CHAPTER 11

THE CONCLUSIONS AND DISCUSSION

The main body of this thesis has presented evidence to show how shells of the flat or European oyster exhibit macroscopic variations that can be demonstrated spatially and temporally on both an intrasite and intersite level. In particular, differences in size and infestation patterns can be related to the place and period of origin. These results are now followed by a discussion of the implications of these findings not only for our understanding of the natural history of oysters but also for archaeological interpretation through the contribution they make to our understanding of diet, shellfish exploitation, oyster trade, and the evolution of oyster farming in Britain.

In this final chapter the substantive results of this thesis can be reviewed under two main headings: the natural history contribution, and the contribution made to archaeology. Understanding the natural history of oysters through the synthesis of published information and the original analyses presented here is a prerequisite for an assessment of the contribution made by oysters to archaeology. In particular, the changes observed in oysters through time must be considered in the knowledge that many natural and man-made factors could have influenced those changes. Factors such as overfishing, salinity variations, changing sea levels, diseases, unexplained mortalities, climate, pests and predators, and recent environmental changes will be discussed here.

From a biological standpoint, the evidence provided by such an extensive analysis of data from the physical examination of both modern and archaeological oyster shells, together with the collation of data from documentary sources, highlights changes taking place in oyster shells in the rapidly changing environment of today.

From an archaeological viewpoint, this is one of the few large-scale studies for the movement of bulk items and for the different uses of oysters through time. For the first time it has been possible to demonstrate an exchange in foodstuffs archaeologically: home and overseas trade in oysters can be considered. Additionally, to facilitate an understanding of the level of exploitation represented by the samples of oyster shells from different sites and periods, I have drawn up and presented here a series of models that show how it is possible to to derive the method and intensity of oyster fishing from the basic information recorded from the shells.

The chapter finishes with a consideration of the achievements of the research project and a discussion of ways in which it might be developed in the future.

NATURAL HISTORY CONTRIBUTION

In Chapter 2 the biology and natural history of oysters were described in some detail where they related to the observable differences in the appearance of oyster shells. Chapter 9 showed how the size variations of oysters could be related to both geographical location and historical period. Chapter 10 demonstrated that infestation patterns also exhibited spatial and temporal variations. In this concluding chapter, the reasons accounting for macroscopic variability in the shells are further explored and are mainly considered to be the result of the level and mode of exploitation plus the effect of long-term or widely felt climate change over the centuries. However, while considering the possible causes of variability, it must not be forgotten that many other interrelated factors, working on a very local scale or over a short-time scale may have affected the abundance and quality of oysters and their importance in the economy.

One of the classic explanations for a decrease in shellfish size in middens is overfishing (Evans, 1973). It is logical to consider that fishing activities directly affect the oysters. The possible effects of exploitation may not be so straightforward - overfishing may not always lead to a reduction in size for age although in many cases it may do so. Although no comparable work on shellfish populations is known at present, it is known that killing fish at a mature age and of a large size can artificially accelerate the process of natural selection so that the population matures at an earlier stage or produces fewer of the large fish which are normally captured; while in fishing for "sizes well before sexual maturation, fast-growing fish which minimise the length of time during which they can be caught before they can reproduce would be at an advantage" (Law, 1991, 35). Law also states "that fishing does not inexorably push a stock towards smallness".

However, a reduction in the numbers of oysters available, as opposed to a reduction in the size of oysters, has been attributed mainly to overfishing in the past. In the mid 19th century the Colchester oyster fishery alone produced seven million oysters a year and at Billingsgate market in London it is recorded that nearly five hundred million oysters were sold in 1864 (Yonge, 1960, 155). Yet by the mid 20th century the vast harvest of native oysters had been reduced to about five and a half million in total. One of the main reasons for the decline was overfishing after the introduction of the railways which enabled the increasing demands by townsfolk to be supplied. Some oyster beds such as the one in the Firth of Forth became extinct. This demonstrates the effects of overfishing (interrelated with other factors) on a nationwide scale in an increasingly mechanised society but also indicates the possible vunerability of oysters to overfishing on a local scale during the past.

The salinity regime has been thought to account for size differences in oysters. It was noticed that oysters in the kitchen middens of the Ertebolle culture of western Denmark showed a regular geographical decline in size, being smaller to the south-east, a greater distance from the fully saline North Sea (Nordmann, 1903 in Rowley-Conwy, 1984, 313). Nordmann thought that a salinity gradient was the only factor which could explain the size cline.

It has also been argued that a decrease in marine salinity in the whole area caused a decline in the availability of oysters to the Ertebolle culture (Rowley-Conwy, 1984, 312-315). Oysters were existing at the limit of their salinity tolerance (Nordmann, 1903) when a drop in sea level effectively narrowed the Kattegat entrances thus preventing the ingress of tidal salt water crucial to the oysters' survival (Nielson, 1938). The oysters disappeared from the places where they were easy to collect in the fiords but were not eliminated altogether by the new regime. They became established in much deeper waters of the Kattegat where heavier salt water descended.

Changing sea-levels may have had an effect on the availability and accessibility of oysters in Great Britain in the period considered. Sandwich, Richborough and Reculver - renowned at various times for their oysters - were linked by the Wantsum Channel in the Roman and Saxon period. The channel separated the Isle of Thanet from the main part of Kent and was an important sheltered waterway. It eventually silted up sometime after the 11th century (Hill, 1981, 14-15). Marine transgressions affected the coastline of south-east England in the Hastings region in the 11th century (Williamson, 1959) while in the 9th century the central part of Somerset was as waterlogged and marshy an area as the Fens (Fowler, 1972).

Changing sea-levels and coastlines could have wiped out oysterbeds or caused settlement of oysters in less accessible areas through long-term changes in both salinity and sedimentation. Investigations into the possible effects of changing coastlines on the availability of oysters in Britain would be a profitable line of research. An *in situ* bed of small oysters contemporary with Later Bronze Age structures was discovered at the interface between the head surface and the estuarine clay on the Crouch Estuary in Essex where they had been smothered by sediment before reaching maturity (Wilkinson and Murphy, forthcoming, 75-78). This could be the type of evidence that would indicate sea-level change.

Oysters are susceptible to diseases and the result of severe infestation could lead to a decline in numbers available for exploitation. Some of these diseases are endemic in the populations at low levels but occasionally can reach epidemic proportions and virtually wipe out the stock; Bonamiasis is such a disease. The amoeboid parasite Bonamia ostreae in the 1980's had a sudden catastrophic effect on flat oysters, eradicating over 90% of individuals in some beds (Bannister and Key, 1982; Balouet, 1983). The disease spread with the relaying of oysters from one place to another and so this activity was banned. Surviving oysters could not be sold for relaying but only for consumption. Infected oysters were harmless to eat and the effects of the infection were not visible to the naked eye either in the flesh or in the shell. It would therefore be possible for a disease to eradicate populations of oysters and leave no trace in the archaeological record. Other diseases that might fall in this category include "gill disease" and "Aber disease".

On the other hand, "shell disease" is caused by a fungus and can be seen on the internal surface of an affected oyster (Alderman, 1969b). It is not known whether evidence of this would be observable in archaeological material.

Oysters are capable of transmitting gastero-enteric diseases like typhoid. An outbreak of great virulence would render shellfish very unpopular for some time (24th Annual Report of the Local Government Board 1894-95; Report of the Fishmongers' Company 1902-1909). Apparently, at the turn of the last century the connection between human waste and disease was imperfectly understood with many oyster layings and storage ponds being fed (indirectly) with water from sewage outlets. Contamination at any stage of marketing or food processing would have similar dire effects.

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Inadequate knowledge and techniques could mean that undiagnosed diseases caused by viral, protozoan, bacterial or fungal agents may have been responsible in the past for sudden deaths on a massive scale in oysters and their subsequent absence from the archaeological record. One well documented case of such an incidence of unexplained mortality occurred between 1920 and 1921 on English oyster beds. Oyster fishermen blamed the Government for causing the situation by dumping unwanted munitions at sea after the First World War. Extensive investigations ruled this out. Many other possible causes for the mortality are discussed in Orton (1923) without establishing the true cause.

Climate affects oysters. Abnormally severe winters can kill oysters in large numbers. Oysters relaid on the shore are thought to be weakened by prolonged cold and frosty weather so that they are unable to withstand sudden influxes of freshwater with suspended silt from melting snow and ice (Cole, 1951). They may even be dislodged from the shore as solid sheets of ice are washed away. This has happened within living memory. In 1939-40 very few beds experienced losses of less than 50% (Cole, 1940). The winter of 1947-48 produced similar results and in 1963-64 oyster losses in Essex and Kent varied from 70% to 95% with 100% failure in imported relaid Brittany oysters (Crisp, 1964).

