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Review

Return of the native – is European oyster (*Ostrea edulis*) stock restoration in the UK feasible?

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Abstract – Throughout much of the UK and in Europe generally the native oyster is in a severely depleted state in the wild. In order to address and potentially to reverse this situation *Ostrea edulis* was designated as a named species in the UK Biodiversity Action Plan as part of a national commitment to the International Convention on Biodiversity. Amongst other initiatives, some of which are summarised in this paper, a feasibility study was carried out to evaluate all the factors, including an economic assessment, relevant to a programme of stock restoration in the UK. The study showed that there is a considerable body of data on the biology, ecology and distribution of *O. edulis* to inform restoration projects. Appropriate legislation is in place to allow for restoration. Non-marketable costs and benefits were estimated. They provide an idea of the high value that may be placed on biodiversity aspects. Nevertheless, this study also shows that stock restoration can be commercially viable if fishery prices and yields are sufficiently high. Restoration efforts and associated studies elsewhere have shown the potential for success of native oyster stock regeneration, especially in disease-free areas. For these, there is a very strong element of re-creating and conserving an ecological resource. The relaying of cultch is seen as an essential component of a successful oyster restoration programme and the use of sanctuaries is generally considered beneficial. The loss of the standing stock is a limiting factor and re-stocking is an effective strategy. There is a basic genetic similarity of wild European *O. edulis* populations such that the source of stocks is not critical. There are some problems with hatchery rearing from these, but using breeding ponds or importing part-grown oysters are viable alternatives.

Key words: Oyster / *Ostrea edulis* / Restoration

1 Feasibility report

In October 2004, CEFAS were commissioned by Defra and Seafish to produce a report on the feasibility of restoration of native oyster stocks in the UK. The final report is available electronically (Laing et al. 2005). The study includes biological, technical and economic aspects as well as examining the legislative framework and lessons learnt from other attempts at restoration elsewhere. The 100-pages report contains 74 conclusions and 26 recommendations. A summary of the main findings, many of which are applicable to stock restoration of this species elsewhere within its native range, is given in this paper.

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2 A species in decline

There has been a dramatic reduction in native oyster stock abundance in the UK and in Europe generally since the middle of the last century. This decline is illustrated in Figure 1 by using data from fisheries in England and Wales. This is attributed mainly to over-exploitation. The species is rapidly fished out because it is relatively long-lived and reproduces sporadically. In this respect it should be noted that a restored resource sustaining a fishery at the historical harvest level is unrealistic, because: (1) harvest probably exceeded biological production for much of the recorded history of exploitation (harvest levels were maintained by periodic exploitation of beds until they were exhausted, followed by the development of fisheries, following a similar pattern, elsewhere); and (2) maximum production, a desired end for fishery support, occurs at approximately half the maximum (virgin, unexploited) biomass, and, thus, can only be achieved with disruption of

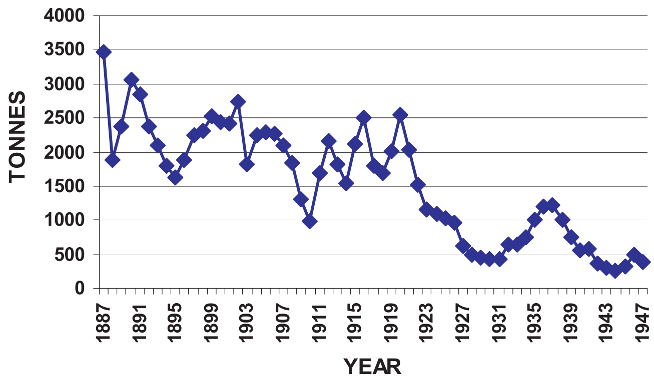

Fig. 1. Native oyster landings (tonnes) in England and Wales (1887-1947).

the virgin complex community structure. Native oyster beds form a biotope, with many associated epifaunal and infaunal species. Loss of this habitat has resulted in a major decline in species richness in the coastal environment. The demise of flat oyster fisheries around the British Isles was not caused solely by over-fishing pressure. The decline in many former fisheries was due in part to a series of unusually cold winters in the 1930s and 1940s (Crisp 1964), which resulted in severe oyster mortalities, especially on North Sea coasts.

