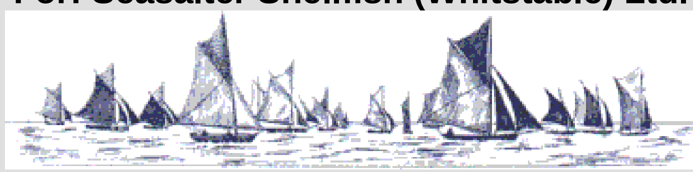
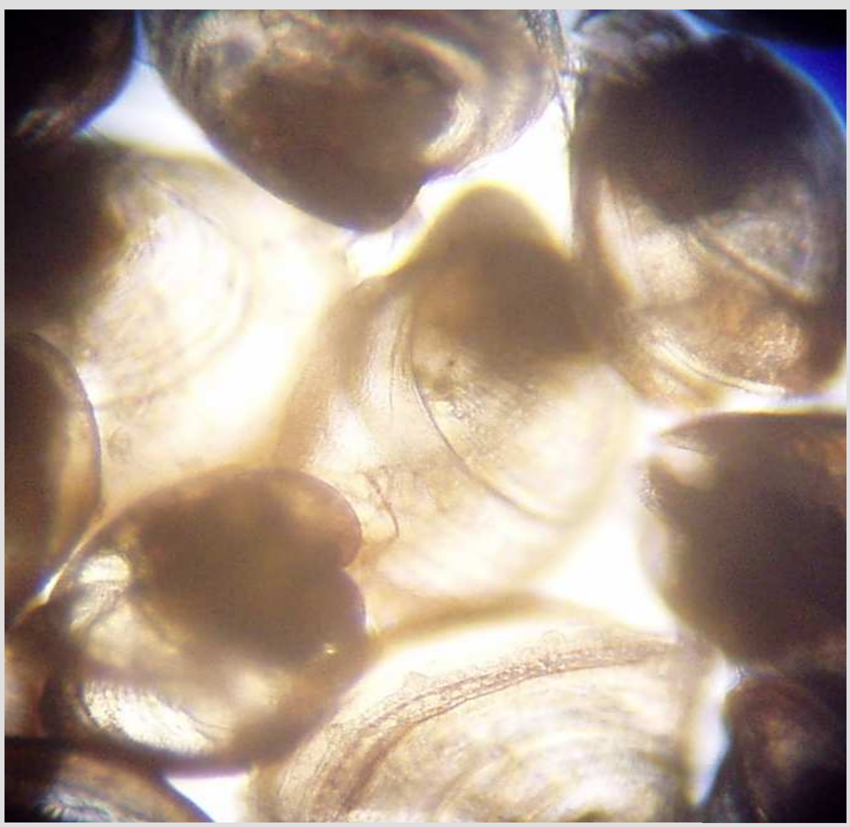
Aquafish Solutions Limited
Aquaculture and Fisheries Consultants

SUSTAINABLE PRODUCTION OF NATIVE OYSTER SPAT FOR ON-GROWING

FIFG PROJECT NO: 06/Eng/46/05

For: Seasalter Shellfish (Whitstable) Ltd.





FINANCIAL INSTRUMENT FOR FISHERIES GUIDANCE

SUSTAINABLE PRODUCTION OF NATIVE OYSTER SPAT FOR ON-GROWING – FINAL REPORT

FIFG PROJECT NO: 06/Eng/46/05

FOR: SEASALTER SHELLFISH (WHITSTABLE) LTD.

FINAL REPORT

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AUTHORS NOTE

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The Project Partners are as follows:

- Seasalter Shellfish (Whitstable) Ltd.;
- Sea Fish Industry Authority;
- Shellfish Association of Great Britain.

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EXECUTIVE SUMMARY

A. Background & Project Objectives

1. The native oyster (*Ostrea edulis*) is a European Biodiversity Action Plan species and the UK therefore has a responsibility to enhance natural stocks (under the Native Oyster Species Action Plan – NOSAP). The native oyster is also a commercially important species supporting many fishermen especially in south west England, the Solent and in Essex.

2. A recent study by Laing *et al.* (2005) on the potential for regeneration, co-funded by Defra & the Sea Fish Industry Authority, came up with recommendations including the following:

   - While recovery of natural stocks has been noted in some areas, including those affected by disease, it is clear that real progress with restoration can only be made through an active programme.
   - Stocking selected sites with strategically located broodstock by using pond or hatchery-produced oysters or half-grown stocks is an effective strategy for oyster restoration and should form an important component of the overall process.

3. Trials were therefore undertaken at a commercial shellfish hatchery in Kent to carry out a pilot/demonstration study to produce native oyster spat in purpose-built, low tech, outdoor ponds as a means of helping to regenerate oyster beds. The key output is an assessment of the technology, techniques and efficiency of producing native oyster spat for stock regeneration and the transfer of this information to the industry and other interested parties.

4. Other research as part of this project was also undertaken in order to identify areas where native oyster spat can be relayed. These areas should ideally be in disease-free protected (e.g. by Several Order) grounds on the foreshore to encourage natural recruitment and stock restoration.

B. Key Benefits

1. The pond production of native oyster spat has already been identified as a key way to progress the NOSAP and pond construction design, larval rearing methodology and pond management techniques have all been investigated and advanced during the current study.

2. This extensive, low-technology technique of using ponds for producing native oyster spat could be used in other areas of the UK for restoring natural oyster beds using local broodstock oysters. Investigations as to what other areas might be suitable in this respect during this project has highlighted a potential role for the use of these extensive shellfish production ponds in managed retreat schemes.

3. The project has been designed and carried out to provide a unique facility for hatchery personnel to train others wishing to construct and manage ponds for the production of native oyster spat and in this way the dissemination of best practice for cultivating and managing native oyster stocks sustainably has been supported.

4. This demonstration project is likely to encourage co-operative partnerships that will be able to benefit from the European Fisheries Fund as a means of regenerating native oyster stocks. Any development of these extensive pond systems in managed retreat schemes will undoubtedly lead to the establishment of collaborative projects and partnerships between industry and other organisations involved in creating these areas.

C. Pond Construction

1. A Larval Rearing System consisting of three 70m x 7m butyl lined-ponds has been constructed at the Seasalter Shellfish (Whitstable) Ltd. bivalve hatchery site in Reculver, Kent. Each pond has an approximately 700m^3 capacity. These 'V' shaped ponds have a maximum depth of 3m and have proved inexpensive to construct in terms of the excavation work required. A further pond with the same dimensions using a polythene liner has also been constructed.

2. A Native Oyster Nursery System has been constructed with a 40m^3 capacity for rearing native oyster spat attached to cultch. The Nursery System allows spat to be on-grown over the winter period after which time they could be relayed in the wild for restocking fisheries or for stock restoration purposes.

3. The Larval Rearing System, whilst based in part on other pond systems, is the first of this scale to be used for rearing native oyster larvae. The development of a separate Nursery System for on-growing the spat over-winter in a new innovation in native oyster production in pond systems.

4. The ponds were constructed in early summer 2006 ready for mature 'ripe' broodstock to be introduced (spawning season is from July to September). Following the preliminary trials in 2006 the main larval rearing trials were carried out in 2007 and 2008.

5. Pond Liners; The use of butyl rubber as a pond liner has proved successful although these liners do require a period of leaching in order to ensure that residual chemicals do not taint the phytoplankton food of the larvae. Polythene liners whilst less expensive than butyl rubber liners are not considered robust or practical for use in this type of extensive pond system.

D. Larval Rearing Trials & Managed Phytoplankton Blooms

1. The general methodology used during the larval rearing trials was to introduce 'ripe' broodstock oysters sourced from *Bonamia* free areas into the larval rearing ponds. The larvae produced by this broodstock then went through their initial development in these ponds feeding on the natural phytoplankton in the pond water. The larvae could then be settled on to shell cultch in the ponds. A few days after the larvae have attached, the cultch with the attached spat could be transferred out into the nursery system and their growth and survival monitored. Spat produced by this method would then be available for relaying.

2. Trials with native oysters to induce spawning in broodstock and to subsequently produce viable larvae were carried out successfully over three seasons from 2006 to 2008. However, despite this the main rearing trials of 2007 and 2008 were characterised by lower than expected numbers of spawnings by the broodstock and therefore only low production levels of viable larvae. The problems experienced in producing larvae that were able to successfully undergo metamorphosis are thought to be due to the unusually poor weather conditions experienced during the summers of 2007 and 2008 as well as difficulties in achieving a stable phytoplankton bloom of the species considered to be a suitable food source for native oyster larvae.

3. Further investigations are required in order to identify alternative types of suitable and available cultch as difficulties have been experienced during the current study with obtaining adequate supplies of shell material.

4. Managed Phytoplankton Blooms; Excessive grazing of the phytoplankton by zooplankton within the pond systems has prevented a stable phytoplankton population from being maintained in the pond systems. Methods to alleviate this problem should be investigated including the use of water that has previously been filtered by shellfish and the use of water that has been filtered through sand/silt.

5. Comparisons of phytoplankton species composition between lined and unlined ponds have highlighted that further work is needed in triggering blooms of the correct species of phytoplankton.

6. The results of the project have clearly demonstrated that in order to successfully manage the phytoplankton blooms in this type of extensive larval rearing pond it is necessary to have other shellfish, i.e. a greater biomass, in addition to the native oyster broodstock in the ponds. These additional shellfish would help to graze excess phytoplankton and thus maintain food levels for the native oyster larvae at a suitable level.

7. Healthy native oyster larvae were observed in the South Pond system which although not part of the main trials may hold some important lessons for future larval rearing trials. The water supplied to this pond passes through the nursery system once every one to two days and is therefore relatively free of the large zooplankton that have caused problems with pond management in the larval rearing Pond No.s 1, 2 and 3. The phytoplankton levels are also reduced to what may be a more suitable level having been grazed down already by the shellfish in the nursery system.

8. It is perhaps a combination of zooplankton free water and reduced or controlled phytoplankton levels that may prove most suitable for rearing native oyster larvae in the future. Further trials in this respect will be carried out by Seasalter Shellfish (Whitstable) Ltd/

E. Potential for Pond Use in Other Areas

1. The use of extensive pond systems for shellfish culture in managed retreat schemes is a new potential area for development between oyster farmers, wildlife organisations and the Environment Agency.

2. The varied and abundant flora and fauna that is in evidence at the Seasalter Shellfish (Whitstable) Ltd. pond systems demonstrates how closely the use of these types of extensive ponds matches the aims and objectives of the wildlife conservation aspects of managed retreat schemes.

3. It was concluded at a meeting held in July 2008 that the pond systems at Seasalter Shellfish (Whitstable) Ltd. constructed during the present FIFG project could be used as a model for managed retreat schemes under development at present and that the UK is probably leading the drive to establish an integrated approach to incorporating differing users and options in managed retreat schemes.

4. Seasalter will continue to develop the potential collaborative partnership with the organisations involved with establishing managed retreats as well as other interested parties in order to help establish pond systems for shellfish culture, and in particular native oyster regeneration, as an integral part of future managed retreat schemes.

F. Conclusions

1. Three larval rearing seasons have been undertaken as part of this FIFG project. Spawning in the native oyster broodstock was successfully induced and viable larvae were produced.

2. Despite difficulties experienced in on-growing the larvae produced through metamorphosis all stated key benefits and targets were realised and achieved. This project has significantly moved forward the understanding of the technology and methodology required in order to successfully rear native oysters in extensive pond systems.

3. Whilst the specified key benefits and targets have been achieved during the current FIFG funded study, Seasalter Shellfish (Whitstable) Ltd. will continue to run trials in these larval rearing ponds in order to continue to develop the methodology required to raise native oyster larvae successfully in this type of extensive pond system.

4. The results of this project work have provided and will continue to provide a unique facility for training of industry and other organisations involved in managed retreat schemes in how to construct and manage ponds for the production of native oyster spat. In this way, the dissemination of best practice, for cultivating and managing native oyster stocks sustainably has been and will continue to be supported.

5. This demonstration project is likely to encourage co-operative partnerships that would be able to benefit from the European Fisheries Fund programme as a means of regenerating native stocks from the environmental perspective and from the sustainable fisheries perspective. The development of managed retreat schemes means that this type of extensive pond production could also offer a means of diversification for agricultural producers who otherwise face losing their land resources.

6. Seasalter Shellfish (Whitstable) Ltd. can now arrange targeted training sessions for industry members and other organisations who wish to learn about the methodology and management underpinning the production of native oysters using these types of extensive pond systems.

SUSTAINABLE PRODUCTION OF NATIVE OYSTER SPAT FOR ON-GROWING – FINAL REPORT

SECTION 1 – OVERVIEW & INTRODUCTION

1.1 Project Overview

The numbers of native oyster (*Ostrea edulis*) spat that would be required for large-scale restoration of this now much declined native species means that normal hatchery production methods are not economically viable. Seasalter Shellfish (Whitstable) Ltd. have therefore, as part of the current Financial Instrument for Fisheries Guidance and Marine and Fisheries Agency funded study, investigated the use of large-scale extensive pond systems for rearing native oysters whereby mature broodstock are held and spawned in managed outdoor ponds.

The main objectives of this project were to:

- Construct outdoor ponds at the commercial shellfish hatchery in Reculver, owned by Seasalter Shellfish (Whitstable) Ltd.;
- Introduce mature ('ripe') native oyster broodstock animals into the ponds where they will spawn naturally, producing larvae that will be settled on to a shell settlement substrate (cultch) in the ponds;
- Introduce native oyster larvae, produced in the hatchery, into the ponds as an alternative to allowing broodstock to spawn naturally (this will be an option outside the natural summer spawning period);
- Identify areas where spat settled on to cultch can be relayed, ideally in disease-free, protected (e.g. by Several Order) grounds on the foreshore to encourage natural recruitment and stock restoration.

A central aim of this study was also to serve as a demonstration site to others in the industry, as well as providing a training and technology transfer opportunity in the future for members of the industry who wish to develop similar systems elsewhere to enable native oyster restoration at a local level and using local stocks. This type of approach could help in the development of local co-operative type ventures.

1.2 Introduction

1.2.1 Decline of the Native Oyster;

The native oyster, *Ostrea edulis*, or flat oyster as it is also known, was once a major commercial fishery, peaking in the mid 1800s after the end of the Napoleonic Wars. Indicative, if not wholly reliable, figures for numbers of oysters passing through Billingsgate at the time put the level at about a staggering 500 million. The first official oyster statistics were not produced until 1886 by which time production levels had dropped dramatically to around only 40 million per annum. This reduction in supply saw prices rise by about seven to eight times their original level from 1860 to 1889 (Neild, 1995) and it was at this stage that the oyster changed from a food of the poor to a dish more commonly associated with the wealthy. Today the stocks of this once abundant species remain at very low levels. Two centuries of over exploitation, TBT (tri-butyl tin) pollution in the 1980s, mortalities due to severe winters in the 1930s and 1940s, competition from exotic pests such as the slipper limpet in conjunction with the parasitic disease *Bonamia* have all meant that current standing stocks are severely depleted. Indeed during the course of the current project new geographical occurrences of *Bonamia* were recorded including in that of the Thames area itself.

1.2.2 NOSAP;

Although now at much reduced levels the native oyster is still a commercially important species for many fishermen, especially those in south west England, the Solent and in Essex. This decline in oyster numbers led in the late 1990's to the development of a Biodiversity Action Plan for this species, the Native Oyster Species Action Plan (NOSAP), for which the lead agency is currently the Shellfish Association of Great Britain. The main aim of NOSAP is to increase the abundance and geographical range of this threatened species where biologically feasible.

It was therefore following the feasibility study by Laing *et al.* (2005) and as part of this Action Plan that Seasalter Shellfish (Whitstable) Ltd. (Seasalter), the Sea Fish Industry Authority (Seafish) and the Shellfish Association of Great Britain (SAGB) have developed and helped fund a project using Financial Instrument for Fisheries Guidance (FIFG) and Marine and Fisheries Agency (MFA) funding to investigate the potential for producing large numbers of native oyster spat at an economic cost. This would then allow their relaying as broodstock in areas free of disease and thus help to regenerate fisheries in those areas.

1.2.3 Key Benefits of Project;

- The pond production of native oyster spat has already been identified as one key way to take forward the NOSAP. This project will help to demonstrate the UK commitment to this European-wide initiative.

- This technique of using ponds for producing native oyster spat could be used in other areas of England for restoring natural oyster beds using respective local broodstock oysters. It is a more extensive and low technology method than producing oyster spat in a hatchery.

- This project will provide a unique facility for experienced hatchery personnel to train others on site wishing to construct and manage ponds for the production of native oyster spat and enable other industry personnel to become familiar with the procedures. In this way, the dissemination of best practice, for cultivating and managing native oyster stocks sustainably will be supported.

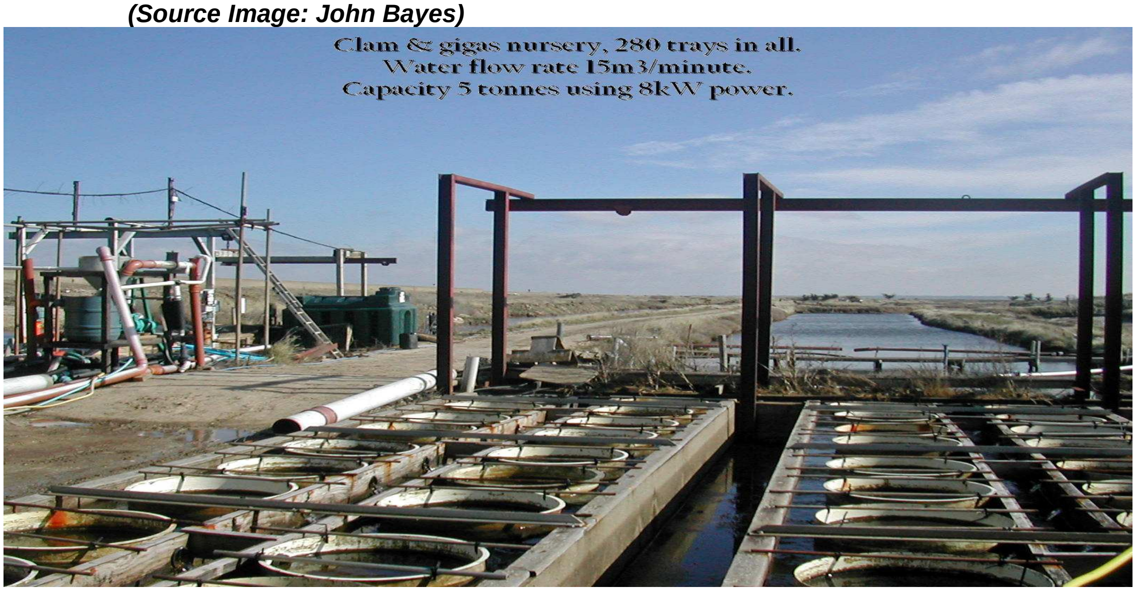
- Such a demonstration project is likely to encourage co-operative partnerships that would be able to benefit from the European Fisheries Fund programme as a means of regenerating native stocks both from an environmental perspective and from the sustainable fisheries perspective.

