Chapter 29

CURRENT ISSUES RELATING TO ARTIFICIAL REEFS IN EUROPEAN SEAS

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1. INTRODUCTION

European artificial reef research has now been active for about three decades. For much of that time research has been conducted within national programmes, focussing on national or local issues, and has taken place predominately in the Mediterranean Sea. Over the past ten years or so interest in artificial reef technology and science has spread into the NE Atlantic and Baltic Sea with an associated variation in aims and ideas. Reef scientists working in European seas have run projects to assess artificial reefs as tools to protect habitat from destruction from trawling (Spain, Italy and France), promote nature conservation (Monaco, Italy and France), aid fisheries (Italy, Spain, Portugal and France), assess novel materials for reef construction (Italy and UK), investigate habitat use for lobsters (UK, Italy and Israel), for aquaculture (Italy), as experimental sites where habitat parameters are known (UK, Holland and Italy) and as biofiltration structures (Finland, Russia, Poland and Romania). This variety of investigation is one of the strengths of artificial reef research in Europe, the community is diverse and there is great scientific value in establishing collaboration and dialogue with colleagues.

The majority of artificial reef investigations have been, and still are, experimental with Italy dominating the research effort and Spain currently leading the way in the tonnage of reef material deployed, primarily for seagrass habitat protection. Problems associated with old descriptive, qualitative research have led to developments in quantification and comparative studies which have allowed a scientific perspective to be put on artificial reef deployments across Europe. Currently, as part of the EARRN (European Artificial Reef Research Network) initiative, there is an acceptance of the need to standardise some of the ecological methods used. If this is not practicable in some cases then at least the reporting of results will be done in such a way to allow comparison with data gathered elsewhere.

2. ACHIEVEMENTS

Artificial reefs have been built, proving European engineering design and practices, in a variety of habitats. The use of ballast mattresses has allowed substantial reef structures to be placed in areas of relatively soft sediment, providing protection against physical disturbance for sensitive habitats such as seagrass beds. The placing of reef units using cranes and barges has generally been found to be more cost effective than techniques using divers, a move away from the low-budget, pilot experiment style placement of many initial reefs.

European artificial reefs have been shown to develop as successful ecosystems over prolonged periods of time. Five years seems to be sufficient time for a relatively stable community to develop in water other than the most oligotrophic areas of the Mediterranean. Studies documenting biological colonisation of reef surfaces and aggregation of mobile species can be found for both southern and northern European waters. Colonisation characteristics reflect the environment: water quality, larval availability and sedimentation rates strongly influencing the ‘fouling’ communities and these in turn influencing, to some extent, the mobile fauna around the reefs.

The variation in community development in responses to season of deployment and water quality has led to suggestions that reefs and their communities would make effective environmental quality monitoring sites.

Artificial reef structures have been shown to have a positive impact on fishery yields, especially in the Adriatic Sea where long-term studies have led to reef developments being managed and used by local fishermen’s associations. Fin fish attraction has been the dominant feature studied but reefs have provided successful habitats for at least two species of lobster in Europe and studies of lobster habitat requirements have led to interest in lobster ranching. Fishery reefs may be with mixed with mariculture initiatives, the leaders in this field are testing reef designs where wild fisheries, bivalve culture and finfish culture are integrated, a significant move from the traditional philosophy that fishermen hunted and others farmed the sea, and one that may prove to be economically very significant.

Reefs have been used as effective habitat protection devices, so called ‘anti-trawling reefs’, especially in Spain and Italy, effectively enforcing a legal prohibition on trawling in waters shallower than 50 m in the Mediterranean and 100 m in the Bay of Biscay. This regulation exists to protect seagrass meadow from physical damage. Such a law enforcement role has led to a development in artificial reef ‘field’ design, which ensures a maximum deterrent for a minimum cost. Additionally the decrease in trawling has allowed static gear fishermen to re-enter coastal fisheries without the fear of trawls ‘carrying away’ their equipment. Such structures may allow, in the future, an increase in previously undeveloped activities such as mariculture. Economically, there is a far greater understanding of the potential bioeconomic implications of reef development. However, the social and economic impacts on coastal communities are, as yet, undetermined suggesting a future line of enquiry. There is also a need for effective reef management practices to be developed to ensure that harvesting pressure on reef populations, wild and cultivated, is maintained at the optimum level.