3 Factors affecting attempts at restoration

3.1 Pests

The introduction of exotic pests created additional problems in many oyster-producing regions. The slipper limpet (*Crepidula fornicata*) is particularly harmful, competing voraciously with the indigenous oysters for space and planktonic food (Walne 1956). The slipper limpet is a recognised serious pest species in both the UK and France, with six papers at the 8th International Conference on Shellfish Restoration dealing with this problem species. There is also a species of introduced oyster drill in the UK, the American whelk tingle (*Urosalpinx cinerea*) that could potentially limit efforts at restoration.

3.2 Water quality

Declining water quality due to municipal and industrial pollution also had a detrimental impact on oyster stocks. In addition, TBT (tri-butyl tin) anti-fouling paints used on ships and leisure craft in the early 1980s caused stunted growth and probably affected reproductive capacity (Thain and Waldock 1986; Lee 1991; Axiak et al. 1995).

3.3 Disease

In the UK, controls (Molluscan Shellfish (Control of Deposit) Order 1974) in force at the time failed to prevent the introduction of the very serious disease organism *Bonamia ostreae*. This was first recognised in Europe in Brittany in 1979 and first diagnosed in England in October 1982, following an investigation into an unexplained mortality in the creeks of the rivers Fal and Helford in Cornwall (Bucke and Feist 1985).

The disease spread through movement of infected stock and it now occurs in most of the major oyster producing areas of the south and east coast of England. In the rest of Europe, *B. ostreae* is known to be also present in parts of France, Spain, The Netherlands and Ireland. Norway and Denmark have areas that are declared free of this disease organism.

Where present, it is perhaps the most important factor limiting production in managed wild and cultivated stocks of native oysters. It has had a significant negative impact on *O. edulis* production throughout its distribution range in Europe. Mortality rates in excess of 80% have been noted. The effect this can have on yields can be seen in the drastic (93%) drop in recorded production in France, from 20 000 t per year in the early 1970's to 1400 t in 1982 (Lapegue et al. 2004). Production in France has since remained at this lower level.

B. ostreae has attracted a lot of attention from the scientific community. Around 1 in 5 of approximately 600 papers and reports on *O. edulis* published in the last 20 years have dealt with some aspect of it. However, we still know relatively little about the biology and life cycle of *Bonamia ostreae*, although some epizootics are well documented (e.g. Cranfield et al. 2005).

The only other serious disease affecting native oysters in Europe is Marteiliosis, caused by the paramyxean parasite *Marteilia refringens* (Grizel et al. 1974; Berthe et al. 2004). This brings about serious recurring mortalities with a significant negative impact on the local industry. Marteiliosis does not occur in the UK.

4 Is restoration feasible?

4.1 Biology

O. edulis has been studied for many years and the biology, ecology and distribution of this species are generally very well known (Yonge 1960; Waugh 1972; Walne 1974; Hutchinson and Hawkins 1992; Spencer 2002; Gosling 2003). There is therefore a considerable body of data available on the species to inform restoration projects. It is generally agreed that there is a basic genetic similarity of wild European *O. edulis* populations (Saavedra et al. 1993, 1995) so that where stocks from other areas are introduced the source is not critical, although some genetic differentiation can be identified with microsatellite markers (Launey et al. 2002; Sobolewska and Beaumont 2005). Great care would still need to be taken to prevent loss of genetic variability in programmes relying on hatchery reared oysters (Saavedra 1997; Bierne et al. 1998). It is very clear that the disease bonamiasis is the biggest biological factor limiting the potential for stock restoration. This is notwithstanding the fact that some degree of resistance to this disease has been achieved (Naciri-Graven et al. 1998; Launey et al. 2001; Conchas et al. 2003; Culloty et al. 2004), as survival is not extended beyond one or two years (Cigarria et al. 1995). Pests and competitors are other important limiting factors.

