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Perspective
Fish and Shellfish Domestication and Stock Enhancement: Current Status and Future Directions

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Abstract
The human demand for fish protein is increasing daily with continuous growth of the global population and economy. Due to the low harvests of wild-caught fish in conjunction with high human fish consumption, aquaculture presents the most effective solution for enhancing the production of fish protein. However, most fish and shellfish hatcheries fully depend on wild-caught broodstock for seed production. The most effective way to resolve this issue is by enhancing the development of domesticated broodstock. Domesticated broodstock would ensure a consistent production of seed for further breeding and stock enhancement programs. Herein, the present perspective describes an important aspect of the current development of domesticated broodstock for future stock enhancement of fish and shellfish in hatchery seed production. The following characteristics were chosen for domestication of species: High market value (either as food or as ornamental), commercially important for fisheries/aquaculture, threatened or endangered, easy to culture, desirable production traits, disease resistant, viral pathogen-free, ability to utilize various food types and have environmental tolerance. The selection of broodstock source is vital for domestication program, as this is the first step for culturing the selected fish and shellfish species. Genetically improved broodstock are usually used in domestication programs along with optimum feeding strategies and space for improved hatchery production. There are many advantages of domestication, particularly for sustainable food protein as well as for future stock-enhancement programs for newly cultured aquatic species. In conclusion, the success in domestication primarily depends on the knowledge of basic fish and shellfish biology.

Key words: Fish, shellfish, broodstock, seed production, sustainable aquaculture

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Recently, wild-caught fish harvests have been decreasing rapidly, primarily due to overexploitation, climate change and pollution. Aquaculture is the most effective strategy to enhance fish production. Production from aquaculture is mostly destined for human consumption. To sustain the production from aquaculture, particularly for food protein, introduction of new culture species should be strongly considered. However, most aqua-culturists depend on wild-caught broodstock to obtain reliable and consistent seed in captivity. An effective method to resolve this problem is by introducing domestication process for cultured species. Domestication is usually defined as a process to control an animal's breeding, care and feeding under human supervision[1]. To be more specific, the complete life cycle of the fish or shellfish species must be concluded in captivity, including broodstock management and larval/juvenile/adult rearing[2]. Domestication of aquatic species first started approximately 2,000 years ago in south-central Europe, however, true domestication began approximately 1,000 years ago in China[3]. The process of domestication of aquatic species has grown rapidly at a global scale[4,5] and domestication appears essential to decrease the pressure on wild-caught broodstock for hatchery seed production. However, only a few fish species have been domesticated, mostly from the marine environment. Stock enhancement is the practice of culturing an early life stage of an aquatic organism in a hatchery and then releasing individuals into the wild. It is currently considered as a management tool for facilitating the replenishment of decreasing fish stocks in the future. With the decreasing wild-caught fish harvests, domestication is a solution to enhance the number of stock in the wild. Before further stock enhancement programs can be implemented, certain species should be domesticated. However, there are a few species that can be considered for domestication, including finfish, shrimps, bivalves and crabs, through stock enhancement program, such as those in place for Salmonidae[6], Penaeidae[7], Haliotidae[8] and Portunidae[9]. Both domestication and stock enhancement programs correlate with enhanced seed production and broodstock development leading to greater opportunities that needs to be explored worldwide. Herein, the present study describe an important aspect of the current domestication of either fish or shellfish species and discuss the future direction of stock enhancement programs for improved sustainable fisheries and aquaculture activities. The appropriate process for successful domestication in both fish and shellfish species was also introduce in the present study.

FISH AND SHELLFISH SPECIES FOR DOMESTICATION

Total global aquaculture production, including fish, crustaceans and mollusks and so on (excluding aquatic plants) has increased from 66.6million tons in 2012-70.5 million tons in 2013, with a monetary value of more than USD 144.4 billion[10]. The aforementioned organization stated that more than 300 species are farmed in the aquaculture industry globally. However, the success of aquatic domestication is limited to a few species, mostly fin-fishes, shrimps/prawns, crabs, oysters and crayfishes with a higher percentage within the finfish species and a lower percentage within the crayfish and oyster species (Fig. 1). The aquaculture of fish and shellfish currently is dominated by aquatic species of high market and commercial value, mostly within the Salmonidae[11] and Penaeidae[12] families, with few from the Moronidae[13], Acipenseridae[14] and Cyprinidae[15] families. From the previous literature, the following reasons for certain species to be selected for domestication are high market value, commercially important for fisheries/aquaculture, threatened or endangered, easy to culture, desirable production traits, disease resistance, viral pathogen-free, ability to utilize various sources of food and a have environmental tolerance. In addition, a basic biological knowledge of the species to be domesticated was also found to be one of the reasons for the selection. During species selection, these aspects play a major role in the success of stock enhancement program in the future.