In less sheltered positions, gale conditions can also disturb the sea bed and cause large numbers of oyster deaths by suffocation during burial (Cole, 1956, 4).

Documentary sources record that there were, for example, severe frosts in A.D. 134, 173, 207, 221 and 231 (Lamb, 1977, 425). Occasional, prolonged, great frosts were widespread over Europe between A.D. 359 and 565, and again between A.D. 664 and 1000. It would be interesting to determine whether there is any evidence in the archaeological shell record for these known instances of adverse conditions.

Cool but not necessarily cold summers can have a detrimental affect on spatfall. Although spawning can proceed at 15-16^{o}C, warmer water of at least 17.5^{o}C and better at 20^{o}C is needed if the larvae are to grow well after liberation (Yonge, 1960, 89). A cool summer climate is indicated by manuscript references for the latitudes near 50°N in Europe between A.D. 500 - 700, in the 9th century and in the 11th century (Lamb, 1977, 426).

Pests and predators can be responsible for localised reductions in oyster numbers. There are many animals which either feed upon oysters, particularly the young ones, or compete with oysters for settlement space and food. These are capable of reaching plague proportions that can virtually exterminate oyster populations and therefore reduce oyster numbers to the point where they are not worth fishing. Native to this country are the European rough tingle (Ocenebra), the starfish or five finger (Asterias), the shore crab (Carcinus), the purple-tipped sea urchin or burr (Psammechinus) and the oyster catcher or sea pie (Heamatopus), all of which feed on oysters (Hancock, 1974). Competitors include the barnacle, nun or chitter, encrusting worms such as "German writing (Pomatoceros), sea squirts such as "pock" (Dendrodoa) and "blubber" (Ciona and Ascidiella), and fan worms (Sabella).

Most of the changes imposed on the actual habitats capable of supporting oysters have taken place in the 19th and 20th centuries and therefore have limited usefulness in making interpretations based on oyster shells from archaeological sites. However, the knowledge gained from studying the characteristics of oysters in the past can highlight and put into perspective changes which are now taking place both in oyster populations themselves and in the environment. Direct effects on oysters are potentially caused by dredging of deeper channels for shipping (although in Southampton Water and Poole Harbour such shipping channels have not affected oyster beds). Land reclamation in harbours and estuaries for docks, residential and industrial expansion have reduced the areas available for relaying oysters. Pollution of these shallow waters has been caused by leachates from compacted rubbish used for reclamation, and (formerly) by domestic effluent as well as industrial waste including all manner of chemicals and hot water. Increasing awareness of the problems has led to the introduction of regulations, monitoring operations and redesign of sewage plants. Raw sewage, for instance, is more likely to be treated to render it harmless and to be disposed of away from running water.

The more spectacular effects of pollution include those caused by oil spillage as in the Amoco Cadiz incident which destroyed the oyster beds on the Brittany coast (Conan et al, 1978), or the overflow of toxic water from the disused Wheal Jane tin mine at the head of the Fal estuary in 1991. However, the most widespread effects on enclosed and sheltered waters today must be those caused by changing agricultural practices which result in increasing silt loads in rivers, together with contaminants like fertilisers and pesticides.

The enrichment of shallow waters in combination with the postulated increase in water temperature caused by the "greenhouse effect" could be the reason why the characteristics of oysters recorded from recent decades have changed in comparison with the previous centuries. Bearing in mind that the results may be biased in some as yet unknown way, the return to a larger average size of oyster (comparable to those recorded in Roman samples) and the dramatic increase in the rate of infestation by burrowing organisms could be related to global warming and the enrichment of water causing an explosion of certain invertebrate populations. The information on macroscopic features in oysters of the past two thousand years gained from this research project has made it possible to recognise that oyster shells of the present are changing rapidly and appear to be recording the major environmental changes of today.

CONTRIBUTION TO ARCHAEOLOGY

Under this heading are four main topics concerned with the role of oysters in the economy. These comprise the dietary contribution of oysters, trade, the evolution of oyster cultivation, and levels of exploitation with outline methods for their determination.

Diet

The discussion of the role of oysters in the economy begins with a consideration of their dietary value and the problems of assessing this on individual sites; the relative importance of oysters in coastal as compared with inland sites; and the significance of oyster meat processing to the accumulation and distribution of shells.

The contribution to the diet made by oysters, on an energy level, can be estimated but not determined exactly for archaeological samples because the paired valves necessary for internal volume measurements are rarely recovered. However, the average raw wet-meat weight for an oyster has been calculated from unpublished figures for Poole oysters provided by the Ministry of Agriculture, Fisheries and Food (MAFF); this would be 7.5 $\pm$ 5.3g with an energy value of 51 Kcals per 100g. In terms of food value, 100g of meat would also provide 10.8g of protein, 0.9g of fat, minerals, retinol, carotene, vitamins B_6, B_{12}, C, D and E with thiamin and riboflavin amongst others (Bowes and Church, 14th ed.; McCance and Widdowson, 4th ed.). Oysters therefore contain less protein by weight than cockles or winkles but more vitamins and minerals.

The assessment of the dietary contribution made by oysters on individual sites is complex. Although it is possible to calculate (approximately) the energy value represented by the oyster shells, it is never possible to know what proportion of the oysters consumed on the site is represented by the shells. It is possible that oyster meats could have been preserved without shells. Shells may not always have been discarded on site with other food refuse. It has been recorded from both archaeological and documentary sources that oyster shells have many uses. They have been used for structural purposes in buildings, for example, as mortar between building stones mixed with lime - particulary in the construction of arches where their propensity to swell and delaminate means that the stones become firmly wedged together.

Oyster shells are also used alone or in combination with bones and stones to make up pathways and yard surfaces (Corfe Castle, Chapter 6; Winder, 1989; and Hamwic, Southampton, Chapter 4; Winder, 1986). Sometimes they are used for infilling derelict cellars as on the Shires excavation in Leicester (Monckton, 1992) or to construct roads (Radcliffe, 1921; Haman, 1893) or floors (2nd century, Pudding Lane, Winder, 1985, 93). Mixed with bitumen, broken oysters were used to plug leaks in Roman baths, while crushed and burnt oyster shells were used in the manufacture of Roman cosmetics, ointments and medecines (Pliny Book XXXII. xxi. 62-65). Crushed shells can be used as poultry grit or in the manufacture of lime (Yonge, 1960, 174). Whole shells were cast on agricultural land to fertilise or lime the soil (Philpots, 1891; example site Alington Avenue, Chapter 6; Winder, 1987). Today oyster shells are mostly unused.

On a national scale, over the past two thousand years in Britain, shellfish have proved a significant food resource, the importance of which to a given community has depended on the degree of its availability. To the dwellers of coastal settlements, shellfish would have been easily accessible, contributing to subsistence lifestyles as well as providing a supplementary source of nourishment when other food was scarce. When oysters were particularly abundant, the surplus would have been available for trading. The ready availability and relative ease with which this resource could be tapped would surely have meant that, to people living by the sea, marine molluscs (including oysters) were always an essential and desirable but low status food.

The coastal sites studied in the thesis included Six Dials, Southampton; Newport Roman Villa, Isle of Wight; Thames Street, Paradise Street and Shipwright's Arms, in Poole, Dorset; Ower Farm, Isle of Purbeck; Burrow Hill, Leiston Abbey in Suffolk; and Colchester and North Shoebury in Essex. Eight out of ten sites produced the large quantities of shells one would expect from a coastal location (despite the fact that in most cases only sub-samples were examined).

The contribution of oysters to the diet of people living away from the coast would be to some extent related to the actual distance involved and the effectiveness of transport systems. For much of the period under consideration, fresh oysters would only have been available to those who could afford the transport costs which would have been disproportionate to the value of the food involved since the amount of meat to shell weight is so low. Oysters would therefore be a luxury food item restricted to households of higher social status. The Roman military would come into this category, presumably enjoying standards of living denied the common people, and having access to an efficient road network and transport system (Davies, 1971).

Oysters from inland sites were examined from Owslebury, Hampshire; Corfe Castle, Isle of Purbeck; Lodge Farm, Dorset; Greyhound Yard and Alington Avenue, Dorchester; Halstock Roman Villa on the Dorset/Somerset border; Ludgershall Castle, Hampshire; Brown Street in Salisbury; Cross Street in Wokingham; Reading Abbey Wharf, Berkshire; Moorgate and Coleman Street, Guildhall House and Pudding Lane in London; and Bury St Edmunds Abbey in Suffolk. With the exception of Pudding Lane and Greyhound Yard, all these sites produced relatively small quantities of oyster shells compared with the coastal sites.

Based on the oyster samples examined in this thesis, it can be stated that the numbers of shells recovered from domestic features such as rubbish pits, cess pits and floors or features such as ditches around settlements indicates that oysters and other shellfish were a common addition to the diet but were never as important a source of protein as fish and mammals.

