

Some possible ways forward development of aquaculture

Abstract

Aquaculture has concentrated on the production of some high commercial value species. Other species may be high success, but we do not control their biological cycles. It is important to know precisely the optimal combinations of salinity and temperature at each stage of their life cycles. It is suggested to bring together into a common system available information, past and present, currently disparate and dispersed, and direct future research towards common goals, with a harmonisation of methods. Moreover the composition of the new compounds foods require new basic research efforts. Restocking operations from hatchery production will pay the utmost attention to the consequences of restocking on the ecosystems in which these are carried out restocking.

Volume 4 Issue 6 - 2016

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Received: September 09, 2016 | **Published:** December 29, 2016

Introduction

In 2007, Taiwan produced over 1.49 million tonnes (MT) of fish, valued at NTD\$ 94.8 billion (US\$ 2.9 billion), according to the Fisheries Year Book 2007 (Fisheries Agency, Council of Agriculture, Taiwan).¹ Finite resources and the land-based expansion of Taiwanese culture have caused environmental degradation. Therefore, the Taiwanese government has supported the development of offshore fish farming as a recent priority for national aquaculture development. Marine cage aquaculture began in the 1970s in the Penghu Archipelago. Among many species of cultured marine fish, cobia has become a popular species for cage aquaculture because of its fast growth rate and comparatively low production cost. Cobia is a finfish species with emerging global potential for mariculture, and it has been the subject of research on spawning and grow-out since the early 1990s.²

Marine aquaculture may also cause environmental degradation from feces, uneaten feed and use of chemicals if the local carrying capacity is exceeded.³ The most important benthic impact relates to the formation of anoxic sediments^{4,6} which can be easily monitored. Both sediment condition and waste accumulati.

Place of aquaculture in food consumed by humans

Today, more than half of what humanity consumes as aquatic food comes from aquaculture. That activity produces 70 million tonnes per year, while global fisheries leveled for over 10 years at around 90 million tonnes 11 million tonnes for inland and 79 million tons for sea fishing (FAO, 2014). Due to the continued exploitation of natural populations through fisheries, aquaculture will continue to grow ineluctably, under the combined effects of the increasing world population, a higher protein consumption per capita better information for consumers who want a balanced diet. Aquaculture is developing in many countries of the world, and it causes significant efforts in scientific research, progress in animal husbandry and breeding techniques. Despite the experience gained in previous decades to achieve new knowledge in biology, in technical and economics of aquaculture enterprises, it is always risky to engage in farming of new marine species because they require new progress in basic sciences, original farming techniques and a new coastal management, adaptation to market needs, physical and financial infrastructure, etc. Curiously, several areas of this research were not sufficiently developed in recent years, so they could provide

very important information to enhance the success of aquaculture, both in the field of basic knowledge in commercial applications. In addition, some of the new results obtained could also be used to analyze the functioning of natural ecosystems. The purpose of this short review is to attract the attention of researchers on few subjects that should allow for better progress in the results of aquaculture. It is necessary to clearly differentiate extensive aquaculture, in which the higher organisms must feed themselves from the natural environment resources, intensive aquaculture, in which these organizations receive food provided by humans. When the species reared receive, indirectly or directly, their food provided by humans in addition to those they find in nature, we are dealing with a semi-extensive aquaculture. The hyper intensive aquaculture is one in which the animals reared only receive food provided by humans, and in a closed environment, whose characteristics are well controlled. In practice, there are no clear boundaries between these different types of aquaculture, some operations taking place in the open sea, or in more or less closed bays or lagoons. In any case, we must rely on more fundamental research results, including physiology, biochemistry¹ and molecular biology.

