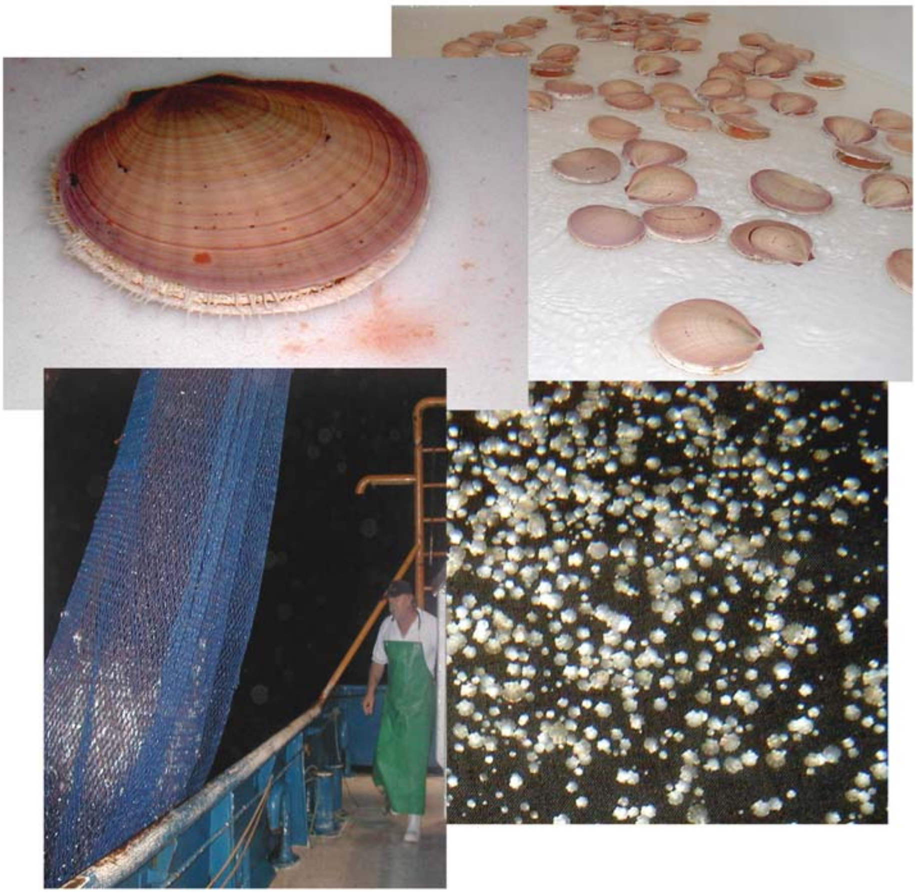
ENHANCEMENT OF SAUCER SCALLOPS (*Amusium balloti*) (BERNARDI) IN WESTERN AUSTRALIA

R J S Scoones and P McGowan



Project No. 2002/048

Australian Government
Fisheries Research and Development Corporation

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Principal Investigator and Senior Author
R J S Scoones
Rick Scoones and Associates
PO Box 853
NEDLANDS WA 6909

Co-Author
P McGowan [1]

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Publisher
[1]West Coast Scallops Pty Ltd
PO Box 2144
Geraldton WA 6531

FRDC Contact details
PO Box 222, Deakin West ACT 2600
Phone: 02 6285 0400
Fax: 02 6285 4421
Email: frdc@frdc.com.au
Web: www.frdc.com.au

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NON-TECHNICAL SUMMARY

2002/048	**Enhancement of Saucer Scallops (*Amusium balloti*) in Western Australia**

PRINCIPAL INVESTIGATOR: **Mr Richard J S Scoones**

ORGANISATION: Rick Scoones and Associates

ADDRESS: PO Box 853
NEDLANDS WA 6909

TELEPHONE: 08 9443 2243

FAX: 08 9443 2243

OBJECTIVES:

To determine the methods, age and timing of *Amusium balloti* spat deployment required to produce commercial recoveries of meat from scallop spat reseeding of natural grounds.

OUTCOMES ACHIEVED TO DATE

The project was successful in improving procedures for rearing *Amusium balloti* in hatcheries and developing methods of transport and deployment that delivered viable juvenile scallops to the seabed. The objective of demonstrating survival of adequate numbers of scallops to support a commercial scallop reseeding operation was not fully demonstrated, although this apparent failure may have been attributable to the project team's inability to distinguish between hatchery-reared and wild-spawned scallops.

Experience gained in the hatchery and in the field during the project has facilitated the production of a list of Research Needs, the main issues that the current researchers believe should be investigated as a priority if reseeding is to be pursued further in *Amusium balloti*.

