of aquaculture. Since European citizens are generally concerned about environmental issues, public information about the results of the Genimpact project is regarded as a way of raising public concern about this problem. However, a different point of view stresses that we should not overexpress our concerns to the point of freezing all activities and demonizing the aquaculture industry. According to this view, the environment is continuously changing and local stocks may be more threatened by overfishing and indirect environmental alteration than by aquaculture escapees and, if left in good demographic health, will always try to find ways to adapt locally. The need to set up conservation priorities for wild stocks is emphasised.

3. Measures to identify escapees are needed

In general, traceability of escapees with genetic techniques is considered to be an expensive approach by stakeholders. The aquaculture industry would currently prefer to spend its resources on preventing escapes rather then assessing the impacts of escapes on wild populations. Economic and technical support by governments and fishery authorities is recommended in the area of genetic identification, since it is considered that many farmers cannot afford the costs of traceability studies. The efforts made by the aquaculture authorities and the industry in some countries and cases should nevertheless be acknowledged, such as the search for the identity of escapees as is being done in Norway.

As has frequently been recognised, molecular markers are the tool of choice to identify the origin of escapees. Reliable information on the origin of juveniles and broodstock is highly desirable to assist in traceability. The difficulty of keeping track of broodstock movements for small companies is recognized, since records are rarely kept. Tracing of origin will be even more difficult when different farms keep genetically similar stocks. In the future, broodstock movements and import/exports are actually expected to intensify when breeding programmes in some species become efficient and fish lineages are genetically improved through selection or other methods. A range of situations is expected, again depending on the species under consideration. Growing problems of disease are also expected to occur as broodstock/juvenile movements increase.

4. Input from modelling assessment and risk

Modelling is a tool to aid understanding, identify data deficiencies, define research priorities and provide advice to inform policy and management decisions. The potential for using modelling studies to assess the importance of the frequency and intensity of escapes on the outcome of the interaction of cultured fish with wild populations was recognized. It is important, however, to emphasise that the modelling is an iterative process and an evolving source of information; results of modelling feed into empirical investigations which in turn feed into model development, so that the model is continuously updated and outputs refined, whilst at the same time knowledge gaps are identified and research priorities defined. At the same time, it needs to be emphasised that outputs are not definitive statements; rather they are the implications which emerge from a synthesis of our best understanding. As models are updated with new information and understanding, outputs may change and so the implications of results obtained must be carefully assessed in the context of the completeness of existing understanding.

The assessment on the extent to which outputs from a model can be considered reliable must be made clear when using them as the basis for advice, and otherwise it must be made clear when presenting results that they are preliminary. Failure to do this, where predictions of impact prove inaccurate, has the potential to cause undesirable or unnecessary economic or conservation impacts, and will damage the general credibility of scientific advice used to inform policy and management initiatives. Finally, the feedback showed that when presenting examples of modelling outputs as part of discussions of models and how they work, it is necessary to avoid the impression of bias by showing full range of predicted outcomes under the full range of potential interaction scenarios.

5. Measures to ensure reproductive isolation between wild and domesticated stocks are also needed

Various measures such as hybridization, sterilization and polyploidy can be employed to protect wild populations from escapees. This will in turn depend on a species basis. Much research remains to be done, but sterile fish could form part of the solution. Induction of triploidy has been successfully employed in several fish and bivalves and it is not regarded as a "genetic modification" because it only alters chromosome segregation, without modification of DNA sequences. The main benefit of triploidy is gonadal or gametic sterility achieved with high efficiency, usually between 90 and 100%. Owing to the lack of the counterproductive effects of sexual maturation, better growth, more consistent fillet quality and/or greater final survival are expected in triploids, but they may manifest initial higher mortality, greater costs of fingerling production and sometimes failure to exhibit greater growth. Problems with consumer acceptance are avoidable, because labelling is not required, and polyploidy is commonly found in marketed fruits (up to 8*n* in strawberries) and vegetables. However, the reaction of consumers to sterile/triploid fish will depend on how the information is presented, for example by pointing out the environmental advantages of using sterile individuals for aquaculture production. The most important needs for research are to improve our knowledge of the effects of triploidy on gene regulation and protein function, of the adaptability of triploids to different culture environments and to assess the potential consequences of restocking with triploid fish. However, triploids could indirectly affect wild populations (i.e. ecological impact through predation or competition for resources).