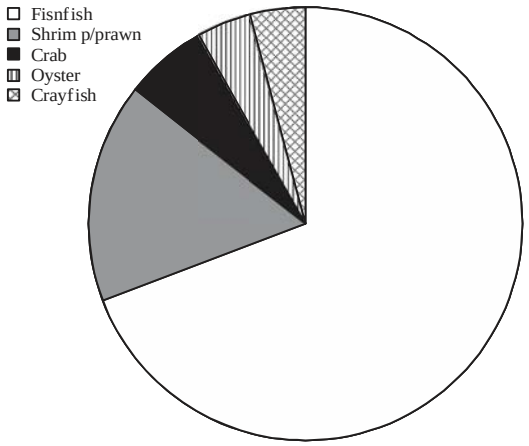

Fig. 1: Pie chart showing the No. of domesticated species of fish and shellfish

SELECTION OF BROODSTOCK SOURCES, THEIR REQUIREMENTS AND MANAGEMENT

The choices of suitable sources of broodstock for fish and shellfish domestication will depend on the availability of genetic studies and local resources of the species. In addition, the selection of either fish or shellfish species for domestication should depend on species that are easy to spawn for a long-term comparison of reproductive performance between domesticated and wild-caught broodstock of cultivated species[16]. This selection of suitable broodstock for a domestication program is vital, because this will form the first step for future breeding of the selected fish and shellfish species. On the one hand, genetic improvement programs have been widely used in the domestication programs of most fish and shellfish species[17,18]. These programs can enhance the reproductive performance of broodstock as well as the production of seed compared with wild species. On the other hand, the cost of genetic improvement has always been a major obstacle in the enhancement of broodstock domestication. Usually, broodstock for domestication programs were carefully bred to produce a maximum reproductive output, their environmental conditions and space were always maintained at an optimum level for best results. Therefore, a successful domestication and stock enhancement program will primarily depend on the following processes: (1) Obtaining basic information on the potential candidate species, (2) Investigating environmental factors affecting the candidate species, (3) Inducing captive breeding, (4) Selecting individuals with better performance and (5) Culturing them to be able to release them in the wild at a desirable stage of the life cycle. This process can be improved in the future for domestication and stock enhancement programs.

ADVANTAGES OF DOMESTICATED BROODSTOCK AND STOCK ENHANCEMENT PROGRAMS

There are many advantages of domestication programs: It helps to meet the present demand for proteins due to the rapidly growing global population and for stock enhancement programs of newly cultured aquatic species in the future. Apart from these, the other advantages include increased production, reproduction of organisms and controlling costs of fish in captivity or in hatchery. Furthermore, domestication programs can decrease predation risks and recover endangered or threatened species. Domestication also plays a major role in sustaining the future of aquaculture, as aquaculture is often viewed as the only solution that can offer

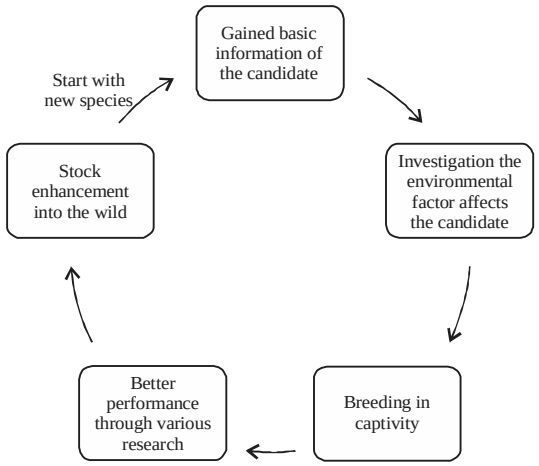

Fig. 2: Block cycle showing the concept of the design of successful domestication to achieve a future stock enhancement program

continued fish products given that the harvesting of wild stocks has reached a plateau. However, stock enhancement programs offer advantages of increased stock for fishing opportunities, provides rapid relief during disaster situation and helps to maintain the economic value of certain species in the wild. Both domestication and stock enhancement programs will lead to an improved future for aquaculture and food production compared with the wild captured fish harvests. With these aforementioned advantages, further domestication and stock enhancement activities involving newly cultured species needs to be conducted in the future (Fig. 2). With increased knowledge about domestication and stock enhancement programs of certain species[19], it is possible to enhance wild-caught fishes.

FUTURE DIRECTIONS AND RECOMMENDATIONS

The study on improving and developing domestication and stock enhancement programs remains in a developmental stage for certain species. Future study on domesticated broodstock should focus on a powerful tool in aquaculture, namely, genetic improvement between hatchery-produced and wild-produced stock. For future domestication program to succeed, the researchers suggest that biologists/researchers are required to contribute to the technical information available for reproduction and larval rearing of commercially valuable target species. Private non-profit organizations, research institutions and private commercial farms should increase the capability of hatchery production to provide consistent stock, perform long-term research on the effects of domesticated species in the wild

and release stock to high-priority areas, including fisheries. For stock enhancement activities, the researchers recommend aqua culturists to develop conservation hatchery technology, introduce pilot-scale production and introduce stock enhancement trials experimenting for new species. The authors also encourage related agencies and government bodies to provide further research funding to identify potential future commercial domestication and stock enhancement species.

CONCLUSION

Knowledge of biological reproduction in fish and shellfish species is essential to understand the potential of particular species for domestication and stock enhancement programs. The stock enhancement programs should gain sufficient support by the appropriate governmental bodies to ensure sustainable future fish protein. Domestication of fish and shellfish species and stock enhancement of commercial species has been thriving in a few countries such as Japan, the United States of America, Norway and Australia and mostly involve species within the Salmonidae and Penaeidae families.

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