Reseeding, or restocking is the practice of placing hatchery-produced animals, normally at relatively young ages, into areas where their natural habitat offers an opportunity for production above that offered by natural recruitment and constrained by early natural mortality.

The variability of natural recruitment which reseeding seeks to even out can be due to a range of factors, many of which are poorly understood in most species in which reseeding is attempted.

Typical of most of the world's scallop fisheries, the Abrolhos Islands and Midwest Trawl Fishery produces a highly variable catch of scallop meat from the saucer scallop. *Amusium balloti*, ranging in total meat production from under 50 tonnes to over 4000 tonnes annually. This variability, which is unpredictable other than in gross terms until recruitment has occurred, creates difficulties for the fishery and all of its stakeholders. The variation in recruitment has been demonstrated not to be the result of fishing pressure or other natural predation, but is thought likely to be due to other environmental forces, in particular the strength of the Leeuwin Current, which affect transport, distribution and survival during the 10 to 15 days of the larval stage.

This project sought to identify methods of hatchery production, transport and deployment for juvenile saucer scallops which would result in the production of commercially viable returns of scallop meat with a view to stabilising scallop meat production in saucer scallop fisheries in Western Australia, with the potential for application of any results to the Queensland scallop industry.

Methods of transporting juvenile saucer scallops and delivering them in viable condition to the seabed were successfully developed in the current project. While appreciable numbers of hatchery-reared juvenile scallops were released, it was not possible to demonstrate their survival rates, or to distinguish between hatchery-produced scallops and wild scallops. Further research into this feature was not conducted as many external factors impeded the settlement of later spawnings – making the marking and location of sown juvenile scallops a less important issue to resolve at that time.

Experience gained in the hatchery and in the field during the project has facilitated the production of a list of information requirements. These have been set out in the form of Research Needs, (Section 7) and identify the main issues which the project working group and steering committee believe should be investigated as a priority if reseeding is to be pursued further in *Amusium balloti*.

KEYWORDS

Saucer scallop, *Amusium balloti*, reseeding, restocking.

ACKNOWLEDGEMENTS

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The WA Department of Fisheries provided Co-Investigator in the form of Dr Lindsay Joll as a valuable contribution to the project, and all of the animal pathology services at no costs through the Senior Fish Pathologist, Dr Brian Jones. Elmwood Holdings Pty Ltd, a partner in West Coast Scallops Pty Ltd, has also received financial support in the early stages of their hatchery research from the Western Australian Department of Fisheries.

The Steering Committee, which oversaw the project and provided advice as needed, included Mr Hamish Ch'Ng of Far West Scallops Pty Ltd, Mr Peter McGowan and Mr Tim Duggan of Elmwood Holdings Pty Ltd, Dr Patrick Hone and later Mr Matt Barwick from the Fisheries Research and Development Corporation, Mr Mike Dredge, Aquaculture Consultant from Queensland, Dr Lindsay Joll from the WA Department of Fisheries, and Mr Richard Stevens, Research and Development Consultant to the WA Fishing Industry Council. Mike Dredge also provided substantial assistance during preparation of the final report. The authors are grateful for the inputs by all members.

Dr Elizabeth O'Brien of Bribie Island Aquaculture Research Centre provided advice and feedback during analysis and reporting for which the authors are grateful. The staff and boat crews of West Coast Scallops Pty Ltd, Far West Scallops Pty Ltd, and Elmwood Holdings Pty Ltd, particularly Mr Tim Duggan, Mr Geoff McGowan, Mr John Pavlinovich, and Mr Larry Lydiatte all provided significant assistance during the entire project.

1.0 BACKGROUND

FRDC Project 190/2000, "Feasibility Of Scallop Enhancement And Culture In Australian Waters", by Mike Dredge *et al.*, examined the potential for scallop enhancement in Australian waters. The report concluded "marine ranching or enhancement of *A. balloti*, rather than hanging cage culture, appears to be economically and socially feasible". It also identified some key issues which need to be resolved if *A. balloti* reseeding is to be successful, noting that a marine ranching or enhancement operation would have to be based on hatchery-reared scallops in its initial and intermediate stages of development and that there is a need to determine the optimum size of release and to develop transport procedures to take very large numbers of scallops from hatcheries to reseeding sites.

The Dredge report noted that, whilst there has been some research on the potential to reseed *Amusium balloti*, there had been little commercial commitment to-date. The animal's transient byssal attachment was seen as the main limitation on wild spat collection. This lead to the conclusion that any enhancement program must be supported by a hatchery as a source of spat before any success is likely.

Dredge *et al.* suggested that a marine ranching operation could be more easily conducted as a single integrated operation, owned and managed by a single business entity or public company, but that a co-operative organisation would probably have greater social benefit in regional areas. Enhancement of a scallop stock for the general benefit of the fishery is feasible but organisationally more complex in terms of management, social implications and cost recovery.