However, there were instances, in non-domestic situations where substantial deposits of oyster shell were discovered. On two sites in Poole, Dorset - at Paradise Street and Shipwrights Arms (late Saxon/preConquest) - millions of oyster shells accumulated on the uninhabited foreshore as the result of what was considered to be large-scale oyster-fishing activities in which the meat appears to have been removed from the shells and transported separately. It was estimated that the midden contained something between 3,808,000 and 7,616,000 oysters depending on the minimum and maximum estimates for the length of the deposit, representing between about 28 and 57 tonnes of raw oyster meat respectively (Horsey and Winder, 1991, 102).

On the former Roman Thames waterfront at Pudding Lane in London similar large quantities of oyster shells were discovered over a metre deep beneath an open-work landing stage (Winder, 1985, 92). Several explanations for this deposit were put forward: that oysters were being sold and eaten straight from the boats that had brought them up river; that the shells were waste thrown overboard from oysters that were eaten or had died on the journey; or that oyster meat was being processed for transport further afield.

At Ower Farm (12/13th century) on the southern shore of Poole Harbour (Winder, 1992a) it was estimated that the excavated part of the midden comprised 25.7 cubic metres of winkle, cockle, oyster, mussel and carpet shells representing 3.7 tonnes wet-meat weight. The entire midden might have been nearly four times greater. This much shellfish may well have been the result of pickling activities, for the smaller molluscs at any rate, to supply the demands of Milton Abbey which owned the site. Although there is no direct evidence, it also seems probable that most oysters could have been sent to the Abbey in the shells, the only oyster shells remaining in the heap (less than 5% of the midden) being rather inferior ones from a small intertidal local population.

The evidence suggests that in the period under consideration in southern England large accumulations of shell occur only when the meat has been processed, and this kind of deposit is usually found on or near the waterside. Although large numbers of shellfish would have been consumed elsewhere, the numbers of shells remaining on site in the usual locations for rubbish deposition are probably underrepresentative, since the majority of shells may have been used for other purposes or discarded off site.

Trade

Trade is the second topic to be considered within the discussion of the role of oysters in the economy. Trade in foodstuffs generally is very important and also very difficult for archaeologists to trace. However, it is obvious from the numbers of oyster shells found all over Britain that oysters were not only consumed near the places where they were fished but also further inland where they had arrived as a result of trade. Despite authoritative assertions to the contrary, there is not a lot of evidence either documentary or archaeological to indicate how oysters were transported and how far they went.

This thesis is able to provide, for the first time, evidence for a home trade in live oysters. The facts presented in Chapters 9 and 10 show that there are regional differences in both the size characteristics and infestation patterns in oysters. On the basis of these regional characters it may be possible to infer the general features of the situation in which the oysters grew and maybe the specific location. Despite the current shortcomings of the system, it has already been possible to differentiate between samples of oysters and suggest the source from which oysters were obtained - thereby indicating its potential for pin-pointing trade links.

The results sometimes confirm the obvious sources when sites are near the sea but sometimes they add another dimension to our understanding of the activities that took place. Thus at Six Dials, Southampton, some of the oysters probably came from a nearby shore but it was not the nearest shore: the nearest beach would not have supported a breeding population. In addition, it appears that people were going out into the West Solent to collect oysters. The oysters found at Owslebury near Winchester could have originated in the West Solent as well. They bore a close resemblance to the modern oysters on the Newtown beds while the majority of Six Dials samples were similar to those on the Sowley Ground. On a local basis, oysters were fished for the home market and to supply the immediate hinterland.

Surprisingly, the oysters from Newport Roman Villa, on the north coast of the Isle of Wight and virtually overlooking the Solent, were significantly different in size from all the modern and archaeological samples from the whole area. In comparisons of size with 71 other samples from Wessex and London, only a few samples from modern Poole Bay, Paradise Street, Shipwrights' Arms, Greyhound Yard and Alington Avenue showed no significant difference. There could be several explanations for this but the presence of black burnished ware pottery at the villa would appear to support the notion that there was a trade in pottery and shellfish along the coast between the two places.

Samples of oysters from sites further inland could possibly have been derived from a number of sources. The oysters from Halstock Roman Villa are similar in many ways to oysters from Poole Harbour but maybe the Halstock shellfish came from the Fleet which is nearer. Flat oysters were grown there in the 19th century. This typifies the need to examine more material both recent and archaeological to define sources more accurately.

In the north of the Wessex region, oysters from Salisbury, Ludgershall, Wokingham and Reading are all similar in size to the small shells recorded for the east coast and all were originally thought to have hailed from that direction. However, both Ludgershall and the Salisbury shells had burrows caused by Polydora hoplura which establishes them as south-coast oysters. This type of damage was only tentatively ascribed to the Reading shells in which the burrows recorded were larger than P. ciliata but not typical of P. hoplura. At Reading there was corroborative evidence for an east-coast origin in the presence of red or almond whelks among the associated molluscs. From Reading Abbey Wharf and Cross Street Wokingham there are grounds for believing that oysters were shipped up river from

East Anglia. These samples exemplify the need to consider all the evidence available before deciding from which direction oysters came.

A special note must be made here about the Roman oyster trade in Britain which has until now been the subject of much speculation in the absence of thorough investigation. There was indisputably a huge trade in oysters across Britain while the Romans were here (Marsden, 1980). There is evidence that the natural beds of the North Kent and Essex coasts around the mouth of the Thames, and on the south coast beds along the Hampshire shores, in the Solent as well as Poole Harbour were heavily fished in the Roman period. The grounds for this assertion lie in the number of sites with large quantities of oyster shell which are located immediately adjacent to suitable oyster growing areas which usually produce oysters today or have been recorded as doing so in the past. Additional evidence is provided by intersite comparisons of size, infestation and other characters in oysters with both modern sites of specified location and archaeological sites for which the source is easily deduced.

Problems arise when it comes to deciding the origin of oysters found on inland sites. Not enough is known about the location of natural oyster beds in the past for areas other than the south coast and around East Anglia. A survey of oyster beds conducted early this century (Fishmongers Company 1902-1909) indicated a paucity of natural beds on the north-east and north-west coasts of England. It is not possible to suggest with any basis in fact, at the moment, the exact location of other natural beds that might have been exploited in earlier times. The methods described in this thesis of using similarities in the macroscopic features of oyster shell samples to determine site of origin could provide a way forward to understanding trade in this marine resource in the absence of modern comparative sites and shells.

The success of the Roman oyster trade would have depended on knowing which sorts of oysters travelled well (see later section in this chapter on the evolution of oyster cultivation), how to enhance their keeping property by adequate packing, and the utilisation of efficient transport systems. Transport of live oysters could have been by road, river or sea. There is a slight indication that some oysters may have travelled with pots, maybe inside them, as these were shipped around the coast from manufacturing sites, e.g. black burnished ware made on the southern shore of Poole Harbour, to the various customers.

There have been many ideas about the way oysters would have been packed for transit. Modern writers have stated that oysters were transported alive in tanks (Frere, 1978, 337); in wooden tubs and packed in snow (Aldrovandi in Rydon, 1968, 11);); in wooden boxes filled with water; and in jars (Smidth, undated). The classical sources are not so definitive. Athenaeus wrote (Deipnosoph, 4, 8) 'When the Emperor Trajan was in Parthia at a distance of many days' journey from the sea, Apicius Coelius sent him fresh oysters, which he had kept so by <u>a clever contrivance</u> of his own'. The clever contrivance may have been the device of putting oysters in bags tightly packed with snow. Oysters were sent this way from Tarentum to Naples in Italy in the 19th century - "which not only by its coolness preserves them, but also, by preventing them from opening their bivalves, enables them to retain in the shells sufficient moisture to preserve their lives for a long period" (Philpots, 1890).

As far as is known, no firm archaeological or documentary evidence exists for the method of packing, although is does seem most unlikely that drawn tanks of water would have been employed since oysters travel well in the dry state. Other ideas which are equally plausible include the use of barrels, baskets, punnets or bags, all of which are recorded in use in the Victorian British oyster industry (Collard, 1902, 73 and 86). It now seems important to look carefully at the artefacts uncovered during excavations for items that might be attributable to the oyster trade.

Concerning the early overseas trade in oysters, the Romans are believed to have sent British oysters to Rome where they were highly

esteemed. British oysters were certainly mentioned in the classical literature but sometimes these original sources have been credited with more information than they actually contain. One of the often quoted sources of information says:
"The coasts of Britain were not yet in service when Orata used to advertise the fame of the products of the Lago Lucrino;"
(Pliny: Natural History Book IX. lxxix. 169 - lxxxi. 172)
Several documentary references of this sort make it likely that this trade did exist. No confirmed archaeological evidence of British oyster shells abroad on ancient Roman sites has come to light so far.