Knowledge of biological cycles of aquatic species

Our knowledge about species that have been well studied because they are consumed by humans, are sometimes not sufficient. And they are even less for species that are not consumed. In many cases, we do not even know the life history of species yet mundane structure marine ecosystems and often fished. And when we know empirically some biological cycles, we do not control in artificial conditions controlled. Then, when these biological cycles are mastered in the laboratory new steps (mass production, optimization) to be reached significant productions and organizations for trade and consumption. So far, marine aquaculture was mainly confined to high demand by the market species and therefore under the direct influence of eating habits, which vary greatly from country to country. Thus, Western consumers rather consume sea bass, sea bream, red mullet, sole, flounder, turbot, penacid shrimp, lobsters and lobsters, while in Japan, for example, in addition to these species, many other varieties are eaten. These specific requests have led, in this country, the creation of special aquaculture enterprises, like certain species of seaweed (nori, wakame) of puffers (fugu), tunicates (hoya), sea urchins (uni), which are raised by producers, let alone species from fisheries that are rarely consumed in other countries, such as cod gonads (mentaiko),

whale meat (kujira), gonads males of many species of fish (Shirako), fry sardines (chirimen jako), jellyfish (kurage), sea cucumbers (namako) and all sorts of crabs, fish and shellfish. For each species which are already high in aquaculture, it was necessary to know in great detail each step of the life cycle of the species, to reproduce in hatcheries in artificial conditions. Control of biological cycles of sea bream, sea bass, penaeid shrimp, sea urchins, abalone, for example, are well known and controlled, requiring only a few minor improvements. For other species, work is under development such as sea cucumbers *Apostichopus japonicus* in Hokkaido (Sakai, 2015) and in the prefectures of Miyagi and Iwate.

But for many other species, for which a large market potential exists, like lobster or tuna, for example, the complete life cycle has rarely been achieved and controlled. This is the case for all larval stages of five species of lobsters, which *Palinurus elephas*, successfully by Kittaka et al.² and, more or less completely, according to the different species of this zoological group.³⁻⁵

It is therefore necessary, even essential, to have available a larger number of experimental laboratories sufficiently advanced, controlling many abiotic factors, breeding of marine species so that we can ascertain the full life cycle many species. Evidently, there are already some very good research aquariums in many countries USA, Canada, Great Britain, France, Japan, Australia, Japan, New Zealand, Spain, etc. But the experimental conditions do not allow to precisely regulate the variables that are subject marine species in their natural environment and especially in the new current conditions.

This is all the more necessary that the natural environment will see their temperature increase, salinity vary accordingly, and that their pH will acidify. Despite some important fundamental ancient and recent work⁶⁻¹³ there is still much research to achieve to establish the life cycles of many marine species. Moreover it is essential to know the optimal conditions for survival and growth of each larval and juvenile stages of many species. Finally, to complete the cycle, we must ensure the most favorable environmental factors to condition females (temperature, lighting, food, environment) to get them to produce good quality eggs, which will give perennial larvae. There is an obvious gap in our knowledge. Finally, the results obtained in this work-oriented aquaculture will better know the duration of each larval stage, and therefore their distribution by currents in the marine space, over time,^{14,15} ensuring the recruitment of the species.

Survival and growth based on the salinity and temperature

In general, the growth and survival of marine animals are better when they live in slightly desalinated sea water: they must fight against the invasion of their internal medium by salt and maintaining the physiological function has a high energy cost. A decrease in the salinity is favorable. Serrano et al.¹⁶ showed experimentally that the fish *Lutjanus griseus* chose the less salty waters and that choice varies with circadian light.

Conversely, marine species poorly regulate when placed in hypersaline waters, which is for them a very harmful environment. Many studies have been devoted to the maximum thermal limit at which the different marine species were able to survive. But this temperature sensitivity varies depending on the salinity. Their adaptation to different temperatures varies with different zoological taxa and sometimes even within the same genus, according to the different species.^{17,18} While many data exist in the literature¹⁹⁻²¹ they need to be much more accurate.

Changes of physiology and osmoregulation are very well known in salmon, shad, eels and other migratory species. But on a smaller scale, physiology successive stages of development of many organisms also varies depending on the larval stages considered^{10,22} which often explains the migration of these stages in the areas of estuaries, less salty, which move in seeking their optimum salinity for a given temperature.²³

Others have pointed out that the biology of the animals was amended by the pH and by air CO₂ content by decreased oxygen.²⁴⁻²⁶ Which is valid in the natural environment, but will also be true in the water used in aquaculture. It should not be forgotten too, as aquaculture in the study of unconfined ecosystems, the possible arrival of parasites some stages swimmers can be active or inactive according to the characteristics of the environment where they are.²⁷⁻³⁰ New work, very important, open in this field of research.

