

# Mariculture in the New Millennium

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## SUMMARY

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Rapid expansion of aquatic production in the world and particularly its marine components were analysed and discussed. The question was raised on the new mariculture development strategy, the new approaches and the possible modernisation of existing models.

Marketing problems, environmental concern and disease outbreaks, feed and energy costs are mentioned as the main factors that contribute to the constraints in the future mariculture development.

An analysis of marine fish farming development indicates some expected trends in rearing technology. It was stated that cage culture technology will dominate in marine finfish farming industry. However, offshore projects as well as closed system technology must prove their profitability prior to being widely applied. As for restocking programs which exist and operate in many countries throughout the world, many lessons are yet to be learned through research from a variety of disciplines.

It is expected that a long-term strategy for expansion will be based on the farming system which improves the overall efficiency of the resource used, which will be both economically and ecologically viable and socially acceptable

Following the current state and recognised local trends of mariculture development, national mariculture prospective and constraints are elaborated.

## KEY WORDS

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**mariculture, production statistics, technologies, prospective and constraints, national trends**

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## Marikultura u novom tisućljeću

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### SAŽETAK

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U radu se analizira i raspravlja brzi napredak proizvodnje u svjetskoj akvakulture, posebno njenoj morskoj komponenti. Pritom se postavlja pitanje nove strategije u razvitku marikulture, novih pristupa i moguće modernizacije postojećih modela uzgoja.

Problem tržišta, zaštite okoliša i pojave bolesti, zatim troškovi hrane i energije se navode kao glavni čimbenici koji doprinose zabrinutosti za budući razvoj industrijske marikulture.

Provedena analiza uzgoja u moru ukazuje na neke očekivane trendove u primjeni tehnoloških rješenja. Konstatira se da će kaveska tehnologija i dalje dominirati u uzgoju kvalitetne morske ribe. Međutim, uzgoj u otvorenim morima (offshore projekti), kao i tehnologije uzgoja u zatvorenim sustavima optoka moraju potvrditi profitabilnost i konkurentnost prije njihove šire industrijske primjene. Što se tiče programa poribljavanja koji već postoje u mnogim zemljama svijeta, još je niz pitanja koja treba proučiti kroz istraživanja u različitim znanstvenim disciplinama.

Za očekivati je da će se dugoročna strategija razvitka temeljiti na takvom uzgojnom sustavu kojim će se unaprijediti efikasnost korištenja sveukupnih resursa, zatim, koji će biti ekonomski i ekološki opravdani i društveno prihvatljivi.

Prateći trenutno stanje i prepoznavajući trendove u razvoju marikulture, sagledavaju se problemi i perspektive nacionalne marikulture.

### KLJUČNE RIJEČI

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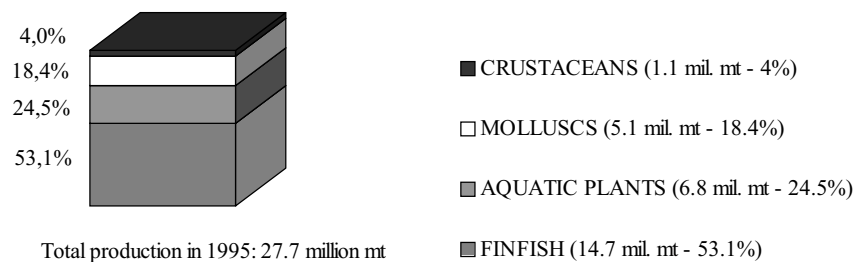
**marikultura, proizvodne statistike, tehnologije, perspektive i ograničenja, nacionalni trend**

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## BACKGROUND

Aquaculture has been the world's fastest growing food production system with production steadily increasing at about 10% per year since 1984, compared with 3% for livestock meat and 1,6% for capture fisheries (FAO, 1997). Such an expansion followed the prediction quite well through the 1980s, and in 1990s the rate of development exceeded the most optimistic expectations reaching in 1995 almost 28 million metric tonnes (Figure 1). In the same time, as was predicted, no appreciable increase in capture fisheries has been recorded. Of the around 300 species being cultured, 22 account for 80% of the production (FAO, 1997). The majority are filter feeders, herbivores or omnivores, and one species (Atlantic salmon) is carnivorous. In the finfish group Cyprinids dominate the production with 10.3 million mt. Plants have rapid growth mainly in the Far East. Molluscs showed rapid expansion in the production of scallops and clams, while the production of oysters and mussels has decreased, mainly because of environmental problems. Crustaceans culture growth also declined



**Figure 1.** Aquaculture production by major species group in 1995 (FAO, 1997)

sharply due to the environmentally related problems and viral disease.

