Grain 04 - Valorization of biodiversity through domestication

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Introduction

The valorization of biodiversity by domestication in the context of aquaculture development is the mastery of the breeding cycle of different species in a production target, either for consumption by humans or other purposes such as ornamental market.

This valorization of biological resources in aquaculture may involve different types of organisms. One thinks of course primarily for target species, representing the main production of breeding cycles, whether fish, crustaceans, molluscs and algae. But it can also be of a species, associated with the main production cycle. Examples include the case of the larvae of the insect *Hermetia illucens* or black soldier, which are produced in captivity in parallel for incorporation into feed for farmed fish. Another example is that of macrophytes plants or algae that, combined with fish farming, can help filter water and reduce negative impacts on the environment by reducing the pollution load of farm effluents. When several species of interest are combined in a single production cycle, it is called polyculture or integrated multi trophic aquaculture. These different approaches of production systems functioning are developed in other grains of this module and will be limited here to look for fish.

This grain main objective is to provide some answers to the following questions:
• What is a domesticated fish and how many species are actually domesticated?
• Which strategy?: expand the use of some species throughout the world or continue in the direction of diversification of cultivated species?
• Which criteria to identify and select new candidate species for fish farming?

Ichtyological Diversity and Domestication

Fish constitute the group of vertebrates presenting the highest species diversity. Some estimates consider that the total number of existing fish species at global level is around 32,000.

According to FAO statistics, the number of species of farmed fish has increased sharply since 1950 and has nearly doubled during the last 10 years, reaching a total of 354 species cultivated in 2012 (Fig. 1). However, 15 species alone are responsible for almost 75% of world production across all environments (Table 1). Therefore, it is understood that the production of most other species remains very limited in comparison.

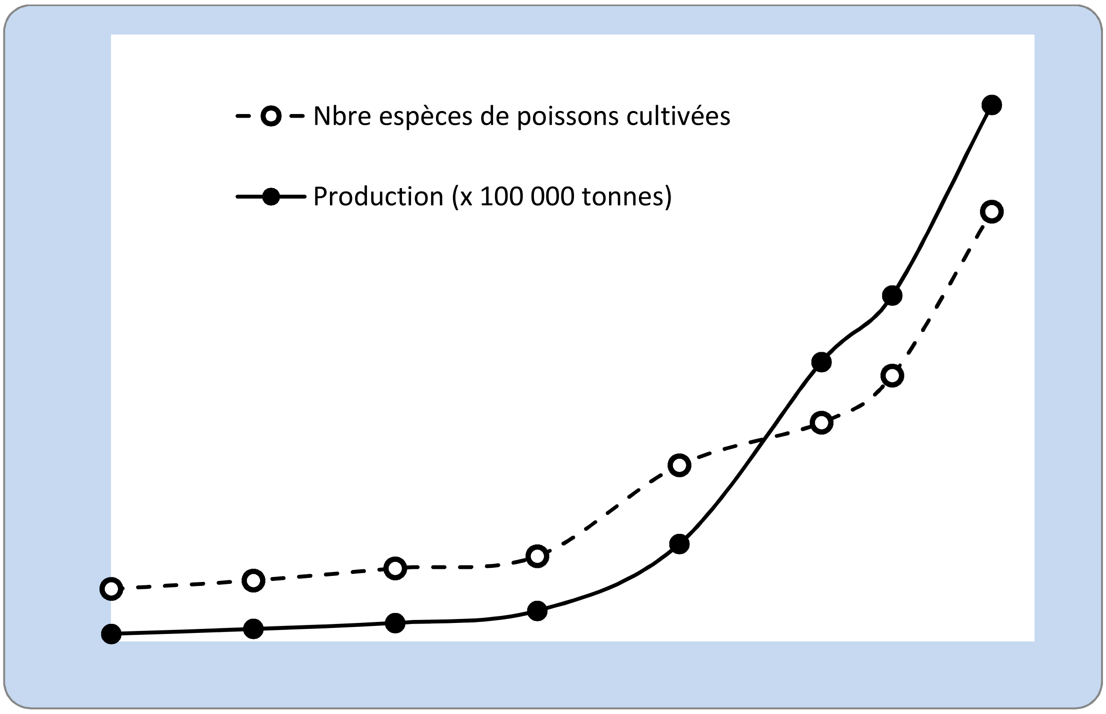

Figure 1: Evolution of the number of farmed fish species and the annual fish production between 1950 and 2012.