This new field is of utmost importance because of global warming seriously affecting marine areas, particularly coastal areas. It is important now to establish precise graphs and abacus of survival and optimal growth for each species and each larval stage, taking into account both changes in temperature and salinity. It is from this database that we can better understand the effects of changes in water quality and dissolved gases as well as in aquaculture to better analyze trends in ecosystems.

Progress in the formulation of foods for intensive breeding

Food is one of the major problems in aquaculture, which is becoming more and more for a number of years with no real good solution. Most high marine species are currently fed compound feed containing fishmeal from the operation of natural stocks of “forage fish” pelagic relatively low cost (sprat, anchovy, sardine, blue whiting, etc.) serving as prey to predatory species³¹ and enriched in marine oils in polyunsaturated fatty acids omega-3. It is estimated that fishing of “forage fish” represent in the world, about a third of the tonnage of professional fishing. It became too much and today, as it is currently overfished, it must be controlled and limited. Furthermore, withdrawals by humans in natural populations strongly disturbs, now, the balance of pelagic ecosystems, depriving natural predators (carnivorous fish, birds, sea turtles, marine mammals, etc.) of their usual prey.^{32,33} Fishing, which is suitable for use, even rational, wild ecosystems, necessarily enter into decline. It is therefore urgent to establish and use reliable indicators to measure this reduction and identify the critical phases of such future imbalances before serious irreversible crises occur. A more accurate assessment of global needs for fish meal should be carried out based on global aquaculture development in the world and potential of natural ecosystems to provide forage fish.

It will aim to limit catches to adjust aquaculture production to the possibilities of production by the ecosystems exploited for making fishmeal, as a first step towards global management of marine natural resources.

It has therefore become imperative to replace the marine components of compound feed for rearing fish and shellfish, with land-based components mainly from agriculture soybean meal, corn, rapeseed, sunflower, pea, lupine beans, sesame, sorghum, etc. experienced in many countries of the world, depending on their availability, their price, their composition, for example, and consumption time experimental diet.³⁴⁻³⁶ The issue is whether, when they have been consumed by animals, digestive enzyme equipment of

these species will be suitable for optimal digestion of basic compounds from agriculture. Inside the same zoological group, as among the penaeid shrimp for example, protein needs can be very different from one species to another and it would be interesting to establish a quantitative measure of their carnivoricity. Dupont Nivet et al.³⁷ found genetic variations in the response of trout consuming more or less rich in compound feed fishmeal. Moreover, these very new foods to their diets modify the flora of the digestive tube,³⁸⁻⁴⁰ opening paths to new research. For carbohydrates, marine species have evolved out of contact with starches from seeds from land, usually graminacea. Also feed efficiency starches in compound feed is not very high.⁴¹ It seems that animals like lobsters grow better when they consume glycogen from other marine organisms such as mussels.⁴² Finally, we must know precisely the extent and composition of the residues of uneaten food that have passed through the digestive tract and which will inevitably end up in the marine environment, often changing, more or less strongly, the normal functioning of ecosystems where farms are installed. The food in excess and feces are most often used as food for other species outside the cages, which increases biodiversity and biomass in natural environments. Other solutions are moving towards the installation of individual artificial reef located below or adjacent cages, offering specific habitats to ecosystem species considered most requested by the market. The integration of aquaculture in the natural environment deserves renewed attention, deeper than the salmon cages in the fjords of Scandinavia.

