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Methodological approach used for the domestication of potential candidates for aquaculture

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SUMMARY – The advantages of domestication are production, reproduction of organisms, and their costs can be controlled. Agriculture developed advanced technologies on a few domesticated species to produce high-yield strains and hybrids. Indeed, about 95% of livestock production are derived from five species. Much of the world's aquatic flora and fauna have yet to be evaluated for aquaculture potential. A minority of the aquatic species are farmed presently. However, the availability of a large number of aquatic species is an advantage to exploit new domesticated species to meet the demand of proteins by the rapidly growing world population. Domestication will be considered synonymous with natural selection in a domestic environment. Growth rates, disease resistance, tolerance of environment, and ability to utilize feed are among the most common targets of selection. Domestication, in this era, will depend on adequate resources for the fundamental and applied researches. Good performances on aquaculture are very important to domestication. Concept of domestication of farmed aquatic organisms is still at its infant stage. This paper aims to introduce the methodological approach and the strategy used for the domestication of potential candidates for aquaculture. Consequences of domestication in aquaculture are discussed. Some examples in Taiwan are given.

Key words: Domestication, aquaculture, breeding, selection, Taiwan.

RESUME – *"Approche méthodologique utilisée pour la domestication de candidats potentiels pour l'aquaculture". Les avantages de la domestication sont la production et la reproduction d'organismes, et que leurs coûts peuvent être contrôlés. L'agriculture a développé des technologies avancées concernant quelques espèces domestiquées pour produire des souches et des hybrides à haut rendement. En fait, environ 95% de la production de l'élevage proviennent de cinq espèces. Une grande partie de la flore et la faune aquatiques mondiales sont encore à évaluer pour leur potentiel aquacole. Une minorité d'espèces aquatiques sont élevées à l'heure actuelle. Cependant, la disponibilité d'un grand nombre d'espèces aquatiques est un avantage pour exploiter de nouvelles espèces domestiquées pour répondre à la demande de protéines d'une population mondiale qui augmente rapidement. La domestication sera considérée comme synonyme de sélection naturelle dans un environnement domestique. Les taux de croissance, la résistance aux maladies, la tolérance de l'environnement, et la capacité d'utiliser l'aliment sont parmi les objectifs les plus courants de la sélection. La domestication, à l'heure actuelle, dépendra de la disponibilité des ressources adéquates pour des recherches fondamentales et appliquées. De bonnes performances en aquaculture sont très importantes pour la domestication. Le concept de domestication d'organismes aquatiques cultivés en est encore à son début. Cet article vise à présenter l'approche méthodologique et la stratégie utilisées pour la domestication de candidats potentiels pour l'aquaculture. Les conséquences de la domestication en aquaculture sont discutées ici. Quelques exemples concernant Taiwan sont présentés.*

Mots-clés : *Domestication, aquaculture, amélioration, sélection, Taiwan.*

Introduction

Domestication is one of the most significant and fascinating achievements and wisdom in human history. Domestication occurred as early as the Neolithic period (roughly 14,000 years ago) (Balon, 1995). Archaeological evidences show that sheep and dog have been domesticated about 12,000 years ago. However, the appearance of fish domestication is quite late. Fish culture may exist in the Nile delta of Egypt and China as long ago as 2500 BC (Bargese, 1980). The origin of domestication of carp, *Cyprinus carpio*, has been only traced to the Romans, and domestication of the goldfish, *Carassius auratus*, was started earlier than that of the carp in China (Chen, 1956). The time lag for the domestication between agriculture and aquaculture is almost 8000 years (Fig. 1). There are several reasons why agriculture and aquaculture did not develop in the same way. First, food in water body, until recently, was abundant. Increases in fishing pressure and development of fisheries technology were sufficient to meet growing demands and therefore there was little need to learn to farm. Moreover, the aquatic environment was hostile and something to be feared. These problems in part stemmed from the fact that people were dealing with organisms that were very different from themselves and with an environment about which they were largely ignorant. These differences caused agriculture to develop advanced technologies on a few domesticated species to produce high-yield strains and hybrids. Indeed, about 95% of livestock production are derived from five species and for cultivated plants the number is about 100 (Prescott-Allen and Prescott-Allen, 1990). The advantages of domestication are that: (i) the growth (quantity and quality); (ii) the reproduction (timing and hybridization); and (iii) the costs (time and labour) of domesticated animals can be controlled or manipulated. The availability of a large number of aquatic species adapted to different environment conditions is an advantage to exploit new species for domestication. Much of the world's aquatic flora and fauna have yet to be evaluated for aquaculture potential. Only a minority of the aquatic species used by humans are presently farmed (Table 1) (Pullin, 1996).