4.2 Technical aspects

The loss of the standing stock is a limiting factor to restoration in that there are insufficient broodstock available for replenishment of grounds. The habitat has also become degraded and is less suitable for recruitment. Re-stocking strategically located areas with oysters is therefore an effective strategy and the technical aspects of hatchery rearing of stocks to enhance natural populations follow standard procedures, although there are some problems associated with the hatchery process and not all batches are successful. Alternative methods, particularly breeding ponds, are available and can be used successfully. Many studies view the relaying of cultch as an essential component of a successful oyster restoration programme, and the use of sanctuaries is generally beneficial (Gerber et al. 2003; Roberts et al. 2003). Permanent sanctuaries permit the long-term growth and protection of large oysters that provide increased fecundity. Closing off a reef may also result in long-term secondary benefits in lieu of oyster harvest revenues.

4.3 Legislation

There are various legal aspects relevant to oyster stock regeneration. Primarily, there must be a high measure of protection of and control over restored stocks to prevent inappropriate exploitation. Legislation such as this dates back many years. It was first introduced in France as early as 1750. In the UK, native oyster fisheries are managed by a mixture of national (Sea Fisheries (Shellfish) Act 1967) and local (byelaws) legislation. Many of the principal oyster fisheries in England and Wales are managed through Regulating or Several Orders (the latter extinguish the public right to fish). There is a national closed season (14 May to 4 August) to protect native oysters during the spawning season, though a dispensation exists for cultivated stocks. Other controls are designed to prevent the introduction and spread of disease. These are based on EU legislation (Commission Directive 91/67/EC) that relate specifically to bonamiosis and marteiliosis. There are also controls to prevent the introduction of alien species that may predate on or compete with and displace native species. Water quality is also important and there is a raft of legislation surrounding this issue. There is new legislation conferring conservation status to sites and this may provide a means of protecting stocks where there is no intention to exploit them commercially. There is a very strong ecological argument for native oyster stock restoration. Various reports have identified native oyster beds as a nationally important marine feature in decline and under threat of further deterioration (e.g. Vincent et al. 2004). Where there is an environmental imperative to restore and sustain stocks this could be achieved in areas designated as such under conservation legislation although the regulatory framework also exists, and has done for some time, for allowing for an increase in production of managed and/or cultivated stocks of native oysters.

4.4 Economic aspects

A Cost Benefit Analysis (CBA) considered the benefits and costs associated with a native oyster restoration programme that can be measured through market transactions. This study shows that non-marketable costs and benefits can be estimated. They provide an idea of the high value that may be behind non-marketable goods (e.g. biodiversity, environmental services), making restoration of native oyster beds as an ecological resource worthwhile. Nevertheless, this study also shows that there are reasons for stock restoration on an economical basis if prices and yields are sufficiently high. This would probably need to be accompanied by an education programme, to restore lost markets. Results of the CBA show that the best option in economical terms to carry out a native oyster restoration program would be to import half-grown native oysters from an area free of disease.

4.5 Experience

Attempts to improve native *O. edulis* fisheries are not a new idea, and date back to the eighteenth century. These have taken the form of both scientific studies and the introduction of legislation to support the industry by allowing protection and management of the remaining beds (Korringa 1946).

Pond culture was the method that was developed originally in early attempts to stimulate production, following the decline of native oyster stocks in the late nineteenth century. Ponds were built near to high water spring tides, filled with seawater and then isolated for the period of time during which the oysters are breeding naturally, usually May to July. Collectors were put into the ponds to encourage and collect the settlement of juvenile oysters. There is an inherent limited amount of control over the process and success is very variable. In France, where spat collectors were also deployed in the natural environment, it was relatively successful and became an established method for a time. In the UK, spat production from ponds built at that time was insufficiently regular to provide a reliable supply of seed to the industry and the method was largely abandoned.

In 1947 the UK Ministry of Agriculture, Fisheries and Food established a Shellfish Research Station at Burnham on Crouch, Essex with the aims of elucidating the causes of the decline of the east coast oyster fisheries and establishing the conditions necessary for the revival and restoration of oyster beds. An extensive scientific programme to study the biology of the oyster, extend cultivation and expand stocks continued for the next two decades. Amongst the work carried out were studies on factors affecting the spawning and settlement of oysters, growth of settled spat, adult distributions, the effects of cultivation practices, pests, diseases and competitors. Much of this work is relatively unknown, but the original reports are extant in the Cefas library (e.g. see Knight-Jones 1952) and form an extensive knowledge base on which any future regeneration projects could be based.