Aquaculture restocking

When some species have been too much exploited, one can imagine that we can sometimes build up populations by restocking swarming in large amounts of post-larvae or juveniles who grow up in areas that have been overfished.⁴³ There is no need to stress here the great stocking operations taking place in the US Canada and Japan for salmon. Good progress has been made in this area in the past.^{44,45} However, we are still far replenish forage fish populations, which are generally close to the base of the food web, but we do not control mass production of larval forms, post-larval and juveniles. For a long time, Japan has an extensive network of dozens of hatchery production and stocking, which for many years^{46,47} rejected billions post-larvae and juveniles at sea of different marine species appreciated by the domestic market, especially salmon and more recently other species such as red sea bream, shrimps, gray sea bream, abalone, sea urchins, etc. Restocking of juvenile crabs *Portunus trituberculatus* are performed every year by Japanese production hatcheries in Osaka Bay, using established techniques.⁴⁸

These operations were carried out under pressure from fishermen and the political and administrative power without first giving precise estimates of the effects of these massive releases on local ecosystems that have been affected.⁴⁹ These ecological studies were undertaken later, relying in particular on the identification of populations by DNA markers.⁴⁹⁻⁵² Much remains to be done and urgently if we do not want to destroy so perhaps ultimately these pelagic ecosystem.

Future development of the coastline necessarily include restocking operations from hatchery production. But it will first choose and decide on major orientations choice of species to produce and disseminate, preparation of habitats needed for good survival of the species, releases of fry or post-larvae in marine protected areas, or equipped not of artificial reefs influence of releases on the functioning of natural ecosystems.

Many of these items were discussed in Japan, for example when stocking penaeid shrimp in various parts of coastal zones, or gray sea

bream on the coast of Hiroshima or sea urchins in various sites of the coast of Hokkaido or abalone (*Haliotis*) in several parts of the country choice of the date of the releases, optimal size at which it will perform restocking, artificial management to create habitats. Similar consultations took place in France during the lobster restocking trials, species whose detailed behavior is not yet very well known despite numerous observations. After several programs of restocking, recently, some release of a few dozen individuals took place in France or in connection with the activities of the Océarium Croisic. On another scale, and after numerous releases programs in Canada, Nova Scotia and United States, recently, experts from New Brunswick as a precaution, release at sea each year 300,000 post-larval lobsters, to try to stabilize the recruitment of this species. To ensure good survival of post-larval lobsters just after metamorphosis, artificial reefs trials were conducted in Canada.^{53,54} On a smaller scale, small concrete shelters were made in France and experimentally, Japan, Sanriku. The management of sea bottoms is a prerequisite because it is necessary that young forms, which molt frequently, can find shelter against predators to pass the time during which their exoskeleton is very soft and they are defenseless.⁵⁵⁻⁵⁹

Final thoughts

To continue to grow in various areas, aquaculture still has progress to make. Control of breeding new species require good knowledge of the life cycles of many aquatic species, whether sought today by man or are later used in human food. Some species such as rock lobsters are characterized by numerous larval stages, and little is yet known on their general physiology and digestive biochemistry. New well equipped laboratories will have to address the original research programs to develop such knowledge's. To complete biological cycles it will be necessary also to know the best possible conditions for maintaining females and parents, in order to obtain eggs and larvae of good quality. Moreover, it is surprising that there has not established mostly survival charts and abacus and optimal growth of larval, juvenile and adult based on combinations of salinity and temperature. Many scientific studies (see above) approached this area in very different disparate point of views. One might suggest that all existing data are collected in order to have general summary information for each larval or juvenile stage, species by species. This information will be extremely useful for both aquaculture and for the evolution of ecosystems, when water temperatures continue to rise and as their characters (pH, dissolved gases, etc) vary with global change. Replacing fishmeal in compound feed for aquaculture should be made at very short notice, otherwise it will be pelagic ecosystems that will be heavily affected and with them, all marine populations that depend on them will suffer. A global management of these natural richness of the oceans become necessary. Moreover, restocking fish farms intended to modify natural ecosystems for species requested by the traditions and culture of human populations consuming, must be carried out with maximum care so as not to disrupt the functioning of natural ecosystems. The ecological impact of aquaculture cages that receive all usable food supplement should be studied carefully to quantitatively measure their effects on biodiversity and on local production, which will necessarily be changed. Finally this modest work has deliberately left out several aspects that are part of the foundations of aquaculture as the functioning of the digestive tubes, pigmentation, the role of light, chronobiology, to mention only these important areas of research.

Acknowledgments

None.

Conflicts of interest

None.

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