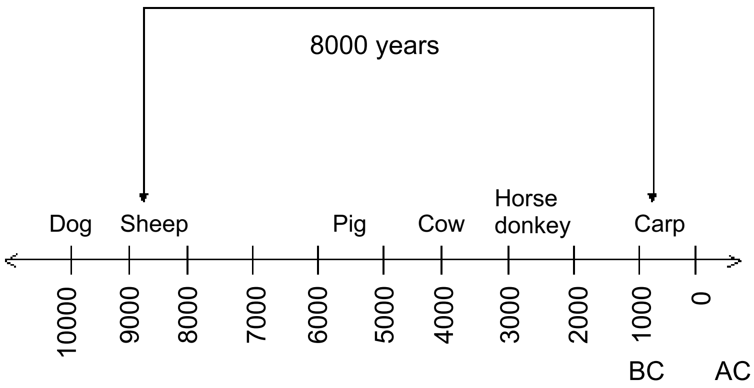

Fig. 1. Time lag between the domestication of livestock and fish is 8000 years.

Table 1. Use of finfish by human (from Pullin, 1996)

	Species		Families		Freshwater[†] species	
	No.	%	No.	%	No.	%
In capture fisheries[††]	2575	10.5	243	50.4	339	3.4
In aquaculture[†††]	178	0.7	50	10.4	91	0.9
As ornamental fish	1965	8.0	134	27.8	1228[††††]	12.3
As sport fish	779	3.2	135	28.0	188	1.9
As bait[†††††]	134	0.5	41	8.5	20	0.2
Totals used by humans[††††††]	4638	18.8	295	61.2	1606	16.1
Totals for extant fish[††††††]	24618		482		9966	

[†]Fish that do not enter brackish or marine water.
[††]Industrial and artisanal fisheries, probably an underestimate.
[†††]For food and for fisheries enhancement.
[††††]Most (707) are bred in captivity.
[†††††]Probably an underestimate.
[††††††]The sum of the numbers and percentages differ from the totals because many species have more than one use. The totals count such species only once.

According to FAO yearbook (1998), there are about 465 species of cultivated aquatic organisms in 107 families. However, success in domestication has only been achieved on a small number of species, such as carp, trout, catfish, tilapia (Eknath *et al.*, 1993; Pullin, 1996) and freshwater shrimp (Liao and Chao, 1983). The world population has rapidly increased as well as the demand for animal proteins. Proteins from aquatic organisms are more healthful to humans and are more affordable to the Third World. Although facilities and gears for fishing are advanced, the production of fishery is in its limitation. Overfishing, the global change of climate, the pollution of environment and change of ecosystem lead to a crisis of the marine fishery. Aquaculture production can be a remedy to this deficiency. The products of aquaculture are getting more and more important to humans as essential resources of animal proteins (Fig. 2) (Beveridge, 1996). The production from aquaculture in 1996 was 34 million tons (FAO, 1998), while the average consumption was only 6.2 kilograms/person/year. Aside from improving culture systems and techniques, the exploitation of new aquaculture species is also important to maintain a stable production from aquaculture. The two main methods of increasing culture species are to introduce exotic species and to domesticate wild or farmed species. However, benefits and/or impacts of exotic species on aquaculture, on native ecosystem, and on biodiversity are debatable and paradoxical (Leveque, 1996).

