Introduction to the special issue on “European aquaculture development since 1993: the benefits of aquaculture to Europe and the perspectives of European aquaculture production”

E. Mente¹ · A. C. Smaal²

Published online: 19 April 2016
© Springer International Publishing Switzerland 2016

During the past three decades, European aquaculture has expanded, diversified, intensified and made technological advances. The potential of this development to enhance food security and provide top quality animal protein for human consumption has been well recognized. Aquaculture will be able to provide food for the world’s population in the future although this will depend on the capacity to expand and grow in a sustainable manner; on climate-driven changes in ecosystems productivity; and on the aquafeed industry reducing its reliance on wild fish. An important parameter for the cultured species is the development of sustainable cost-effective and nutritionally complete feeds, along with efficient feed management systems. Aquaculture “the farming of waters” is rightly viewed as an important contributor to the European economy and to the wellbeing and health of communities throughout Europe and in particular in the more remote and rural areas. It has the potential to take the pressure off wild fish stocks whilst meeting the dietary needs of the population for omega 3 fatty acids, essential amino acids and other key nutrients such as vitamin D. The need to achieve sustainable aquaculture production in order to provide products for the expanding export market demand and for European consumers has never been greater.

Guest editors: Elena Mente and Aad Smaal/European Aquaculture Development since 1993: The benefits of aquaculture to Europe and the perspectives of European aquaculture production.

✉ E. Mente
emente@uth.gr

A. C. Smaal
aad.smaal@wur.nl

¹ Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, University of Thessaly, Fytoko Street, 38446 Vólos, Greece

² Aquaculture and Fisheries, IMARES, Wageningen University, Korrिंगaweg 5, P.O. Box 77, 4400 AB Yerseke, The Netherlands

The aquaculture sector in European Union (EU28 countries) are divided in three main sectors, marine, shellfish and freshwater production. Aquaculture production from brackish and marine waters in Europe has experienced high average annual growth rates during the 1980s and 1990s. The aquaculture production in EU28 has increased by 25 % from 1992; however, since 2002 the production has been stagnant. The European Union aquaculture production was 1.4 million tons in 2000 and 1.26 million tons in 2010 with a value of €2.79 billion in 2000 and of an estimated turnover of €3.58 billion in 2010. Marine capture fisheries represented 79 % (Atlantic and Mediterranean aquaculture combined) and inland capture fisheries 5 % (STECF 2012, 2014). In 2012, EU aquaculture had increased with 1.34 million tons of production and with a first sale value of €4.76 billion Euros compared to 2010. Around 50 % of the direct output value was generated using marine cage systems (28 % by volume) whilst less than 3 % of value was generated in recirculated aquaculture systems (<1.5 % by volume). Around 5 % of value was contributed by extensive to semi-intensive inland and coastal pond systems. Five countries accounted for around 78 % of the direct output value of aquaculture in 2012, the UK, France, Greece, Italy and Spain. Norway became the sixth million-tons producer in the world in 2010 (FAO 2014). Norwegian production showed an increase of over 246 % from 1995 to 2009. The EU (27) represents 1.6 % of the world aquaculture production in volume and 3.3 % in value. In 2010, marine aquaculture represented 78 % of the total EU (27) aquaculture production in volume and 75 % in value, and its economic importance has been increasing in the last two decades (FAO 2012). STECF (2014) estimates there are between 14,000 and 15,000 aquaculture enterprises in the EU employing around 80,000 people, approximately 40,000 full-time equivalent (FTE).