1.2.4 The Reculver Nursery;

In 1896 a wooden hatchery was built on the site that is now occupied by the current hatchery. It consisted of some open top tanks inter-linked with others. History does not recount whether it was successful, but it is known that a natural spat fall occurred in the Thames around that time which made it unnecessary to breed more oysters. This hatchery was within a secondary seawall where brackish water stood in various parts. As it was not suited to agriculture it lay derelict for many years. Around 1970, Tim Lucas acquired the land and built a lobster farm. It was designed to take lobsters of minimum legal size during the summer and sell them one moult later in the winter when prices were high. Water requirement was very limited and consisted of a small butyl rubber-lined tank which was filled with seawater using a pump. The farm was not profitable and about four years later it was bought by Geoff Reece.

The idea at this stage was to build a small oyster nursery for native oysters. These would be bought from the Seasalter & Ham Oyster Fishery Limited whose hatchery was then based at Whitstable. It was necessary to get permission to flood the area with seawater from the River Authority which is now the Environment Agency. It was a narrow plot which presented some problems because in order to get enough water, it was necessary to have one of the ponds close to the Berm. This is an embankment adjacent to the seawall whose purpose is weight the surrounding ground so as to ensure that the seawall doesn't subside. The River Authority were concerned that it might become water logged and unstable. This in fact never happened, but Seasalter still take care to ensure any surface water laying on it drains straight into the pond systems. There were no other objections. Permission was also granted for Reece to flood the ponds tidally via some 600 and 400mm concrete pipes. These were fitted with surge towers so that exceptionally high tides would not allow excess water into the system. The nursery was successful but proved more suited to the production of Pacific oysters (*Crassostrea gigas*) than native oysters. However, around this time (~1981) natural production of Pacific oysters had become highly successful in France and the price collapsed, although by today's standards it was still quite good! At this time, The Seasalter & Ham Oyster Fishery Company bought the facility. In 1986, this became the current company, Seasalter Shellfish (Whitstable) Limited. The current clam and Pacific oyster nursery system in use at Seasalter is shown in Figure 1.

Figure 1. Modern Seasalter clam and Pacific oyster nursery shown in 2008 (Source Image: John Bayes)



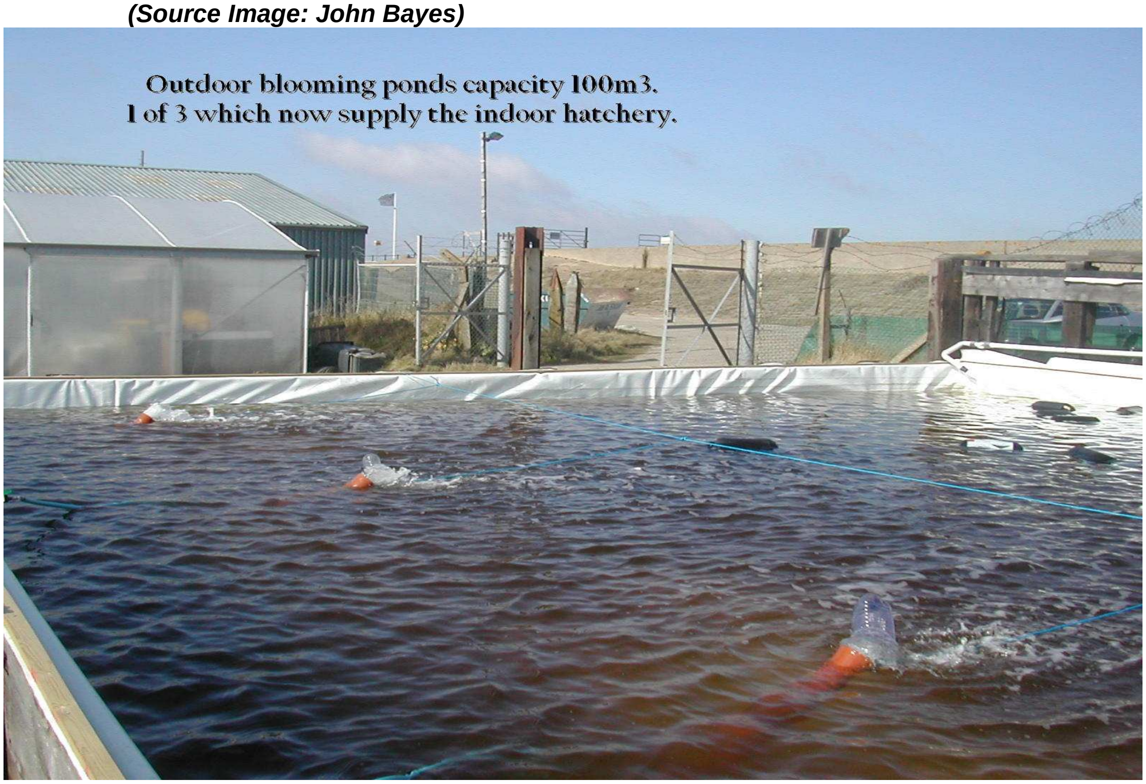
At this time Seasalter also had another nursery at Oare, Near Faversham, 30km east of Reculver. This was a very fertile and easily managed site, however, the landlords required it for other purposes and so production of shellfish ceased. Seasalter enlarged the Reculver nursery by purchasing an extra 15 hectares of agricultural land. No objections were raised because it was obvious that the pond management activities greatly improved the biodiversity of both the flora and fauna. The only complication was that the perimeter pond is a freshwater dyke and is a RAMSAR site and had to be preserved as such. This did not prove particularly difficult despite the fact that the freshwater dykes were lower than the seawater ponds. There has been some increase in the salinity of parts of the dyke. The part close to the shore was prone to becoming hypersaline during the summer before the ponds were created due to sea spray. This area therefore supports sedges rather than reeds or rushes, which are typical of the remainder of the dyke.

SECTION 2 – POND CONSTRUCTION

2.1 Introduction

Two separate 'serpentine' ponds were originally created at the Seasalter site which are referred to as the 'North' and 'South' Systems. A minimum of two ponds is required in order that one can be emptied to dispose of unwanted molluscs and macroalgae whilst the other pond system is still in use. The ponds have to be serpentine in shape so as to avoid long straight stretches which would allow waves to form. Any such waves can lead to the erosion of the alluvium based banks. Various ponds have been sectioned off which are only connected to the main channels using 400mm plastic twin walled polythene pipes. These 'sub-ponds' can be isolated and pumped dry independently of the main system. When refilled, a natural phytoplankton bloom will then occur in these sub-ponds which can then be fed into the main nursery system as a food source. The main indoor hatchery itself is supplied with phytoplankton through the production of three 100m^3 capacity outdoor blooming ponds that are located next to the main hatchery building as shown in Figure 2.

Figure 2. Outdoor phytoplankton blooming pond
(Source Image: John Bayes)



The management of the phytoplankton blooms remains one of the most challenging aspects of operating this type of extensive pond system for shellfish culture. An example of the problems that can be encountered is that often initially successful phytoplankton blooms do not go on to trigger further better blooms in the main pond system. Another problem sometimes experienced is that these blooms do not remain sustainable for a long period of time. What has been learnt over many years of developing the main pond systems is that the ponds each have different characteristics, and of these ponds, two in particular have tended to be more successful at maintaining phytoplankton blooms than the others.

The first of these ponds (numbered Pond No. 4 in this study) has a butyl rubber liner and a volume of approximately 1500m^3. This pond can currently be supplied with seawater from various sources such as water leaving the hatchery and nursery, as well as fresh water pumped from the adjacent freshwater Rushbourne Dyke. This dyke is in fact a drain that carries treated sewage effluent and agricultural run-off and so is rich in nitrate, silicate and valuable soil leachates. In general Pond No. 4 maintains a very satisfactory bloom and has for instance during the last twelve month period been used to supply the Pacific oyster spat in the hatchery resulting in excellent production results.

The second successful pond for maintaining phytoplankton blooms is essentially similar to Pond No. 4 but has no butyl lining. This pond can receive water from a number of sources. These sources of water are from the main pond system, which is effectively water that has been through the nursery, as well as some new seawater from Rushbourne Dyke and the 'well''. The 'well' as it is called is in fact a long trench cut down the centre of the nursery into which water seeps from the surrounding ponds bringing with it large amounts of iron silicate. In terms of water quality, salinity in this pond is considered normal for marine shellfish production. However the water has proved to be toxic to most phytoplankton and oyster larvae although not to small fish and crustacea. This pond also maintains a good phytoplankton bloom at most times of the year and production in this pond is also used to successfully support the hatchery. Neither of these main large-scale phytoplankton production ponds have triggered dense blooms in the rest of the nursery system.

In 2002 Seasalter acquired a further 20 hectares of land. After obtaining the necessary consents this area of land was developed using a different methodology to the rest of the existing pond systems. The ponds were excavated down to about 1m below mean high water mark which therefore allowed them to be filled by gravity. The relative actual sea height at around high tide relative to the pond systems is shown in Figure 3.

Figure 3. Image showing sea height relative to pond systems at Seasalter (Source Image: Martin Syvret)

This new pond system was expensive to create in terms both of excavation costs and also in terms of the land that had to be sacrificed (approximately half of the area) in order to store the spoil in the form of embankments.

At this time it was also decided to start reusing the nursery water as water sourced directly from the seashore was proving to be increasingly toxic, particularly to shellfish larvae. This toxicity issue has in fact worsened in recent years to the point where nowadays raw seawater proves to be unsatisfactory for rearing shellfish larvae. This new zone has now been designed to incorporate three main areas for shellfish production. The first is a Clam Nursery System and the second and third areas are the Larval Rearing System and Native Oyster Nursery System constructed as part of this project.

2.2 Methodology

2.2.1 Construction of Water Management Systems;

Extensive work was carried out during the construction of the pond systems required in order to undertake the present study. The first requirement was to install an adequate Water Management System capable of supplying both the Larval Rearing System and Native Oyster Nursery System. The construction of the Water Management System is described in the following sections in order to provide a practical guide on pond construction.

2.2.1.1 Twin wall polypipe: An important feature of the development of the pond layout and design undertaken during the current study has been the introduction of this twin wall polypipe**.** It has many features that greatly reduce the workload of constructing pond systems. An example of this type of pipework can be seen in Figure 4 below.

Figure 4. Twin wall polypipe
(Source Image: John Bayes)

Amongst the advantages of this type of pipework for water management are the following:

- It is lightweight. Two men can easily lift a 6m length of 600mm diameter pipe. By comparison, concrete pipe only comes in 2.4m lengths and each pipe would weigh more than 1 tonne. A large number of pipes can be delivered by one vehicle.
- A great many different diameters of pipe are available.
- 6 metre lengths are easier to lay and there are generally few problems experienced with alignment.
- It has a very smooth bore. Fouling does occur but is relatively easy to remove.
- The corrugated outer surface makes it possible to seal the pipe in the ground provided it is backfilled carefully to ensure that some fines penetrate the corrugations. Most other pipes allow seepage round the outside of the pipe which in time can become a major leak as the substrate around the pipe erodes.
- Although the makers do not recommend it, our experience has been that if the buried pipe is carefully backfilled, no other support is required. In fact, we are able to drive a 20 tonne digger over the pipe immediately after it has been buried. The advantages described above have resulted in a huge saving in time and money.

There are some drawbacks to using this type of pipe. One is that the pipe floats and so great skill is required on the part of the digger driver if they are to be set below water level. The way Seasalter achieve this is for the driver to use a wide bucket (in our case 3m wide). First then fill the bucket with loose spoil, then put the pipe on top of the spoil. Then drop the pipe where it is to be laid, pressing it down into the water, at the same time emptying the spoil on top of the pipe. It is a difficult manoeuvre, but works well at the Reculver site where there is no very deep water. The other drawback is that the pipe is very delicate. Usually this doesn't matter but sometimes when a pipe has to be moved, then two problems occur. Firstly, if the digger touches it then there is a danger of perforation. The other problem is that spoil stuck in the corrugations, greatly increases the weight and it has occasionally resulted in the pipe breaking in half.

T-pieces, Straight connectors and Elbows are available in all sizes although these are not often needed. Other features and fittings required for the current project were constructed in-house by Seasalter.

2.2.1.2 The "Lollipop" System: The system for controlling water flow into and out of the ponds is known at Seasalter as the "Lollipop System" as shown in Figure 5 below.

Figure 5. The "Lollipop" System (Source Image: John Bayes)

These are made from heavy duty plywood and a short section of pipe. Around the perimeter is high density black foam glued to the wood. The lower one pictured is for the female end of the pipe and the upper one, without pipe, fits the male end. The "Lollipops" have proved very practical, being lightweight and, when properly installed, completely watertight.

This is illustrated in the Figure 14 where a series of 600mm pipes, being the inlet and outlet to the Native Oyster Nursery System, have to be blocked, while the eastern section of the nursery is being drained, leaving the western section full. This means we can continue running the nursery, keeping part of the pond system dry in order to kill off pond weed and cockles, which have proved a major problem in the past. Modifications to the lollipop system are also in use in other parts of the water supply system as shown in Figure 6.

Figure 6. Modified lollipop system incorporating swing-flap valves (Source Image: John Bayes)

In this example the lollipop system has been modified with swing-flap valves. Again plywood and foam are used, but here are attached with a steel ring to the end of the pipe and with a steel bar and counterweight so that the gate remains firmly shut when the flap is in a vertical position. This is an important feature when filling the ponds tidally and also to prevent water from circulating in the wrong direction around the pond system. The water is not of a uniform quality and generally improves as it passes around the pond system, so it is vitally important not to get new raw water into those parts of the pond that supply the hatchery.

2.2.1.3 Supply channels: Maintenance of the water supply channels is vital to ensure adequate amounts of seawater are supplied to the pond systems. In Figure 7 the brownish colour on the banks of this channel and to the right is the algae *Chaetomorpha* which has been drying for some time following excavation and clearance works. This algae requires regular removal if it is not to block the supply channels.

Figure 7. Channel banks showing drying Chaetomorpha (Source Image: John Bayes)

In Figure 7 the *Chaetomorpha* is not completely dead and there is green weed underneath the brown crust. It may take several months to eliminate it during the winter period. Any cockles generally die within two weeks. Figure 8 shows the use of a mechanised digger to remove the *Chaetomorpha* in 2008 after removal by hand became impossible.

Figure 8. Mechanised removal of Chaetomorpha from water channels (Source Image: John Bayes)

2.2.1.4 The weir system: In some of the ponds it is important to maintain a precise level and this has been achieved through the construction and use of a weir system as shown in Figure 9.

Figure 9. The weir system of pond level management (Source Image: John Bayes)

The weirs are constructed from pallet boxes as illustrated and the weir is cut to size after installation. It can of course be adjusted upwards just by attaching a wooden board. This is an important feature but some precautions have to be taken. It is essential to anchor the box firmly to the ground so that it doesn't float. You can see on the left of the image that the polypipe is passed through a hole in the box and sealed in position with polyurethane foam. This is a remarkably effective way to connect two rather incompatible plastics together. The seal is completely watertight and lasts for some years.

2.2.1.5 Plumbing: Water transfer is achieved through the use of PVC land drainage pipes, mostly 110mm as shown in Figure 10.

Figure 10. PVC land drainage pipes
(Source Image: John Bayes)

These 110mm pipes are less expensive than the 62mm polythene pipe and are readily available from any hardware supplier. These pipes are not liable to bursting as the pumps used at the Reculver site are not powerful enough for this to be a problem. The end of the pipes are 'plumbed' together to prevent separation by putting a small self-tapping screw through the sockets.

The pipe shown in Figure 10 has a reducer to enable a 2" hose to be quickly coupled to the system where necessary. This type of pipe is used for filling and emptying the Larval Rearing Ponds and also the rest of the phytoplankton blooming ponds.

2.2.1.6 Other phytoplankton production ponds: Figure 11 is an aerial photo of the new arrangement of the Clam Parks. These have now been divided into six ponds aligned north-south.

Figure 11. Phytoplankton blooming ponds and new Clam Parks (Source Image: John Bayes)

Once completed, any of these ponds will be capable of being emptied independently of the rest of the system and dried out. Thereafter, on refilling a good phytoplankton bloom will develop naturally and this can then be used to supply the rest of the nursery system.

2.2.2 Construction of Larval Rearing Ponds;

An initial site meeting was held prior to the design of the Larval Rearing Pond Systems in order to gather all available information as to how these ponds should be constructed. David Hugh-Jones of Rossmore Oysters, who have previously raised native oysters in pond systems, contributed to these discussions in order to add their experiences in this respect. Excavation works for the Larval Rearing Ponds at the Reculver site in Kent started in early June 2006 with the first of the liners being installed by mid-June 2006 (see Figure 12) thus allowing the preliminary trials to commence. Three 70m x 7m butyl rubber lined-ponds (Pond Numbers 1, 2 and 4) were used as part of these trials. A further pond (Pond No. 3) located next to and with the same dimensions as Pond No's 1, 2 but instead using a polythene liner was also constructed. The Larval Rearing Ponds (No.s 1 to 3) run north to south and have an approximate volume of 700m^3 each.

These ponds were filled with water from the Seasalter 'North Pond' system which consists of those ponds on the north side of the access roadway running from the hatchery in the west to the new ponds in the east. This is the water normally used to operate the hatchery.

Pond No. 4 which is located next to the hatchery has been designed to have access to a variety of different water sources including raw seawater, nursery water and water from the nearby dyke which is brackish and usually rich in nutrients. This pond is also equipped with an aeration system and is adjacent to a small algal blooming pond that can be used as a source of algal inoculum.

Figure 12. Pond No.1 shown after installation of the butyl liner in summer 2006 (Apparatus shown on the bank is a biological filtering system to manage phytoplankton levels in the pond. Source Image: Martin Syvret)

These three Larval Rearing Ponds are normally supplied with seawater that has first been through the hatchery system as previous research in this respect at the Reculver site has shown that raw seawater is not as effective for rearing native oyster larvae.

2.2.3 Nursery Construction;

The purpose of the large Native Oyster Nursery System is twofold:

1. The water in this system is moved by a paddle wheel rather than a pump. This has the advantage that large amounts of water can be moved at a minimal cost. It is estimated that a 1kW motor can move 30,000 litres of water a minute.

2. Large and bulky trays can be contained in this system so that native oyster spat set on shell cultch could easily be accommodated. Most existing spatting ponds either have to be emptied and the spat put out to sea at such a small size that the bulk of them are lost due to predation by crabs etc. or alternatively, as in the Norwegian system, spat are left for a further year, thus restricting its use as a spatting pond. Using the large nursery design that was created for this project, oysters could then be taken through the winter at relatively little expense and put out direct on the seabed the following spring when better survival could be expected.