It is now recognised that reef habitat design is of great importance if a reef is to be successful. Reef deployment will only achieve it’s targets if appropriate habitat is created. Whilst some deployments are general in concept and can be designed with existing knowledge, (e.g. the idea of increasing habitat variety to promote biological diversity requires a long-lasting material with a wide range of niches (shelter size) this knowledge is generally not yet detailed enough to allow effective design for a single or group of species. One exception to this has been the growth of red coral in artificial caves, here the habitat required was well known and the species valuable and threatened by overexploitation. Where biological knowledge is lacking there is a tendency for human design aesthetics to dominate reef design, it is a cheaper and faster option than developing targeted research programmes but may lead to ineffective reefs. Well intentioned yet poorly ‘designed’ reefs, when monitored and appraised against original expectations, may lead the assessors to conclude that ‘reefs don’t work’ when, with the correct habitat requirement information for the target species the end result would have been successful.

3. ATTITUDES

Within Europe the attitudes of scientists, legislators and administrators to the deployment of artificial reefs varies. Broadly, reefs are much more acceptable in the Mediterranean than northern Europe, possibly reflecting the longer period of activity and greater volume of deployment of reefs in the Mediterranean than in northern seas. This discrepancy is seen in the two international (which includes artificial reef deployment) conventions for the protection of the marine environment that apply to European seas. The Barcelona Convention (Mediterranean Sea) allows for the deployment of artificial reefs within its remit without specific material and deployment guidelines. The OSPAR (Oslo and Paris) Convention (NE Atlantic) is currently (1999) debating a series of artificial reef specific guidelines covering materials, deployment and assessment. Many of the signatories to the OSPAR Convention appear to feel that artificial reef deployment has a such a potential ill effect on the marine ecosystem that international specific controls are required whilst other coastal developments, such as harbours, jetties, breakwaters, dikes and artificial islands do not. This attitude seems somewhat illogical and conflicts with that of southern Europe as well as opinion in Japan and the USA, the two most active countries in reef deployment. Much of the concern relating to reefs appears to be driven by a desire to prevent the use of oil and gas platforms as artificial reefs in the North Sea. The arguments are based on philosophy and opinion rather than data as research into the topic is limited and results relating to fish presence and behaviour are only just starting to become available.

Scientists and environmentalists concerned about fisheries often raise the issue of ‘attraction versus production’, artificial reefs attract fish, so facilitating commercial catches but (it is asked) do they contribute to a net increase in commercial stock biomass? If reefs cannot be proven to benefit commercial fish populations by significantly increasing numbers they are considered by many to have failed. This requirement ignores the almost insurmountable scientific difficulties of proving that reefs increase stock numbers; conventional fisheries monitoring techniques using catch data and acoustic survey techniques find assessment of stock biomass difficult, if not impossible (the recent cod stock collapse off eastern Canada is a good example of how difficult it really is). Given the current small scale of European experiments to date which have relatively small numbers of fish in association with the reefs the task truly becomes impossible, especially in stocks that visit reefs for a short period of time. However, indicators of biomass increase may be obtained by assessing factors such as growth rates of fish around reefs, fecundity of reef associated fish and the survivorship of juveniles around artificial reefs. Physiological studies of the possible bioenergetic adavantage provide by a fish gaining sheltering from currents may also be worthy of study. Much of this work remains to be addressed.

This expectation for artificial reefs to be net producers of commercial fish biomass often ignores the role that hard habitat plays in a fish’s life history and that not all commercial fish species (for example many flatfish or pelagic species such as tuna) utilise rocky habitat. Artificial reefs are not a 'cure all' solution for fishermen and fish stock managers.

There are benefits of habitat provision for commercial fishery species other than fish (lobster, possibly edible crabs, bivalve molluscs and cephalopods) and several essential, subtle, elements of the function of an artificial reef within a coastal fishery which may produce benefits which are hard to quantify: the provision of habitat for a wide variety of prey species; shelter for the juveniles of exploited species from trawling and possibly some natural predation; protection of nursery habitat (e.g. seagrass), from physical disturbance and provision of spawning structures for those species which do require a hard substratum on which to lay their eggs. In some cases the value of a reef in the production of new biomass can be inferred to some extent but absolute proof evades scientists at present because of the small scale of experimental structures.