Regarding the actual shipments of British oysters to Rome, the frequently mentioned Rutupian oysters are considered by Courtney (1980, 227) to be a synechdoche for Britannica taken by Juvenal from the adjective Rutupina litora in Lucan 6.67. So although it is likely that some oysters from Rutupiae (the terminal of the Roman channel crossing from Bologne), which is modern Richborough near Sandwich on the east coast of Kent, provided for the banqueting tables of Rome, they may not have done so exclusively.

Extravagent claims have been made for the foreign markets to which the Romans allegedly introduced British oysters. Philpots (1890, 35) quotes the anonymous author of "Tabella Cibaria" when describing how the Emperor Constantine had native British oysters forwarded to him in Constantinople, whence they were introduced to the Greeks.

The possible modes of transport by which live British oysters could have been sent to Rome were discussed in some detail over a century ago by Dallas (1868, 189-190) and there seems little reason to disagree with his conclusions that once over the Channel they were sent overland by road and river. And if they were famished on arrival at their destination, they could have been fattened in the Lucrine Lake like the oysters sent up from Brindisi. A logical progression from this situation might perhaps have been the establishment of breeding populations of British flat oysters in Italy along the lines recorded for Lake Fusaro.

For archaeological evidence of a trade in live oysters with Europe, shells would have to be examined from sites in other countries. Although there are indications in the literature for such trade, perhaps from the sixteenth century onwards, the necessary documentary research has not been accomplished.

The examples above have dealt with the trade in live oysters where at least some of the shells have remained on site at their destination. The trade in preserved oysters must not be underestimated. It is likely that there was also a trade in pickled oyster meats.

The Romans may have temporarily kept live oysters fresh but there is no mention of actual pickling in the old cookery book attributed to Apicius (Flower and Rosenbaum, 1958; Edwards, 1984; Vehling, 1977). This method involved washing the shells in vinegar and placing them in a bitumen-lined jar which had also been rinsed in vinegar. There is a slight hint in the first century Pudding Lane shell dump that the Romans in London may have been preserving oysters for a wider market.

Hitherto there has been no indication of the extent to which pickled oysters may have been traded prior to the 17th century when there are references to oyster meats being sent overseas in barrels from Poole Harbour (Hutchins, 1796, 16). But large oyster middens dating from the late Saxon and Conquest periods in Poole apparently testify to the fact that this kind of processing was probably being carried out much earlier, although the intended markets are unknown.

In the last couple of hundred years, but particularly in the 19th century, references have been made to pickling oysters for the London markets. For example, oyster preservation using a local recipe was reputedly seen going on in almost every cottage in Glamorganshire and the end products were placed in stone jars, corked and covered with pitch (Philpots, 1890, 301). Today shucked oysters either smoked, salted or frozen can easily be found in most supermarkets.

Oyster cultivation in Britain

The third topic in this discussion of the role of oysters in the economy deals with the evolution of oyster culture in Britain. This is a particularly important subject because the widespread assumption that cultivation was introduced by the Romans is not borne out by the facts. The evidence available in this thesis now makes it possible to outline the way in which oyster farming probably developed over the past two thousand years in Britain.

From the Iron Age very few oyster shells have been recovered. This has been remarked upon by Friendship-Taylor (1989) in the context of Piddington Roman Villa, and noticed on three sites examined for this thesis, namely Owslebury in Hampshire (Chapter 5; Winder, 1988), Alington Avenue near Dorchester in Dorset (Chapter 6; Winder, 1987) and in Poole Harbour (Coy, 1987b; Winder, 1992a). Oysters may not have been available or other species of edible mollusc may have been preferred.

Sites of the Roman period in Britain are characterised by the great abundance of oyster shells. These are typically large and bear the characteristics of oysters that have grown in the intertidal or shallow sublittoral zone. Samples of this type have been examined from Newport Roman Villa (Isle of Wight), Greyhound Yard and Alington Avenue (Dorchester, Dorset), Halstock Roman Villa (Dorset/Somerset border), Pudding Lane (London), Colchester and North Shoebury (Essex).

There is no direct evidence either archaeological or documentary, so far, to support the widely held view that the Romans introduced oyster cultivation to Britain. It would probably be more accurate to say that the Romans introduced the appreciation of oysters into Britain rather than cultivation itself. The most quoted original sources have been Pliny the Elder's Natural History (A.D. 77; translated by Bostock and Riley, 1855; Jones, 1963) and the Satires of Juvenal (about A.D.100; commentaries by Courtney, 1980; Ferguson, 1979). The only artefactual evidence is a series of engraved glass vases reputedly depicting Roman oyster culture. Descriptions of such vases have been provided by Gunther (1897), Coste (1861), Smidth (undated 19th century) and mentioned by Yonge (1960). Two similar vases were on view at the "Glass of the Ceasars" exhibition at the British Museum in London in 1987-88. The illustrated catalogue presents both photographs, drawings and descriptions which verify Gunther's interpretation of the engravings and raising doubts about Coste's and Smidth's version - unless the vases they described had completely different pictures.

The glass vases appear to have been sold as mementos to holiday visitors in The Bay of Baiae and the Lucrine Lake and date from the late 3rd to early 4th century A.D.. The engravings depict a pier jutting out over the water and the word "ostriaria". Oysters on ropes dangle in the water from the trellis-like pier. In Tarento in Italy and in the Gulf of Spezia oysters were recently cultivated in a similar way by suspending them entwined between the strands of loosely twisted ropes known as "pergolari". It is known from Pliny that oysters from Brundisium in the south of Italy were brought to the Lucrine Lake off the Bay of Naples to be fattened up prior to being sold in Rome.

There are several reasons why it is unlikely that the Romans carried out the same type of cultivation here in Britain. In the first instance, oysters had apparently been a hitherto underexploited resource in Britain. When the Romans arrived in Britain with their well-established liking for sea-food and shellfish in particular, they must have become immediately aware of the vast unexploited beds of oysters in the shallow waters around the coasts, some of which would be visible at low tide. So, at least to begin with, there would have been plenty of oysters. Secondly, if the existing beds became depleted and the need arose to augment supplies to meet heavy demand, the elaborate system used in the Lucrine Lake would not have been necessary. It was probably because of the soft lake bottom as well as for ease of access that the oysters were suspended in the lake. In Britain, the natural beds of oysters are found on firm substrates.

Flat oysters cannot survive naturally on very soft muds. Even in enclosed and sheltered places the sediments are only relatively soft. Many suitable areas for relaying would have been available adjacent to existing beds. Elaborate structures and techniques for catching spat and fattening oysters would not have been necessary.

The only evidence to date that the Romans may have been improving oyster stocks was seen in the shells from Pudding Lane where there was a demonstrable change in the size, shape and infestation of the shells from the 1st century to the 2nd century (Winder, 1985). However, there were alternative explanations for this change in appearance including the fishing of different oyster beds and the long-term effect of regular fishing on natural beds.

The key to understanding about the long- and short-distance Roman trade in oysters must lie in their knowledge of the survival rates and mechanisms of survival in oysters (see the previous section on oyster trade in this chapter).

As early as 1868 it was noted by Dallas that oysters could survive long periods out of water. Current observations confirm that an oyster will stay fresh and in good enough order to eat for about three weeks or even longer in cool conditions but only when the oyster has learnt either naturally or has been "trained" to survive out of water.

Oysters that live in the intertidal zone must learn naturally to keep their valves tight shut in order to survive periods out of water or they would dry up, get eaten by predators or die. This naturally occurring phenomenon makes this type of oyster most suitable for sending on long journeys.

This behaviour can be artificially induced in cultivated oysters at the present time. For example, in Holland oysters are placed on the supermarket shelves by 12th December for the Christmas trade and will remain there unless sold up to New Year. These oysters will have been kept in tanks of sea water for some time previously. Every day the tanks are drained down, presumably for progressively longer periods of time, during which period they are conditioned to keep their valves shut for longer and longer lengths of time in preparation for transit and retail.

This recent deliberate training of flat oysters no doubt evolved from observations of oysters in the natural state. The propensity of intertidal oysters to remain firmly shut for long periods out of water would eventually have been recognised by the oyster fishermen and it would not have taken too long after that to understand the commercial implications. The Romans were probably the first to take full advantage of this occurrence.