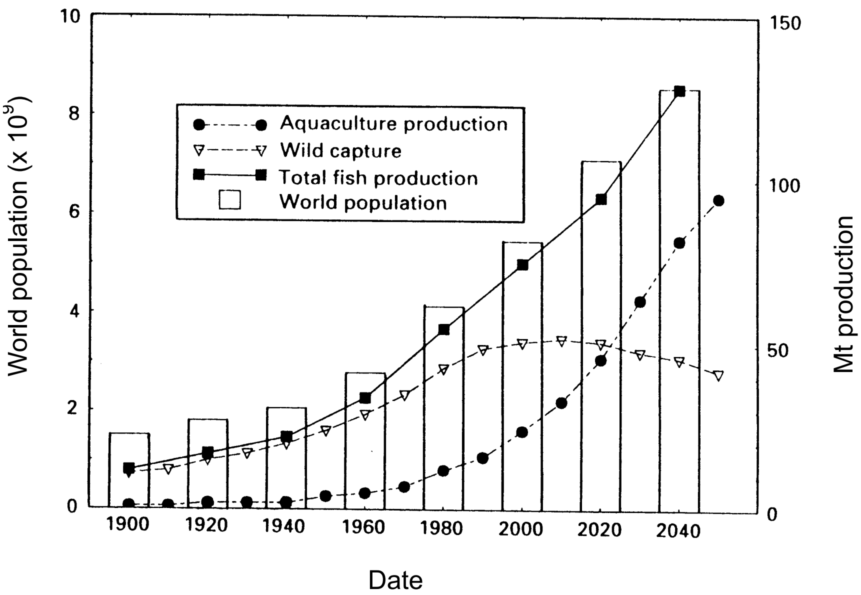

Fig. 2. Growth, real and projected, in world capture fisheries production, world fish culture and population (from Beveridge, 1996).

This paper aims to introduce the methodological approach and the strategy used for the domestication of potential candidates for aquaculture. Consequences for the domestication in aquaculture are discussed. Some examples in Taiwan are given.

Definition of domestication and this concept in aquaculture

Broadly speaking, domestication can be defined as that condition wherein the breeding, care and feeding of organisms are more or less controlled by man (Hale, 1969). From the viewpoint of agriculture, the true domesticated organism is: (i) the individual valued and kept with a specific purpose; (ii) its breeding is subject to human control; (iii) its behaviour is different from that of the wild ancestor; (iv) its morphology (including size and coloration) exhibits variation never seen in the wild; and (v) some of which would never survive without human protection (Balon, 1995). It is true that certain strains of livestock can not be found in the wild. Indeed, from this point of view, until now, in aquaculture, there may be only few domesticated species, such as coloured carps, goldfish and red tilapia. This situation indicates and suggests that domestication in aquaculture is not widely nor historically exerted as in agriculture, although aquaculture is more or less involved by man. In aquaculture, domestication is regarded as an acclimatization to captive conditions, the two key points being rapid growth rate and a potential for induced spawning in captivity (Hassin *et al.*, 1997). In this paper, domestication for aquaculture is regarded as the total control of the life cycle of an organism as well as the manipulation of breeding in captivity (Fig. 3).

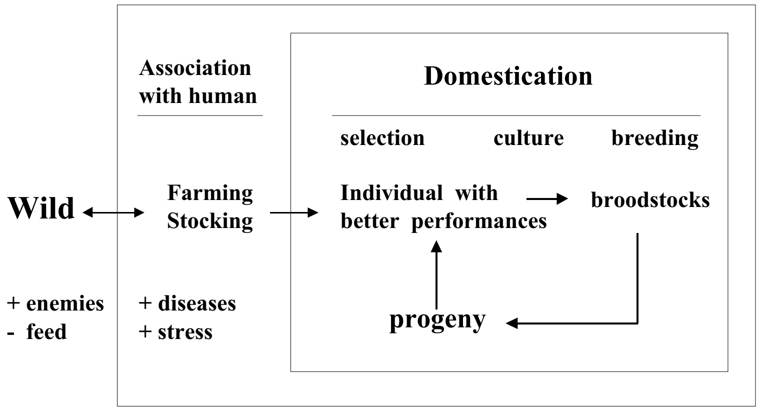

Fig. 3. Concept of domestication in aquaculture.

Consequences of domestication

Domestication is different from farming or stocking, although these are essential to domestication. Certain traits, such as behaviour and tolerance to bad environment, can be selected during the farming or stocking. True domesticated organism can keep these traits from parents to progeny. Indeed, breeding in captivity is a prerequisite to domestication (Pullin *et al.*, 1998).