In Europe, almost 50 % of the total aquaculture production is derived from shellfish farming. Main product is the mussel, followed by oysters and clams. Spain is leading in mussel production (200 million kg) and France in oyster production (85 million kg), and Italy produced 31 million kg of clams in 2011. In terms of value, shellfish contributed for 28 % to the total first sale yield. This figure is growing, despite stagnation in shellfish production. Market pull also attracts import from outside Europe (Chili), as competing spatial claims, carrying capacity issues and disease outbreaks limit developments in various production areas. Shellfish is extensive aquaculture with no additions of feed and medicine. It is a low food chain production with a corresponding low ecological footprint. It uses nature, but it also depends for a large part on natural processes. This makes shellfish culture vulnerable for natural disasters but also relatively sustainable. Further expansion of aquaculture can make use of the ecosystem services of shellfish. Shellfish culture not only produces food but also provides regulating and supportive functions to the ecosystem, like habitats with a high biodiversity, ecosystem engineering for coastal protection and eutrophication control by nutrient accumulation.

These opportunities deserve more attention in aquaculture policy. EU policy is generally supportive of sustainable aquaculture expansion for reasons of sustainability of global aquaculture production, food security and economic development. Policies encouraging improvement of environmental standards in aquaculture production and greater commitment to address governance weaknesses in improving environmental standards give reasons for aquaculture to meet the current and future consumption rates. However, constraints to growth also exist in the form of regulatory barriers, costs that reduce industry competitiveness and changing market requirements. The technological change in aquaculture ensures that it is maximizing the quality and health benefits of farmed products, whilst improving resource efficiency and minimizing impacts. Thus, aquaculture will continue to be a significant contributor to biodiversity conservation and to food production.

The papers selected in this special issue address key topics for the European aquaculture development. The first three papers examine the structure of the European aquaculture sector, the contribution it makes to the EU economy, the policy environment for past and future development and evaluate Atlantic salmon farming and assess the feasibility of offshore aquaculture development and its potential for multi-use with other maritime activities. John Bostock, Alistair Lane, Courtney Hough and Koji Yamamoto conclude that an overall increase in production by 55 % is possible by 2030 based mainly on expansion of marine cage-based farming using larger systems in more exposed sites and similarly shellfish farming using larger-scale suspended systems. Expansion of recirculated aquaculture systems appears likely based on entrepreneurial and European policy for research and technological development (RTD) activity, although constrained by currently low competitiveness. The offshore cage farming is representing a relative low-cost production system, where the potential for further growth is great. Henrice Jansen, Sander Van Den Burg, Bas Bolman, Robbert G. Jak, Pauline Kamermans, Marnix Poelman and Marian Stuiver contribute to the discussion on the feasibility of offshore aquaculture development and its potential for multi-use with other maritime activities. A review of national and international projects forms the basis of the paper, where the Dutch North Sea is used as a case-study area. Analysis of technical, economic and ecological boundaries indicated that the potential of fish culture is limited that seaweed cultivation is likely to gain potential when challenges related to processing will be overcome and that mussel culture has the highest potential in the near future. The North Sea is an area where many stakeholders claim space, which might set boundaries to the number of sites available for mussel culture. Competing claims are a potential source of conflict, but may also lead to mutual benefits when smart combinations are sought, e.g. with wind parks, fisheries and nature conservation; in particular, the possibility of combining mussel culture in or around wind parks is worthwhile to be further explored. A spatial distribution model adapted for the Dutch North Sea conditions demonstrated that offshore mussel production in wind farms could be profitable. Yet, the commercial interest for offshore development of mussel culture is still limited. A review paper by Odd-Ivar Lekang, C. Salas-Bringas and John Bostock summarizes the effective production system for farming Atlantic salmon, which has grown rapidly from its start in the early 1970s until today, with production approaching two million tons. The development and improvement of the sea cage farming system, which is a system with a lower investment and running costs than land-based systems, have been one of the most important factors for the growth of the salmon farming industry. However, during recent years certain problems related to their placement in the open marine environment have proved highly challenging, increasing operating costs and impacting on industry public relations. The problems are mainly due to parasites, diseases and escape of fish. They also describe emerging technical solutions for solving those problems. The future will probably hold a greater diversity of production methods and technologies. The development of land-based systems with different percentages of water reused, closed cage technology and sea cage technology tolerating larger mechanical stresses will continue. The typical two-stage salmon production process may be redrawn, and there will probably be a variety of production regimes. Besides new technologies and new production methods, the most important contributor to ensure a further economically sustainable growth in salmon farming will be vaccine development. This has so far been very effective for a number of diseases in salmon aquaculture. It will also be interesting to follow the production of triploid salmon regarding production economy. If both prove to be successful, they will be an important contributor for the future growth of farming in sea cages.