In the mid to late Saxon period oyster shells apparently make a reappearance in the archaeology following a relative absence for a few centuries after the departure of the Romans. This may be related more to the absence of excavated sites or lack of retrieval of marine molluscs than to an actual decline in exploitation. There is reference to "a brief phase of shell middens along the Hampshire-Sussex coastline dating from the eighth or ninth centuries" (Hodges, 1982) suggesting that this is "evidence of the wealth of almost every part of Anglo-Saxon England before the ninth century."(The given example of such a shell midden is perhaps a poor one since the report on the excavations at Becket's Barn, Pagham, West Sussex (Gregory, 1976) fails to mention shells even once.)

However, large quanties of oysters and other marine molluscs were recovered from the excavations at Melbourne Street (Winder, 1980) and the Six Dials sites in Southampton (Chapter 4; Winder, 1986) in relatively small, discrete deposits; while the massive deposits of oyster shells from the Paradise Street and Shipwrights' Arms sites in Poole possibly belonged to this period (radiocarbon dated to a.d. 1095 ± 108 and a.d. 935 ± 81 respectively),(Horsey and Winder, 1991).

The analyses of the shells from these Saxon sites demonstrates for the first time that deeper water beds of oysters were being exploited as well as more local, shallow sublittoral or intertidal beds. The evidence from the Six Dials site points to the exploitation of oysters in the West Solent and also, nearer to hand, an intertidal bed such as might be found at Hamble. The Paradise Street oysters were similar to those growing wild out in the deeper water of Poole Bay at the present time while the Shipwrights' Arms samples were closer in their characteristics to oysters from the shallow waters of the Harbour (Chapter 6; Winder, 1992).

This period coincides with the end of a warm climatic period when oysters might have been more abundant and weather conditions more conducive for dredging in deeper waters, particularly in the cooler months of the year when oysters are in the best condition for eating.

The ability of intertidal oysters to keep their valves shut has already been mentioned. Conversely, oysters in deeper water which have been accustomed to a heavy weight of water over them that aids in maintaining closure, gape very quickly when brought to the surface. Oysters fished from deeper beds do not therefore have such natural keeping properties as those from intertidal beds. They are best suited for immediate local consumption in the fresh state. However, the gaping tendency of the valves means that it is extremely easy to insert a knife and remove the meat. (Normally great skill or tremendous effort is required to break the ligament and gain the knife an entry). This facility may have engendered the idea of wholesale removal of the meats and the preservation of them for more distant markets. At Poole the huge accumulation of oyster shells on the former foreshore is thought to be the result of such processing because their condition indicates primary deposition, there is no evidence that they could have washed up naturally on the shore; there are no other faunal remains or artefacts incorporated within the deposit, and there is neither archaeological nor documentary evidence to indicate that they were associated with any nearby habitation. They predate the building of Poole.

Rights to fish on lucrative oyster beds may have been established in the Saxon period. The first known legislation concerning oyster fisheries dates from the 12th century. The earliest Charter possessed by the Corporation of Colchester, given by Richard I, A.D. 1189, confirmed the rights and privileges they had enjoyed, including the oyster fishery of the Colne and its creeks, in the time of "our Lord, the King our father and grandfather and from time immemorial beyond that". It is clear that the right had extended from the Saxon period (Laver, 1916, 56-57). Yonge (1960, 153) states that "the Colne fishery was, and is, a natural, self-perpetuating bed - unlike many of the beds which are 'layings' where suitable young oysters obtained wherever possible are laid to grow and fatten". This statement verifies the idea that despite oysters being an important business in Saxon times they were not yet being relaid.

The medieval period seems to be characterised by the relatively sudden appearance of many small deposits of oysters and other marine molluscs appearing on inland sites. These oysters are much smaller than those from earlier periods. Their growth rate is also slower, showing that the small size is not a factor of age (Chapter 10). Examples of sites with shells like these include Ludgershall Castle near Andover, Brown Street in Salisbury, Cross Street in Wokingham, Reading Abbey Wharf in Berkshire, Leiston Abbey in Suffolk (data in previous chapters) and Burton Dassett in Warwickshire (Winder, 1991) and the Shires in Leicester (Monckton, 1992).

The main clue as to why oysters became more widely distributed at this time (for the first time since the Romans left Britain, even though roads were nowhere near as efficient as during the occupation), may be provided by the small sizes of the shells. It has already been deduced that in the first four centuries the Romans fished natural stocks in intertidal or shallow sublittoral waters around the coast where stocks were in plentiful supply; and the intertidal specimens in particular were believed to travel well. There is scant evidence for either farming of oysters or processing by the Romans in Britain. By the mid to late Saxon period, people were fishing in deeper water for oysters which were not able to survive so long out of water. Advantage was probably taken of their habit of gaping on contact with air to remove the meats for preservation - starting a large scale industry in pickled shucked oysters. Evidence of this kind of trade would be detectable only at source, not destination.

Between A.D. 1000 and 1200 the warm climatic phase drew to an end and for six hundred years Britain entered a Little Ice Age. As winters became more severe, oyster fishing in deeper waters would have become more hazardous and indeed it might not always have been possible to put the boats out. It would have been necessary to catch as many oysters as possible when conditions were favourable and store them against future demand in more convenient locations. This could well have been the phase in British history when oysters were first relaid, that is, the start of oyster farming as opposed to oyster fishing.

It would already have been common knowledge among oystermen that oysters in shallow inshore waters had plumper meats. It would have been a simple transition to transfer young oysters from the deeper water beds where they bred so easily to intertidal areas in sheltered estuaries and creeks for fattening. By relaying the oysters very high on the shore, where they would be uncovered for more time than they were submerged, their accessibilty could be improved even further. The main disadvantage of this location is that it impedes growth. So although relaying oysters in this way would have made marketing them very much easier, the oysters themselves would be small. In addition, such beds would be susceptible to extremes of weather and could easily be destroyed.

Oysters maintained in these conditions would soon acquire the ability to keep their shells shut (in the way that the Dutch train their oysters today) and thus they would have been admirably suited for long-distance trade making fresh oysters available to the general public however far from the sea. The trade in live oysters may have augmented a continuing trade in salted shellfish.

Later on, fish ponds became common (Currie, 1987). Some of these ponds were on the sea-shore. It has always been assumed that they were for holding fish, but Hockey (1970, 50) suggests that on the Isle of Wight they may have held oysters. It is entirely possible that both fish and oysters could have been held in these ponds which were renewed with sea-water at high tides.

In the post-medieval period the trend in small size of oysters on many sites continued. It is assumed that this was caused by a combination of colder weather and relaying techniques. Fresh oysters were still probably supplemented by oysters pickled in brine to an an unknown extent.

As time went on, the demand for oysters exceeded the sustainable supply. Certainly by the 19th century with the introduction of the railways oysters were distributed on a hitherto unprecedented scale at a greatly reduced cost. Soon demand outstripped supply and desperate attempts were made to increase stocks. Mostly this took the form of introducing methods of spat collection and intensive culture in the way that the French had practised for some time. Unfortunately these experiments were not a success and oyster populations dwindled.

Other species of oyster were introduced to Britain in more modern times in the hope that they could replace the declining stocks of Ostrea edulis. However, neither the Portuguese (Crassostrea angulata) nor the American blue points (Crassostrea virginica) oysters were able to breed in British waters. Attention has turned more recently to the culture of the Pacific oyster (Crassostrea gigas) which is now more readily available in Britain than the native flat oyster. The Gigas oyster (as it is known in the trade) is spawned in laboratories and sold to oystermen for growing on. It is more resistant to disease and is commercially more cost effective because it grows to market-able size in just two years in contrast to the four years taken by the flat oyster.

Most surprisingly, in this period size and infestation data from the few available relatively modern deposits of flat oyster shell (and for live (O. edulis) oysters collected over the past three decades) indicate that flat oysters are on average achieving greater size for age despite heavy exploitation pressures. The shells are also becoming much more heavily infested. Sizes are almost comparable with those of Roman samples of oysters. Some of the reasons why these changes are occurring are discussed in the preceding section of this chapter which considers the influence of natural and man-made changes to the environment and the way these changes affect oyster populations.

Levels of oyster exploitation

Having considered the contribution of oysters to diet and trade in the past, and the evolution of oyster culture in Britain, this last section on the role of oysters in the economy demonstrates the way that the accumulated evidence allows an assessment of the varying degrees of oyster exploitation practised at different times and places.

We have seen in Chapter 9 that variations in shell size may be related to the place of origin of oysters. There is a greater probability of oyster samples that have originated in the same geographical area having sizes and size distributions that exhibit no significant difference from each other. There is also evidence that size and shape can differ on a more local scale in relation to substrate type, water depth and salinity.

Chapter 10 shows that the type and frequency of infestation also differs significantly from region to region. For example, the most noticeable features of east-coast oyster shells are the absence of Polydora hoplura and calcareous tubes with correspondingly high levels of barnacles and Polyzoa. On the other hand, south-coast samples were characterised by the presence of P. hoplura, calcareous tubes and sponge borings - all of which were virtually absent from the other regions - and the greatest number of boreholes. As with size and shape, damage by infesting organisms can vary according to smaller scale environmental variations.