Compared to the knowledge on the behavioural, physiological, and morphological consequences of domestication among terrestrial vertebrates, there is very little information on aquatic vertebrates, such as fish. Domestication is exerted in captivity, in a stressful circumstance, disturbing the growth rate of wild animals. This disturbance may be caused by individual interaction (aggressive and subordinate), physical condition (e.g., space, food, water quality/quantity), or both resulting in substantial changes in behaviours and, even, in physiology. Evidences from salmonids showed that domestication can alter aggression (Ruzzante, 1994) and can increase growth rate (Johnsson *et al.*, 1993, 1996). Not only affecting behaviours and growth rate, domestication also seems to alter metabolic patterns (Johnsson *et al.*, 1996). Age of sexual maturation is affected by domestication. Milkfish (*Chanos chanos*) mature in different facilities under varying conditions. An earlier maturation of five to six years for hatchery-produced fish was achieved, as compared with the six to seven years maturation for fry caught in the wild (Liao, 1991). All observations indicate that certain traits, genetic or morphological, are altered during domestication. Actually, during the early stages of domestication, the variation in traits brought about by the fluctuation of the environment and the performance of the organisms may be considered as indicators for selection. Selection may favour the individuals that can withstand the stress of crowding. This process occurred in the domestication of herd animals, one result being the smaller sensory lobes and adrenal glands of the domesticated animals. It is worth noting that in rainbow trout, groups of cortisol (a stress response steroid) "high responders" and "low responders" could be selected for breeding purposes (Colombo *et al.*, 1990; Tave, 1994).

Problems provoked by domestication in aquaculture

The advantages of domesticated organisms are that their production and reproduction can be controlled or manipulated, artificial selection and hybridization can be exerted and diseases or predators can be eliminated to improve production efficiency. However, there are also some negative effects provoked by domestication. Since in captivity, only a small population size of parents can be maintained, the problems of lost genetic variation (genetic drift) (Falconer, 1989) and increase in the number of homozygotes (inbreeding) (Agnese *et al.*, 1995) emerge. Furthermore, the escape or release of artificially propagated juveniles from domesticated parents into the open may lead to an imbalance of local ecology. The growth of salmonid aquaculture has raised concerns about the possibility of detrimental effects on the genetic integrity and diversity of wild population (Allendorf, 1991; Thorpe, 1991). Indeed, a large difference has been shown in the offspring from domesticated and wild parents. Offspring of hatchery-reared salmonids showed lower reproductive success and higher morality rate, compared with wild offspring (Lachance and Magnan, 1990; Berejikian, 1995). Competitive interactions between domestic and wild fish can result in reductions in the size of wild populations with negative consequences on their genetic variability. This interaction can result in changes in the distribution of the native population.

Consideration before domestication in aquaculture

Two factors, biological and non-biological (environmental), have to be considered first before starting domestication.

Biological considerations

During the early stages of domestication, factors which will affect the general adaptation and traits of the organism such as variation in fitness, fecundity and viability due to genetic differences will be considered. In fish, like other organisms, growth rate, minimum biological size, egg number, resistance to disease and unfavourable environmental conditions, and ability to utilize feeds effectively are among the most common targets of artificial selection during the first steps of domestication. Characteristics that determine the suitability of a candidate species for domestication in aquaculture are:

(i) fast growth rate,
(ii) high economic value,
(iii) resistance to stress,
(iv) docility,
(v) simple life cycle,
(vi) acceptance of artificial feeds,
(vii) positive physical characters (body colour, appearance, shape and flavour),
(viii) maintenance of genetic variability and performance during domestication.

Non-biological considerations

The environmental and social aspects of domestication must also be considered. Aquaculture is one of part of agriculture, the policy and socio-economics involved should be addressed. Environmental factors are important for domestication. The changes or appearances of certain traits are induced by the fluctuations of environment. Domestication is exerted in captivity, in which individual density, nutrients and water quality are different from the natural habitat. Generally, positive traits can be kept or induced under favourable conditions, while negative ones are always induced by unfavourable conditions. From this viewpoint, culture types and facilities may be different according to different purposes: outdoor culture (pond culture, cage culture), indoor culture; monoculture, polyculture; super-intensive, intensive, semi-intensive, or extensive culture; etc. Sometimes, the meteorological, geographical and topological factors are also critical to domestication, since temperature, rainfall, water resources (freshwater and seawater) and factors affected by altitude and elevation are not easy or too expensive to control.