		Production (tonnes)	
Total mondial de la production en poissons d'élevage (2012)		44 151 000	% cumulé par rapport au total
1	*Ctenopharyngodon idella*	5 028 661	11,4
2	*Hypophthalmichthys molitrix*	4 189 578	20,9
3	*Cyprinus carpio*	3 791 913	29,4
4	*Oreochromis niloticus*	3 197 330	36,7
5	*Hypophthalmichthys nobilis*	2 898 816	43,2
6	*Catla catla*	2 761 022	49,5
7	*Carassius carassius*	2 451 845	55,0
8	*Salmo salar*	2 066 561	59,7
9	Pangas (*Pangasianodon hypophthalmus*)	1 631 158	63,4
10	*Labeo rohita*	1 555 546	66,9
11	*Chanos chanos*	943 259	69,0
12	*Oncorhynchus mykiss*	855 982	71,0
13	*Megalobrama amblycephala*	705 821	72,6
14	*Clarias spp*	554 738	73,8
15	*Mylopharyngodon piceus*	495 074	74,9

Table 1: Top 15 farmed fish represent 3/4 of world fish production (FAO data, 2014).

On the other hand, among the 44 fish species exceeding a threshold of 100 000 tons of annual production in 2012, 50% (22) were not produced 50 years ago. This shows that the increase in global aquaculture production is not the work of a few champions but results also of a strong livestock development of new species. A particularly striking example that illustrates this situation is the Asian catfish family Pangasiidae. As a matter of fact, the production of “pangas”, essentially corresponding to that of *Pangasianodon hypophthalmus*, has increased from few ten thousand tons in the early 90s to more than 1.6 million tons 20 years later. This rapid expansion is linked to an important technological achievement : the control of reproduction of captive fish by fish farmers, knowing that the culture of this species was, before 1995, mainly based on the collection of juveniles in the wild (Lazard et al., 2009).

It should be noted that the production of certain species can be proven anecdotal globally, but economically significant locally. This is for example the case of the perch (*Perca fluviatilis*), which corresponds to a traditional or niche market (Fontaine et al., 2009).

The market of ornamental fish should not be ruled out from this panorama. The production of ornamental fish, of little interest in term of tonnage, indeed represents an important source of income and employment in many countries. In 2004, the OFI (Ornamental Fish International) estimated the economic weight of the aquarium industry about $ 15 billion. Therefore this form of aquaculture should not be overlooked. Ornamental species still come too often from individuals caught in the wild. In some popular, species such as the clown loach *Chromobotia macracanthus*, the capture of juveniles in the wild directly threatens the balance of natural populations. The domestication of species of interest for the ornamental market is therefore an important issue, both to better meet market demand and to limit the impacts on natural stocks (Legendre et al., 2012).

How many domesticated fish species?

An animal can be considered fully domesticated when it is bred in captivity and has changed from its wild ancestor becoming more useful for human who control its breeding cycle. Domestication is a long and continuous process of evolution (gradual).

For farmed fish, Teletchea and Fontaine in 2014 proposed 5 levels of domestication considering various states of lifecycle mastery in captivity and the involvement or not of wild specimens in the rearing cycle (Table 2). From the 250 fish species included in their analysis, based on data from FAO 2009, these authors considered that 39 are at a stage of acclimatization trials to the breeding environment, 75 have a life cycle incompletely controlled in captivity, 61 have a life cycle fully controlled but with participation of wild animals, 45 have a cycle controlled without using wild animals and 30 are involved in genetic selection programs.

Niveau de domestication	Description	Nombre d'espèces	Quelques exemples
1	Premiers essais d'acclimatation en conditions d'élevage	39	Brème bordelière (*Blicca bjoerkna*)
2	Maîtrise incomplète du cycle de vie en captivité	75	Thon rouge de l'Atlantique (*Thunnus thynnus*) ; anguille européenne (*Anguilla anguilla*)
3	Cycle de vie entièrement maîtrisé mais avec apport d'animaux sauvages	61	Thon bleu du Pacifique (*Thunnus orientalis*) ; sole sénégalaise (*Solea senegalensis*)
4	Cycle de vie entièrement maîtrisé avec indépendance par rapport aux animaux sauvages	45	Carpes indiennes (*Catla catla* ou *Cirrhinus mrigala*)
5	Existence de programmes de sélection génétique	30	Carpe commune (*Cyprinus carpio*), saumon atlantique (*Salmo salar*), truite arc-en-ciel (*Oncorhyncus mykiss*)

Table 2: Classification of 250 fish species produced in aquaculture (among 313 species or groups of cultivated species listed by FAO for the year 2009) according to their level of domestication (modified from Teletchea and Fontaine, 2014).

Which species for aquaculture development: introduced species or local species?

The question of choosing species the most suitable for aquaculture in a given context still arises in various parts of the world, whether to initiate an aquaculture production until then non-existent or in the view of diversifying the cultivated species.

Decision-makers can then either have recourse to the introduction of non-native species, or proceed to the screening of aquaculture potential of the species present in the local fish fauna.

As a matter of fact, aquaculture has often been based on the use of introduced species, with the package of their farming techniques, in order to get a faster start of the activity. At the same time, knowledge about the biology of local species often remained limited and their aquaculture potential neglected. In Latin America, despite the high species richness of the local fish fauna, introduced fish species still recently contributed to more than 96% of the total fish production on this continent (Garibaldi, 1996). This trend is also clearly marked in many Asian countries where the contribution of non-native species was estimated to exceed 40% of the freshwater fish production (De Silva et al., 2006).