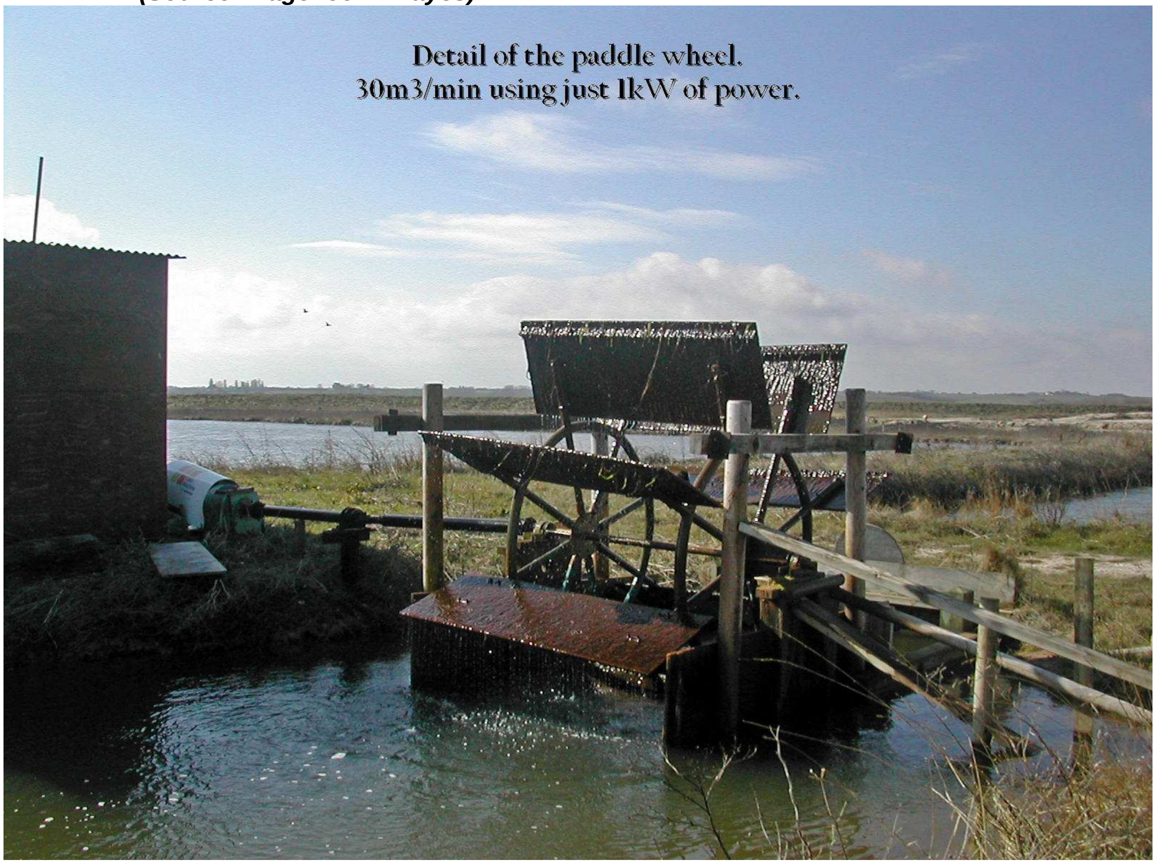
The Native Oyster Nursery System for on-growing is shown in Figures 13 and 14 during its construction phase.

Figure 13. Native Oyster Nursery System under construction
(Showing paddle wheel at far end and individual sections for seed trays during the nursery stage. Source Image: Martin Syvret)

Figure 14. Inlet and outlet system to Native Oyster Nursery System
(Source Image: John Bayes)

Figure 15 shows a paddle wheel in detail. The paddle wheel system employed at Seasalter is capable of moving over 30m^3 of water per minute using just a 1kW of electricity.

Figure 15. Paddle wheel system for moving water between ponds (Source Image: John Bayes)



2.3 Results

2.3.1 Pond Construction; Figure 16 gives an aerial view of the Larval Rearing Pond and Native Oyster Nursery Systems constructed as part of this current project (shown with the old Clam Park design).

Figure 16. Overview of Larval Rearing and Native Oyster Nursery Ponds (Source: reproduced by kind permission of Google Earth)

Key: A = Larval Rearing Ponds; B = Native Oyster Nursery System; C = North System; D = South System; E = Hatchery

2.3.2 Larval Rearing System;

2.3.2.1 Larval Rearing Ponds: Figure 17 shows Pond No. 1 of the Larval Rearing System in 2008 after 3 years in-situ.

Figure 17. Larval Rearing Pond shown in 2008 after 3 seasons in-situ (Source Image: John Bayes)

The pond image shown in Figure 17 shows how the butyl rubber liners have continued to remain functional and watertight after three seasons.

2.3.2.2 Pond liners: The use of butyl rubber liners has proved to be an effective method of creating pond systems for larval rearing. However careful consideration needs to be given to fully 'leaching' the liners prior to undertaking any larval rearing as there appears to be evidence from the preliminary trials in 2006 that the liners may cause a tainting of the phytoplankton that will prevent the larvae from feeding and developing, thus resulting in high mortality levels.

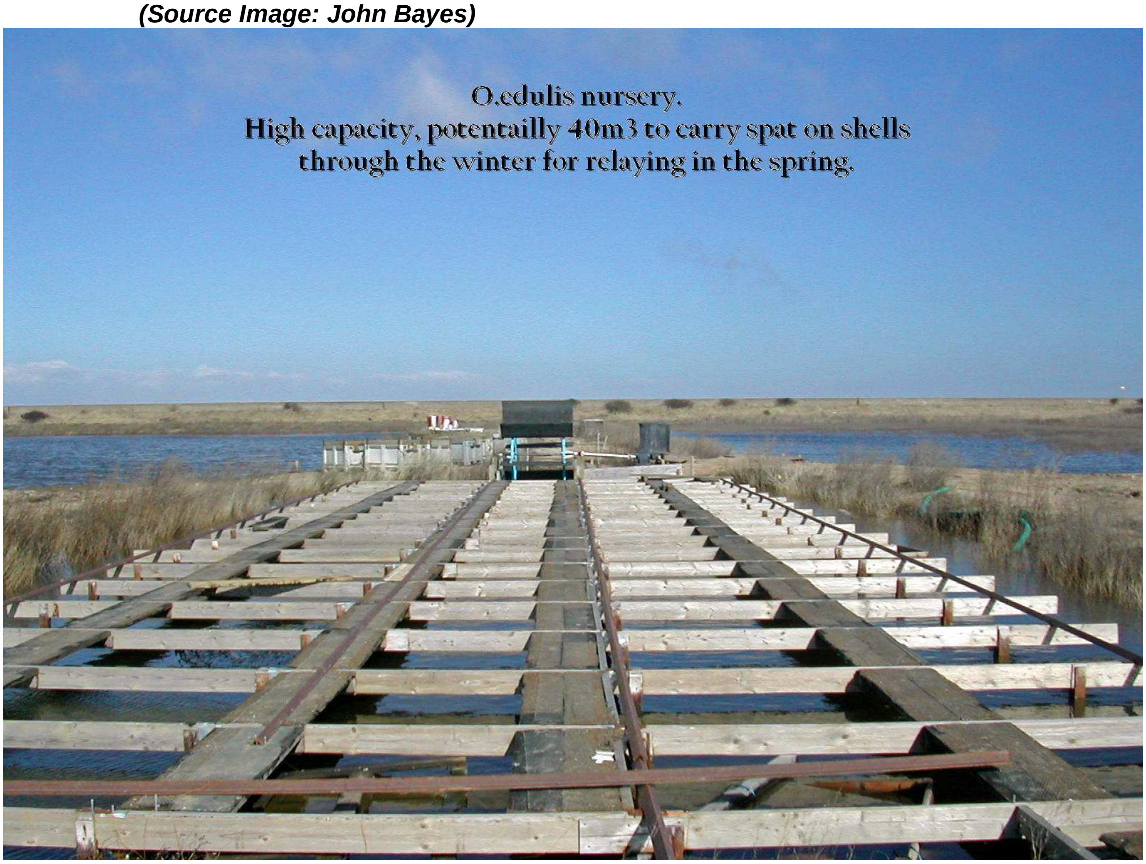
The polythene liner used in Pond No. 3 (see Figure 18) has a tendency to 'float' under certain wind conditions/directions with consequent problems for management of the pond during larval rearing.

Figure 18. Pond No. 3 showing the effect of a northerly wind on the polythene liner (Source Image: Martin Syvret)

2.3.3 Nursery Construction;

The final layout of the Native Oyster Nursery System for spat on-growing is shown in Figure 19.

Figure 19. Final layout and infrastructure of the Native Oyster Nursery System (Source Image: John Bayes)



The Nursery System constructed has a 40m^3 capacity for rearing shellfish. The design shown is capable of rearing native oyster spat attached to cultch over the winter period for subsequent relaying the following spring.

2.4 Discussion

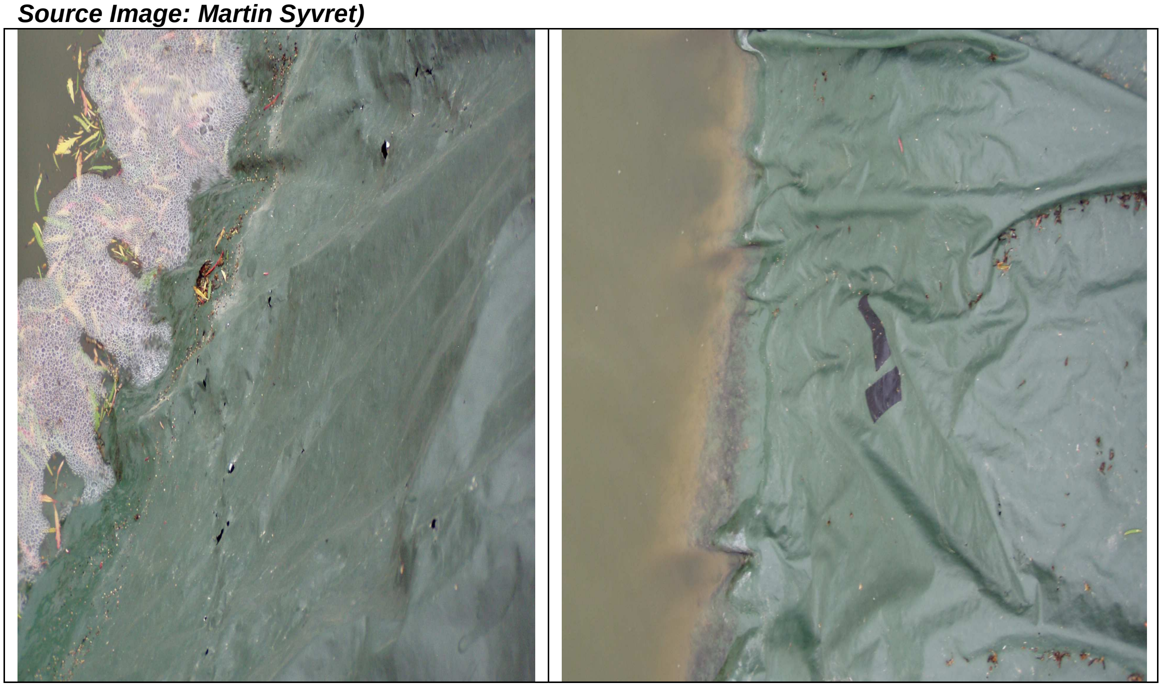
2.4.1 Pond Construction;

The use of large-scale pond systems for rearing native oysters has been carried out before at Rossmore Oysters in Cork, Southern Ireland. As described previously an initial site meeting was undertaken with David Hugh-Jones of Rossmore Oysters in order to better understand their experiences in raising native oysters in pond systems. The Larval Rearing Ponds and Native Oyster Nursery System that were constructed by Seasalter differ however in several aspects to that used by Rossmore Oysters. The Seasalter ponds are constructed on a much larger scale than the Irish ponds with a different 'V' shaped design profile and a separate nursery system for the spat.

2.4.1.1 Pond liners: The polythene liner used in Pond No. 3 has shown a tendency to 'float' under the influence of wind from certain directions and although it is has an advantage of being relatively non-toxic it is likely that this liner will need to be replaced in the future with a butyl rubber liner. The physical characteristics of the butyl rubber used for the liners of Pond No.s 1, 2 and 4 have resulted in its successful use in the creation of these Larval Rearing Ponds. However, certain chemical residues have resulted in a degree of initial tainting of the phytoplankton meaning that long leaching periods would be recommended for further pond developments.

In addition to the problems experienced with the wind affecting the polythene liner this material has also been shown to be far less resistant to wear and damage than that of the butyl runner liner. An example of the damage and subsequent repairs that were necessary for use of the liner during the 2007 trials in shown in Figure 20.

Figure 20. Damage to polythene liner (shown during 2007 trials)
(Left hand image shows damage; right hand image shows repairs undertaken;
Source Image: Martin Syvret)



SECTION 3 – LARVAL REARING TRIALS

3.1 Year 1 Larval Rearing Trials (Summer/Winter 2006)

3.1.1 Introduction;

The project started in early summer 2006 when the first mature 'ripe' broodstock were introduced (spawning season is from July to September). These broodstock after spawning should produce viable larvae. The larvae then normally reach the pediveliger stage of development after 2-3 weeks when the appearance of a foot can be seen. At this stage they sink to the seabed and explore the substrate until they find a suitable surface on which to settle permanently (Sea Fish Industry Authority, 2002) which in this project is the cultch in the ponds. The production process is continuously monitored and the success of each pond for the production of spat assessed. Daily records are kept of the changes in environmental parameters, phytoplankton/zooplankton levels and spawning/growth of larvae (See Appendix 3).

After a period of time in the Larval Rearing Ponds the spat would then be transferred out into the Native Oyster Nursery System and their growth and survival monitored. When they are of a sufficient size they would then be able to be re-laid onto existing native oyster grounds. After relaying the growth and survival of these spat would again be monitored. These preliminary trials in 2006 were designed to help in refining the methodology and pond management techniques for use in the main trials which were at that stage anticipated to be during the spring/summer of 2007.

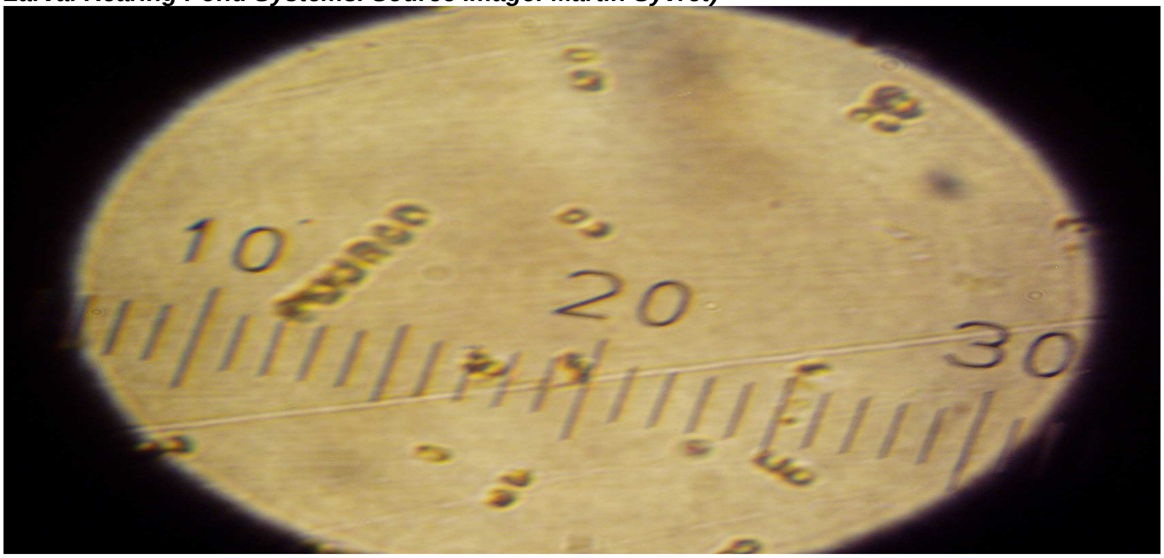
3.1.2 Methodology;

3.1.2.1 Larval production - summer 2006 trials: In preparation for the 2006 trials broodstock oysters were sourced from local *Bonamia* free areas. At the end of June 2006 200 oysters were put into Pond No's 1 and 3. Further stocks of broodstock oysters were to be obtained for the main trials in 2007. These broodstock oysters in early summer 2006 proved difficult to source as the oyster grounds were at that time covered in seaweed. Because of these difficulties in obtaining broodstock a further 1,000 new broodstock were then ordered with an option to obtain up to 1,000 more for the 2007 trials.

3.1.2.2 Managed phytoplankton blooms: The larvae produced by this broodstock go through their initial development in the Larval Rearing Ponds feeding on the natural phytoplankton in the pond water that is maintained due to the active management of the pond systems. This management of the phytoplankton blooms is required in order to ensure that suitable non-pathnogenic/toxic species of phytoplankton are produced and that the concentration of algae remains at an optimum level in order to ensure maximum larval growth. Figure 21 shows a managed bloom of *Skeletonema costatum* a chain-forming diatom with cell sizes of 7-15µm which is common in British coastal waters (Newell & Newell, 1966).

Trials with phytoplankton blooms were also undertaken in Pond No. 4 (nearest to the hatchery and running east to west) which is a larger pond than that of the Larval Rearing Ponds with a capacity of 1,500m^3 and is also lined with butyl rubber. These trials were carried out in order to try and better understand the changes and progression in algal species and to help with refining pond management techniques. The use of ultrasonic technology (at ~£1-k cost to Seasalter) to control algal levels was also assessed.

Figure 21. Skeletonema costatum
(View through a microscope of a sample taken from a managed phytoplankton bloom from the Larval Rearing Pond Systems. Source Image: Martin Syvret)



3.1.2.3 Larval production - winter 2006 trials: In order to act as a form of control with regard to producing native oyster larvae on the Reculver site, hatchery trials took place over the winter of 2006/07 in order to see if larvae could be raised successfully outside the pond systems.

3.1.2.4 Trials with an alternate source of cultch: Sources of cockle shell for use as cultch proved difficult to obtain in 2006. These fluctuations in availability of different types of shell waste are becoming more common and it was therefore proposed to test another form of material for use as cultch that would be more readily available throughout the year. The material considered for these trials was crushed limestone.

3.1.3 Results;

3.1.3.1 Larval production – 2006 summer Trials: The following is a chronological log of the main findings for July 2006 which serves as an example of the type of work undertaken during the larval rearing trials undertaken in this study:

04 July 2006 – The first native oyster larvae were spotted in Pond No. 1. These larvae were of a size range of between 170/180µm to 220µm. As these larvae hatch at about 170-190µm (Walne, 1979) and then grow at around 20µm per day, this size range indicated that there had been more than one spawning. These larvae were of poor quality (brown colouration and rough around the margins). The larvae were seen to have 'rafted' near the surface of the north end of the pond and were outnumbered by about 10-1 by copepods.
05 July – Larvae were now more numerous and copepod numbers had reduced. Copepod reduction may have been due to predation by small shrimps which appeared later in the ponds. Phytoplankton levels remained good in the ponds. Larvae were also in evidence in Pond No. 3 together with copepods. As larvae were present cultch was now introduced into the ponds.
10 July – Larvae still present in Pond No. 1 but had not grown past their initial hatch/start size of around 180-220µm. Larvae at this stage should have been around 320µm at which size they would metamorphose. Phytoplankton levels remained adequate to support larval development.
12 July – No larvae now present in the ponds which indicated high mortality rates.

13 July – Broodstock moved to Pond No. 2 which was followed by a spawning (estimated at about 6 larvae per 100 litres).
24 July – Pond maintenance carried out on Pond No. 1. Very few oyster larvae remained in Pond No. 2. Of those larvae remaining the majority were still of the size range of 180-200µm which would indicate that no growth had occurred.
26 July – A new spawning occurred in Pond No. 2 with larvae seen of the size range 170-180µm.
28 July – Larvae in Pond No. 2 were seen to be making good progress and were of the size range 230-260µm.
31 July – No larvae were visible in Pond No. 2 with only copepods being present.