Processes of domestication in aquaculture

Domestication, in this era, will depend on adequate resources for the necessary research. Successful domestication has been the result of a long-term effort in basic and applied researches coupled with information gathered from aquaculture. Certain biological or non-biological factors, such as with a long growth- or juvenile-phase, special feeding behaviour as well as food preference, unknown reproduction history, high rearing costs, and climate would prevent the possibility of domestication. Following these concepts, some researches must be carried out first:

(*i) To obtain basic information on the potential candidates for domestication in its natural habitat*. Such as: biological position (species); life-cycle (biological size, sex ratio, breeding seasons); feeding (habit, nutrients requirements); mortality (diseases, predators); and behaviours (hibernation, territory, cannibalism).

(ii) To investigate the environmental factors present in the natural habitat of potential candidates for domestication. Such as: annual fluctuating factors (temperature, rainfall, dry season); water quality (DO, pH, salinity, DOD, COD, ionic strengths, dissolved materials, transparence); water quantity (current, pressure); bottom characters (substances, flora, fauna); and physical factors (luminance, vibration).

Because the circumstance of aquaculture ponds (water body) is a man-made environment and an artificial ecosystem, some factors that occasionally appear in a condition which are harmful to the organisms must be defined or avoided first: (i) lethal temperature; (ii) lethal pH; (iii) lethal DO concentration; (iv) lethal salinity (rainfall); (v) space requirement (cause cannibalism, aggression behaviour); (vi) toxic and pharmacological tolerance (cause mortality, susceptibility to stress and diseases); (vii) nutrients requirement (reduce costs and promote growth); and (viii) others (noise, vibration and hydro-pressure).

Strategies for domestication in aquaculture

Choice of appropriate strategies for domestication will depend on adequate resources.

Species choice

Local species is often the first candidate. In the primary stage of domestication, local species are usually chosen. Costs of raising these species may be more economical. They are familiar with the local conditions and have less site-specific problems. Since certain problems of aquaculture are often site-specific, even well-established technologies have to be adapted or modified for local application and tested to determine their economic viability. Furthermore, impacts on native ecology and biodiversity by exotic species are still controversial. These reasons will prevent the introduction of exotic species as potential candidates for aquaculture. However, with the increasing food demands and other economic and market considerations, it may be very difficult to avoid the introduction of exotic culture species. Exotic species are acceptable under a sound monitoring system. To evaluate the impact on environment is quite important (Bartley, 1996).

Stage choice

For breeding selection. On the same biomass and the bio-capacity of captivity, the possibility for juvenile to adapt to or to acclimatize to a new environment is greater than that of adult. Because juveniles are from mixed wild parent population, there are more genetic diversities in the population to cope with the fluctuations of the environment. Spawners caught from the wild had difficulties in acclimatizing to the captive environment. Since there was little or no feeding activity, the spawners died of starvation and stress. So, certain species must be cultured from the fry or juvenile stage.

Feeding control

Domestication can select growth rate by controlled feeding regime (Bagenal, 1969), and by either increasing or decreasing aggression, depending on the amount of food provided in the hatchery, as well as its spatial and temporal distribution (Ruzzante, 1994). The progress of domestication can be monitored by feed intake conditions and the results can help aquafarmers to inspect the organisms' status. An umbrella tray or use of floating feeds can be employed for this purpose.

Culture form choice

In the primary stage of domestication, another non-interaction species can be introduced into the same culture condition to enrich or to stabilize the culture environment. Indeed, aquaculture depends heavily on a wide diversity of aquatic organisms for maintenance of water quality: for example, the filter-feeding of bivalve and the grazing fish on microalgae in culture pond (Pullin, 1996). The co-culture species, sometimes, functions like a signal organism to monitor the domestication condition.

From the viewpoint of nutrition, domesticating fish can obtain at least a proportion of their nutritional complement from the natural productivity of their culture environment. This case is obvious when fish are cultured in fertilized pond with green water. But for some species, a clean, highly transparent water with high DO content are necessary. In this case, cage culture is the optimal choice.

Facility aid choice

Achievement of domestication, sometimes, needs the aid of well-designed culture facilities. In captivity, organisms can not exhibit certain behaviours that are important to their life style, such as living-bait-take behaviour, or by contrast, certain behaviours are enhanced, such as escape behaviour. By using well-designed culture facilities, these situations can be remedied. Also, problems like bottom-dwelling behaviour, reactive characters, and nocturnal characters can be relieved.