Chapters 4 to 8 demonstrated other aspects of shell variation including abundance, age, growth rate, chambering, chalky deposits, cultch and attached oysters. Considered together with size and infestation these recorded features can be used to give an idea of the level at which oysters were exploited and the methods that were used.

To assist in the analysis by which the raw data is used to make decisions about the level of exploitation, I have drawn up a set of formal models which are illustrated in Figure 11.1 on page 299. The raw data enable a first level of interpretation to be reached. For example, the abundance of shells will provide some indication of the level of exploitation of this resource by showing the numbers fished or consumed. Size frequencies and age groupings may indicate either the preferred size of shell or reflect restrictive fishing practices in force, and similarly will reflect the long-term effects of exploitation practices. Clues to the region or locality in which the oysters originated may be supplied by knowing the associated molluscs, size frequencies, growth rate and infestation types and levels. Infestation and shape could be indicators of the type of seabed location, for example, intertidal littoral, shallow sublittoral, deep sublittoral, hard substrate or softer sediments. Fluctuating salinity regimes can be detected from the presence of certain infestation types, chambering of the shell, and chalky deposits. A natural population might be suggested by the size frequencies, age grouping, regularity or its absence in the shell, and whether other oysters were attached. Cultivated populations might exhibit the opposite extremes of the characters for a natural population - in addition to cultch of a specific type such as cockle shell.

These first level interpretations can in turn be used to arrive at a series of models for the exploitation of oysters as revealed by the archaeological record. Five theoretical models are described here but in reality there would probably be intermediate and combined systems. The models represent an intensification of the processes involved from casual collection on exposed beach deposits (model 1) to full-scale commercial production and marketing (model 5). Each model consists of a series of interpretations described in text and summarised in diagrams, accompanied by details of archaeological sites and modern instances that illustrate the model, which together constitute the templates for determination of the level of exploitation.

Model 1 - Sporadic collection by hand from natural oyster beds

At the least organised level of exploitation there would be sporadic collection by hand of oysters from natural populations in the intertidal zone on the sea shore, estuaries or creeks (see Figure 11.2 on page 300.

The exploitation level would be low and indicated by small quantities of shell, possibly in isolated pockets or separate layers exhibiting short-term periodicity. Oysters in this kind of location would be available for collection without specialised equipment only at extreme low tides or at the most every couple of weeks.

In this scenario it might also be assumed that the collectors would be interested in amassing as much food as possible during the short time that the oysters were exposed by following the tide down the shore as it receded over the oyster beds and up the shore as it flowed. They would probably have no preference for any particular size of shell. Quantity would be the aim rather than quality. There would therefore be a wide range of sizes fairly evenly spread throughout the sample. Similarly there would be a wide range of ages represented.

The region or locality of the oyster beds might be suggested by three factors - size, growth rate and associated molluscs. The sizes of shells in the sample, and the size distribution would be characteristic of a certain locality (as explained in Chapter 9). The growth achieved each year might also be typical of a certain place. Shell growth rate would be relatively slow because of the periods spent out of water when no shell is added and when some shell may be dissolved by the products of anaerobic respiration. A dominance or preponderance of shore-living species of marine mollusc associated with the oyster shells would be expected. Limpets, winkles, mussels or cockles might well alternate with the oysters in the stratigraphy since it is likely that another source of shellfish would have been sought out when the oyster beds were inaccessible.

A high proportion of oysters in the sample exhibiting all or a combination of such features as irregular shape, chambering or chalky deposits could be a pointer to both a littoral bed and a natural population. Distorted shapes result from group settlement and adhesion to hard objects such as rocks where the oysters grow undisturbed into maturity. Energy may be diverted from increase in the diameter of the shell to an increase in thickness. A change in salinity concentration or a change in the volume of the meat of the animal might result in the rapid formation of chambers or chalky deposits within the shell structure that effectively ensures that the mantle is kept in contact with the nacreous lining. Salinity changes are most likely to take place in shallow, partially enclosed waters, either concentration in hot weather or dilution by precipitation.

Besides shell shape, the constituents of the epibiont population which has burrowed into or attached to the oyster shell might be an indicator of an intertidal origin of the native bed. Higher numbers of animals seem to be recorded on present-day oysters from shallow, estuarine waters. Exposure-tolerant species and those able to survive salinity changes would also be present.

One final indicator of a natural population would be the proportion of oysters in the sample found attached to each other. This refers to oysters of all ages and sizes - from minute spat (recently settled larvae) to fully mature oysters. The spat show a healthy, self-propagating population and the groups of adult oysters clumped together are the eventual outcome of spat competing for space as they develop on the same object.

An example of a Model 1 situation is provided by the oyster shells from the 12th/13th century shell midden at Ower Farm on the southern shore of Poole Harbour in Dorset (see Chapter 6 and Winder, 1992a). Here the shells were on average small, predominantly young but with a wide range of ages, and with a high proportion of irregular specimens. Small spat oysters were recovered from the washing residues and had obviously become detatched from larger shells. Older oysters were sometimes stuck to each other. The oyster shells occurred in well-separated lenses of varying size within the midden. All these pieces of evidence suggest that oysters at Ower Farm were collected sporadically from a small, natural, overcrowded population that had settled on a rough substrate that included accumulations of empty cockle shells. The oysters may only have been uncovered at very low spring tides.

Model 2 - Dredging inshore shallow natural oyster beds

The second model of oyster exploitation shows an advance over Model 1 in the use of special equipment. It involves dredging inshore shallow sublittoral natural beds of oysters (see Figure 11.3 on page 301). This model requires greater expenditure of effort and a more organised approach to collection which is probably carried out on a more regular basis because the use of equipment makes the resource more accessible.

The increased level of exploitation may be seen in greater numbers of shells (but caution should be used here because of such factors as possible marketing and redistribution of empty shells for sundry purposes). The oyster shells in the archaeological record could show a seasonal periodicity as a result of bad weather in winter preventing the boats from going out or inedibility of pre- or post-spawning oysters (cf. short-term periodicity in Model 1 due to problems of accessibility). An example of this postulated seasonal periodicity was found in the deposits from Moorgate and Coleman Street in London (Chapter 7 and Winder, 1987). At this site numerous whelk shells alternated with the oyster shells in a domestic refuse pit.

The sizes of the shells in the sample may be larger than those recovered from the intertidal zone because growth will not have been interrupted by periodic exposure to the air. The size range may possibly be narrower if a dredge net had been used. The mesh of the net bag would allow small, loose oysters to pass through.

Age distribution as well as size distribution in the sample might be narrower than in Model 1 and reflect restrictions imposed on the oyster fishing either directly by regulations or indirectly through mesh size. Larger or older oysters might also be absent from the sample because they are thrown overboard as unsuitable for eating or for breeding stock.

Along with size, the other molluscs found with the oysters might provide clues to the region or locality that was fished. In this model the associated molluscs might include sublittoral species such as whelks and scallops. Some species might have a known regional distribution or habitat preference. For example, Neptunea antiqua the red, or almond whelk, is not found at the present time on the south coast at all but is frequently found off the Norfolk coast (Reading Abbey Wharf Chapter 7; Winder, forthcoming). The sting winkle has a localised distribution in the Solent - being confined to the western arm (Six Dials, Southampton Chapter 4).

Growth rate might be faster than in intertidal oysters due to the more constant conditions under water. Growth rate might also match known regional characteristics. For example, the double tides experienced on the south coast, particularly in the Solent, Southampton Water and Poole Harbour may affect shell growth patterns.

Infestation rates might be higher in oysters growing in shallow nutrient-rich waters where warmth and shelter are provided. Certain species of marine invertebrate favour these kinds of conditions. Cliona celata, the sponge, is common in shells from creeks and estuaries on the south coast and so is Polydora hoplura and Gastrochaena dubia. All three organisms tend to occur in thicker, older oysters.

Particular characteristics have been noted in the shells of modern oysters from within the sheltered waters of Poole Harbour in contrast to oysters from out in Poole Bay. The Harbour oysters tend to have a deeper cupped (left) valve. The right valve, which is typically flat, may become outwardly convex. The margins of unattached shells tend to become blunt from abrasion by water-borne particles, general wear on the sea-bed, and possibly the diversion of the energy of shell growth from increase in diameter to an increase in internal capacity. The shape may also be affected by the relative softness of the sediments in this kind of location. Work on the modern oysters from Poole has demonstrated a well defined difference in shape between oysters from the open waters of the Bay and the enclosed waters of the Harbour (Chapter 6; Winder, 1992b). The archaeological oysters appear to reflect this difference too. A comparison has been drawn with American species of oyster where shape changes have been noted in oysters on softer muds (Galtsoff and Luce, 1930; Gunter, 1938).