Early results for August 2006 showed a similar pattern to those of July with spawnings followed by some larval development and then high mortality levels. Further analysis work was undertaken during this period of the progression of phytoplankton and zooplankton over time so as to try and better understand the mechanisms and processes at work in the pond systems. During late August the broodstock were moved to Pond No. 3 (containing the polythene liner) to see if this would prove more effective. A new spawning occurred at the end of August with larval numbers up to approximately 500 per 100 litres. Samples taken from Pond No. 3 in early September showed that few larvae remained and that phytoplankton levels were low. By the 12 September these larval numbers had decreased still further although some growth was evident. High copepod densities were however in evidence. A further spawning occurred around the 22 September in Pond No. 3 with estimates of about 70 larvae, within the 160-180µm size range, per 100 litres. There was also some evidence of larger cockle larvae and high numbers of copepods. By late September no oyster larvae were present. This concluded the pond trials for 2006.

3.1.3.2 Managed phytoplankton blooms: Pond No. 4 proved to be highly productive in terms of producing large quantities of phytoplankton. Trials with phytoplankton blooms in Pond No. 4 however proved difficult to control with particular problems being experienced in maintaining a stable phytoplankton cell concentration level. This problem was due mainly to excessive grazing by zooplankton. The ultrasonic device for controlling the level of phytoplankton proved to be ineffective.

The phytoplankton species that were produced were not suitable for native oyster larvae. The main species identified were *Skeletonema*, *Nitzschia* and other large diatoms. The cultures produced were too dense initially and the cell size too large for native oyster larvae.

3.1.3.3 Larval production - winter 2006 trials: Native oyster broodstock held in the hatchery produced an unusually high number of larvae. These larvae produced in the hatchery were however subject to a high mortality rate due to what were believed to be water quality problems.

3.1.3.4 Trials with an alternate source of cultch: Due to the late start of the project it had not been possible to build the cultch storage facilities as had originally been intended and as such it was only possible in the time available to dig a small pond and line this with polythene in order to serve as a storage and conditioning area. This pond storage area however proved to be a very efficient and economic method for cleaning the shell for use as cultch and as such was retained for use in this respect.

Crushed limestone was obtained for use in these trials during July 2006. However, after this time no larvae were successfully brought through to the pediveliger stage and so it was not possible to test the use of this material as a source of cultch.

3.1.4 Discussion;

3.1.4.1 Larval production – 2006 summer trials: The following is a summary of the main points learned from the 2006 trials;

- The 'rafting' of larvae due to the influence of the prevailing wind made it difficult to estimate overall larval numbers as these larvae were not spread evenly through the water column or evenly across the pond.

- Cockle shells were to be the primary source of cultch but this material proved hard to obtain. Whelk shells are more easily available but tend to be 'dirty' due to high flesh levels and thus require more conditioning. The flat shell from scallop processing once crushed may be a future option for use as cultch.

- The larvae that were first seen on the 04 July 2006 remained in good health for approximately one week but did not grow or develop which would indicate that they were not feeding. The phytoplankton present in the ponds were of the correct size range (2-3µm) with only a few cells in evidence of the dinoflagellate *Prorocentrum* which is toxic to shellfish larvae. As discussed in Section 2 it was felt that tainting of the phytoplankton may have been an issue and so some laboratory based trials were carried out to test this possibility.

- These laboratory trials showed that larvae in water from the butyl rubber lined pond survived but did not grow or feed. Larvae in the same water but with externally added phytoplankton from the algae production unit did feed and grow. In both treatments phytoplankton levels were adequate to support growth. This therefore supported the hypothesis that chemical tainting of the phytoplankton in the pond system was probably the cause of the larvae not feeding and thus subsequently suffering high mortality levels.

- Spawnings of the native oyster broodstock continued through July and August 2006 and up until mid/late September. However the general pattern that was observed was of poor growth and development with no larvae achieving a size at which settlement would take place. It seems that this was at least in part due to tainting of the water by the butyl rubber liners but was also probably linked to high copepod numbers and the resultant impact on managing the phytoplankton blooms.

- Significant amounts of time were involved in monitoring and supervising the larval rearing trials. This exceeded the capacity of the project Pond Manager to undertake alone. Other Seasalter staff therefore became involved in running and monitoring the results of the preliminary trials. This also proved to be the case in the later rearing trials.

3.1.4.2 Managed phytoplankton blooms: Further work is required in order to establish/design a system of excluding zooplankton/copepods from the pond systems. A second but less favourable alternative is to find a method of eliminating/removing these zooplankton once they appear in the pond systems. The use of drum screen technology on the pond inlet systems might be one alternative, however these systems have a high capital cost. A screen for these pond systems would be likely to cost around £60-K (Bayes, pers. comm.). Other less capital intensive methods of excluding zooplankton should also therefore be investigated.

One possible low cost solution of controlling zooplankton levels may be to supply the ponds with water that has passed through the hatchery system several times. As such there would be a biological control of zooplankton levels through the natural filtering action of the shellfish contained within those hatchery systems. Pond No.s 1, 2 and 3 situated at the eastern end of the site are close to a source of 'well' water i.e. salt/ground water that has been filtered through the sand/silt and so contains no zooplankton. This water may therefore be another alternative. It does however have high iron and silicate levels as well as *Vibrio* species bacteria and so would require remediation work before it could be used for larval rearing.

The problems experienced with the density of the blooms and cell size of the phytoplankton proved impossible to overcome in Pond No. 4 and as such therefore this pond is now being utilised to provide a supplemental feed source for the spat production room.

Further investigative work is also needed on establishing methods of ‘triggering’ blooms of the correct species of phytoplankton. The high nutrient levels in the ponds also means that keeping the blooms of phytoplankton under control could be an issue and so ways of diluting the phytoplankton levels or grazing down algal numbers will need to be addressed. Added to this, management techniques also need to be established in order to ensure that the pond systems can be protected in the event that an adverse algal bloom occurs (typically of dinoflagellates). An adverse bloom occurred in 2005 when the dinoflagellate *Gymnodinium* was found in the other pond systems. In 2006 the dinoflagellate *Prorocentrum* (Sub-order Adinida) was found in the pond systems that proved to be toxic to all forms of bivalve larvae.

3.1.4.3 Larval production - winter 2006 trials: The hatchery trials over the 2006/07 winter indicated that there were some water quality problems within the hatchery system.

3.2 Year 2 Larval Rearing Trials (Summer 2007)

3.2.1 Introduction;

Following the preliminary trials in 2006 the winter period was spent studying and managing Pond No. 4 next to the hatchery in order to try and optimise the production of phytoplankton blooms. Pond No's 1, 2 and 3 were left fallow and empty to help with the process of sterilisation and cleaning after the 2006 trials. The broodstock from the 2006 trials were brought back to the hatchery for the winter period. Work continued on constructing the Native Oyster Nursery System until the weather made further progress impossible. Work on these systems (including the installation of the paddle wheel) recommenced in the spring of 2007 and the Native Oyster Nursery System was completed in the early summer of 2007.

3.2.2 Methodology;

3.2.2.1 Larval production - summer 2007 trials: In April 2007 new broodstock native oysters were purchased and brought on site. These oysters were placed in the hatchery system until needed. Stocking density for the 2007 trials was approximately 500 oysters per pond. Pond No's 1 and 2 were then thoroughly cleaned and checked for damage. Where necessary repairs were carried out. The polythene liner in Pond No. 3 was checked to see if it would still be useable for the 2007 season.

During May the ponds were refilled with salt water and then the broodstock introduced in order that the main project trials could be commenced. These larval rearing trials continued throughout the summer until no further larvae were produced by the broodstock. Figure 22 shows Pond No. 1 with the floats from which the broodstock native oysters were suspended during the 2007 larval rearing trials.

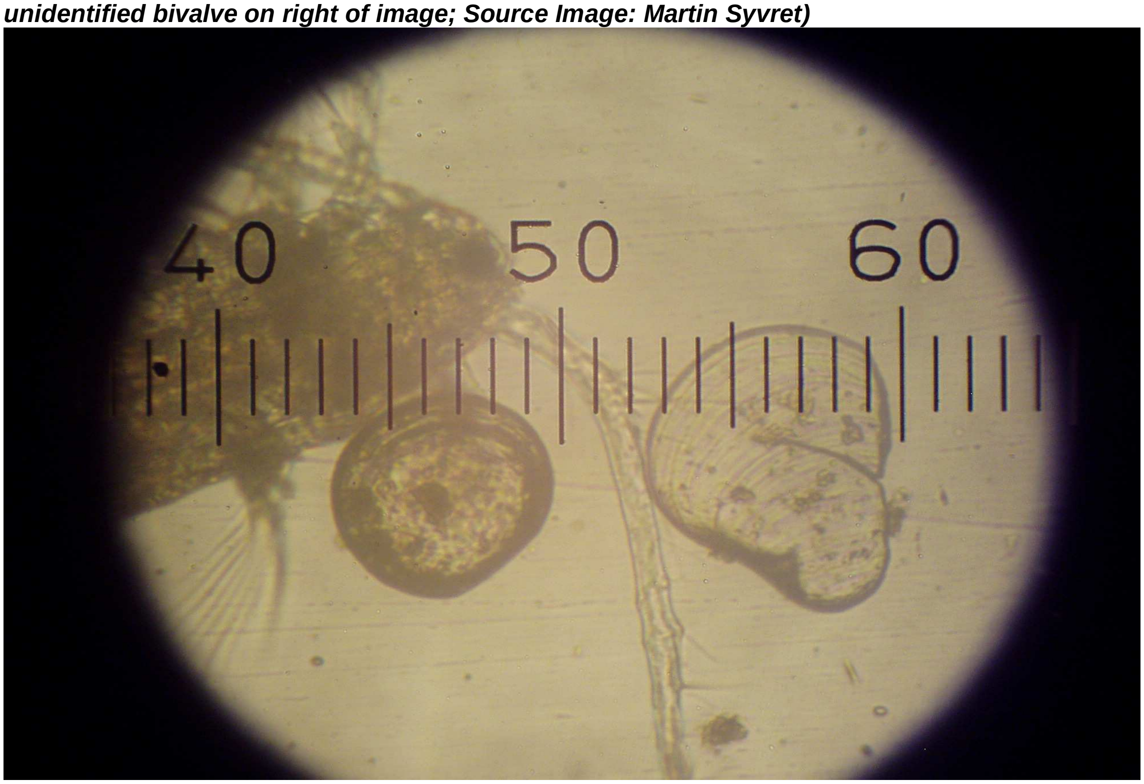
Figure 22. Pond No. 1 shown during 2007 trials with broodstock suspended under floats (Source Image: Martin Syvret)

3.2.2.2 Trials with an alternate source of cultch: Since it was not possible to test the crushed limestone as a source of cultch in 2006 these trials were scheduled to be undertaken as part of the main 2007 rearing trials. If this material proved successful then it would have significant advantages over the use of waste shell material. For instance, crushed limestone is readily available and has a cost of only around £200 per tonne. Its reported particle size range is good at about 70-1000µm with a nominal average of about 300µm which is an acceptable size for settlement of native oyster larvae. At this level of cost crushed limestone would be a practical and economic method of obtaining cultch that may also have fewer implications in its use than would shell waste with regard to such things as the Animal By-products Regulations etc.

3.2.3 Results;

3.2.3.1 Larval production – summer 2007 trials: During 2007 monitoring of the water temperatures in the Larval Rearing Pond System showed that temperatures remained low throughout the normal breeding season for the native oysters. As a consequence only sporadic spawnings of the broodstock occurred during the 2007 trials. An image showing a native oyster larvae together with a copepod from a sample of pond water is shown in Figure 23.

Figure 23. Microscope image of native oyster larvae from 2007 trials
(Larvae shown in middle of image ~160µm width; zooplankton shown on left of image; unidentified bivalve on right of image; Source Image: Martin Syvret)



Of the viable larvae that were produced by the spawnings, analysis of water samples from the ponds revealed that none survived for more than a few days.

These water samples also revealed that there was heavy contamination of the water with crustacea larvae. These larvae proved to be mainly those of barnacles (see Figure 24).

Figure 24. Barnacles shown settled on the broodstock float system.
(Source Image: Martin Syvret)

3.2.3.2 Managed phytoplankton blooms: Observations of the phytoplankton blooms in the differing ponds over the course of the 2007 larval rearing trials showed that the unlined ponds supported a better mix of phytoplankton in terms of larval rearing than that found in the lined ponds.

3.2.3.3 Trials with an alternate source of cultch: Trials carried out to test the effectiveness of crushed limestone as an alternative source of cultch proved unsuccessful. Figure 25 shows a sample of the crushed limestone after it has been removed from the bags in which it is transported. The reason that the crushed limestone proved unsuitable as a source of cultch was that whilst the stated average size of the particles should have been within the optimum range for native oyster settlement, in reality the wide range of particle sizes actually present, and in particular fine particles, meant that the particles would be prone to movement in any wind-driven water movement which would have a detrimental effect on any settled larvae. These particles would also have been likely to have fouled the ponds and would have required manual removal between larval rearing seasons.

Figure 25. Crushed limestone that was considered for use in alternate cultch trials
(Source Image: Martin Syvret)

3.2.4 Discussion;

3.2.4.1 Larval production – summer 2007 trials: Low water temperatures were recorded in the Larval Rearing Pond Systems throughout the 2007 summer period. It appears that 2007 had the wettest May to July for the UK since 1766 when reliable records were first collected (Environment Agency, 2007). These adverse weather conditions and consequent poor conditioning of the broodstock are believed to be the main reason why recorded spawning frequency and larval production levels were so low during the 2007 trials. However, it is also possible that the unusually high levels of freshwater in evidence throughout the summer may have affected water quality both within the pond systems and in the source waters.

In addition to the poor weather it is suspected that *Vibrio* species bacteria may have also been a cause of the high mortality levels experienced when spawnings did occur. An indication that *Vibrio* species bacteria were present is the discovery of the crustacea larvae in the ponds which experience has shown is often associated with dense blooms of this type of bacteria, but to which crustacea larvae are resistant.

3.2.4.2 Managed phytoplankton blooms: The magnification range of the standard laboratory microscopes of the type used at Seasalter make it very difficult to identify the phytoplankton in the blooms down to a species level. However over many years of pond management it has become possible to generally identify what mixes of phytoplankton can be considered as a suitable food source for native oyster larvae.

The observations of the species composition of phytoplankton blooms in the differing ponds over the course of the 2007 larval rearing trials showed that the unlined ponds supported a better mix of phytoplankton in terms of larval rearing than that found in the lined ponds. This is an important consideration as the single biggest expense in developing a pond system is the cost the liner. This observation also fits in well with the observations of phytoplankton blooms in the main blooming ponds near to the hatchery, one of which is lined and one of which is unlined.

3.2.4.3 Trials with an alternate source of cultch: Trials to test crushed limestone as an alternate source of cultch were not undertaken as an analysis of the average particle size showed that there was an excessive amount of fine particles which would have been too small for use as a settlement substrate for native oyster larvae. These fine particles would also have been liable to movement under any wind action and would have led to fouling of the ponds. Further investigations will be carried out by Seasalter after the current study in order to try and identify other possible sources of suitable and available cultch.

3.3 Year 3 Larval Rearing Trials (Summer 2008)

3.3.1 Introduction;

The larval rearing trials undertaken as part of this study were originally intended to be carried out over two summer seasons (2006 and 2007). However the poor weather and consequent problems with trying to rear larvae in 2007 meant that a project extension was requested in order to allow further larval rearing trials to be carried out in 2008. This project extension was agreed by the Marine and Fisheries Agency.

3.3.2 Methodology;

3.3.2.1 Larval production - summer 2008 trials: Due to the previous problems experienced with excessive phytoplankton grazing by zooplankton, the 2008 trials were undertaken with water that had been passed through a screen to help minimise the amount of zooplankton present.

Broodstock native oysters were suspended in the three spatting ponds using lantern nets supported by a buoy.

3.3.3 Results;

3.3.3.1 Larval production – summer 2008 trials: As in the previous two years successful spawnings were achieved with larvae of 170-180µm initially being identified. These larvae generally progressed slowly to a maximum size of around 220µm. However the observed pattern was that this slow size increase also coincided with continuing reductions in larval numbers until all larvae eventually disappeared.

The overall pattern of larval production was very similar to that of 2007. Monitoring of the water temperatures in the Larval Rearing Pond System showed, that as in 2007, temperatures remained low throughout the normal breeding season for the native oysters. As a consequence of these low temperatures only sporadic spawnings of the broodstock occurred during the 2008 trials with consequent low larval production levels.

3.3.4 Discussion;

3.3.4.1 Larval production – summer 2008 trials: Again, as in the previous two seasons, the native oyster larvae that were produced in Pond No.s 1, 2 and 3 only progressed slowly to a maximum size of around 220µm. During this time larval numbers continued to drop as had been experienced in the previous two years until no larvae remained in the three Larval Rearing Ponds. One other small native oyster larvae spawning was also recorded in a large pond in the South Pond system that did not form part of the larval rearing trials in this study and that was not supplied with cultch. These larvae exhibited good growth rates and survival rates seemed to remain high over an extended period.

The 2008 larval rearing trials, as in 2007, were again dominated by poor weather with England experiencing its 10^{th} wettest summer since records began in 1914 (Met Office, 2008). These wet conditions and low recorded sunshine levels led to low water temperatures throughout the pond systems during 2008. The low water temperatures were thought to be responsible for the poor conditioning by the broodstock and consequent low frequency and levels of spawning events. Seasalter have therefore confirmed that they will continue to undertake these trials after the current study in order to better assess the effectiveness of these pond systems for larval rearing under more normal summer conditions.

SECTION 4 – POTENTIAL FOR POND USE IN OTHER AREAS

4.1 Introduction

As part of the present study consideration has been given to what other areas of the UK might be suitable for use of this type of extensive pond system for spat production of native oysters. Examples of areas highlighted include a site in Cornwall based at the Duchy of Cornwall Oyster Farm and Fishery on the Helford River and a site on Hayling Island near Portsmouth. However, as enquiries were made about potential sites on the east coast of England it became obvious that there was a new potential type of site that might become available for pond production as part of the managed retreat schemes that are now either under construction or being considered for the east coast.

These managed retreat (or managed realignment) schemes involve the controlled flooding of an area by the sea due to the removal of the current coastal protection in that area. In general the areas subject to these managed retreat schemes are low lying and have generally been reclaimed by the sea at some stage (see Figure 26). These reclaimed areas are often utilised for agricultural production. The use of managed retreat schemes is a move towards dealing with rising sea levels and the consequent increasing cost and difficulties faced when trying to stop flooding of these regions. As the land to be considered for managed retreat schemes is often agricultural in nature the potential for pond production of shellfish may also offer a means of diversification to those farmers affected in this respect.

Figure 26. Tollesbury Managed Realignment site in Essex
(The first large scale attempt at saltmarsh restoration in the UK. Source: Wikipedia http://en.wikipedia.org/wiki/Managed_retreat)

The use of managed retreats is considered in more detail in the next section.