Inducing breeding in captivity

The assurance of reproduction is quite important to domestication. Domesticated fish can spawn spontaneously in captivity. At sex maturation, some fish can spawn spontaneously in captivity, but some fish will spawn under controlled conditions only if properly induced. The most common used method is by the injection of hormonal materials. After hormonal injection, some fish will spawn in ponds, but others would require stripping to get the gametes. However, these methods are questionable because they inflict physiological stress and injury to the fish, particularly during stripping, making fish susceptible to diseases, sometimes, causing death. Fry produced using this method have low fertilization rate and are weak (Liao, 1993). Spontaneous spawning involves the use of well-balanced and sound approaches to hatchery practice, thus, high percentages of healthy fry can be obtained (Liao, 1993).

Approach to the quantitative analysis of domestication in aquaculture

The aim of aquaculture, like in agriculture, is to get a maximal output (biomass) with minimal input (costs). The output of biomass may be the first indicator to show the effect of domestication quantitatively (Doyle, 1983). For example, organisms selected for growth rate can be controlled by feeding regime (Bagenal, 1969), and by either increasing or decreasing aggression (Ruzzante, 1994), but the latter methods are less numerical. It has to be noted that, sometimes, the output of growth rate is not always the best indicator, because growth rate is also affected by development stage (Moller *et al.*, 1979), by traits interaction, not just single traits (Fujimura and Okamoto, 1972; Gall and Gross, 1978), and by social interactions (aggressive or subordinate) (Li and Brocksen, 1977). So, for determining the effects of domestication on growth rate, other factors must be considered, such as life stage, rearing density, social interaction, and environmental effects.

Obstacles on domestication in aquaculture

Obstacles hampering domestication in aquaculture species are the problems which affect growth, reproduction and immunity, such as default of reproduction in captivity, inadequate nutrients supply, outbreak of diseases, and stress.

Default of reproduction in captivity

Some prominent farmed aquatic species, such as the Chinese and Indian carps, have long been farmed on a massive scale, but have been bred in captivity only since the 1960's (Pullin *et al.*, 1998). The mating and spawning of kuruma prawn, *Penaeus japonica*, were not commonly achieved until the mid-1970's (Shigueno, 1975), although this species had been cultured for a long time. The culture of Japanese eel, *Anguilla japonica*, is quite important in Asia. Artificial propagation has not yet been fully successful, with elvers still coming from the wild. This species, is far-from domesticated. These results indicate that the production of fry is a limiting factor for domestication.

Inadequate nutrition supply

Most of the nutrition intake of domesticating or domesticated organisms is totally relied on artificial feeds. Even the high quality commercial feed is susceptible to degeneration during storage. In the wild, fish have full opportunity in their natural environment to acquire reasonable levels of all their nutritional requirements. Although domesticating fish may obtain at least a proportion of their nutritional complement from their culture environment, this case is true only if fish are cultured in a fertilized pond. Some fish diseases are poorly known and still under study, and may be involved in the nutritional state of the animal. In the wild, nutritional diseases are uncommon. Imbalance or deficiency of nutrients provokes poor growth resulting in a high mortality rate for the larvae. Reproductive performance (gametogenesis) is also linked to the nutrient condition. Growth and reproduction are hampered by malnutrition.

Outbreak of diseases

Disease problems should be considered seriously. In semi-intensive and intensive culture systems, the occurrence of diseases has significantly increased. The outbreak of diseases is often an interaction among organisms, environment and pathogens, and may result in an uncontrollable epizootic. Diseases interrupt growth and the process of reproduction. This situation is more significant when fish are in a stress state, since the immunity of fish is also inhibited by stress (Ellis, 1981).

Stress

It is widely recognized that practices common in aquaculture today, such as social interactions at non-natural stocking densities, handling, and confinement, are stressful to fish, particularly to wild fish, and may affect growth and reproduction negatively (Pankhurst and Van der Kraak, 1997). This situation indicates that certain stress-sensitive species or individuals are not easy to domesticate. Consequently, a complex of nutritional-immunity-endocrine problems may result in severe stress, which is lethal to the fish (Sumpter, 1997).