Aquaculture in Europe represents 5.1% of world total in quantity and 8.9% by value, respectively. The major species groups have been finfish (mostly salmonids) and molluscs (oysters and mussels), with only limited production of aquatic plants and crustaceans. In contrast to finfish production, which is constantly increasing, the decline in mollusc production was mainly recorded due to the drastic fall in mussel production in Spain. However, the decrease in Eastern and Central Europe fish production (mainly carp) was due to the economic and social problems and the transition from central planned to market economies.

Mariculture was a relative latecomer in the food production industry. It didn't seem so profitable until the spectacular success of salmon farming in marine environment in northern European countries during the late 1980s. Following positive experiences in production of salmonids in floating cages at high densities, marine finfish farming in cages was successfully initiated in coastal waters of Mediterranean countries.

For a long time marine fish presented big problems for the fish culturists and until recently fry supply was a

bottle-neck in expanding of industrial mariculture. Marine fish eggs and small size larvae at first feeding made it too complicated a matter to rear them throughout their life cycles. Fortunately, it took only a few years to reach the real industrial production. Culture of marine fish has a high growth rate in the last decade mainly due to the promotion of cage culture of sea bass and sea bream and to the constant improvement of the hatchery techniques which has enabled the fry production under a lower price. Around 600 intensive seabass/seabream farms have been operating in the Euro-Mediterranean region with an estimated production of about 80,000 tons supported by about 300 million fry units. There is a limited number of industrial farms producing over 500 tons, a small number of medium-sized farms (100 to 300 tons) and the majority are the small scale/family farms producing below 50 tons. Only 10% are fully integrated, having a hatchery to produce their own fry, and not one has integrated a processing activity.

The main problems the mariculture sector is facing are as follows:

(i) Decrease of finfish prices and profitability. The Italian market, being a traditional consumer of sea bass and sea bream in Europe (around 60%) has three times lower prices today compared to those in 1988. This is because of an increased production and saturation of the European market. The profitability ratio that was very high, 40-50 percent in the late 1980s, has decreased to 10 percent (Harache and Paquette, 1998). With the payback time exceeding 7 years, the new investors are not very motivated.

(ii) Lack of genetically improved species. For example, duration of the grow-out phase is comparably long; to attain 350 to 500 grams it takes between 16 and 30 months. Flesh quality, body shape and desired coloration as related to the increase of farmed product value is to be incorporated in the genetic improvement program. This must include methods and techniques such as selective breeding, chromosome manipulation, hybridisation, production of mono-sex and gene transfer.

(iii) Dependence of finfish farming system on capture fisheries for their feed inputs (fish meal, fish oil). At present, the quantity of inputs in fish feeds, in terms of fish meal, fish oil and trash fish exceeds outputs in terms

of farmed products by a factor of 2 to 3. That is why carnivorous marine fish are considered net resource reducers rather than producers (Tacon, 1997).

The current dependence of carnivorous finfish species upon fish meal and fish oil is of particular concern due to their recent price increases on the international market. This problem is particularly pronounced in the context of the need to reduce costs of salmonids and marine finfish as to maintain profitability.

(iv) The lack of species diversification and the diversification of the final products. As for diversification, two approaches have been attempted in the Euro-Mediterranean region. One involves medium priced fish having rapid growth, such as *Thunnus thynnus*, *Seriola dumerilly*, *Coryphaena hippurus*, while the other (*Dentex sp.*, *Diplodus sp.* and *Sargus sp.*) includes higher priced fish with lower growth rate. The first approach is oriented towards diversification of the existing market, and in the second case a new market should be considered (i.e. sashimi market in Japan for tunafish).

(v) Decreased mollusc production within Southern European countries. It is mostly due to the increasing occurrence of toxic red tides and consequent incidence of shellfish poisoning. This resulted in a drastic drop in mussel production in Spain, from 250,000 mt in 1986. to 90,000 mt in 1993. (Pedini, 1996).