4.2 Managed Retreats

As part of the present study Seasalter have investigated how the potential for the use of extensive larval rearing ponds could be developed in other regions of the UK. One possibility that Seasalter have highlighted as having potential in this respect is to seek to develop these pond systems in association with the managed retreat schemes that are currently being undertaken along some parts of the east coast of England.

As part of this investigation Seasalter hosted a meeting in July 2008 of organisations involved in managed retreats in order to highlight the potential future use of pond systems in managed re-alignment sites (see also Appendix 1F for article relating to this meeting). The organisations that attended the meeting included representatives from the shellfish industry (such as the SAGB), the Environment Agency, Seafish and wildlife organisations including Kent Trust for Nature Conservation and the RSPB. The broad range of organisations that attended the meeting stems from the fact that the oyster ponds and their banks form an ideal site for maritime wetland plants and seabirds. This therefore produces a strong mutual interest for all of these organisations. The wide and diverse range of flora and fauna that can be seen in or around the pond systems at Seasalter has already been extensively documented by John Bayes of Seasalter and details in this respect were presented at the July meeting. Further information on the local flora and fauna are available on request from Seasalter.

The driver behind initiating discussions with the organisations involved with managed retreats is that if the techniques behind successful pond culture can be satisfactorily demonstrated, then this might allow extensive pond systems for shellfish production to be constructed and run at other managed retreat sites around the coast. Managed re-alignment sites, where seawalls are strategically breached and abandoned under managed retreat, were confirmed during the meeting as having great potential in this respect. Steve Colclough who attended the meeting on behalf of the Environment Agency stated that "to date managed retreat areas had been mainly viewed from their wildlife value, but other uses, for example as fish nursery areas and now oyster production and holding sites for selected broodstock could be foreseen". Often the land which is subject to a managed retreat is agricultural farmland and so the rearing of shellfish may be of interest to the farmers and may offer a diversification opportunity that would allow them to still utilise the area rather than just leaving it as a wildlife area.

It is known that historically, native oysters were found in creeks and inlets infiltrated by the sea. Many such creeks were cut off from the sea by the sea walls, many of which were built around the south east coast following the great flood of 1953. Others have become so silted that there is no clean shell 'cultch' for oysters to settle on, even if larvae are present in the water. Steve Colclough said the extent of eutrophication from land-based nutrient sources was being re-assessed under the EU Water Framework Directive. It appears to be more widespread than previously thought and would need to be considered for future improvement. An ability to demonstrate successful survival of sensitive species like native oysters in estuarine and even creek situations could be a valuable tool in confirming good water quality. The oyster nursery at Reculver has shown that there are marked differences in water quality between the open coast and the excavated ponds in which phytoplankton is bloomed to feed the oysters and clams. Eel grass, which is now a nationally rare species but which was once common, has established itself in one of the nursery ponds. This is taken as a sign of good water quality.

An earlier project as part of the Native Oyster Species Action Plan (NOSAP) identified a need to establish populations of native oysters which could be left unfished in semi-controlled conditions. These could provide a stock from which disease-resistant broodstock oysters could be allowed to self-select or be managed to provide selected breeding oysters. A combination of these pond systems and managed retreat sites could also prove to be effective in this respect. Additionally there may be scope for pond systems to be constructed whereby newly settled native oyster spat reared in a hatchery are introduced into the ponds and then on-grown in semi-controlled conditions. This may be one method of increasing numbers of native oyster under cultivation and control in a relatively short space of time.

The main issues highlighted in the present study with rearing native oyster larvae in extensive ponds have been mainly centred around the problems experienced in managing and controlling phytoplankton blooms. These technical issues were not unexpected and stem from the learning process that is needed in order to manage this type of enclosed pond system. Any ponds established as part of a managed retreat would have one possible advantage in this respect in that they would be a semi-natural system as opposed to a highly managed one. As such it would be interesting to investigate if such a semi-natural system could help overcome the phytoplankton management problems that have been experienced in the present study.

Steve Colclough of the Environment Agency went on to state that other members of his organisation would be interested in viewing the pond systems constructed during this project as they were actively investigating other possible uses of managed retreat schemes in addition to their use as wildlife areas.

4.3 Conclusions

The meeting held at Seasalter in July 2008 to discuss the incorporation of extensive pond systems for shellfish culture as part of managed retreat schemes reached the following conclusions:

- It was agreed that the pond systems at Seasalter constructed during the FIFG project could be used as a model for managed retreat schemes under development at present and that the UK is probably leading the drive to establish an integrated approach to incorporating differing users and options in managed retreat schemes.

- Seasalter will continue to develop the potential collaborative partnership with the organisations involved with establishing managed retreats as well as other interested parties in order to help establish pond systems for shellfish culture, and in particular native oyster regeneration, as part of future managed retreat schemes.

SECTION 5 – CONCLUSIONS & FUTURE WORK

5.1 Introduction

Seasalter have now completed three years of native oyster larval rearing trials at their Reculver site. The first summer of 2006 and winter 2006/07 were spent constructing the Larval Rearing Pond Systems and Native Oyster Nursery Systems. This then enabled the main larval rearing trials to be undertaken in 2007 together with an additional season's trials in 2008. This section summarises the main findings and conclusions of the current FIFG and MFA funded project.

5.2 Analysis of Project Costings

The original projected equipment and staffing requirements etc. were based upon a best estimate at the time that the project proposal was drafted and submitted for consideration for funding. In reality the complex nature of this pilot project has meant that there have been some unexpected additional costs, some costs that were outside the original estimates and in some cases there were savings where certain pieces of equipment were not actually needed. As part of the interim claim therefore it was necessary to discuss these changes with the MFA and to seek their approval to reallocate some of the project funding to cover expenses not originally included in the project costings. The overall changes and reallocation of project funding at that time resulted in a saving to the project i.e. the overall project cost was reduced.

As discussed in Section 3.3.1 a third season of larval rearing trials were undertaken in 2008 due to difficulties that had been experienced previously due to adverse weather conditions and water quality issues. In order to keep the project within its original costings it became necessary therefore to focus the remaining funding on the achievement of the key aims of the project with respect to investigating and refining the pond management techniques necessary to rear native oyster spat in extensive pond systems. A further reallocation of funding was therefore undertaken in order to cover the core costs necessary to undertake the third season trials. This reallocation was discussed with and approved by the Marine and Fisheries Agency.

5.3 Publication and Dissemination of Results

The aims and methodology of the project have attracted much interest both in terms of its potential for re-establishing native oyster fisheries and also its potential for safeguarding this species in British waters. The project has been the subject of several articles (either published or in press) and has formed a part of one workshop. The Project findings have also been disseminated by the SAGB via their website and through review and discussion at Committee Meetings. Copies of the articles and results of the workshop are contained in the Appendices. The details of the articles and workshop are noted below:

Syvret, M., 2006. *Going native at Seasalter Shellfish*. Fish Farmer. Vol. **29** Number 05, September/October 2006, pp. 36-37.

Association of Scottish Shellfish Growers, 2007. Presentation by Dr. Sue Utting at a native oyster workshop held at Dunstaffnage Marine Laboratory (sponsored by Scottish Natural Heritage and the Crown Estate), 24 January 2007.

Syvret, M., 2007. *Going native at Seasalter Shellfish*. In: Shellfish News No. **23**, Spring/Summer 2007, pp. 23-24.

Syvret, M., 2007. *Native oyster project hopes to boost species*. FISHupdate, May 2007, p. 21.

Syvret, M., 2007. *Regenerating the Natives at Seasalter Shellfish.* The Grower, June 2007, p.6.

Syvret, M., 2007. *Native oyster project hopes to boost species.* Seafish News, June 2007, p. 14.

Askew, C., 2008. *Oyster Farmers and Wildlife Managers Share Common Interests.* Fish Farmer (In Press).

5.4 Training for Industry and Support Organisations

Prior to the meeting to discuss the potential use of managed retreats for pond culture in July 2008 the first on-site training to highlight project findings was held at Seasalter. This initial training session focussed on dissemination of results and conclusions to industry and its British trade association, industry consultants, support organisations, wildlife organisations and government agencies, student researchers and sea fisheries committees. The main organisations and their representatives who attended are as follows:

- John Bayes - Seasalter Shellfish (Whitstable) Limited as host for the training session;
- Sue Utting - The Sea Fish Industry Authority
- Martin Syvret – Aquafish Solutions Limited
- Mark Dixon – The Royal Society for the Protection of Birds
- Steve Colclough – The Environment Agency, Essex
- Karen Thomas – Coastal Processes Engineer, Environment Agency, Essex
- Bill Watts – Senior Economist, Environment Agency, Essex
- David Jarrad - Assistant Director SAGB & River Exe Shellfish Farms
- Clive Askew – Fisheries Consultant to the Fishmongers Company
- Joss Wiggins – Kent & Essex Sea Fisheries Committee

It is anticipated that Seasalter will invite and actively encourage more industry visits to the native oyster ponds now that this first phase of the project work has been completed. Further trials are to be undertaken by Seasalter to continue refining the pond management techniques and these findings will also be passed on to industry members and other organisations who are interested in this technique. As the potential for use of these types of pond systems in managed retreat schemes is developed then it is expected that further on-site training will also be required in this respect.

Seasalter have stated that they are open to enquiries and visits from industry members and all other organisations who wish to undertake a site visit to see the pond systems in operation. Targeted training can then be discussed for those persons who require a more detailed understanding of the methodology and management underpinning the production of native oysters using these types of extensive pond systems.

5.5 Conclusions

5.5.1 Pond Construction and Use of Pond Liners;

The use of larval rearing ponds for large-scale shellfish production is not a new concept. However, of the numerous attempts that have been made at utilising these types of extensive systems very few have been successful. Seasalter have been involved with work carried out in Norway in this respect and these Norwegian Systems based in the Fjords have proved successful. The type of land available in Kent obviously rules out the use of these systems and so the ponds constructed as part of the present study were therefore modelled to a small extent inline with the ponds built by David Hugh-Jones at Rossmore Oysters in Cork, Southern Ireland. To construct ponds similar to those at Rossmore Oysters would have been prohibitively expensive and therefore would have been incompatible with the aims of the study which is to try and produce spat for relaying at a low economic cost. A different design was therefore chosen using three ponds each of approximately 70 metres length and approximately 5 metres wide. These ponds are 'V' shaped in section with a maximum depth at any one point of 3 metres. This type of excavation is relatively inexpensive, each pond taking only a matter of hours to construct by a skilled operator. The use of a separate nursery system for on-growing native oyster spat over winter is also a new innovation developed during this project.

The ponds are aligned north to south so that when empty, the sun shines on all surfaces for the maximum amount of time. This is an efficient and low cost method of 'sterilising' the ponds between trials. In retrospect, an end of project review of the design indicated that it would have been better to have set the ponds higher in the ground. This is because the bottom 500mm of the ponds is below the existing water table level and so part of the pond is not easily drained.

Pond No.s 1 & 2 are lined with butyl rubber whereas Pond No. 3 was lined with polythene which is considerably cheaper than the butyl rubber lining. This polythene liner has however proved to be highly susceptible to wind action when it becomes buoyant thus creating floating sections within the pond. The polythene lining is still in place but has needed extensive repairs over the three years of the project and this added to its susceptibility to wind action means that this type of liner has proved to be unsuitable for use in larval rearing ponds.

The three Larval Rearing Ponds were first commissioned in the late summer of 2006. Initially the butyl rubber lined ponds proved to be unsuitable for rearing native oyster larvae which was as expected. The reason for this was an initial toxicity problem due to leaching of chemicals from the liner into the pond water which then tainted the phytoplankton which are the food source of the oyster larvae. Once the pond liners had however been successfully 'weathered' there were several successful spawnings of the native oyster broodstock suspended in the ponds.

5.5.2 Larval Rearing Trials;

Trials with native oysters to induce spawning in the broodstock and subsequently produce viable larvae were carried out successfully over three seasons from 2006 to 2008. However, despite this the main rearing trials of 2007 and 2008 were characterised by lower than expected numbers of spawnings by the broodstock and therefore only low production levels of viable larvae. The larvae that were produced generally failed to grow or progress much beyond their initial size range of 170-180µm. The largest size of larvae recorded in any numbers were approximately 230-260µm and this was in the preliminary trials carried out in 2006 when the warmest and driest weather occurred of the three larval rearing seasons. It is thought that there were two main reasons for the problems experienced in rearing native oyster larvae during this study. The first is the unusually wet summer weather conditions experienced in 2007 and 2008 and the effect this had on water temperatures in the ponds and also possibly on water quality. The second main reason was believed to be due to the problems that have been experienced in maintaining and controlling phytoplankton blooms in the Larval Rearing Ponds.

The summers of 2007 and 2008 were two of the wettest since records began in 1914 according to the Met Office and it is thought that this may have resulted in poor conditioning of the broodstock and therefore low larval production levels. Poor conditioning is likely to have resulted in larvae with inadequate initial energetic reserves to help them develop through to metamorphosis. Research has shown that success at metamorphosis and lipid levels in bivalve eggs are often linked and that lipid levels can even be used as a method of assessing their viability (Gallagher and Mann, 1986).

5.5.3 Managed Phytoplankton Blooms;

As mentioned in the previous section, in 2007 and 2008 problems were experienced in maintaining and controlling phytoplankton blooms in the Larval rearing Ponds. During the first year trials in 2006 these problems were experienced due to toxicity of the phytoplankton caused by contamination from the butyl rubber lining, which was as expected. This issue was easily dealt with by the use of repeated water changes. However, across all three seasons the phytoplankton blooms that have occurred spontaneously in the ponds have differed in species composition between each pond and have also been of a consistently poor quality in terms of acceptability for native oyster larvae.

Typically the phytoplankton blooms have been very dense with cell counts often initially in excess of 1,000 cells per µl. These phytoplankton cells were generally small and predominantly non-motile with a green or sometimes brown colouration. With the laboratory equipment available it was impossible to identify the species other than to describe them as being 'similar to *Nannochloropsis*'. Trials carried out in the laboratory with oyster larvae indicated that neither native oyster nor Pacific oyster larvae were able to digest the cells.

The healthy native oyster larvae observed in the South Pond system whilst not forming part of the main trials may hold some important lessons for future larval rearing trials. The water supplied to this pond passes through the nursery system once every one to two days and is therefore relatively free of the large zooplankton that have caused problems with pond management in the Larval Rearing Pond No.s 1, 2 and 3. The phytoplankton levels are also reduced to what may be a more suitable level having been grazed down already by the shellfish in the nursery system. It is perhaps this combination of zooplankton free water and reduced or controlled phytoplankton levels that may prove suitable for rearing native oyster larvae in the future. Further work is therefore needed to develop cost effective methods to exclude zooplankton from the pond systems.

The results of the project have clearly demonstrated that in order to successfully manage the phytoplankton blooms in these types of ponds it is necessary to have other shellfish, i.e. a greater biomass, in addition to the native oyster broodstock in the ponds. These additional shellfish would help to graze excess phytoplankton and thus maintain food levels for the native oyster larvae at a suitable level. A continuing problem is that it has proved impossible to date to sustain blooms of small flagellate phytoplankton for more than a few days during the summer months. This is generally due to the rapid grazing that takes place due to the presence of various herbivores and in particular *Oxyrrhis* which is capable of grazing down a substantial flagellate bloom within half a day.

There were also indications that the species composition of phytoplankton in some of the unlined ponds was better suited to rearing native oyster larvae than that of the blooms that were experienced and recorded in the lined Larval Rearing Ponds. Further work is required to better understand why unlined ponds might produce a better mix of phytoplankton in terms of a food source for native oyster larvae. Once established this information may then help to improve the triggering blooms of the correct species of phytoplankton in the lined ponds.

5.5.4 Future Uses for Extensive Pond System Culture for Shellfish;
As well as considering other possible areas for extensive pond use the current study has highlighted that the incorporation of extensive pond systems for shellfish culture in managed retreat schemes offers a new potential route for development in this respect between oyster farmers, wildlife organisations and the Environment Agency. This method of coastal management or realignment should open up the opportunity for collaborative projects and partnerships as the use of managed retreats becomes more widespread in future. Seasalter will continue to explore this option for the use of extensive pond systems as part of a contribution to NOSAP. A meeting of organisations involved in managed retreat schemes held in July 2008 concluded that the pond systems at Seasalter developed as part of the current study could be used as a model for managed retreat schemes under development at present.

5.6 Lessons Learned

The following is a summary of the main practical conclusions of the current study:

5.6.1 Use of Pond Liners;
The use of butyl rubber as a pond liner has proved successful although these liners do require a period of weathering or leaching in order to ensure that residual chemicals do not taint the phytoplankton food of the native oyster larvae.

5.6.2 Larval Rearing Trials;
The unusually wet summer weather conditions experienced in 2007 and 2008 led to poor conditioning of the native oyster broodstock with consequent low frequency and levels of spawning events. It is also thought that the excessive rainfall may well have led to poor water quality conditions both in the pond systems and in the source water for these ponds.

Despite these difficulties significant experience was gained in pond production techniques for rearing shellfish larvae. This experience will now be taken forward to further trials that will be undertaken in 2009 by Seasalter as a further contribution to NOSAP. It is hoped that the experience gained during this project when applied to more normal summer weather conditions will lead to significant production of native oyster spat for relaying. Information and knowledge gained during the trials described in the present study and future experiences in this respect will all be made available to industry and other interested parties as part of a continuing commitment by Seasalter to continue this work and disseminate its findings.

5.6.3 Managed Phytoplankton Blooms;
A main aim of the project was to try and establish how to create the right bloom, at the right concentration level at the time when the larvae are present. Significant technical developments have been achieved during the course of this project in understanding how these blooms originate and might be better managed. This area of investigation requires further work to refine the methodology underpinning successful pond management. Seasalter will continue to undertake this research and development work after the conclusion of the current FIFG study and will make this information available to industry and other interested parties.

Excessive grazing of the phytoplankton by zooplankton within the pond systems prevented a stable phytoplankton population from being maintained in the pond systems. Further methods to alleviate this problem need to be investigated including the use of 'hatchery water' i.e. water that has been previously passed through the hatchery system and therefore subject to filtering by the shellfish present in those systems. The use of ground water is another area that requires investigation for the future as it is free of zooplankton. However pathogenic *Vibrio* species bacteria and contaminates would be present in ground water and this issue would need to be addressed prior to its use for rearing native oyster larvae.

5.6.4 Trials with an Alternate Source of Cultch;

Trials with crushed limestone as an alternate source of cultch were to be undertaken during 2007 as fluctuations in waste shell supply proved problematic during 2006. However an analysis of average particle size prior to the trials showed that there was a wide size range of particles present, many of which were too fine to be of use as cultch and which would therefore only have fouled the ponds. The smaller particles would also have been prone to movement which might have resulted in damage to native oyster larvae thus resulting in increased mortality levels. It was decided therefore not to test the crushed limestone as an alternate source of cultch but instead to continue to investigate what other suitable materials may be available. One such potential material may be coralline sand which will be considered for trials once further work has been undertaken on the development of the pond management systems.