The growing knowledge about fish nutrition still needs to be given priority to assist in the continued development and improvement of sustainable practices in aquaculture. The next two papers address the current state of fish nutrition for aquaculture and the benefits of the consumption of farmed fish in promoting human health. Knowledge about fish nutrition still lags behind that of the domesticated terrestrial animals. Malcom Jobling evaluates fish nutrition research by considering some of the major challenges faced by fish nutritionists, how these challenges were addressed, the advances made, and knowledge gaps that need to be filled. The spotlight is focused on nutrient requirements, feed ingredients and their evaluation, and the formulation of diets that promote effective production whilst serving to maintain fish health and well-being. New methods and techniques will be used to an increasing extent, and the application of genomics, transcriptomics, proteomics, metabolomics and bioinformatics is likely to become routine in fish nutrition research. The effects of dietary components on the composition of the gut microbiota and the influence of diet on the fish immune system, health and well-being are given a special attention. It is clear that global supplies of fish meal and fish oil will be insufficient to meet aquaculture demands for growth. Reducing the use of fish meals and fish oils for aquafeed production means improvements in practices (e.g. the use of alternative feed ingredients, larval nutrition of marine species, diversification of farmed fish species) that have a decreasing negative influence on biodiversity conservation. Over the years, global aquaculture production has increased and more fish for human consumption originate from aquaculture. Analyses of the fatty acid composition of the muscles in several farmed fish species have proved; as a rule, notable concentrations of n-3 PUFAs and two lipid-rich fish meals per week may be adequate for cardio protective nutrition. Werner Steffens reviewed the significance of long-chain unsaturated n-3 fatty acids in human nutrition. The long-chain unsaturated $n = 3$ fatty acids have antiatherosclerotic efficacy and other beneficial health effects too. Aquaculture fish, e.g. cyprinids, such as silver carp (*Hypophthalmichthys molitrix*), big-head carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), tench (*Tinca tinca*), and salmonids like Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) as well as European catfish (*Silurus glanis*), Baltic whitefish (*Coregonus maraena*), European seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*) and Nile tilapia (*Oreochromis niloticus*), are rich in these fatty acids. When fed on suitable diets, the fatty acid composition of cultured fish can be influenced and improved advantageously. Several clinical tests proved the effectiveness of the consumption of farmed fish in promoting human health. Thus, farmed fish can be recommended as healthy, nutritious food.

The following papers of the special issue deal with different aspects of shellfish culture. Two papers show the concept of ecosystem services that are linked to shellfish culture, whilst two other papers focus on developments in larvae and spat culture in hatchery–nursery systems.

Joao Ferreira and Suzanne Bricker present a review on the role of bivalve culture in water quality control and nutrient management. As filter feeders, bivalves have a large capacity for filtering particles from the water column and improve underwater light climate, oxygenation and benthic life. The review is based on information from case studies in the USA on how this works and what economic basis can be given to nutrient management by nutrient credit trading programs. The uptake of particles by the bivalves not only promotes water transparency, but also implies uptake and accumulation of food components such as associated nutrients. As bivalve culture is extensive, harvesting the product implies extraction of the accumulated nutrients from the system. This ecosystem service can be validated against other methods for nutrient management such as in waste water treatment plants. By introducing nutrient credits, parties such as shellfish farmers can

exchange their capacity for nutrient removal with parties that need to invest in nutrient removal from their outlets. Moreover, non-point sources are becoming the main input mode for nutrients in watersheds, and these inputs are difficult to control; hence, mitigation through biofiltration and bioextraction looks promising. Yet, for implementation in Europe, legislation is critically reviewed in the paper and specific attention is needed as this is completely lacking in the actual water and marine framework directives.