(vi) Increased competition with other coastal users for water and sites and growing public concern about environmental issues for aquatic food products. It is only in the last ten years that some aspects of mariculture have been mentioned as polluting. The increasing concern about environmental impact requires an assessment of environmental costs of a particular project and a comparison of such an impact with the potential benefits. This means that future mariculture project assessments may involve defining not only the technical, economic and social aspects of a project, but also its environmental efficiency. There is an increasing pressure on the use of the existing sites, and there are fewer new sites available, particularly in the coastal zones of the highly developed countries where shore margins have an increasingly high value for the settlements, recreation and conservation. Mariculture, like any other sector, must compete for and justify its claims on those resources.

#### **FUTURE TRENDS IN MARICULTURE TECHNOLOGY**

Until recently, the emphasis in mariculture was on rapid expansion. However, nowadays the trend is towards 'sustainability' of the mariculture sector. This means a concept with lesser amounts of energy (Stickney, 1998), less net utilisation of natural resources (Tacon, 1997) and finally a concept that does not cause harm to the environment.

Mariculture development must be sustained by basic and applied research and development in all the major fields such as nutrition, genetics, culture system

management, product handling, socio-economics etc. Technological advances oriented to lower both capital and operating costs are particularly needed to counteract the tendency for prices to fall as production increases.

#### **Closed system**

Closed systems in commercial mariculture are seriously considered in some countries (i.e. France) as an alternative to widely accepted intensive cage farming. In theory, it can be constructed everywhere (artificial sea water), it may guarantee high quality and product freshness. Also important is that such a technology is considered environmentally more friendly when compared to the inshore cage culture. However, investment and operational cost (energy) must be lowered for such a technology to show profitability. Otherwise, the use of closed systems will remain a part of the hatchery operations, while further rearing will, at least in the near future, take place in one of the existing conventional systems in which water and energy to heat are available at a low or no cost.

#### **Cage culture**

Mariculture in cages began in Japan in the 1950s but developed largely as a result of the salmon farming industry in northern Europe and North America during the past two decades. Cages account for about 60% of coastal fish culture, and if considering Mediterranean aquaculture it account above 90% of all seabass and seabream production. The main advantages of cages when compared to conventional land-based systems include low capital costs and simple management. However, their vulnerability (storm weather, poachers and vandals) characterising such a production risky.

There have been frequent objections concerning organic waste and nutrient enrichment of water. In sheltered, inshore sites. Also of concern were the transmission of diseases from captive to wild fish, interference with tourism, navigation and traditional fishing activities. Although of local importance, visual effect, excessive noise and foul odours have all been under attack. To avoid conflicts with other coastal users there is an increasing trend towards offshore sites which are less exploited and restricted in planning. In the countries which coast offers very few inshore areas (e.g. Malta, Cyprus) offshore cage farming in exposed areas is the only solution that came into practice several years ago.

Besides reducing conflicts with the human activities, the siting of cages further out from the shore may also reduce the environmental degradation and offers some additional benefits to the farming practice itself. Water quality at offshore sites is often better and there are stronger currents and better water exchange to facilitate higher stocking density and less pronounced fouling.

However, the major disadvantage of such a strategy lies in increased risk of storm damage. Capital and some operational costs are also greater and still there are many

technical difficulties associated with operating in deeper water and at a distance from the shore.

Two approaches have been taken to development of offshore technology: improvement of the site and construction of cages that can withstand exposed conditions. It was found that floating breakwaters may provide only limited protection to the floating platforms, and by the way they are expensive to build and maintain. Floating rubber-framed design such as Bridgstone cages were found quite successful in rearing of salmonids at exposed sites. Such design, although attractive options for fish farmers (according to manufacturers claim it withstand 9m wave heights) are very expensive and many of the routine operations are much complicated.

Semi-submersible cages, also designed for salmonids has proven its stability even under extremely rough weather conditions. Under normal operating conditions the system is located several meters below the water surface where motion is very low. Compare to flexy-float design such a system can be more expensive on a per unit volume basis.

Submerged designs have been developed on experimental and pilot scale operations only. Their high price and unknown effects of isolation from the water surface for many species may prevent their wider commercial exploitation.

In terms of costs associated with the offshore mariculture, it was indicated that a minimum production level of 200 tons of finfish per year must be reached (McVey and Treece, 1998). It was also stated that a minimum production of 18.5kg of fish per cubic meter must be given at a sales price of 10 US\$/kg. It is only recently that the offshore technology has begun to be used for sea bass and sea bream. Considerable work still remains to be accomplished in developing the appropriate methods for handling the fish, and lowering the risk of storm damage (for both fish and the installations), and lowering the capital and operational costs to an economically realistic level, which will be competitive to other production systems.