The existence of new hard substrata (a reef) that is colonised by a variety of species suggests that additional settlement beyond that which is possible on the existing natural habitat has occurred. This must be balanced with the loss of biota on and in the seabed on which the reef has been placed. In the case of commercial species requiring hard habitat, such as lobsters, any increase in the numbers of individuals will be proportional to the habitat's complexity and the availability of shelter and food. The impact on the fishery will be related to the scale of an artificial reef, to have a realistic effect structures need to be much bigger than at present.

Similar arguments can be put forward for fish, if artificial reefs provide shelter from predators (including trawl fishing), protect or provide juvenile habitat and/or enhance food supply then juvenile/adult survivorship may be improved and/or adult fecundity increased. Increased survival or increase in egg numbers will only have a measurable effect when the scale of this effect is increased so that it becomes demonstrable in fisheries terms, and means that structures will have to increase in size before final proof can be established.

It is noteworthy that all European reefs are well below the size of large reefs (around 50,000 m^3) used by the Japanese (Stone *et al*., 1991), a country which Simard (1995) estimates will have modified an estimated 12% of its fishing grounds by 2000 to increase production of 'seafood'. Here fishery and aquaculture managers are confident of the positive effects of artificial structures, applying a pragmatic judgement of catch levels over time rather than requiring statistical proof of new biomass production.

European artificial reefs are proving to be quite a complex and subtle technology and are capable of doing much more than just aggregating commercial fish for harvest.

4. REEF DEPLOYMENT

There are some inconsistencies of approach and attitudes to reef deployment when compared to 'conventional' coastal engineering in Europe. In some areas of northern Europe engineering works to build coastal defence structures, harbours and dikes (some of which have reef-like attributes) appear to be, in general, acceptable to environmental lobby groups and local government but the construction of artificial reefs which introduce hard habitat onto a previously sedimentary seabed are, in some countries, often considered to be undesirable. Factors such as an increase in local biodiversity and the potential for protecting sedimentary seabed from trawling and dredging being totally discounted in the apparent political desire to maintain the seabed in a supposed 'pristine state' (apparently unaware of the physical impact that trawling and dredging has in coastal waters and the negative impacts of so-called land reclamation).

The legal requirements for permits and permissions vary widely across Europe, no two countries have the same approach to licensing reef deployment. Some European standardisation, at least in overall licensing policy and requirement would be welcomed by reef scientists and developers. Positive policy statements relating to what constitutes an artificial reef deployment so that no doubt was left in the minds of those who see reefs as a disguised disposal option, coupled with a definition of an artificial reef, possibly based on the EARRN model (a submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef.) would be welcomed by the European artificial reef scientific community who do not wish to see the term 'artificial reef' used for something that is truly a waste disposal option.

5. REEF MATERIALS

Concerns are often voiced is that reef programmes using 'waste' or 'recycled' materials (in the USA 'materials of opportunity') are, by definition, toxic waste disposal in disguise. Assumption of knowledge, often erroneous, is frequently evident in these cases and European reef scientists are working to clarify matters. Tyre utilisation as a reef material provides a classic example. Tyres are often used as a material for artificial reef construction outside of Europe, the Philippines and Australia being two countries where tyres form an important component of reefs. In these countries tyres are seen as being a durable material with the economic benefit of being inexpensive and providing a positive environmental benefit as habitat for commercial marine species. In terrestrial situations scrap tyres can have rather negative effects often seen when tyres clog land-fill sites, hold water for breeding mosquitoes or release toxic fumes when burnt at low temperatures. In Europe tyres (or leachates from tyres) are considered by many to be toxic in the marine environment (no such definitive proof exists in the published literature; for review see Collins *et al.*, 1995) and, at present, it seems unlikely that a licence/permit to deploy a large scale tyre reef would be given. This surety of acquired knowledge (based on perception rather than information) ignores the fact that tyres are the most frequently used fender material in ports and, where left submerged recruit fouling communities. Tyres used on roads wear by producing dust particles which enter our rivers and estuaries in run-off and, apparently, have no obvious toxic effects. If tyres are environmentally acceptable, and can be deployed as an effective, targeted artificial reef (both points need to be clarified in an European context) then opportunities exist to re-use a material that is a problem in the terrestrial environment in a positive fashion in the marine environment. Experimental research has recently started in the UK (1998) (K. Collins and A. Jensen pers. comm) to assess the impact of a tyre reef in the marine environment.