5.7 Summary of Project Aims Achieved

- This project has contributed to the aims of the Native Oyster Species Action Plan (NOSAP) and the UK's commitment to the Biodiversity Action Plan.
- The project has considered what other areas may be suitable for the use of this type of extensive pond system in rearing native oyster spat for restocking at a relatively low economic cost.
- As part of this work an opportunity has been highlighted by Seasalter with respect to the possible inclusion of extensive pond systems as part of the managed retreat schemes that are now either under construction or being planned for the east coast of England.
- A preliminary site visit and training session has taken place for industry and other organisations, including those involved with managed retreat schemes.
- A meeting has also been held in 2008 to discuss how to further develop the potential for extensive pond systems to be incorporated into managed retreat schemes. The development of such schemes would without doubt see the formation of collaborative and cooperative partnerships between existing industry, new entrants, wildlife organisations, government agencies and other interested parties.

Whilst the current FIFG and MFA funded study has now finished, Seasalter will continue to run trials in the Larval Rearing Ponds so as to continue to develop the methodology required in order to raise native oyster larvae successfully in this type of extensive pond system. As further results and findings are discovered then these will also be made available to other interested parties by way of a contribution to the Native Oyster Species Action Plan.

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APPENDIX

List of Appendices

Appendix 1. Articles and Dissemination re. Pond Project.

Appendix 2. Action Plan from Dunstaffnage Workshop.

Appendix 3. Daily Record Sheet.

Appendix 1 – Articles and Dissemination re. NOSAP Pond Project

Appendix 1A; Fish Farmer Magazine (August, 2006)

Going native at Seasalter Shellfish

By MARTIN SYVRET

Today the stocks of this once abundant species remain at very low levels.

JOHN Bayes of Seasalter Shellfish (Whitstable) Ltd has recently been awarded funding through the EU Financial Instruments for Fisheries Guidance (FIFG) and the Marine Fisheries Agency (MFA) for a pilot project designed to investigate pond production of native oyster spat.

The project has been developed in response to a recent Defra/Seafish sponsored study by CEFAS that concluded that it was feasible to try and restore native oyster stocks in the UK.

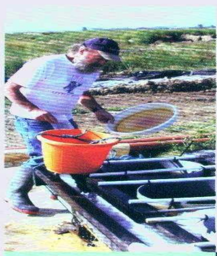
Food of the poor

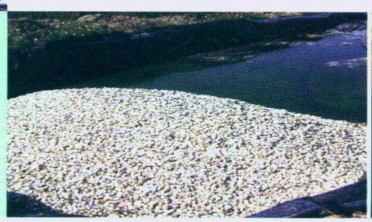
The native oyster, *Ostrea edulis*, or flat oyster as it is also known, was once a major commercial fishery, peaking in the mid 1800s after the end of the Napoleonic Wars. Indicative, if not wholly reliable, figures for numbers of oysters passing through Billingsgate at the time put the level at about a staggering 500million. The first official oyster statistics were not produced until 1886 by which time production levels had dropped dramatically to around only 40million per annum. This reduction in supply saw prices rise by about seven to eight times their original level from 1860 to 1889 and it was at this stage therefore that the oyster changed from a food of the poor to a dish more commonly associated with the wealthy.

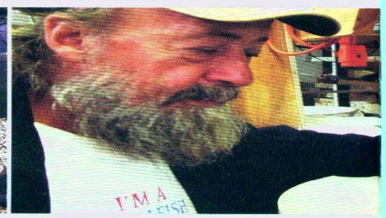
A comprehensive history of the remarkable decline of this fishery can be found in 'The English, The French and THE OYSTER' by Robert Neild. Today the stocks of this once abundant species remain at very low levels. Two centuries of over exploitation, TBT (tri-butyl tin) pollution in the 1980s, mortalities due to severe winters in the 1930s and 40s, competition from exotic pests such as the slipper limpet in conjunction with the parasitic disease *Bonamia* have all meant that current standing stocks, and thus broodstock, are so depleted that a natural recovery of the native oyster has been made much more difficult.

NOSAP

Although now at much reduced levels, the native oyster is still a commercially important species for many fishermen, especially those in south west England, the Solent and in Essex. This decline led in the late 1990s to the development of a Biodiversity Action Plan for this species, the Native Oyster Species Action Plan (NOSAP), for which the lead agency is currently the Shellfish Association of Great Britain. The aims of NOSAP are to increase the abundance and geographical range of this threatened species where biologically feasible. It was therefore following the feasibility study and as part of this Action Plan that Seasalter, Seafish and the SAGB developed and helped fund a project to investigate the potential for producing large numbers of native oyster spat at an economic cost that would allow their relaying as







Above: John Bayes of Seasalter Shellfish (Whitstable) Ltd, sampling for native oyster larvae in larval production ponds.

Right: Cultch preparation for pond systems.

Centre: Larval rearing bin for native oysters in a hatchery environment.

Seasalter have turned to a method previously used with success in Ireland whereby mature broodstock are held and spawned in managed outdoor ponds

broodstock in areas free of disease and thus help to regenerate fisheries in those areas.

Methodology

The numbers of spat needed mean that normal hatchery production methods are not economically viable and so Seasalter have turned to a method previously used with success in Ireland whereby mature broodstock are held and spawned in managed outdoor ponds. The resultant larvae are settled onto a suitable settlement substrate, or cultch, such as cleaned cockle shells and then grown on until they are of a sufficient size that they can be re-laid on existing native oyster grounds. After relaying, the growth and survival of these spat will be monitored. The project started in early summer 2006 when the first mature 'ripe' broodstock were introduced (spawning season is July to September). In spring/summer 2007, the process will be repeated incorporating modifications and improvements gleaned from the first spawning season.

Pond Construction

To carry out this project, three 70m x 8m butyl-lined ponds are being constructed at the Seasalter site in Reculver, Kent. Due to the sizeable amount of shell that will be required to act as cultch in the ponds it will be necessary to employ a mechanical digger together with a small dump truck and an agricultural-type elevator. 'Ripe' parent broodstock oysters will be held in the ponds using Japanese lantern-type trays suspended below the water surface. The larvae produced by this broodstock will go through their development in these ponds feeding on the natural phytoplankton in the pond water.

Training Centre

The main initial focus of this two year FIFG project will be to refine the pond management techniques, efficiency and economic viability of producing native oyster spat using this extensive, low technology method. As this progresses, other areas around the UK that are suitable for the relaying of spat produced in ponds will also be assessed and identified.

One of the main eventual aims of the project is that Seasalter will become a training centre for industry in the practical methods of how to construct and manage these ponds. Through this approach the lessons learned during the project can then be used to help other areas which have suffered similar declines in native oyster numbers. It is hoped that this pilot oyster regeneration project will help to encourage the formation of other co-operative partnerships in traditional oyster areas and that they, along with the native oyster, will be able to benefit from the European Fisheries Fund that is due to be introduced in 2007.

Above: Attempts are being made to restore native oyster stocks.

Below: Native oyster larval nursery pond under construction.

Appendix 1B; Shellfish News 23 (Spring/Summer 2007)

GOING NATIVE AT SEASALTER SHELLFISH

By Martin Syvret

This article first appeared in Fish Farmer magazine and is reproduced here with the kind permission of the publishers. Photographs are by the author.

John Bayes of Seasalter Shellfish (Whitstable) ltd. has recently been awarded funding through the EU Financial Instruments for Fisheries Guidance (FIFG) and the Marine and Fisheries Agency (MFA) for a pilot project designed to investigate pond production of native oyster spat. The project has been developed in response to a recent Defra/Seafish sponsored study by Cefas that concluded that it was feasible to try and restore native oyster stocks in the UK.

Food of the poor

The native oyster, *Ostrea edulis*, or flat oyster as it is also known, was once a major commercial fishery, peaking in the mid 1800's after the end of the Napoleonic Wars. Indicative, if not wholly reliable, figures for numbers of oysters passing through Billingsgate at the time put the level at about a staggering 500 million. The first official oyster statistics were not produced until 1886 by which time production levels had dropped dramatically to around only 40 million per annum. This reduction in supply saw prices rise by about seven to eight times their original level from 1860 to 1889 and it was at this stage therefore that the oyster changed from a food of the poor to a dish more commonly associated with the wealthy. A comprehensive history of the remarkable decline of this fishery can be found in 'The English, The French and THE OYSTER' by Robert Neild. Today the stocks of this once abundant species remain at very low levels. Two centuries of over exploitation, TBT (tri-butyl tin) pollution in the 1980's, mortalities due to severe winters in the 1930's and 40's, competition from exotic pests such as the slipper limpet in conjunction with the parasitic disease *Bonamia* have all meant that current standing stocks, and thus broodstock, are so depleted that a natural recovery of the native oyster has been made much more difficult.

Native oyster larval production ponds at Seasalter

NOSAP

Although now at much reduced levels the native oyster is still a commercially important species for many fishermen especially those in south west England, the Solent and in Essex. This decline led in the late 1990's to the development of a Biodiversity Action Plan for this species, the Native Oyster Species Action Plan (NOSAP), for which the lead agency is currently the Shellfish Association of Great Britain. The aims of NOSAP are to increase the abundance and geographical range of this threatened species where biologically feasible. It was therefore following the feasibility study and as part of this Action Plan that Seasalter, Seafish and the SAGB have developed and helped fund a project to investigate the potential for producing large numbers of native oyster spat at an economic cost that would allow their relaying as broodstock in areas free of disease and thus help to regenerate fisheries in those areas.

Methodology

The numbers of spat needed means that normal hatchery production methods are not economically viable and so Seasalter have turned to a method previously used with success in Ireland whereby mature broodstock are held and spawned in managed outdoor ponds. The resultant larvae are settled onto a suitable settlement substrate, or cultch, such as cleaned cockle shells and then grown on until they are of a sufficient size that they can be re-laid on existing native oyster grounds. After relaying the growth and survival of these spat will be monitored. The project started in early summer 2006 when the first mature 'ripe' broodstock were introduced (spawning season is July to September). In spring/summer 2007,

Articles

John Bayes sampling for Native oyster larvae in the ponds

Native oyster seed

the process will be repeated incorporating modifications and improvements gleaned from the first spawning season.

Pond Construction

To carry out this project, three 70m x 8m butyl lined-ponds are being constructed at the Seasalter site in Reculver, Kent. Due to the sizeable amount of shell that will be required to act as cultch in the ponds it will be necessary to employ a mechanical digger together with a small dump truck and an agricultural-type elevator. 'Ripe' parent broodstock oysters will be held in the ponds using Japanese lantern-type trays suspended below the water surface. The larvae produced by this broodstock will go through their development in these ponds feeding on the natural phytoplankton in the pond water.

Training Centre

The main initial focus of this two year FIFG project will be to refine the pond management techniques, efficiency and economic viability of producing native oyster spat using this extensive, low technology method. As this progresses other areas around the UK that are suitable for the relaying of spat produced in ponds will also be assessed and identified. One of the main eventual aims of the project is that Seasalter will become a training centre for industry in the practical methods of how to construct and manage these ponds. Through this approach the lessons learned during the project can then be used to help other areas that have suffered similar declines in native oyster numbers. It is hoped that this pilot oyster regeneration project will help to encourage the formation of other co-operative partnerships in traditional oyster areas and that they, along with the native oyster, will be able to benefit from the European Fisheries Fund that is due to be introduced in 2007.

Appendix 1C; FISHupdate Article (May, 2007)

Native oyster project hopes to boost species

A NEW project, supported by Seafish, is investigating rearing native oysters in ponds to increase their abundance.

Seasalter Shellfish (Whitstable) Ltd is carrying out a pilot project, funded by FIFG and the Marine Fisheries Agency (MFA) that will investigate whether native oyster spat (larvae) can be reared in ponds before being transferred to the sea.

The native oyster, *Ostrea edulis* – or flat oyster as it is also known – once formed a major commercial fishery that peaked in the mid 1800s after the end of the Napoleonic Wars. It is thought that at this time, a staggering 500 million oysters passed through Billingsgate each year, although production soon slumped. By the end of the 19th Century, the oyster changed from a food of the poor to a dish more commonly associated with the rich.

Today, stocks remain at very low levels due to a combination of factors. These include the impact of two centuries of over-exploitation and high mortality rates experienced during severe winters in the 1930s and 1940s. The situation has been further exacerbated by TBT (tri-butyl tin) pollution in the 1980s and competition from exotic pests such as the slipper limpet, in conjunction with the parasitic disease *Bonamia*.

Biodiversity

The new project at Seasalter – which will continue research originally developed in Cork, Ireland – forms part of the UK commitment to this species under a Biodiversity Action Plan, known as the Native Oyster Species Action Plan (NOSAP). Seafish will contribute support and project management to the research.

Aquaculture consultant Martin Syvret, working on behalf of Seafish on this project, said the work is "very important", as the native oyster remains a commercially important species for catchers, especially in south west England, the Solent and in Essex.

Martin said of the project: "Due to a variety of factors, this once abundant species is now at much reduced levels. In an effort to try and halt this decline, NOSAP was developed in the late 1990s, with the aim of increasing the abundance and geographical range of this threatened species where biologically feasible.

"The joint project between Seasalter, Seafish and the Shellfish Association of Great Britain will develop practical and cost effective methods of producing large numbers of native oyster spat for relaying and development as broodstock, in areas free of the oyster disease *Bonamia*, and thus help towards the regeneration of fisheries in those areas."

The initial aims of the two-year project are to refine the pond management techniques and ensure the efficiency and economic viability of rearing native oyster spat, using what is an extensive, low technology method. The butyl-lined ponds were constructed at the Seasalter site at Reculver, Kent, during summer 2006 and the initial trials have identified some preliminary constraints to using this technique.

"It is now hoped that the trials in 2007 will help to refine the methodology further, so that larger numbers of spat can be produced and then relayed," said Martin.

"Once the technique has been sufficiently developed, the eventual aim is that the Seasalter project will be used as a training centre for other industry professionals who are interested in developing their own pond culture projects for this species."

The introduction of the new European Fisheries Fund in 2007/08 will offer further possibilities for grant funding towards increasing native oyster numbers. This would enable the information gained from this project to be used nationally through other cooperative ventures.

The project is due to get underway again this year once water temperatures begin to rise.

The native oyster once formed a major commercial fishery

Appendix 1D; The Grower (June, 2007)

Regenerating the *Natives* at Seasalter Shellfish

By Martin Syvret Aquafish Solutions

The background information in this article first appeared in Fish Farmer magazine and is reproduced here with the kind permission of Special Publications.

An FIFG pilot project, with additional funding from the MFA, Seafish and the SAGB, designed to investigate pond production of native oyster spat for relaying has completed its first season's trials. The project that is being run by John Bayes at Seasalter Shellfish (Whitstable) Ltd. and managed by Martin Syvret on behalf of Seafish has been developed in response to the Defra/Seafish sponsored study by CEFAS that concluded that it was feasible to try and restore native oyster stocks in the UK. The project hopes to demonstrate that large scale production of native oyster spat can be achieved at a cost level that makes pond production a viable method of regenerating stocks of this species.

Decline of the Native Oyster

The native oyster, *Ostrea edulis*, or flat oyster as it is also known, was once a major commercial fishery, peaking in the mid 1800's after the end of the Napoleonic Wars. Indicative, if not wholly reliable, figures for numbers of oysters passing through Billingsgate at the time put the level at about a staggering 500 million. The first official oyster statistics were not produced until 1886 by which time production levels had dropped dramatically to around only 40 million per annum. This reduction in supply saw prices rise by about seven to eight times their original level from 1860 to 1889 and it was at this stage therefore that the oyster changed from a food of the poor to a dish more commonly associated with the wealthy. A comprehensive history of the remarkable decline of this fishery can be found in 'The English, The French and THE OYSTER' by Robert Neild. Today the stocks of this once abundant species remain at very low levels. Two centuries of over exploitation, TBT (tri-butyl tin) pollution in the 1980s, mortalities due to severe winters in the 1930s and 40s, competition from exotic pests such as the slipper limpet in conjunction with the parasitic disease *Bonamia* have all meant that current standing stocks, and thus broodstock, are so depleted that a natural recovery of the native oyster has been made much more difficult.

NOSAP

Although now at much reduced levels the native oyster is still considered a commercially important species for fishermen in the south west of England, the Solent and in Essex. This decline led in the late 1990s to the development of a Biodiversity Action Plan for this species, the Native Oyster Species Action Plan (NOSAP), for which the lead agency is currently the SAGB. The aims of NOSAP are to increase the abundance and geographical range of this threatened species where biologically feasible. It was therefore following the feasibility study and as part of this Action Plan that Seasalter, Seafish and the SAGB have developed and helped fund this pilot project. The project looks to investigate the potential for producing large numbers of native oyster spat at an economic cost that would allow their relaying as broodstock in areas free of disease and thus help to regenerate fisheries in those areas.

Continuing on from his role for Seafish as Aquaculture and Inshore Fisheries Advisor, Martin Syvret now runs a consultancy business specialising in FIFG/EFF project management and funding advice including project proposal development/submission and management of the funding application process. Martin also specialises in the provision of targeted training courses for industry as well as offering advice, support and research services to industry covering a wide variety of subject areas including business development, culture techniques, invasive species management and new species/ technology development. With a background in business and finance and an MSc in Aquaculture from Stirling University, Martin has worked as a researcher on shellfish and finfish at CEFAS as well as a commercial shellfish grower and restaurateur. Martin also writes regularly for several trade publications covering both issues facing and developments within the industry.

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Spat Production

The numbers of spat needed means that normal hatchery production methods are not economically viable and so Seasalter have turned to a method previously used with success in Ireland. With this production technique mature native oyster broodstock are held and spawned in managed outdoor ponds. The resultant larvae are settled onto a suitable settlement substrate, or cultch, such as cleaned cockle shells and then grown on in nursery systems until they are of a sufficient size that they can be re-laid on existing native oyster grounds. After relaying the growth and survival of these spat can then be monitored. The project started in early summer 2006 when three 70m x 8m butyl lined-ponds were constructed following which the first mature 'ripe' broodstock were introduced (spawning season is July to September). The main focus of this two year FIFG project is to refine the pond management techniques, efficiency and economic viability of producing native oyster spat using this extensive, low technology method. Amongst the initial findings which will be incorporated into the 2007 trials were the following:

Pond Liners; The use of butyl as a pond liner has proved successful although these liners do require a period of leaching in order to ensure that residual chemicals do not taint the phytoplankton food of the larvae.

Managed Phytoplankton Blooms; Excessive grazing of the phytoplankton by zooplankton within the pond systems can prevent a stable phytoplankton population from being maintained in the pond systems. Methods to alleviate this problem will be investigated during 2007 including the use of water that has previously been filtered by shellfish and the use of water that has been filtered through sand/silt.

Sources of Cultch – Obtaining good quality cockle shell for the 2006 trials proved problematic and so trials with alternate sources of cultch such as coralline sand and crushed limestone will be undertaken during 2007.

Appendix 1E; Seafish News (June, 2007)

Native oyster project hopes to boost species

Rearing native oysters in ponds to increase their abundance is being investigated in a new project supported by Seafish.

Seasalter Shellfish (Whitstable) Ltd is carrying out a pilot project, funded by Financial Instrument for Fisheries Guidance Fund and the Marine Fisheries Agency, investigating whether native oyster spat (larvae) can be reared in ponds before being transferred to the sea.

The project, which will continue research originally developed in Ireland, forms part of the UK commitment to this species under a Biodiversity Action Plan known as the Native Oyster Species Action Plan (NOSAP). Seafish will contribute support and project management to the research.