6. New techniques of direct genetic manipulation should be considered

The commercial farming of transgenic fish is generally viewed with widespread scepticism. For example, indefinite moratoria have been enforced on patented GH-transgenic fish. Although it is generally agreed that their consumption would be essentially safe, as they express a protein that is already present in the fish, their possible release into the wild is regarded a serious threat to ecosystem stability and conspecific genetic integrity. It has been concluded that only totally sterile transgenic fish would represent a commercial innovation. Transgenic fish from non-carnivorous species could eventually represent a convenient source of cheap animal protein in countries afflicted by heavy demographic pressure. It is also important to further explore the potential of somatic gene transfer, such as DNA vaccination, which has proved effective against certain fish viruses, though further research is needed to improve administration routes. Finally, transgenesis with RNA interference deserves to be investigated as a possible way of making fish resistant to viral pathogens.

7. Debate on the use of local stocks as broodstocks is ongoing

The main point under consideration, especially for the aquaculture industry, is what constitutes a "farmed" individual. In some cases, fish and shellfish have gone through a process of selection, but in others they are simply captive wild. At the same time, there are also different degrees of domestication even within species, since the impact of domestication on captive individuals is immediate if they survive. Therefore a general answer cannot be given. Initial information from wild local populations should be required in order to determine the phylogeographic structure of wild populations. In cases where there is genetic structure, the use of local stocks for selective breeding is an option worth considering, but the risk of these stocks being uncompetitive in the market should be pointed out. On the other hand, fully domesticated strains could have an e deleterious impact on wild populations, though at the same time the traceability of these selected lineages/broodstocks in the wild will be easier than local stocks. It is quite evident, however, that we still lack a great deal of information on interactions between wild and farmed individuals. The performance of farmed individuals in the wild needs to be examined on a case-by-case basis. Fitness experiments (common garden experiments - similar to those performed on Atlantic salmon) should be carried out on other species and situations.

Stocking (i.e. the deliberate release of hatchery individuals to supplement or enhance wild populations, such as brown trout in most of western Europe and sea bream released into Italian and Greek lagoons) is recognised as a particular and different case. Avoiding stocking is highly recommended but in some cases it may be necessary in order to restore lost populations or to sustain local small-scale fisheries. Wherever possible, the individuals used for restockingshould be produced from captured wild local broodstock

8. Site selection / conservation of wild populations

The siting of aquaculture facilities plays a major role in determining the impact of farmed stocks on wild populations. Conservation measures are also important for protecting wild populations. Priority (as already stated above) should be given to 1) habitat enforcement, 2) sustainment of large wild populations, and 3) control of fishing.

9. Common legislation throughout the EU is needed

We believe that reinforcing voluntary collaboration between the authorities and the industry is much better than imposing protective measures by law. For example, too many constraints on some aspects like broodstock movements between farms are undesirable. Self-regulation of the industry via a voluntary code of practice could be a good way of protecting the wild populations. At the same time it is now realised that there is a growing awareness and willingness by governments as well as the industry to protect wild populations. The need for legislation to implement control and/or compensation measures in some cases should be pointed out. The possibility of establishing a policy of fines or financial compensation for the impact of aquaculture on the wild should be considered.

Differences between countries at this level are recognized; for example, environmental-protective legislation such as that existing in Norway and Scotland has not been developed in other countries. Different management policies in different regions have also been set out. For example, in many countries there is no legal requirement to provide information about aquaculture escapes. In other cases, local governments

have no jurisdiction over aquaculture activities (i.e. movement of stocks, origin of farm broodstocks and others). In some countries only international treaties exist, without further development at national or regional level.

10. Genetics and the aquaculture industry interaction

More interaction between ecologists, quantitative genetics/molecular biologists is recommended because of a lack of exchange of information between different sectors; for example, misunderstandings when specialised terminology is employed. Science must be communicated with clarity, care must be taken that correct terminology is used, and ambiguous scientific terms and ideas should be avoided or defined. Educational programmes aimed at producers are much needed in order to bring information down to the farmers' level, with simple communication tools that can be understood by everyone. At the same time, the participation of scientists in producers' workshops in order to present these issues in an understandable way would be highly desirable.

The information obtained by scientists often does not answer the issues raised by the industry. It is suggested that as far as implications for operating practices are concerned, those actions that will involve the least resistance by producers for the maximum benefit should be applied to the data and recommendations made by scientists.

The application of the genomic revolution is regarded as premature in aquaculture, due to a general lack of understanding and to the technical difficulties involved in applying genomic approaches. However, it is widely felt that the industry will benefit from the genomic revolution as soon as its practical implications become better known. The capacity of the industry to incorporate new techniques to increase productivity and profit should be emphasised. Indeed, we should recognise that the industry has made a major effort to employ scientists and experts in the field of genetics in order to benefit from their know-how and increase production.