European and Israeli workers have developed expertise in the environmental assessment of waste materials such as cement stabilised PFA (UK, Italy and Israel) and dredged harbour muds (Italy) for reef construction and European experimental protocols exist for reef material trials and assessment (Jensen, 1998a). The utilisation of environmentally acceptable materials has the potential to lower reef construction costs, reduce pressure on conventional terrestrial disposal methods and lessen environmental impact of quarrying to produce ‘natural’ materials for reef construction.

European experiments with the re-use of materials such as Pulverised Fuel Ash (PFA) have shown (as did the Coal Waste Artificial Reef Program in the USA) that such materials can be stabilised with cement and used in artificial reef structures and support biologically indistinguishable communities when compared to control surfaces. The adoption of high flyash content cement by the Japanese (Suzuki pers.comm.), who have consistently promoted use of ‘prime materials’ (cement, steel and rock) against ‘materials of opportunity’ in reef construction confirms the belief of some European reef scientists that benign waste materials are worthy of evaluation as components of artificial reefs. A ‘high ash’ cement (35%

flyash) has also been used successfully in coastal defence breakwaters (Díaz Rato and Martiní Unanue, 1998), a high energy environment. Work focussing on the re-use of material in reefs always attracts criticism from those convinced that the project is just an excuse for dumping waste in the marine environment. Within the European reef community the emphasis behind such work is two-fold; the acceptance of economic reality that artificial reefs are expensive to build and that re-use of materials with a low value may make some programmes cost effective and that; in some cases, re-use can provide a positive benefit to the environment as a whole, effectively recycling materials that cause problems in the terrestrial environment into materials that are benign in the marine environment. It is the intention of the European artificial reef community that re-use of acceptable materials should only proposed where the requirement for an artificial reef is proven and that the material can be used within the design parameters. The creation of so called artificial reefs as a disposal option where any other outcome is, at best, secondary is not acceptable to the European artificial reef community.

Other issues have impinged on the consideration of re-using materials for reef construction. One such example is the negative publicity surrounding the deep sea disposal of the Brent Spar Oil storage facility (made to store oil and constructed from concrete) which has been used to colour any logical consideration of the re-use of the steel jackets from North Sea oil and gas production platforms (made of steel and designed as a lattice to support the 'topsides' of platforms. Lattice structures are frequently used in Japanese fish reefs). Discussions should be focused on whether there would be value in using these large objects to establish fishing lanes to exploit fish attracted to the steel jackets or indeed as a method of excluding trawlers from 'no-take' areas which would act as reserves for fish and also benthic species whose populations have been affected by the physical disturbance of trawling. The benefits of reducing fishing pressure in this way require evaluation which can then be entered into the decision making process. At present it appears that this is unlikely to happen on a significant scale, as the political debate is taking precedent over the provision of scientific data.

In a similar vein, the use of artificial reefs as tools to 'mitigate' environmental impacts of coastal developments are looked upon with suspicion. Many, although not all, are concerned that artificial reefs for mitigation purposes will reduce the pressure on cynical developers to fully assess and minimise any negative impacts of coastal projects when building a 'mitigation reef' would be a cheaper option. Regulation, guidance and a holistic approach to coastal zone management would minimise this risk.

6. PROGRESS

The scientific community has been making progress in assessment of artificial reefs in several areas of coastal zone management, the dominant success being that of seagrass habitat protection in the Mediterranean Sea. The Spanish lead in this area at present, creating efficient deployment patterns to minimise trawler intrusion into the sensitive habitat (workers in Sicily report re-colonisation of seagrass in protected areas which suggests that reefs may have a role to play in habitat remediation as well as protection from further damage (S. Riggio pers. comm.)). An interesting result of habitat protection from illegal trawling has been the effective division of the fisheries resource, with the decrease in the threat of damage to equipment, static gear fishermen are again exploiting the seagrass habitat. These fishermen, generally artisanal in scale of effort, are using techniques that are more discriminating in their catch and less physically damaging than trawling. Income from fishing can now be generated by coastal communities using fishing areas in their locality rather than trawlers from a distant port. This has socio-economic consequences beyond the scientific habitat protection issues.