Aquaculture consultant Martin Syvret, working on this project on behalf of Seafish, said the work was "very important", as the native oyster remains a commercially important species for catchers, especially in south west England, the Solent and Essex.

"Due to over-exploitation, pollution, disease and severe winters in the 1930s and 1940s, this once abundant species is now at much reduced levels. In an effort to try and halt this decline, NOSAP was developed in the late 1990s, with the aim of increasing the abundance and geographical range of this threatened species where biologically feasible," said Martin.

"The joint project between Seasalter, Seafish and the Shellfish Association of Great Britain will develop practical and cost effective methods of producing large numbers of native oyster spat for relaying and development as broodstock, in areas free of the oyster disease *Bonamia*, and help the regeneration of fisheries in those areas."

The initial aims of the two-year project are to refine the pond management techniques and ensure the efficiency and economic viability of rearing native oyster spat, using what is an extensive, low technology method. The butyl-lined ponds were constructed at the Seasalter site at Reculver, in Kent, during 2006 and the initial trials have identified some preliminary constraints to using this technique.

"It is now hoped that trials in 2007 will refine the methodology further so that larger numbers of spat can be produced and then relayed," said Martin.

"Once the technique has been sufficiently developed, the eventual aim is that the Seasalter project will be used as a training centre for other industry professionals who are interested in developing their own pond culture projects for this species."

The introduction of the new European Fisheries Fund in 2007/08 will offer further possibilities for grant funding towards increasing native oyster numbers. This would enable the information gained from this project to be used nationally through other cooperative ventures.

Appendix 1F; Fish Farmer Magazine (In Press, 2008)

Oyster Farmers and Wildlife Managers Share Common Interests (Article by Dr. Clive Askew)

Possible new approaches to restoring native oyster stocks were discussed in July at a meeting held at Reculver in Kent, home to the hatchery and nursery operated by Seasalter Shellfish (Whitstable) Ltd.

A project, funded by FIFG is already underway at the site, seeking to clarify the critical conditions for the production, growth and successful settlement of native oyster larvae in outdoor ponds. Work to date has had some success, but water quality and phytoplankton bloom production remain difficult to manage.

The meeting, hosted by Seasalter Shellfish, brought together key representatives from the shellfish industry, the Environment Agency and wildlife interests including Kent Trust for Nature Conservation and RSPB. The oyster ponds and their banks form an ideal site for maritime wetland plants and seabirds. This produces a strong mutual interest for all involved. If techniques can be satisfactorily demonstrated, they might be applied at other sites around the coast. Managed re-alignment sites, where seawalls are strategically breached and abandoned under managed retreat, could be ideal locations. Steve Colclough of the Environment Agency said that to date these had been mainly viewed from their wildlife value, but other uses, for example as fish nursery areas and now oyster production and holding sites for selected broodstock could be foreseen. An earlier project as part of the Native Oyster Species Action Plan (NOSAP) identified a need to establish populations of native oysters which could be left unfished in semi-controlled conditions. These could provide a stock from which disease- resistant brood oysters could be allowed to self-select or be managed to provide selected breeding oysters.

It is known that historically, native oysters were found in creeks and inlets infiltrated by the sea. Many such creeks were cut off from the sea by the sea walls, many of which were built around the south east coast following the great flood of 1953. Others have become so silted that there is no clean shell 'cultch' for oysters to settle on, even if larvae are present in the water. Steve Colclough said the extent of eutrophication from land-based nutrient sources was being re-assessed under the EU Water Framework Directive. It appears to be more widespread than previously thought and would need to be considered for future improvement. An ability to demonstrate successful survival of sensitive species like native oysters in estuarine and even creek situations could be a valuable tool in confirming good water quality. The oyster nursery at Reculver has shown that there are marked differences in water quality between the open coast and the excavated ponds in which plant plankton is bloomed to feed the oysters and clams. Eel grass, which is now a nationally rare species but which was once common, has established itself in one of the nursery ponds. This is taken as a sign of good water quality.

The new common interest between oyster farmers, wildlife interests and the Environment Agency in coastal management should open up collaborative projects as managed retreat becomes more extensive in future.

Appendix 2 - Action Plan from Dunstaffnage Oyster Workshop

Action Plan from Oyster workshop

- Stakeholder review of their responsibilities, including :

- The Crown Estate to investigate the scale of the resource and a simplification of the licensing process (the lack of knowledge of the dispersed resource was repeatedly emphasised, along with concerns about the effect of current harvesting on long term sustainability);
- Industry to consider the economics of large scale restoration;
- SNH/police/Councils to extend public awareness exercise, assess communication effectiveness (public, industry, police, Sheriffs, etc);
- Researchers to consider projects focusing on genetic differences (including a review of Loch Ryan *O. edulis* genetic characteristics) and management of risks associated with restoration projects.

- Greater transparency of the food chain, to better enable monitoring of illegal product (traders/agents as well as producers, retailers and restaurateurs.
- Refresh NOSAP or create Scottish equivalent, including a review of programme objectives, as 'brand' for future portfolio of projects, including :

- Market assessment (elasticity of price with respect to volume);
    - Review CARD Report Recommendations and prioritise;
    - Risk assessment of restoration operations;
    - Establish Code of Good Practice for restoration activities;
    - Testing for disease – non-destructive methods.

- Build on synergy with SNH 'Species Framework', reflecting inclusion *of O. edulis* as "Species for sustainable use", as well as its inclusion on the Scottish biodiversity list and its status as a UKBAP Priority Species.
- Review opportunities of new Fish Health Directive to create more efficient control mechanisms.
- Establish an over-arching strategy for species development, with an emphasis on sustainability.

The group agreed to consider the formation of a 'Native Oyster Forum', with the participants at the day's Workshop forming the core of the forum representation.

Appendix 3 – Daily Record Sheet re. NOSAP Pond Project

DATE:	Pond 1 (Butyl)	Pond 2 (Butyl)	Pond 3 (Polythene)
Water Temperature (^{O}C)			
Salinity (‰)			
Number of oyster broodstock in Pond			
Presence (P)/absence (A) oyster larvae			
<u>If Present</u>; Size(s) seen (μ)			
Developmental stage			
Estimate of numbers			
Condition & motility of larvae			
Phytoplankton levels + main species I.D. where possible			
Presence (P)/Absence (A) of zooplankton + main species I.D. where possible			

NOTES TO ACCOMPANY SPATTING POND RECORDS

There are five managed ponds, Three of which were built specifically for the NOSAP project. The three are numbered 1-3 West to East. Each approximately 7.5m wide and 70m long by approximately3m deep.. 1 and 2 are butyl lined and the third one was polythene lined. The lining to the third pond was unstable and soon became ineffective and would best be regarded as unlined.

Filling was initially from N2, a subsidiary pond the North circuit of the nursery system. (The two main pond circuits will be referred to just as N and S) Periodically these are emptied and, when this happens the subsidiary pond are also emptied. Later the pipework was re-arranged so that water could be taken from N or S return circuits which are close to the spatting ponds.

We had hoped to arrange for a water supply direct from the sea, at the Request of Sue Utting, but this proved too expensive due to the length and size of pipe that was required. Added to that, sea water pumped direct from the shore line has seldom proved suitable for mollusc larvae during my time here, (since 1966) and probably much longer.

It would be useful to know why this is. Obviously water from further off shore is suitable for larvae otherwise spat-falls would be very rare events. Over the years I have sampled water from the shore between Faversham and Reculver and only rarely found it to be suitable for larvae. The water needs to be stored and bloomed for a period of 1 day or more before it will support larvae. It is clearly demonstrated by the fact that cockles never set in those parts of the pond subject to incoming sea water, even though the larvae usually come with it rather than from spawning in the ponds.

A fourth pond, initially intended for use as a spatting pond, runs East-West and is partially shaded by the secondary sea wall to the south of the farm. This is larger than the others with an estimated volume of 1,500 m3. It is close to the hatchery and so is easier to study and manage. This pond called R1 can be supplied with water from Rushbourne Dyke, which carries water from a sewage works at Hillborough some 3 k away and agricultural run off from arable farms covering a few hundred ha. Crops are mostly winter wheat or rape. The water is frequently high in N, P and Si and probably other trace elements. R1 can also bee supplied from with water from S, ex nursery and ex hatchery water.

We are progressing well with managing the blooms These have tended to be dominated by Skeletonema. Not a suitable spp. for small larvae but very good for large larvae spat and brood-stock. Once a bloom has established it can have a cell count of between 1 and 200,000 per ml which, under average weather conditions, can be diluted at a rate of 10,000 l/hour. This is approaching the rate at which the hatchery operates when in full production. As R1 is not suitable for a spatting pond it is now used to supply the hatchery. Initially it was used to supply the spat, which consume about 90 % of the food. This has greatly increased the hatchery capacity. Since Dec 2008 the conditioning and larvae have been supplied with R1 water. This latest move was prompted by the continued deterioration of the incoming water. It is no longer sufficient for the water to be stored in the pond for one day prior to use for the larvae . R1 water is largely recirculated and receives no raw sea water. The presence of long chains of Sk. does not trouble even very small larvae. They just don't eat it. There have been no unexplained larval losses since we made this change but it is early days yet. Winter is a time when water quality problems are usually minimal.

When time permits we plan to bring the O.e. Broodstock into the hatchery to see if we have an improvement of survival with this spp.

A fifth pond, R2 is longer than R1 and around three time the size with a volume approx 4,500m3 and can be filled from S, ex hatchery, R dyke and “well”. The Well is a long cut into the centre of the nursery complex which is deeper than the rest of the pond systems. It fills by gravity from the surrounding ponds. We know this because, when the well was first excavated, the water ran fresh. It is very rich in Fe and Si and probably much more. We pump water from the well to various parts of the nursery in the hope of utilising this cheap source of nutrients. I have made some studies of the well water which show that it is toxic to larvae and and most types of phytoplankton. One notable exception is Pavlova which grows to a remarkable density, 30Mcells /ml, and survives for a very long time, months. Initial trials suggested that the Pavlova grown in this water might also toxic, but that has yet to be confirmed. (see diary 02/02/07) I have arranged for the option to pump well water into the spatting ponds but have not done so. First I have to establish that the well water does any good whatever. We will continue to study it as this is the only water that is significantly different from the shore water and may yet prove a valuable alternative.

All the above ponds are monitored on occasional basis, though things are likely to become more systematic now that wee have an additional staff member to manage the ponds. Nutrient levels are recorded elsewhere.
Abbreviations are:
<u>Dinoflagellates</u>

Pro. = Prorocentrum, a nuisance, indicates poor water quality and at >10,000 / ml. can be toxic. It is ingested by larvae and spat and passed intact in the faeces. It is a recurring problem in those ponds that can not be routinely excavated. Perhaps it forms very long lasting cysts in the substrate.

Eb = Ebbria (which eats Skeletonema and can wipe out a culture overnight, survives temperatures down to 0C but only devastates culture when warmer than 5C)

Ox = Oxhyrris (which eats all small flagellates can reproduce at an alarming rate and generally is responsible for the fact that we seldom see flagellate blooms for more than 5 days),

Hc = Heterocapsa. Tends not to exceed 1,000/ ml. There can be problems if it does.

Both Pro and Hc are strongly phototactic and can sometimes be flushed out to sea.

Gym. = Gymondinium spp. Frequently occurs. Not known to be harmful and may even be edible to larger larvae and spat.

Flagellates

As yet we have made no attempt to identify these. We just class them as I (Isochrisis) size or T (Tetraselmis) size. Ie. = Isochrisis equivalent. From the Conwy notation where T= 10 Ie. Anything much bigger that T (8 – 10 micrometer) deemed to be unsuitable food for bivalves. In the absence of any strong evidence to the contrary all flags are assumed to be good food..

Included under flagellates though not necessarily in that family are the small cells generally referred to as 'chlorella like' . These seem to be a nuisance species particularly common in the spatting ponds. They are not consumed by bivalves. Often they are in dense blooms, maybe green or brown. Generally just referred to as 'pico' (pico plankton).

Diatoms.

Sk= Skeletonema is dominant. In fact we rely on it for 90% of the wild food. Generally occurs in long chains which tend to break up when the water is pumped. By the time it reached the hatchery the chains are typically 4-6 cells long. We count the number of cells per ul (= micro litre) or per 20 ul if there is less of it. Not only is it good food but I think it is important in maintaining water quality. Consequently a lot of pond management it dedicated to producing it.

All other diatoms are regarded as good food but tend to be rare. Small box shaped □ or cigar shaped are given a symbol, very good food especially for clams. We have had no success isolating these , so, can only wait for them to crop up.

Grazers (zooplankton)

Cop = copepods some years we get a sudden dense bloom of these but they are seldom a problem in the nursery but they have proved menace in the spatting ponds. This is partly because they compete for food, but also they are generally associated with levels of the bacteria Vibrio which can be lethal to oyster larvae.

Rot = rotifers - not common.

Tin = tintinids These are present most of the year, except during very cold weather. They tend to eat mostly flagellates and the impact is not clear.

Large zooplankton.

These are just recorded by description as none of us can name them. Shrimps and sticklebacks are common but tend not to accumulate in the spatting or blooming ponds. Their role in keeping down other grazers is important but we have not studied this. They are believed not to feed on bivalve larvae so they could be an important management tool in the spatting ponds.

Other abbreviations

SP spatting ponds

BT blooming tanks 1 and 2 are 11 x 11m square x 80cm deep 100 m3 number 3 is circular with a volume of 30m3 we expect soon to construct two more square ones. They are all supplied with water from the hatchery. This is ex spat room water. Conditioning and larvae water go to waste to avoid contaminating the blooms with unused food from the larvae or eggs and larvae from the broodstock The spat are very efficient grazers and remove almost all food. Leaving just sufficient to inoculate the blooming tanks. Some nutrients remain in the water from the algae supply which always has an excess of nutrients.

CSF. Cockle shell filter. This is a remarkable device invented here. A tank filled with sea water to which cockles shell are added gently so that the bulk of them rest with the cavity facing upwards. Water passing down through the filter deposits debris in the shells In the case of ex spat water this is largely faeces. Algae, being for the most part, smaller and neutrally buoyant sweep by. The only drawback it that larger dinoflagellates, which may not be grazed down by the spat also pass the CSF. The filter will run for years between cleaning. Backwashing does not work so it need to be broken down and the shell washed using the oyster grader.

N 1,2 and 3 subsidiary ponds of the North nursery pond Numbered in the direction of the water flow.

Clockwise.

S 1,2 and 3 subsidiary ponds of South nursery pond. Numbered in the direction of flow, anticlockwise.

These subsidiary pond were designed to be isolated from the main nursery so that they could be dried out, re-filled then bloomed and used to initiate bloom in the main pond.

ppt = parts per thousand (for salinity)

Spatting pond records.

19 and 20/06/06 pond filled from N2

22/06/06

1 very little pro Sk tin flag 31ppt

2 similar 1 + Hc

3 25 ppt

04/07/06

1 larvae 180-210 um not v good brown colour rough shell margin. Most at N end and outnumbered by cop 10:1

05/07/06

1 more larvae and fewer cop. 180-210 Food should be OK with 30 I sized cells /ul.

3 very brown with rot, no larvae.

Set up test with the lime sand I bought for setting 0 to 1.0 gm / l

06/07/06

Lime trial. All larvae normal. So it is not toxic but whether spat will set on it is another matter

1 T 24.5 C "lively" larvae 170-220 (230) um little growth. Food mainly I size, looks good.

07/07/06

1 good larvae 170 – (220) um no growth food seems OK 50 I sized cell /ul

10 07 06

Gd larvae but still no growth 170 220 (230) um food similar Pro = d small flags.

22 07 06

Start to commission R1 plan to fill and empty twice before attempting to use it.

See this date also for some lab trials to compare ponds 1-3 no obvious conclusion but 2 and control, (main pond) were best.

Broodstock moved from 1 to 2 which has been lowered and refilled from S. Stock look good, a few dead but good growth on others. The water was replaced because I was of the opinion that the butyl liner had adversely affected larval survival

13-21/07/06. this was a period of poor water quality throughout the pond system, not unusual for this time of year. Several laboratory trials gave no indication of a more suitable water source for the spatting ponds.

24/06/06

Pond 1. Started to refill from N. 10 to 20% of the previous water remained.

Pond 2. Very few O.e larvae . 180 -200 um. Lots of copepods and gastropod larvae.

25/07/06

Pond 1 still filling

Pond 2. Increasing O.e. density indicting that there had been a spawning. 170-230 um.

26/07/06

Pond 1. Very few larvae. 200-240 um. Some of the 240 um are eyed. (would normally expect eyed larvae to be 270 um or larger0

Pond 2. Lots of larvae mainly 170-180 um plus a few 230-260 um. Evidently there has been a further large release.

1/8/06

Pond 1. Few very small larvae. 150-160 um. Outnumbered 100-1 by copepods

Pond 2. No larvae. Just copepods.

4/8/06

Pond 1. Lots of copepods and coelenterates. One of which was eating a copepod. No O.e. Larvae.

Pond 2. As 1 but a lot less copepods. Jellyfish now dominant and lots of them eating copepods.

8/8/06

Ponds 1, 2 and 3. Lots of flagellates and little else. No O.e. Larvae.

11/08/06

Pond 1. No O.e. Larvae. A lot of flagellates more than 200 i.e. (too many but good)

Pond 2. No O.e larvae. A wider range, small diatoms and flagellates. 100 i.e. + small non motile cells, (chlorella like).

18/08/06

Arranged a small nursery container to stand beside Pond 1. to contain some clam stock. This was to try to graze down and stabilise the phytoplankton density and also to look out for releases of clam eggs.

Pond 1, small diatoms. Few flags. Good.

Pond 2. similar to Pond 1. Approx 10M larvae from the hatchery added.

Pond3. Lots of small flags. Very good but there is no broodstock.

22/08/06

Pond 1. Very dense pico. > a 1000/ul.

Pond 2. Food high similar to 1 but less dense. 3 O.e/50 litres. Of which 2 V.p (velum protruding) and 1 active.

Pond 3. Good flags 100 I.e. + diatoms. Copepods 1-2/ml.

23/08/06

Pond 1. Brown pico. Clams won't eat. Start to exchange water

Pond 2. similar to 1 but less dense.

Pond 3. O.e .stock moved to here.

29/08/06

Pond 1. Water changed during the last 3 days. Good. I. Sized flag. 30 i.e. Sk.30-20ul. Tins, Pro and Gym 1/ul.

Pond 2. Mainly large cells. Hc. Pro. Ox. And a few flags.

Pond 3. Good range of flags I to T size >100 i.e. (All O.e now in this pond as of 23/08/06.

30/08/06

Pond 3. 100 ltr. sample. 100,s of copepods. 1 hydrophobia, 5 O.e. 160-170um.

31/08/06

Pond 3. Big increase in O.e larvae 500/100 ltrs 160-170um. Food Flags 50-100 i.e. + Pro and some good Sk.

4/09/06

Pond 1. Good small flags 100 i.e. + good Sk. 20/ul

Pond 2. Green with pico +Sk 20/ul

Pond 3. Very few O.e larvae remain 50/100 ltrs approx. 140-170ul. No growth. Outgrown by copepods and gastropod larvae. Bloom poor, few small flags and little else.

07/09/06

Temperatures not generally recorded. Today 21.5C. Well within the range satisfactory for larvae.

