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Conclusions

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As a productive resource for aquaculture, open marine waters are immense in scale, and would offer almost unlimited potential for output, but so too would appear to be the challenges of developing viable and effective systems (Muir and Beveridge, 1994; Polke, 1996). In the N. Atlantic, the Mediterranean basin and S. Australia, high market prices for key species have encouraged technical development and innovation, and a small number of sites and systems can now be said to have at least some of the characteristics of genuine offshore production. However, progress has been unsteady, and technical innovation and specific design studies have been slow in moving into practical commercial application. While offshore production apparently has interesting potential, many consider it to carry considerable risk, and the criteria for success, in very challenging technical and operational conditions, are poorly defined.

In order to define basic criteria, and clarify the objectives, Table 1 summarizes some of the key distinctions required of genuine offshore production, and the differences from common forms of coastal aquaculture (Muir; 1998, see also Willinsky and Huguenin, 1996).

Table 1. Key distinctions of offshore aquaculture (Muir, 1988)

Characteristics	Coastal (inshore)	Offshore aquaculture
Location/hydrography	05-3 km, 10-50 m depth; within sight, usually at least semi-sheltered	2+ km, generally within continental shelf zones, possibly open-ocean
Environment	Hs <=3-4 m, usually <=1 m; short period winds, localized coastal currents, possibly strong tidal streams	Hs 5 m or more, regularly 2-3 m, oceanic swells, variable wind periods, possibly less localized current effect
Access	>=95% accessible on at least once daily basis, landing usually possible	Usually >80% accessible, landing may be possible, periodic, e.g., every 3-10 days
Operation	Regular, manual involvement, feeding, monitoring, etc.	Remote operations, automated feeding, distance monitoring, system function

To date, it can be seen that much of the development of offshore aquaculture has been based on cage systems for marine fish culture, and this has been the focus of much of the present volume. However, there may also be wider possibilities, given a primary objective of using offshore resources more effectively for aquatic production, and the features outlined in the previous table. Table 2 outlines some of the potential areas for development.

The present volume has dealt primarily with the first category of such systems, and these systems, based on current technologies of fish and mollusc culture, are most directly accessible on technical grounds. We have made the points at various stages in the text that successful offshore aquaculture systems will have to be seen as composite systems, in which site, environment, holding unit, attachment systems and service/handling units have to be seen as a working, integrated unit, with suitable levels of reliability and workability, and the means to support the aquaculture stocks to the required degree. Continued pressures on environmental control, welfare of stock, control and timely delivery of high levels of product quality, together with market pressures and restricted margins of profitability, impose notable constraints on design and operational features of offshore systems. A common feature of most of these is that economies of scale may be increasingly important – reduced site scale limitations together with the need for substantial overhead costs in terms of high specification service vessels and handling systems, together with a drive towards automation and reduced manual inputs, provide a compelling logic for larger scale systems.

Table 2. Potential areas for offshore development (Muir, 1998)

System	Technical features	Potential locations	Potential development
Containment/ control	Large volume nets, behavioural or other barriers, or constraints; supplementary or complete feeding	Attached or free-moving, surface, sub-surface or variable; most open waters	Large single/multiple cage units with service modules, ship-like structures
Placement/ harvest	High surface areas for attachment/interaction, designed micro-habitats; possible nutrient addition	Attached sub-surface with suitable productivity and protection from other activities	Lines, trays, reef-like structures fished or retrieved/activation released
Release/ recapture	Dispersal into single/serial support zones; natural or modified behaviour concentration and harvest; possible nutrient addition	Ecosystem/oceanographic defined zones with suitable lifecycle requirements, plus accessible harvest points, suitable protection	With higher value relatively static/defined path species, limited predation, seasonal or lifecycle aggregation and effective ownership system
Integrated	One or more of the above in association with other off-shore development, sharing infrastructure, protection, management, etc.	Adjacent/linked with suitable integrating elements, with suitable environments and ownership/partnership agreements	With power stations, OTECs, industrial, urban developments, "ocean parks" multi-function floating complexes

The development of the marine aquaculture sector in W. Europe and in the Mediterranean in particular has been very dramatic, in technical, economic and output terms. As described in the various contributions of the workshop, the development towards offshore mariculture has been variable, depending on the necessity to use more exposed sites for practical use. The Mediterranean region can be seen as a complex system with a number of key constraints, with physically demanding environments, but excellent access to prosperous markets. Much of the present level of development for fish culture originated from N. Europe, in partly via Japan. Salmon producers and suppliers in N. Europe developed many of the practical approaches, which had then been developed more specifically for Mediterranean conditions. The situation has now changed somewhat, in that the Mediterranean fish culture sector is now seen as an important market for systems and applications, and new technologies are as likely to be developed in this context as they are to be introduced from elsewhere. In association with this, the particular environmental and operational characteristics of the region are becoming better understood at a practical level, and we may expect better and more cost effective systems as a result.

The mollusc culture sector has developed far more directly within the region, though it also has opportunities to borrow concepts and technologies from elsewhere. In both sectors we may expect a more active co-evolution of systems and techniques, with open transfer at international level of new developments. The overall competitiveness of the Mediterranean aquaculture sector has in part been due to the use of more favourable environments and relatively simple systems. Future competitiveness, though still likely to be good, if for no other reason than the proximity of good markets, will have to rely more strongly on well developed and managed systems, and the aquaculture sector is likely to have to meet a range of technical and management challenges in the future.

The potential for development within the sector appears to be good, with the additional dynamic of new species development and inter-relationships with system design; however, the consequences of greater supply and reducing demands are important and need to be well understood. As noted by Stephanou (this volume), the need is now emerging for the adoption of more advanced technology for the exploitation of deeper waters, further away from the coast, in exposed areas, including new cage designs, self-contained units, remote sensing/control equipment, new management practices, higher levels of mechanization and more sophisticated mooring systems. More research may also be needed on environmental aspects and on the interactions of offshore aquaculture and the environment, to overcome the existing reservations on their perceived impact.

In the interval over which this text has been edited, a number of developments can be recorded along the directions already outlined. These include the modification of existing systems to improve their capability and reliability in more demanding offshore conditions, the development and testing of completely new system concepts, and the steady progress towards more robust systems with greater degrees of mechanical assistance and information/control systems (see also Muir and Bostock, 1994). A relevant government policy and infrastructure, to safeguard the sustainable future development of aquaculture in an environment of free competition and in harmony with the environment is considered to be of utmost importance. As also note by Stephanou (this volume), it may be appropriate to consider setting up a limited number of new farms in "new" areas, whose establishment may be scrutinized according to a set of technological, financial, managerial and other criteria. As proposed by Turner (this volume) the opportunity to develop an independent process of site and loss evaluation would also be important in developing acceptable standards for installation and design, and better and more detailed climate records would also be important.

We hope that future reviews of this very interesting and challenging subject will demonstrate that the industry and its development and service groups has been able to make clear and definable progress in the creation of safe, cost-effective and efficient production systems which will ensure the continued strength and growth of Mediterranean marine aquaculture.

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