The use of artificial reefs in such a habitat management role has wide application throughout the Mediterranean where fisheries legislation and enforcement is unable to prevent destruction of seagrass habitat by trawling. There does seem to be a role for artificial reefs, or possibly a much simpler structure, in the enforcement of suggested ‘no-take’ zones in northern Europe. These would provide simple, effective and positive ‘on-the-ground’ enforcement, ensuring damage to the nets of those who entered such areas illegally, rather than a later legal prosecution which would be the outcome of the use of ‘black box’ navigation and winch activity recording equipment. Design to maximise enforcement would be unlikely to exclude elements that would provide some biological benefits beyond protection of habitat.

Italian workers are showing how reef structures can be used to promote aquaculture, using the reefs as surfaces for mussel settlement and growth, protection for fin-fish and lobster cages and anchor points for conventional suspended bivalve culture. They have also pioneered the use of PFA for settlement and on-growing of piddocks, a high value, burrowing bivalve. This combination of uses for reef technology is novel and one that shows much promise for the future. As aquaculture develops the availability of ‘traditional’, sheltered inshore sites that can be used without significant environmental damage is decreasing, forcing new entrepreneurs to consider moving facilities into less sheltered waters. Artificial reefs may serve as a focus for rope, cage or seabed culture of bivalves and fish; the natural reef biological community may act as a partial ‘sink’ for excess food flushed from fish cages, possibly also providing habitat for labrids (which may help to control fish lice) and/or lobster. There is considerable scope for developing such structures, collaboration between scientists, mariculturalists and engineers will be essential.

The success of experimental reefs in providing lobster habitat in Israel, UK and Italy has raised the possibility of developing habitat for lobster ranching, either creating entirely new lobster habitat or augmenting existing habitat to provide a full range of shelter sizes. Here the habitat requirements of the target species must be well understood if design is to maximise stocking density. Much of this information is lacking, even in such a well researched species as *Homarus gammarus*, the European clawed lobster, less is known about spiny lobsters.

The value of purpose designed habitat construction can also be seen in the artificial caves off Monte Carlo into which red coral ‘stubs’ have been transplanted and allowed to grow. This ‘farming’ of a valuable, overexploited and threatened Mediterranean species is an example how provision of habitat by an artificial structure may offer opportunities for both conservation and harvesting.

Italian reef scientists (among others) have used reefs to promote local fisheries, and fishermen in the Adriatic are now initiating reef development to promote catches in their area. At a time when dissemination of research results to the end user are of political importance in the assessment of marine technologies, this serves as a good example of how investigation into fisheries management can result in an appreciable positive result for the fishermen.

7. FUTURE

European reef scientists have not, generally, succeeded in communicating their results to a wider audience outside the scientific community. If reefs are to become accepted management tools within Europe the scientists and economists working within the field will have to become more proactive in informing managers, administrators and the public what function artificial reefs can fulfil in our coastal zones. Currently it seems that there is potential for mariculture, fishery management, habitat protection, nature conservation, coastal habitat mitigation, ranching and tourism. The latter is a new feature to the European reef research agenda, brought about by realisation that artificial structures may be used by surfers, SCUBA divers and anglers to create conditions suitable for their recreational activity. Whilst surfing reefs are always likely to remain specialist structures to promote wave breaks (possibly integrating with coastal protection schemes) the concept of multipurpose artificial reefs that would serve the need of commercial fishermen, anglers, divers and nature conservation is an attractive one from an economic and social view and a considerable design challenge for artificial reef scientists and engineers.

Effective reef design is one of the research topics of the future. Understanding the requirements of species with commercial and conservation value will become more important as managers develop a holistic approach to fisheries and nature conservation within the coastal zone. Using reefs to manage habitat could be an integral part of the whole process. Reefs could be designed to encourage target species to become resident, feed and/or reproduce, deter/encourage specific fishing techniques and provide additional income from tourism. It is this latter aspect that has been so well developed in the USA which remains almost unknown in Europe. The socio-economic benefits of such structures have yet to be assessed (although a start has been made) but diversification of coastal fishing community income sources appears, on a general level to be a sensible goal.