The effects of fish introductions on aquatic ecosystems are controversial, sometimes with very strong positions for or against.

In a review of the negative impacts identified as resulting from past introductions, Gozlan (2008) considered that the ecological risk associated with introductions does not exceed 10% in the majority of freshwater fish introduced. However, he stressed that this risk can be very different depending on fish families considered. The risk is considered low for Acipenseridae (sturgeon) but very high with Percidae. In other fish families, the risk of negative impacts appears highly variable and largely unpredictable so (it is particularly the case with some catfish families, such as Clariidae). Many authors and institutions also consider that the decision of introducing or not an allochthonous species should not be based solely on the ecological risk, but must be balanced regarding the potential benefit to human populations.

The difficulty with fish introductions is that their environmental impacts are generally difficult to assess a priori. Fish transfer are often justified by economic objectives in the short term, however potential negative consequences of these introductions are part of the long term and are generally irreversible (Vitule et al., 2009).

Despite the precautions that can be taken, it is unrealistic to consider that no fish escape will occur from the rearing structures. Specimens of introduced species so always end up staying in the natural environment and possibly adapt. The introduction of non-native species in aquaculture may thus lead to invasion of the local ecosystem by the introduced species, which can result in inter-specific competition, predation pressure, genetic introgression, modifications in habitat or in ecosystem functioning (Gido at al., 2003 ; Na-Nakorn et al., 2004 ; Canonico et al., 2005). The introduction of non-native pathogens or parasites, concomitant with that of the fish, is also a major problem often raised by such practices (Ercan et al., 2015).

The valorization of local species: a reasonable alternative for the sustainable development of fish farming and diversification of products

Requesting more time and initial investment, the development of local species, however, has many advantages for a sustainable development of aquaculture:

- It allows to minimize potential impacts on biodiversity; it can even help to mitigate the negative effects of other activities, such as reducing fishing pressure.
- Local species, better known, are generally more accepted and appreciated by consumers than introduced species;
- Domestication of new species in line with the request of local human populations can allow a more integrated development of fish farming in the respective territories.
- This diversification, in terms of species produced, can also allow the fish farming industry to better adapt to fluctuations in demand and prices for products.

This approach is even more relevant for regions where natural species diversity is high and offers greater potentialities.

Which criteria for the selection of new candidate fish species for aquaculture

The choice of a species for aquaculture is initially based on many of economic, social, cultural, biological and ecological criteria.

In some cases, the preferred choice of a species appears fairly natural when it corresponds to a flagship species sought by most consumers in a given territory with inadequate supply compared with demand. This choice may also reflect a desire to overcome a seasonal market supply or preserve overexploited natural resources. In other situations, a comparative assessment or screening of aquaculture potential of local species should be conducted in order to pre-select the most promising candidates for a given environment.

Methodologies to achieve such screening of species of interest for aquaculture across the fish community of a given aquatic system have been proposed by different authors and applied for example to fish of the Amazon Basin (St. Paul, 1986), lagoon environments of West Africa (Legendre, 1992), the Mekong River Basin (Cacot and Lazard, 2009) or more recently for mariculture in the Caribbean (Alvarez-Ibarra and Lajonchere-Castro, 2013).

The time needed to acquire the biological and technical knowledge to complete the full cycle of a species in captivity is estimated to 5 to 10 years from its placing in captivity (that is to say, to obtain progeny from broodfish themselves born in captivity). This figure is indicative, however, it may be shorter for a species that adapts perfectly to standard rearing conditions or reach several tens of years for a species with a complex life cycle, as is the case of eels for example.

Given the overall increase in the level of knowledge on fish biology and the existence of culture systems already adapted to a great diversity of species and aquatic environments, the trend is in the direction of a shortening of the time necessary to obtain a first full cycle in captivity.

Generic methods are sought to increase the technical and economic rationalization of the diversification of farmed species. It has been shown for example that in the absence of accurate experimental data, the maximum observed length in a given fish is a good indicator of its growth rate (Legendre and Albaret, 1991). In terms of constraints on reproduction and fingerling production, fecundity and egg size are other important criteria. In this way, the very low fecundity of catfish of the family Ariidae, about fifty eggs per female per year, represented a major limitation to their use in aquaculture, despite their economically important in many parts of the world (Legendre et al., 1996).

Conclusion

Aquaculture is a relatively recent activity that has grown considerably over the last 50 years. Today 3/4 of the world fish aquaculture production is ensured by fifteen species. However, more than 350 species of fish are listed by FAO as cultivated species. A recurring question is whether the future aquaculture development should now be based on the widespread use of a limited number of species already domesticated or if the effort of cultivated species diversification should be continued. This question raises many debates and divided opinions.

Without considering that any introduction of species is to be avoided, it seems essential to make a prior examination of the aquaculture potential of local biodiversity and to favor the domestication of indigenous species in the environments considered. This appears particularly desirable for a sustainable development of fish farming in areas where specific fish diversity is high.

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