12/09/06

Pond 1. Good I to T sized flags. 100 i.e. Rots.

Pond 2. I to T size flags 150 I.e. Cops.

Pond 3. Few surviving O.e. Larvae 10/100 litres, 160-180 ul. Cops 1000/100 litres. Good ,mainly I sized flags 30-50 i.e.

19/09/06

Pond 1. Good I to T size 100 Ie.

Pond 2. I to T size 50 i.e. + a lot of pico.

Pond 3. No O.e. In 100 litres. 27 larvae, presumed to be cockles. I sized flags 20 I.e. T size 1-2/ul.

22/09/06

Pond 1. Nice I to T size flags. 100 i.e. Few crustacean, perhaps crab larvae 1cockle/100 litres.

Pond 2. I to T size flags 30-50 I.e. + pico >1000/ul.+ 1 D larva possible C.g.

Pond 3. Sparse. I to T size flags <30 i.e. Few D larvae. Cops TNTC. O.e. 68/100 ltrs. 160-180ul.

Cockles 450/100 ltrs. 140-180 um.

26/09/06

Pond 3. No O.e. Only 24 cockles per 100 litres, biggest 140 um. No growth or they set very small.

27/09/06

No further records are entered for this year. At a later date the stock was removed and returned to the Nursery. There was no evidence of spat of any kind. The following year a few O.e. Spat were found in another part of the pond system, not connected to the spatting ponds. This was one managed as part of the nursery system, and was evidently better water quality than the spatting ponds.

2007

06/05/07

Purchased 132 O.e. From Rodger Cooper, Whitstable. 10% of these were roughs (too old and stunted to be good broodstock). Native oysters from Whitstable are not available from Whitstable any later in the year than this, and will be stored in the Nursery until required.

2/07/07 Lined ponds are left full during the winter to avoid storm damage.

Pond 1 had useless algae, emptied with a view to refilling soon.

6/7/07

Pond 1 empty. Pond 2 almost empty. Pond 3 still full. Various flags and some non motile cells.

12/7/07

Pond 1 liner pulled up and secured. Now refiling from S.

19/7/07

Pond 1. Wide range of flags all sizes + Sk.5/ul.

Pond 2. Good range of flags +Tin + various dinoflag. Sk 7/ul

26/7/07

Pond 1 sparse. I to T size flags 10-20 i.e. + Pro.

Pond 2. Very good. 100=150 i.e. all sizes of flags. Some Ox. Broodstock added. (Broodstock has been in store in the nursery for 2 months.)

Spatting ponds were commissioned late this year because of adverse weather conditions.

31/7/07

Pond 1. No food. Need to inoculate somehow.

Pond 2. Good flags but less than 50 i.e. Not enough to stimulate spawning. Some barnacle larvae.

Barnacle larvae were a problem last year. They are not normally a problem anywhere in the nursery system as there is no suitable substrate for them to settle on. The floats supporting the oyster containers were the problem and steps have been taken to keep them clean.

2/08/07 For much of this year pond water generally has had a nice amber colour, not caused by the presence of algae, presumably humic acid.

Pond 1. brown but flags less than 1 /ul.

Pond 2. Good brown mainly I to T size flags. 100 i.e. Both ponds had lots of crustacea,

presumably copepods and no bivalve larvae.

6/8/07

Pond 1. Sparse except pico at 1000's/ul.

Pond 2. good flags mainly I. Sized 50 I.e.

13/8/07

Pond 1, dark brown with v. small flags and pico

Pond 2 similar but with 50 I. sized flags /ul.

Combined sample, lots of Cops and worm larvae. Few O.e 150-200 um.

17/08/07

Pond 1. Brown 1000's of pico / ul

Pond 2. Brown/green. Good range of flags. I to T size. 100 i.e. “should be perfect.” Combined (ponds 1 and 2) sample O.e. 160-190 um. But no bigger than the previous sample. Presumably a new release. Good shape, good dark gut. Copepod and worm larvae.

23/8/07

Pond 1. No O.e. Small flags +lot of pico.

Pond 2 similar.

Pond 3. Range of flags and some diatoms. Salinity 30ppt. (Salinity is not regularly measured because it only varies slightly on a year round basis.)

29/8/07

Conclusion of some laboratory tests on the pico plankton.

Does not support larval growth but is not harmful.

30/8/07

Pond 1. Small number of O.e. Larvae. 170-180 um. Presumably yet another release. No large larvae.

Pico + a good number of small flags around 100 i.e.

Pond 2. similar. Flags at 50 i.e.

3/09/07

Pond 1.

No O.e. Larvae, only copepods.

Pond 2. No O.e. Only copepods. Dark brown/green, thick with pico, little else. Few I to T size flags.

4/9/07

Pond 1. Good flags. T. size 10/ ul. (100 i.e.)

Pond 2. Good flags. I. Like 50 ul (50 i.e.) some Sk. 10-20 ul.

Pond 3. Pro. But little else.

6/9/07

Ponds 1 and 2

No bivalve larvae. Both green and thick with pico.

12/9/07

Ponds 1 and 2. no larvae found. Both ponds bright green. Few good flags but mainly pico.

18/9/07

Pond 1. Pico and a few herbivores.

Pond 2. Pico + herbivores , few I. Sized cells.

Pond 3. No pico + various flags and box shaped diatoms. Ponds temperatures generally now less than 16C.

This concludes a rather disappointing year. Good quality blooms were never sustained long enough to support the larvae through to metamorphosis. The fact that the broodstock continued to release larvae suggests that the food regime was adequate to support them. The water quality was not adequate to sustain the larvae. There has been a similar situation in the hatchery in recent years.

In the years to come we will continue to work on the difficult problem of water quality in order to continue operating the hatchery. The hope is to find a a grazing and blooming regime that enhances water quality on a scale that can be applied to open pond systems.

2008

15/5/08

Broodstock

Bonamia had been detected in oyster samples from Whitstable Bay. Not a heavy infection rate – 3 out of 20, I believe. I can't even guess how it might have got there, but we decided to take the broodstock from a known bonamia free area, Stranrear in Scotland. The small stunted looking oysters, evidently capable of breeding as they are part of a self sustaining population in the area. They are stored in the nursery pro tem.

5/6/08

Pond temp up to 19.2C, warm enough to start outdoor breeding programme.

29/6/08

Pond 1. Dark brown. Dense pico, so small as to be barely visible on x100. O.e. 5000/50 litre sample. 170-190 um. Looking good, but copepods 10000 in same sample.

Pond 2. Dark brown good range of flags <I to T size. O.e <10 . very little else. Clumps of debris.

Pond 3. 50 litre sample. No life. Particles of grit. 10-500um, Possible dust blown in from surrounding ground. This hasn't been an obvious problem. Long term steps should be taken to prevent too much wind blown debris such as trees, etc. Temp 21.3C

2/7/08

Pond 1. Brown. Pico bacteria size. Not food. O.e. 600 larvae/50 litres +empty shells. 170-210 um. (Decimated from 29 June). Fewer copepods.

Pond 2. small release 100/50 litres. 170-200 um. Brown with a good range of flags. I to T size. Should be good for O.e. Larvae, but Ox at 1/ul.

Pond 3. No O.e. Larvae Some unidentified eggs. Brown very dense. 2um dots, probably small diatoms. Ox very dense at 10/ul.

7/7/08

Pond 1. Plankton hard to see, just tiny dots. Has been another O.e. Release evidently. O.e larvae 10000/50 litres. 180-200 um, all pale. Large copepods. 2000/50litres.

Pond 2. Lot of small flags 1-2um. Good food?. O.e larvae 1000/50 litres. 170-210um. Some look good colour.

Pond 3. I to T size flags. Ox dominant at 10ul. O.e. <10/50 litres temp 17.5C. Salinity 27ppt.

8/7/08

Pond 1 -3 Much as yesterday.

Pond 2. Biggest O.e. 220um , 1 only.

17/7/08

Pond 1.O.e 2000/50 litres, mostly small plus 1% 230-240um, biggest yet. Mostly pico + 50-100 v. small flags/ulood for larvae

Pond 2. O.e. <100/50 litres. 170Um only Pico + small flags 50-100um and a few larger T size flags. OK for larvae.

Pond 3. O.e. 10/50 litres .170-230um. Lots of slightly motile flags, 500/ul + v. small dinos. Good for larvae? Better progress than last year.

20/7/08

Pond 1. <100 O.e. /50 litres . All dead + some empty shells, All copepods dead alsoo+ v. few 1-2um flags less than 20/ul.

Pond 2. <10 O.e/50 litres. All dead. Small copepods. Pico. No flags.

Pond 3. <1O.e./.50 litres . Good flags I size. Ox. 3/ul. Should be OK for larvae if there were any.

Temp 18C. Cold wind today possibly driving the larvae down if they were rafting.

27/7/08

Pond 1. Mostly pico, flags <10 i.e. No O.e. Larvae

Pond 2. Pico + debris. Shrimps and faeces, no O.e.

Pond 3, as 2.

12/8/08

Pond 1. Has been topped up during the last few days. Pico + Ox. Not good for larvae. No O.e./50 litres

Pond 2. Very good I to T size flags around 100 i.e. should be ideal for larvae, but there are none.

Pond 3. Mostly pico , small dinos. Sk 90/20ul, good but pale. No O.e./50 litres

13/8/08

Pond 1 and 2. Debris and little else.

1/9/08

Pond 1. Faecal pellets similar to barnacles. No bivalve larvae.

Pond 2. Debris and large pellets. No bivalve larvae. No other life except nematodes.

Pond 3.

pellets as 2. Some swimming cones, I have seen these before but I have no idea what they are. See little drawing 1.9.08 Lots of chains of blue-green algae and little else , salinity 31.5ppt.

8/9/08

Pond 1. Not so bad, still lots of pico but also various flags 100 i.e.

Pond 2. I to T size flags + pico. Few v. small diatoms .OK. No larvae recorded in 1, 2 and 3.

Pond 3. Not good, debris and small Gym.

17/9/08

Pond 1. Pico and pro.

Pond 2. Pico +good flags 20 I.e.

Pond 3. Pico + I to T size flags. 50 I.e. No larvae found

10/10/08 Pond temp down to 13.1C

Pond 1. pico, nothing else.

Pond 2. Good flags, almost perfect 100 i.e. + Ox.

Pond 3. Pico and silt. Nothing good.

This is the last entry in the diary relating to the breeding ponds. Broodstock is still in the ponds as of 17/1/09 and will be recovered and returned to the nursery and eventually used for broodstock in the hatchery. We have not recorded progress of O.e. Spat successfully produced in the hatchery. Survival has been poor as usual the best of them are now 400mm in dia. We plan to keep these in the system at Reculver, so that we have our own broodstock presumed to be disease free as there is no reason to suppose bonamia could have accessed the system.

Date	Location	Nitrate (mg/l NO3)	Phosphate (mg/l P)	Urea (mg/l)	Silica (mg/l SiO2)	Iron Total (mg/l Fe)	Iron Ferrous (mg/l Fe2+)	Copper (µg/l Cu)	Nitrogen Ammonia(mg/l N NH3)
02/12/2004	North/South Ponds	2.25	0.37		4.2	0.03			
13/12/2004	Filtered Algae	>5.00	1.87			0.28	0.04	0	
15/01/2004	South Pond	4.72	0.53		0.9	0.16	0	1.3	
	Rushbourne Pond	>5.00	2.39		0.43	0.04		0	
21/01/2004	North Pond	4.67	0.88		0.45	0.1	0.02	0	
29/01/2004	North Pond	4.42	0.58		0.93	0.11		0	
	Filtered Algae	>5.00	2.09			0.16	0.01	0.7	
	Filtered CH.M Bag				2.6				
	Rushbourne Pond	>5.00	1.48		0.36	0.07		1.6	
30/01/2004	Filtered Big Bags	>5.00	4.78		12.5	0.34		3	
05/02/2004	South Pond	2.53	0.61		0.26	0.08		1.6	
	V pstains Algae	>5.00	5.46			0.66	0.01	4.3	
	Rushbourne Pond	>5.00	1.36		0.36	0.02		1.3	
13/02/2004	South Pond	3.16	0.57		0.38	0.11		0	
18/02/2004	Filtered Algae	>5.00	1.66			0.18		0.03	0.05
25/02/2004	Filtered Well				18.2	0.85			
	Filtered Well (upstairs)				7.2	>3.30			
	North Pond				0.29				
01/03/2004	South Pond				0.22				
10/03/2004	Filtered Algae	>5.00	1.71			0.15		0	
	Filtered Algae (upstairs)	>5.00	5.23			0.8			
	North/South Ponds	1.22	0.65		0.23	0.09			
22/03/2004	South Pond	1.08	0.51		0.31	0.13			
24/03/2004	South Pond	2.04							
25/03/2004	Filtered Algae	4.87	1.45			0.13			
31/03/2004	Filtered Algae (upstairs)?	>5.00	1.78			0.17			
	South Pond	0.47	0.33						
06/04/2004	North/South Ponds	1.12	0.21		0.63				
14/04/2004	South Pond	1.04	0.2		0.42				
21/04/2004	North/South Ponds	1.24	0.84		0.57	0.01			
22/04/2004	Filtered Algae	4.15	1.24						
	Filtered outside bags	1.32	1.7		11.3				
05/05/2004	North Pond	1.03	0.27		1.71	0.06			
	South Pond	0.65	0.23		1.04				
10/05/2004	Filtered Algae	1.78	1.26						
18/05/2004	Rushbourne Pond	0.19	0.38		0.63				
	South Pond	1.24	0.21		0.91				
09/06/2004	South Pond	1.08	0.22		>1.76	0.07			
17/06/2004	South Pond	1.19	0.38		4.6				
21/06/2004	Filtered Algae	0.93	0.7						
25/06/2004	North Pond	1.06	0.54		3.8				
	Filtered Algae	1.46	1.59						
	Filtered outside bags	0.4	0.27		3				
01/07/2004	North/South Ponds	1.62	0.22		2.6				
09/07/2004	North Pond	1.42	0.46		3.8				
14/07/2004	North Pond	1.78	0.31		2.8				
29/07/2004	North Pond	1.12	0.23		4				
17/08/2004	Big Bags	4.18	0.43		6.7				
	North Pond	0.64	0.26		8.9				
27/08/2004	North Pond	1.89	0.23		5.8	0.05		4.7	
09/09/2004	South Pond	0.43	0.12		3.2				
20/09/2004	South Pond	3.52	0.28		4.4	0.04			
07/10/2004	North Pond	1.65	0.36		2.9				
20/10/2004	North/South Ponds	0.5	0.35		1.4				
12/01/2005	North/South Ponds	2.23	0.29		2.7				
13/04/2005	South Pond	0.37	0.1		0.38				
	Rushbourne Pond 2	0.78	0.36		8.3				
24/06/2005	North Pond	1.44	0.8	1.9	1.65				
05/08/2005	Rushbourne Pond 2	1.07	0.3	0.2					
11/07/2005	North Pond	1.25	0.67	1.6	0.82				
	South Pond	1.22	0.21	0.8	0.22				

18/08/2005	Rushbourne Pond 2	1.24	0.61	1.8	0.08	0.02			
	South Pond	1.36	0.39	0.5	0.57	0.04			
	Filtered Algae	>5.00	2.1			0.26			
15/09/2005	South Pond	1.19	0.54	2.2	0.77				
06/10/2005	South Pond	1.31	0.48	1.5	0.7				
23/11/2005	North Pond	1.43	0.39	0.5	1.61				
13/12/2005	Clam Parks	0.39	0.38	1.2	1.76				
15/12/2005	Blooming Tank	>5.00	>0.90		1.62				
	Rushbourne Pond 1	1.39	>0.90	1.4	0.75				
	Rushbourne Pond 2	0.82	0.88	1.5	0.86				
16/12/2005	Blooming Tank	7.1	>0.90		0.68				
	Rushbourne Pond 1	1.75	>0.90	0.8	1.09				
	Rushbourne Pond 2	0.44	>0.90	0.8	0.96				
19/12/2005	Blooming Tank	1.5	0.61		1.34				
	Rushbourne Pond 1	1.11	1.12	0.2	1.2				
	Rushbourne Pond 2	0.39	0.21	0.2	0.55				
20/12/2005	Blooming Tank	5	4.27		0.69				
21/12/2005	Rushbourne Pond 1	1.13	0.93	0.2	1.49				
22/12/2005	Rushbourne Pond 1	3.5		2.1					
	Blooming Tank	5.5	3.94		0.71				
23/12/2005	Rushbourne Pond 2	0.2	0.15	0.98	0.2				
	Clam Parks	0.06	0.2	>1.76	<0.1				
28/12/2005	Rushbourne Pond 1	1.06	0.95	1.51	3				
	Blooming Tank	7.1	4.38	1.11					
29/12/2005	Rushbourne Pond 2	0.42	0.37	0.52	<0.1				
30/12/2005	Clam Parks	0.3	0.73	1.71					
	Blooming Tank	6.8	3.37	0.43					
03/01/2006	Blooming Tank	6.2	2.73	>1.76					
04/01/2006	Rushbourne Pond 1	2.1	>0.90	1.49	1				
	Rushbourne Pond 2	0.49	0.37	1.11	<0.1				
06/01/2006	Clam Parks	0.39	0.11	1.72	0.5				
	Blooming Tank	1.9	>0.90	1.08					
09/01/2006	Blooming Tank	4.7	>0.90		1.2				
10/01/2006	Rushbourne Pond 1	1.09	1.38	0.2	0.98				
	Rushbourne Pond 2	0.42	0.51	<0.1	1.17				
13/01/2006	Rushbourne Pond 2	0.48	1.12	0.2	1.18				
	Rushbourne Pond 2	1.07	1.11	0.2	1.29				
17/01/2006	Blooming Tank	3	>0.90		1.01				
	Rushbourne Pond 1	1.69	0.71	0.3	0.85				
18/01/2006	Rushbourne Pond 2	1.8	1.13	0.2	1.19				
	Rushbourne Pond 2	1.18	0.74	0.2	1.31				
02/02/2007	Rushbourne Pond 2(Near)	2.07	0.38	>3.0	0.96				
	Rushbourne Pond 2(Far)	2.41	0.33		>1.61				
22/03/2007	North/South Ponds	0.11	0.23		0.37				
23/03/2007	North/South Ponds	0.02							
27/03/2007	North/South Ponds	0.49							
04/07/2007	CH.m Bags				3.8				
05/07/2007	South Pond	1.13	0.33		>1.76				
02/10/2007	Clam Parks	0.16	0.23		0.36				
	Swan Lake	0.14	0.45		0.51				
05/10/2007	Swan Lake	1.87							
07/12/2007	North Pond	0.2	0.27						
06/02/2008	North Pond	1.06	0.22						
05/03/2008	North Pond	0.03	0.14		0.28				
17/03/2008	North Pond	0.48	0.12						
11/09/2008	North/South Ponds	1.43	0.29	2.4					
19/09/2008	North/South Ponds	0.29	0.53	2.2					
06/10/2008	North/South Ponds	1.42	0.26	2.3					
21/10/2008	North/South Ponds	1.06	0.32						
04/11/2008	North/South Ponds	1.15	0.26						
12/11/2008	North/South Ponds	1.26	0.34						
19/11/2008	North/South Ponds	0.28	0.12		1.06				