**Biomanipulation and stock enhancement programme**

Future increase in finfish supply may come through 'biomanipulation' using aquaculture-based knowledge and techniques to enhance the productivity of the natural environment and therefore lower the costs of fish production (Welcome, 1997). This approach involves maintaining and spawning of brood fish, rearing larval fish in a hatchery that may be combined with additional grow-out in cages/ponds and followed by release into their natural habitats. Through known management practices, both commercial and recreational fisheries might benefit from this approach (Smith and Jenkins, 1993, Blankenship and Leber, 1995). Such an idea was recognised over a hundred years ago, but it may work well just today, because mariculturists have the ability to produce the fry of many fish species. Many countries have been involved in the

repopulation of marine fishes; in Japan the quantity of marine seed units exceeds several billion per year (Fushimi, 1997).

Although in most cases no increase in commercial catch has been reported many lessons have been learned in the meantime. It was concluded that better survival may be expected in marine fish if advanced juveniles are released and if they are well adapted to the natural conditions prior to release. Predation soon after release is the major cause of mortality among hatchery reared fish (Olla et al., 1994). Natural mortality usually stabilises by the end of 1-2 group stage (Sundly et al., 1989). The profitability of this undertakings will depend upon the return rate and market price of recaptured fish as related to the cost of hatchery produced juveniles (Moksness and Stole, 1997).

This means that hatcheries aiming to produce marine fish for restocking may be designed differently from those used to produce fish in captivity. Furthermore, it is also obvious that a large number of carnivores (i.e. sea bass) should not be stocked in waters that do not have sufficient food organisms. This requires environmental surveys, which cover the primary and secondary productivity, aiming to support the survival and growth of introduced fish. It will be necessary to maintain the diversity of the wild stock, and this may be accommodated by avoiding broodstock inbreeding so that introduced fish are not genetically or behaviourally much distinct from the wild fish..

### **Seaweed production**

After a period of stagnation in 1984 -1989, world seaweed production has steadily increased over the years reaching 7.8mt (FAO, 1997). It is becoming a major industry in Asia-Pacific mariculture. The market for seaweed products (agar, alginate and carageenan) is very diversified with a wide range of applications as food, medicine, fertiliser etc. A growing seaweed demand may speed up further production, particularly in the integrated polyculture systems aiming to reduce the environmental impact of animal aquaculture, and increase the economic returns of the sector in whole. (Hanisak, 1998).

Expected increase in demand, particularly in some of Asian countries (China, Korea, Japan) may keep the market value of seaweed products relatively high, even as production increased. This group could gain more importance in the future because of several reasons. First, coastal areas where these plants could be farmed are far from saturated. Second, seaweed culture does not need inputs that are potentially harmful to the environment. Third, seaweed farms are not labour-intensive and farmers could earn more than from other mariculture sectors.

### **Mollusc culture**

Mollusc production through mariculture has increased in the past decade, but proportion by specific groups completely changed. The culture of scallops and clams

has become much more important than decade ago, while oysters and mussels substantially declined. Clams and scallops will probably gain more importance due to a good market price on the international market. However, it is likely that the overall mollusc growth will decline because of the deterioration of water quality in coastal areas that may limit the marketability of the products, as has already happened with mussels and oysters.

### Crustaceans

After an extraordinary expansion in the culture of crustaceans, primarily marine shrimp during 1980s, the levelling of world production over the last few years is a result of viral and bacterial epidemics. These pathogenic agents are often the consequence of a deteriorated environment caused by the farms themselves or by related activities (Lucian-Brun, 1997). A further prospect will probably be limited by difficulties in expanding the areas under culture due to the problems associated with the very intensive industrial forms of culture and environment related problems.

## WHAT WILL MARICULTURE LOOK LIKE IN CROATIA?

### Present status

Commercial mariculture in Croatia, being a typical governmental project, was initiated in the early 1980s. That began to change by realising a joint-venture project with an Italian partner. After that, activities expanded rapidly during the 1990s through 20 small, mostly family owned private marine farms. It is oriented towards the production of higher value fish, seabass and gilthead seabream for export market. There exist difficulties in promoting molluscs (mussels and oysters) on the international market mostly because of European Union (EU) barriers and requested quality standards.