The problem of scale and functionality of artificial reefs has yet to be addressed. It has become obvious as discussion within EARRN has progressed that as yet we have no idea how large an artificial reef needs to be if it is to function as a self sustaining ecosystem. We are aware that the European structures have not reached that scale as yet. The Japanese have an arbitrary volume figure (2500 m^3) below which they consider a fishing reef to be ineffective and a volume of 150,000 m^3 for a regional reef development (Simard, 1995). Research to establish the effective size of artificial reefs to accomplish a specific aim will be needed soon.

In the UK it has been made clear by the regulatory authorities that any reefs deployed for other than experimental purposes will have to be multipurpose. There is significant interest in blending habitat provision with new ideas in ‘soft’ coastal engineering, ‘offshore’ reefs which have some portion submerged at all states of the tide. Whilst this may have limitation for some fisheries applications, as these structure move offshore the potential for significant habitat engineering combined with coastal protection will increase.

Currently artificial reef science continues to develop in Europe. Greece deployed their first major artificial reef in summer 1998, Denmark is considering artificial reefs seriously for habitat replacement, there is considerable interest in the UK and Norway in re-using steel jackets in a positive manner in the North Sea. There is renewed interest in France in developing artificial reefs. In the southern Mediterranean Tunisia has an interest in artificial reefs and in the Black Sea, Romania has developed artificial structures as biofilters to help in solving pollution problems. The established reef research countries are also pushing ahead with new ideas for aquaculture, habitat design and protection, tourism and the use of reefs as test beds for scientific experiments. All of this activity is aimed at producing a greater understanding of how artificial reefs can be used as an integrated management tool within the European coastal zone. It its final report to DG XIV the EARRN (Jensen, 1998b) has outlined research topics (Table 1) important in future research proposals.

Table 1. Summary of future research topics recommended by EARRN

Aquaculture	A1 Development of reef based aquaculture systems for coastal waters A2 Economic and social analysis of developing coastal mariculture A3 Development of equipment and methodology
Ranching	R1 An understanding of the habitat requirements R2 Reef Design R3 Economic appraisal R4 Legal assessment
Biomass Production	BP1 Survival of juveniles BP2 Linked to BP1 would come a consideration of food availability and value BP3 Energetic advantage BP4 Scale of habitat
Fisheries	F1 Fishery exploitation strategies F2 Protection of habitat F3 Fishery resource partitioning F4 Impact of a reef on existing fisheries
Reef System	RS1 Understand why reefs prove attractive to fish and other mobile species RS2 Predicting reef performance RS3 Energy flow through a reef system
Monitoring and Appraisal	MA1 Evaluation of socio-economic and technical performance MA2 Prove proposed EARRN monitoring programme in the field MA3 Appraisal and assessment of physical, biological and chemical parameters around artificial reefs
Recreation and Tourism	RT1 Design. Reef design will have to maximise the needs of the user community RT2 Socio-economic benefits
Materials	M1 Use of scrap tyres in artificial reefs. M2 Use of shipwrecks. M3 Re-use of steel jackets from oil production platforms M4 Development of concrete mixtures
Reef Design	RD1 Design to prevent trawling and/or encourage other fishing methods. RD2 Design to promote availability of food species (sessile or mobile). RD3 Design to provide specific habitat. RD4 Design to promote tourist benefit
Nature conservation	NC1 Biodiversity development. NC2 Scale of reef area – how big to have a measurable impact? NC3 Environmental assessment

Many of these aspects interrelate, any single research project would involve a variety of differing topics. Research projects in the future should seek to produce quantified, comparable data that will lead to the construction of planned, targeted, designed and assessed artificial reefs. The development of such structures should involve socio-economists, engineers, scientists and local communities and users as well as those with responsibility for coastal management. For European artificial reefs to progress researchers must strive to reveal how reef systems work and how they may be manipulated to provide desired biological and socio-economic end-products. Artificial reefs are starting to be used as tools in Italy and Spain, but there is some way to go before reefs are accepted throughout Europe as effective and responsive tools in habitat management. The key to acceptance is the effective dissemination of knowledge gained through good quality research.

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