The paper of Pauline Kamermans and co-authors reviews the application of a recirculation aquaculture system (RAS) for bivalve spat culture of mussels, oysters, clams and scallops. The paper is based on the EU project REPROSEED. The RAS technique has advantages over flow through systems (FTS) in terms of water quality and quantity control including flow rate, temperature and oxygen concentration. Optimal feed addition and waste removal are critical for the RAS application. Results showed no difference in spat performance between RAS and FTS. It is concluded that RAS systems can be used as a nursery for bivalve spat.

Another approach for analysing the effects of culture conditions in bivalve rearing is demonstrated in the paper of Tim Young, Andrea Alfaro and Sillas Villas-Bôas, from Auckland, New Zealand. The authors used metabolic profiling of small metabolites in the cells of mussel larvae in hatchery systems to investigate whether short-term handling stress was reflected in physiological traits that were not morphologically observable. By using multivariate pattern recognition tools, significant differences were detected in energy, protein and lipid metabolism related to low-density static vs high-density flow through conditions. This novel approach aims to improve assessment and monitoring of the physiological condition of larvae as a function of rearing condition.

Both papers on larval and spat rearing conditions show progress in hatchery–nursery technology that is a prerequisite for further development in bivalve production. Increase and innovation in culture through hatchery–nursery systems allow the production of high-quality spat and reduce the dependence of wild spat. Given the need to improve production in Europe, research output as reported by the New Zealand team is relevant for aquaculture progress in Europe, hence a valuable contribution to the special issue. It also demonstrates the value of Aquaculture International as the Journal of the European Aquaculture Society with a worldwide scope.

The paper of Jens Kjerulf Petersen, Camille Saurel, Pernille Nielsen and Karen Timmermann reviews the application of shellfish culture for eutrophication control. Nutrients that have accumulated in shellfish tissue can be removed by harvesting. Other functions are improvement of water transparency by filtration, enhancement of nutrient cycling through biodeposit production and mineralization, enhanced denitrification and burial of nutrients in the sediment. The paper describes case studies in the Scandinavian waters where mussels have been applied for mitigation of excess nutrient input by diffuse runoff from land. Site selection of mussel mitigating farms by using multicriteria analysis was evaluated for Danish sites. Further applications are foreseen in the framework of IMTA (integrated multitrophic aquaculture), for areas with no apparent bivalve culture practice and as an additional service in existing bivalve culture areas and systems.

This paper illustrates the practical application of the goods and services concept, in this case of marine bivalves. Together with the review of Ferreira and Bricker, a novel approach that is relevant for bivalves in extensive aquaculture has been demonstrated. It exemplifies recent developments in shellfish culture including the paradigm shifts from culture *sensu stricto* to the integrated approach based on the services to the ecosystem.

With this special issue, the reader will get an impression of progress in aquaculture during the first 20 years of Aquaculture International, regarding the benefits and the further perspectives.

References

- FAO (2012) Global Aquaculture Production 1950–2010 database (Release date: March 2012). <http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en>
- FAO (2014) The State of World Fisheries and Aquaculture 2014. Opportunities and challenges, (SOFIA). Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/3/a-i3720e.pdf>
- Scientific, Technical and Economic Committee for Fisheries (STECF) (2012) Economic Performance of the EU Aquaculture Sector (STECF-OWP-12- 03). JRC Scientific and Technical Reports. In: Guillen J, Contini F, Doerner H (eds) Publications Office of the European Union, Luxembourg. <https://stecf.jrc.ec.europa.eu/data-reports>
- Scientific, Technical and Economic Committee for Fisheries (STECF) (2014). The economic performance of the EU aquaculture sector (STECF 14-18). JRC Scientific and Technical Reports. Nielsen R, Motiva A (eds) Publications Office of the European Union, Luxembourg. https://stecf.jrc.ec.europa.eu/documents/43805/839433/2014-11_STECF+14-18+-+EU+Aquaculture+sector_JRC93169.pdf