Chalky deposits of microcrystalline calcium carbonate are formed as a rapid response to the need for a change of internal shape following a change in volume of the meat of the animal. This could include a change in the salinity of the surrounding water, rapid growth, or depletion following spawning. Rapid salinity change and rapid growth would both be more likely in shallow inshore waters. Thus the frequency of chalky deposits would be correspondingly high in oyster shells from this type of location. Chambers in the shell are also considered to be more prevalent in this kind of situation for the same reasons.

A high proportion of shells with an irregular shape may be typical of the unmanaged oyster beds envisaged in this second model, as would groups of mature oysters clumped together and young spat oysters attached to adults

A possible example of the Model 2 category is seen in the samples of oyster shells from Greyhound Yard in Dorchester which as a result of comparisons with both modern and archaeological samples were thought to have come from the shallow waters of Poole Harbour but definitely not from the deeper water of Poole Bay (Chapter 6)

Model 3 - Dredging offshore deep natural oyster beds

This represents a similar situation to Model 2 but involves dredging deeper offshore sublittoral natural beds of oysters. The deeper waters and the distance from shore would require more effort than in Models 1 and 2, better boats and equipment, and more advanced skills. Many of the characteristics that would be expected in Model 2, would also be found in Model 3 (see Figure 11.4 on page 302).

However, some differences would be likely. Infestation damage and shape could well be affected by the new type of fishing locality. It has been observed on the shells of living oysters from natural beds in the West Solent and Poole Bay that the frequency of encrustation or infestation of the type that would leave a permenant record on the shell tends to be low compared to the very high rates that can occur in places such as Poole Harbour or the Colne estuary. Fewer types of organism would be expected as well as relatively low rates of infestation. This is thought to be due to the poorer nutrient levels and cooler temperature of the water.

In contrast to the sediment-rich conditions which tend to prevail in the sheltered waters of Models 1 and 2, it is probable off-shore oyster beds would be on firmer substrate in cleaner water with less suspended matter. Oysters on hard bottoms may have rounder shells than those on softer sediments. Regular dredging of natural beds can also lead to the oysters achieving more regular shape since the action of the dredge can disperse and separate the oysters. Constant salinity would mean that chambers would not form in the shells. The left valves would tend to be shallow because of the poor meat growth; the right valve might actually have an outwardly concave shape and be inset within the left valve. The shell margins might be sharper because rapid shell growth exceeds development of meat: shell growth can take place when there is not enough food for the animal itself to grow. Lack of abrasion maintains the sharp, thin edges which may be horny, flexible and unconsolidated.

A modern example of the Model 3 type of exploitation is seen today in the fishing for wild oysters in Poole Bay (for relaying or for direct sale). Archaeological samples which parallel the size characters and infestation patterns of the natural oysters from Poole Bay include all the medieval oysters from Paradise Street, Poole. The same Model 3 type of activity is carried out in the Solent but the Solent samples used for this research project have not been commercially fished but collected for population surveys only, therefore the size and age distributions do not reflect the effects of the normal fishing practices.

Model 4 - Dredging inshore relaid oyster beds

The first three models describe a trend towards the more systematic and expert recovery of oysters. The fourth model illustrates a further intensification of procedures which are designed to increase stocks and improve quality in the production of oysters. This model postulates, for the first time, the introduction of deliberate management of the oyster stocks. It implies a greater degree of understanding of the natural history of the oyster, foresight and planning, and the development of deliberate cropping policies. It ensures a readily accessible source of this marine resource to cater for demands. The scenario is for dredging inshore sublittoral relaid oyster beds (see Figure 11.5 on page 304).

Relaying oysters is the first stage of oyster farming. Young oysters are separated from the cultch on which they have settled in natural beds and taken to locations where the conditions are better for fattening up the meat. In this case the beds fished for relaying stock are usually of the type described in Model 3 as found today, for example, in Poole Bay and the Solent. The fattening grounds are usually in enclosed harbours, estuaries and creeks. The Fal and Helford Rivers in Cornwall, Poole Harbour, the creeks around the Isle of Wight (in the recent past), Langstone and Emsworth Harbours in Hampshire, the north Kent coast and West Mersea in Essex are some of the areas well known for relaying oysters.

In addition to the characters already described for oyster samples from this type of local environment, the higher level of exploitation may be seen in the greater abundance of oyster shells in the archaeological record of the site. In a site with a long sequence of deposits there may be greater numbers of shells, greater frequency in the contexts and there may be a regularity in their occurence in the stratigraphy suggesting seasonality.

The size distributions are likely to have a well defined upper and lower cut off point because this kind of farming involves cropping, usually at around four years which is the most cost effective time. Restrictions may be in force to conserve stocks by advocating the return of undersized oysters to the sea. Preferences for young oysters with tender meat for raw consumption would enhance the requirement for oysters around four years old. On the other hand, a preference for larger meats suitable for cooking might raise the size of cropped oyster. Quality grading of the oysters might be involved. The age range would be restricted like the size range for the same reasons.

Although the location of oyster beds in warm shallow waters could give rise to high levels of infestation, by good husbandry methods, the damage could be minimised. In the way that land farmers would prepare fields by clearing before sowing, and by hoeing afterwards to keep levels of weeds down, oyster farmers would also prepare the sea-bed before transferring oysters and remove attached organisms from the shells when harrowing the relaid beds. Of course, many of these organisms would leave no trace on the shell. The ground could be consolidated by the use of shram such as broken shells, twigs and branches. Evidence of this might be sought in the sample or during waters-edge excavations.

The shape of shells in this sort of sample might be less distorted and the shells less likely to adhere in groups. Softer sediments could lead to lateral outgrowths of shell at the ligament end and a general broadening of the shell in laymans' terms (a greater measured biological length than width (Chapter 6; Winder, 1992b). Spat would be rare because the stock being fished would have been deliberately separated out from the natural breeding stock. Also the places suitable for fattening oysters are usually not suitable for settlement of oyster spat.

Consistently finding a particular species of shell attached to the heel of the oyster or the impression of the same species might be a sign that a deliberate attempt had been made to provide suitable surfaces for the settlement of spat by laying down cultch on the prepared beds. Cockle shells have been commonly used for this purpose. Caution must be used before assuming that such attached material is cultch. At Ower Farm (Chapter 6; Winder, 1992a) many oysters had settled on cockle shells but all the other characteristics of the sample pointed to a Model 1 type of exploitation. Underwater invertebrate survey work in the area demonstrated drifts of old cockle shells accumulating naturally nearby (Dyrynda, 1988, 13).

A modern example of Model 4 is found in the relaid oysters from Wych Channel and South Deep in Poole Harbour and the sample from the 1971 Colchester Oyster Feast. Recognition of the archaeological equivalent of relaid oysters by direct comparison with modern relaid oysters has not been possible so far. Oysters from the Poole region have maintained a larger than average size since Roman times and are atypical in this respect. Secondly, wild Poole Bay oysters have a history of being relaid on the Essex coast (and other places) where after maybe a few months immersion in local waters they emerge as, for example, Colchester oysters. This means, that as far as detecting relaid oysters in the archaeological record is concerned, direct comparisons of archaeological and modern material are not valid unless the origin of the relaying stock is verifiable. However, in the previous section in this chapter on the evolution of oyster culture in Britain a theory is proposed that may enable the recognition of oysters relaid in certain specific conditions.

Model 5 - Full scale cultivation and marketing of oysters

This model is the opposite extreme to Model 1 and represents the maximum amount of effort for the maximum gain in terms of food for the local market and surpluses for cash or goods trade. Model 5 describes a situation where the oyster populations are managed to the fullest possible extent from spawning to table. It includes for the first time cultivation in which spawning is monitored, spat collected, nurtured in specialised conditions, cropped, stored live, graded and marketed. In other words it is full scale commercial cultivation and marketing of oysters (see Figure 11.6 on page 305).

Some of the characteristics of oyster samples and associated structures would be specific to the model while others would be the same as Model 4. Size range might be restricted, net sizes governed by regulations. Additionally, from at least the 19th century, a brass oyster ring of a specified internal diameter may have been employed. The internal diameter varied from region to region (in Falmouth it was 2 5/8 inches) but any oyster capable of passing through the ring had to be returned to the sea.

Special equipment and special structures might be involved. Three general examples can be mentioned as falling into this category of oyster exploitation. Nowadays, oysters can be induced to spawn in laboratory conditions and the fertilised larvae nourished in special nutrient media until the young spat are large enough to be placed out in trays on the shore, or in floating racks, to grow to maturity. This laboratory-based culture is generally more successful on the commercial scale with the Pacific oyster, Crassostrea gigas than with the native British flat oyster, Ostrea edulis.