### Constraints to development

Croatian mariculture industry is far from being self-sufficient. Complete feeds have to be imported, but the production is also becoming more and more dependent on imports of seeds, although there were some remarkable successes in the early stage of hatchery production. Namely, because the domestic hatchery sector is not modernised, it cannot compete with foreign seed suppliers and they have directed their efforts towards the decline or even closure of their own production. The fry market is becoming more and more competitive as more enterprises are operating within various production systems and by using different resources. As the main hatchery production season is during the winter with an ambient temperature between 8 (North Adriatic) and 13 (South-east Adriatic), costs of fuel portion may be large due to the heating requirements to optimise the larval rearing at around 20°C. Capital investment for the building itself and mechanical equipment needed for re-circulation of the

water can reach up to 60% of the hatchery hardware. (Stephanis, 1995). The smaller hatcheries are finding it difficult to compete with greater, well managed hatcheries, particularly if the supply comes from underground warmer water with constant temperature. The cost of the fry will play a significant role in the national mariculture industry, as it contributes presently with between 15 and 20% of ongrowing costs.). To get in line with the constant improvement of on-growing technology, it will be necessary to improve education in the sector. While higher studies in biological sciences, oceanography, marine biology and fisheries sciences are available, there is a lack of qualified, experienced and job-trained personnel.

### Prospective and global needs

Croatian mariculture sector is being attacked on several fronts such as investment, technology (inshore vs. offshore), diversification, market, regulation etc. Assuming major global and specific local problems will be overcome, what will the Croatian mariculture look like in the future? From many aspects we can speculate about mariculture development in Croatia, but at least one gives it a greater importance – its unique coastal environment, which is becoming increasingly scarce in most European countries.

An increasing demand for mariculture product coupled with a decrease in supply from capture fisheries may stimulate the further development. Such development is likely to be continued through production of seabass because of its better market acceptability, particularly once some technical problems in its production have been solved (i.e. sex ratio in hatchery produced fish). Considerable potential also exists through the introduction of new fish species, through diversification of finfish products and expansion of molluscs production.

As for the production in closed systems it will remain as a part of the fish early life history (through hatchery operations) while the further rearing will, at least in the near future, take place in cage systems. With tuna cage culture for Japanese market, there is an increasing trend towards offshore sites. This may be a particularly attractive option for Croatian island areas, given the severe pressure in the coastal zone and the poor water current and water quality in existing seabass/seabream inshore farms. However, unless such a technology is not competitive to inshore cage operation, it will not be widely applied in Croatia.

It is also interesting to point out a serious problem of tuna culture here, due to the drastic drop of the sardine fisheries. Pelagic pilchard was used by tuna culturists as a complete feed and the cheap source of high grade protein. As the catch of this species decreased rapidly in 1998, farmers were forced to use non-sardine feeds based on imported herring and cephalopods.

Appropriate governmental intervention should be oriented towards the following:

- elaborate general management plan for water resources and properly integrate mariculture into government structures and policy framework
- rehabilitation of the previously stated-owned enterprises which are now in transition to new ownership structures; this must include a provision for supporting the infrastructure and fry production in particular
- marketing and distribution system of mariculture products.

Otherwise, in the given circumstances it will be difficult to expect an economically sustainable mariculture development in Croatia, particularly when dealing with small-scale enterprises.

## CONCLUSION

Responding to the challenge of filling the gap between growing demand and capture fisheries supply, aquaculture production and its marine component in particular has exceeded most of the optimistic expectations. Significant progress is being made as evidenced by both the scientific achievement and most recent production statistics. Future aquaculture development must be sustained by research and development in genetics, nutrition, health management, production economy, product handling etc. Technological advances aiming to reduce capital and operating costs are particularly needed as to counteract the tendency for prices to fall as mariculture production increases. Future project assessments should involve not only technological and socio-economic consideration, but also its environmental efficiency.

Mariculture has become the subject of public interest in Croatia. While this has some advantages, it has exposed mariculture activities to intensive examination and often to criticism. Public knows that high valued marine fish and shellfish supply cannot be sustained unless mariculture expands. Attention has been drawn to the need to include mariculture into regional master plans. These plans are important mainly for the purpose of mariculture own development and management, but also because of potential conflicts with other activities competing for the same space and water usage (e.g. tourism). Responsible authorities are currently reviewing legislative processes applicable to mariculture (criteria for siting mariculture, monitoring protocol for mollusc farms etc.)

There are some encouraging signs to be recognised as regard employment in economically disadvantaged rural area which have a long history of de-population. The creation of even a few jobs on islands can secure the existence of shops and schools and ensure the vital services remain. Co-operation between government, investors and financial institutions is a prerequisite to achieving a new era of mariculture development in Croatia.

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