The 1960s and 70s saw the development of hatchery techniques (Walne 1974) for *O. edulis*. Hatchery rearing of native oysters was never made entirely reliable, although it can be achieved with care. Survival rates of up to 90% through to metamorphosis are possible with some batches of larvae, although this figure can be much lower than 50% with others. It has a limited application to restoration of oyster beds, due to the large numbers of seed oysters that would be required, although hatchery rearing of scallop seed has been used successfully in the enhancement of the scallop fishery in the Bay of Brest (Boncoeur et al. 2003) and in France genetic improvement programmes are based entirely on hatchery production (Lapegue et al. 2004).

More recently, restoration efforts and associated studies in disease-free areas have shown the potential for success of native oyster stock regeneration. Valuable information on the factors affecting success has been gathered to inform initiatives elsewhere. Such efforts in Strangford Lough in Northern Ireland (Kennedy and Roberts 1999), Spain (Perez Camacho 1987; Guerra 1998) and in Limfjord in Denmark (Dolmer and Hoffmann 2004) are of particular note. In Denmark landings have increased from virtually nil in 2000 to over 900 tonnes in 2003.

There are also valuable lessons to be learned from the practical experience of an extensive native oyster restoration programme in Chesapeake Bay (e.g. see Brumbaugh et al. 2000; Mann 2000; Hicks et al. 2004; Mann and Evans 2004). Not least of these is that all stakeholders can and must work together to develop an effective Oyster Management Plan.

All of the above combine to show that restoration of native oyster stocks is indeed feasible.

5 Discussion – the prospects for restoration

It seems that it is very unlikely that market forces will drive restoration. If this were possible it would probably have happened already. The legislation framework exists to support enhancement through fisheries but annual production of native oysters in Europe has been static, at an average of around 5.5 thousand tonnes, for the last 18 years (FAO data). Native oysters occupy a niche market and the Pacific oyster is now the species of choice for farmers. Mussels have also become a predominant species in the UK, accounting for almost 96% of cultivated production by weight.

All the major native oyster stocks in the UK are in areas affected by Bonamiasis. There is evidence to show that disease-resistant stocks can be developed (Naciri-Graven et al. 1998; Launey et al. 2001) and have possibly arisen by natural selection at some sites (Cigarria et al. 1995; Conchas et al. 2003; da Silva et al. 2005). However, this has only been to an extent that will allow oysters to live for one or two years longer in the presence of disease. They will still succumb eventually, although their contribution to the reproductive effort will be increased and this may well be significant.

Overall, prospects for restoration in the UK are considered to be more likely to be successful away from areas affected by pests and diseases, except that these will tend to be more northern sites where seawater temperatures are lower and so growth rates are slower and spawning is less frequent and reliable.

There is increasing interest in biodiversity, and in the UK the native oyster is a biodiversity Action Plan Species. Perhaps the best chance of restoration of native oyster beds is for re-creating and conserving an ecological resource in order to re-establish a biotope that was once common and covered wide areas of the seabed. There are parallels here with the approach to restoration of *Crassostrea virginica* stocks in Chesapeake Bay (see above for references). Depending on the provisions, the proposed new UK Marine Bill could assist the potential for oyster stock restoration, particularly by the creation of protected areas. There is good evidence that such areas will then benefit recruitment to adjacent fished areas (Beukers-Stewart et al. 2005). Against this, native oyster stocks, although at historically very low levels, are currently relatively stable and perceived to be at a lower risk of extinction than many other species and habitats.

The many water quality improvements in recent years can only increase the prospects for restoration. The use of TBT-based anti-fouling paints on small vessels was banned in 1987. Oyster growers believe this ban is helping to reduce the adverse effects on oysters. A biological study of the Crouch Estuary confirmed that the population of native oysters was increasing since the reduction in TBT concentration in the water column (Rees et al. 2001).

Restoration of native oyster beds is a very long-term commitment and perhaps the major obstacle is finding the appropriate multidisciplinary funding. The CBA identified site protection as a considerable proportion of the total cost and monitoring, which is essential to assess and direct any programme, is also expensive.

In conclusion, the CEFAS report has shown that native oyster stock could now start somewhere, perhaps with a pilot project. To have any chance of success there needs to be a local management plan involving all stakeholders.

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