Examples of domestication in aquaculture in Taiwan

Taiwan lies astride the tropic of Cancer in the Pacific Ocean. Taiwan with an area of 36,000 Km^2 is bounded by the East China Sea, the Pacific Ocean, the Bashi Channel and Taiwan Strait. About two-thirds of Taiwan's total area are composed of mountains and hills. Climate of Taiwan ranges from subtropical in the north to tropical in the south, the mean monthly winter temperature is about 15°C, and for the summer is 30°C. In southern Taiwan, water temperature rarely drops below 10°C. Mean annual precipitation is 2000 mm, ranging from 1270 mm on the west coast to 6350 mm and more on the mountain slopes. These properties made aquaculture development in Taiwan relatively easy. Aquaculture has been exerted in Taiwan for 300 years. In the early stage, aquafarmers collected juveniles from the wild. Extensive aquaculture was the main culture type. But, since rivers in Taiwan have a sharp slope and a rapid current, and since there is no natural large lake or pond in Taiwan, economically acceptable bigger body sized freshwater culture species are mostly exotic.

The first step on domestication is selective breeding. In Taiwan, there are two ways to get fry or juveniles: (i) inducing wild-caught parents to spawn in captivity during the breeding season, such as grass prawn (*Penaeus monodon*), silver grunt (*Pomadasys hasta*); and (ii) rearing parents from fry or juvenile, such as great yellow tail (*Seriola dumerili*), milkfish (*Chanos chanos*), groupers (*Epinephelus* spp.). After rearing wild fry or juveniles in captivity, they became acclimated and they can be induced to spawn once they reach sexual maturity. Now, in Taiwan, most of economical aquaculture species can spawn spontaneously in captivity.

In 1960's, there were several breakthroughs in aquaculture, including the successes of artificial propagation for grass carp, *Ctenopharyngodon idellus*, and bighead carp, *Aristichthys nobilis*, in 1963 (Liu, 1963; Tang *et al.*, 1963); then for grass prawn, *Penaeus monodon*, and sand shrimp, *Metapenaeus ensis*, in 1968 (Liao *et al.*, 1969a,c); for gray mullet, *Mugil cephalus*, in 1969 (Liao *et al.*, 1969b). A total of seven species were successfully artificially propagated during this decade.

In 1970's, nine more species were successfully propagated. It was also during this decade that Taiwan's economy started growing. With the rapid economic development, consumers were now willing to buy seafood, propelling the search for more species to be produced and domesticated (Liao, 1993).

The 1980's was a golden period for fish domestication in Taiwan. A total of 17 species were successfully artificially propagated. The decade saw a shift in government policy, from supporting freshwater species culture to supporting marine species culture. There were clamours for more species diversification, for aquafarmers to have more species for their culture activities and for consumers to have more variety (Liao, 1993).

In early 1990's, four species have already been successfully propagated, including red drum, an exotic species introduced from the USA (Liao *et al.*, 1992). Now, with the development of techniques and technologies, aquaculture has become an industry. About 100 species are being cultured and about 70 species are being artificially propagated in Taiwan.

Controls of feeding and diseases are essential to domestication. The adaptations to artificial feeding and artificial feed are quite important. In Taiwan, trash fish, moisture feed (mass as well as grain form) and dry feed (floating as well as sinking) are three most used feeds in aquaculture depending on different purposes. For domestication of carnivorous fish, trash fish is usually used as the first stage feed, then transferring to moisture mass form feed. In Taiwan now, trash fish is being replaced by artificial feeds. Floating or sinking feeds are employed according to the natural habitat and feeding behaviours of cultured organisms. For control of disease, prevention is better than cure. Diseases are provoked by the interaction among organisms, pathogens and environments. In aquaculture, to prevent break out of diseases, all of them must be strictly checked. In 1970's, the grass prawn culture was very important in Taiwan. Techniques for artificial propagation in captivity were also established. The break out of viral diseases in 1988 almost destroyed the whole culture industry in Taiwan and in other Southeast Asian countries.

Conclusion

Both concept and practice of domestication of aquatic organisms is still at its infant stage. Although Taiwan has practiced aquaculture over 300 years and has become one of the leading countries in the industry, only 65 species of finfish have been domesticated (can be artificially propagated) so far. The domestication of potential candidates for aquaculture requires thorough evaluation of their genetic resources, closed life cycle for captive breeding, production of high quality progeny, assurance of adequate nutrition and health in captivity. The occurrence of genetic drift and inbreeding caused by a captive condition must be noted. To domesticate new species in aquaculture may be an important approach to meet the demand for animal proteins of the rapidly growing world population. Based on Taiwan experiences, both good performances of aquaculture and fundamental researches are very important to contemporary domestication.

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