In the recent past, certainly in the 19th and 20th centuries, sample oysters were examined to see if they were full of spawning products in order to predict the spatfall. Collectors of various designs, both natural and man-made, were placed in the water just before spawning to receive the spat. After a year, the young oysters would be removed from the collectors and placed out to grow in beds. This was sometimes in protected, enclosed areas of the intertidal zone. This method was carried out with greater success on the Continent than in England as far as is known.

In the more distant past, the Romans practised an ingenious form of culture in their native country. According to Ausonius, in the 4th century A.D. oysters were brought from Brindisium in southern Italy to the neighbourhood of Puteoli in the north of Naples where they were fattened in the Lucrine Lake which communicates by a narrow channel with the Mediterranean. Engravings on glass souvenir vases of the time depict depict a trellis-like pier called an ostriaria from which thick ropes, with oysters entwined in their strands, dangled in the nutrient-rich water (see above).

All three methods of cultivation involved storage facilities for holding mature oysters ready for marketing. Today this would involve the retention of oysters in tanks of filtered and oxygenated seawater under ultra-violet lights for purification. In earlier times pits would be constructed on the upper shore where the water would be replenished at high tides. Pits such as these were common in the last century in England; some survive today (Paglesham, Essex; Yonge, 1960, plate X).

So in the Model 5 situation, not only is evidence to be found in the shell samples themselves but also in structural evidence and artefacts associated with the whole process of fishing and processing the oysters. Special nets, tongs, rakes, knives, baskets and other containers are recorded as being associated with the oyster industry (Laver, 1916, 48-54). The early history of oyster cultivation, and the use of specialised equipment and structures is not actually known in this country although many assumptions have been made.

With regard to what evidence might be determined from the oyster shell samples themselves, the result of extensive farming and cropping, would probably be greater numbers of shells in the archaeological record both on the coast and further inland. Intensive farming would result not only in greater numbers of oysters being available but would assume a wider distribution of oysters. Inland sites would have greater numbers of oysters only where the consumer could afford the high cost of speedy transport or where transport systems were efficient. This presumes that most oysters were eaten alive but, of course, rapid transit would not be essential if the oysters were pickled.

Size and growth rate might be affected by the extra handling and artificial environments. The proportion of 'stunters' could rise. Stunters are oysters which never achieve normal size for their age. Oyster fishermen throw small oysters back on the beds each time hoping they will grow to the required size (see Chapter 2 for further details of the cause of stunting). Growth rate might be affected by the intertidal conditions in which the oysters are sometimes kept, by repeated handling as in the removal of spat from collectors and by placing in artificial protected enclosures on the beach.

Winkles might be scattered through the otherwise homogeneous deposits of oyster shell since winkles are used to graze the algae in storage or holding pits for oysters. The encrusting organisms would have been scraped from the shells before marketing. The outside frills of the left valve and the edges of the whole shell might have been trimmed to avoid shell fragments breaking off in transit or getting into the meat as the shell was opened. Grading of oysters might have taken place according to size, weight and shape.

Structural evidence for oyster culture prior to the 19th century is unknown unless medieval seaponds contained oysters as well as fish (see above). No artefacts have been specifically attributed to oyster fishing or oyster culture with the exception of a knife associated with the shell midden at Ower Farm (Cox and Hearne, 1992, 161-162). Oyster shell samples clearly demonstrating evidence of Model 5 exploitation would be most readily found in sites belonging to the last two centuries but deposits from this period are rarely retained. However, a sample of oysters from 11 The Hundred, Romsey dating between 1830 - 1840 showed clear signs of being graded for market by their extremely narrow size and age range although it was thought unlikely that they had been relaid.

The descriptions outlined above of five theoretical models of oyster exploitation provide a framework on which to build hypotheses about exploitation of oysters. By adding greater detail to some areas of recording, particularly the infestation characters, and by using more sophisticated analytical techniques, it should be possible to deduce more accurately the probability of an oyster sample originating in a specific location as the result of particular exploitation strategies.

ACHIEVEMENTS OF THE RESEARCH PROJECT

At the outset, it was hoped that it would be possible to use the large quantities of oyster shell in deposits from the last two millennia to aid in the interpretation of archaeological sites. Once it had been established that oyster shells exhibited such great variations in appearance, the idea of using recorded macroscopic features as a means of comparing and contrasting samples of oysters was formulated. An essential part of the work was the examination of modern oysters and documentary evidence relating to all aspects of oyster biology and culture. Additionally, it was necessary to gain information from a range of disciplines concerning all factors inter-related with oyster growth and culture. The processing and analytical methods were kept very simple because it was hoped that they could easily be practised in a cost-effective way. Despite the simplicity of the approach, the results have been encouraging. It has been possible to make intra- and intersite comparisons that demonstrate both spatial and temporal differences; these differences have been shown as having the potential to help our understanding of the contribution of oysters to the diet, the levels at which this marine resource may have been exploited, and the nature and direction of trade in the commodity. With further refinement, by examining samples from a greater number and variety of sites, and the application of more accurate and efficient recording and analytical procedures, it can be modestly asserted that oyster shells from archaeological excavations should prove an important tool for making site interpretations.

The research work has also provided a surprising bonus. The use of data from modern oyster populations has helped to unravel the circumstances surrounding the capture, trade and consumption of oysters in the past. On top of this, the archaeological material has demonstrated its potential to enhance understanding of changes taking place in oysters today - showing the importance of an historical dimension to studies of modern oyster populations. It would seem that the capability of the shells of oysters to respond to various factors in their immediate environment in such a readily observable way is allowing modern oysters to reflect present changes in their surroundings. The availability of a large bank of information relating to oysters in the past has highlighted how dramatically and rapidly these current changes are taking place.

THE WAY FORWARD

Any future extension of this research work would necessitate the construction of a computer database for all existing information as the majority of raw data is only available as hard copy and manipulation of the data at present is time-consuming. The database itself must be extended to include further well provenanced and dated samples of oyster shells to form a more complete range both in terms of geographical cover and chronology in Britain and Europe.

Infestation should be recorded with greater precision in both the qualitative and quantitative sense. For example, a reference collection should be built up of British marine and brackish water Bryozoa (Polyzoa) to enable identification to species level of this type of encrustation on archaeological shells. This in turn may increase the precision in identifying both the general habitat type and geographical location of the source oyster beds. Another example could involve recording the size and number of burrows caused by boring sponges in excavated and live oysters to investigate the supposed relationship between their dimensions and frequency with the salinity of the water in which they grew.

The examination of thousands of oyster shells to date indicates that either the damage in shells caused by the two marine polychaete worms of the Polydora genus exhibits greater variety of forms than previously understood, or the damage evident in the shells can be attributed to more than two species. The only way to find out which is the case is to undertake a study of live oysters from natural beds in aquarium conditions, removing epibiont worms for identification and examining the damage to the shells.

While it is still feasible to do so, in view of the prevalence of disease and pollution, samples should be sought of exploited and unexploited oysters from natural beds.

Methods of predicting the probability of an archaeological sample originating in a specific location and resulting from a certain level of exploitative activity should be devised along the lines of the River Invertebrate Prediction and Classification System (RIVPACS) designed by the River Communities Team of the Institute of Freshwater Ecology run by the Natural Environment Research Council. RIVPACS uses biological and environmental data to predict which invertebrate animals should be found in a clean river of given physical parameters for comparison with the animals actually found there. The idea could be adapted to compare excavated samples of oyster shells with samples fished from known locations by certain methods.

Many details of the way oyster farming has developed in Britain will remain unresolved unless evidence is found of the types of structures and equipment that are known to be related to the oyster business. Therefore archaeologists should be made aware of the possibilities, especially while excavating waterfront sites.

Experimental work with live oysters and a collation of recent oyster research papers may clarify cause and effect in shell change. While the possibility of applying current knowledge of such techniques as microsopic growth line and oxygen isotope analysis should not be overlooked.

The envisaged new database and programme package should facilitate a confident approach to solving many problems concerning oysters - from finding out once and for all whether British oysters really did go to Rome, to reaching an understanding of the cyclical nature of changing characteristics and abundance in the past which could help the formulation of predictive models for the future of Ostrea edulis.

It is even possible that the future of oysters could be linked to the future of mankind - if we are to believe the suggestion of Rayner Pitt and John Bayes of Seasalter Shellfish (Whitstable) Ltd (New Scientist 9th December, 1989) that the annual emissions of 7 billion tonnes of carbon dioxide which are contributing to the global warming problem could be mopped up by the worldwide production of around 20 billion tonnes of oysters each year. Regrettably it must be stated that there have to be drawbacks to this ingenious solution - it could not be so simple - but a study of the past may point to a solution in the future!