Elmwood Holdings Pty Ltd (EHPL) owns and operates a hatchery in Geraldton that produces spat from *Amusium balloti* and *Pinctada margaritifera*. EHPL has spent in excess of $500,000 over the last four years establishing the hatchery and developing knowledge and techniques for capture and transport of scallop broodstock, spawning in the hatchery, handling and husbandry of the early stages of the life cycle, scallop pathology and disease management, and has achieved significant spat settlements on more than one occasion. The learning process, and the resolution of technical problems at all stages, has provided the EHPL Hatchery Manager and staff with a strong background of experience on which to draw for this new research program, which was designed to develop information on optimum procedure, size and timing for transporting and releasing hatchery-reared spat to grow-out sites. In November 2001, EHPL conducted a number of spawnings with 20 to 30 female scallops, producing approximately 12 million D-stages from over 75% fertilisation and strong survivals into day 5 at the time of writing [the original application].

EHPL owns and operates two licenced scallop vessels in the Shark Bay (WA) and Abrolhos Islands scallop fisheries. The company also holds a Western Australian Aquaculture Licence over an area of approximately 25 square kilometres in the Geelvink Channel between the mainland and the Abrolhos Islands at approximately 28.27.00 S, 114.10.00 E. That area has produced wild scallops in the past but has received negligible recruitment and fishing effort in recent years. It was therefore selected as a suitable reseeding site and was licenced for the reseeding of *Amusium balloti*. The area is now a formally gazetted aquaculture site that is a significant distance from the commercial scallop grounds. Any reseeded stock will be protected from illegal harvesting by the requirement for all vessels capable of trawling in the area to carry and use Vessel Monitoring Systems (VMS).

Subsequent to gaining funding from the FRDC, EHPL was joined in the project by Far West Scallops Pty Ltd from Fremantle. Far West Scallops owns and operates 6 trawlers in the west coast scallop fisheries. A new company, West Coast Scallops Pty Ltd, was then formed to operate the scallop-reseeding project.

The WA Department of Fisheries has been a strong supporter of this project, with all legislative and regulatory issues having been resolved during the licensing process. Accordingly, Elmwood Holdings Pty Ltd qualifies under all of the important or limiting criteria identified by Dredge *et al.* as having the best chance at achieving success in scallop enhancement.

2.0 NEED

The Western Australian scallop fisheries are, as with most wild scallop fisheries, highly variable in terms of annual production, with variability being attributed to a range of environmental factors. The fisheries are "managed in a precautionary manner and the risk of overfishing is minimal" (Dredge *et al.*, 2001).

A reduction in the variability of the annual production in the Western Australian scallop fisheries, and an overall increase in production, will be of major benefit to the Western Australian and Australian economies. Before any increase in production can be achieved, some further research is required.

Dredge *et al*. (“The Dredge Report”) noted a need to determine the optimum size at which spat should be released, in order to balance gains through reduced mortality and costs related to hatchery and nursery production. They also identified the need to develop transport procedures to take very large numbers of scallops from hatcheries to reseeding sites. They noted a need for a development phase in the industry to develop and translate hatchery technology to a fully commercial scale, consistent operation, and also a need to test the assumptions made in their report in respect of natural mortality rates of *A balloti* at given sizes. This project sought to address those initial research needs.

The Dredge Report noted that there would be considerable economic and social gains to be made from a successful marine ranching or enhancement operation. This project offers the first opportunity to trial commercial scallop enhancement in Australia, noting the eminent qualifications of Elmwood Holdings Pty Ltd according to Dredge *et al.* (2001).

3.0 OBJECTIVES

To determine the methods, age and timing of *Amusium balloti* spat deployment required to produce commercial recoveries of meat from scallop spat reseeding of natural grounds.

Detailed Objectives

The procedures used to achieve the project Objective involved resolving a number of technical issues, described in the Milestones of the original application document as follows:

<u>30/06/2003</u>

Continuation of the project beyond each year will depend on the conduct of a satisfactory review by the Steering Committee. The project seeks to achieve successful completion of the first season's spat deployments by April 2003. Modifications to equipment and deployment methods will incorporate decisions made by the Steering Committee. Progress report.

<u>30/06/2004</u>

Test fishing for scallops in about August 2003 and intensive trawling over the entire reseeding site and quantification of scallops resulting from each spat deployment by about October 2003. Completion of the second season's spat deployments by April 2004. Continuation of the project will depend on the conduct of a satisfactory review by the Steering Committee. Modifications to equipment and deployment methods will incorporate decisions made by the Steering Committee. Progress report.

<u>30/06/2005</u>

Test fishing for scallops in about August 2004 and intensive trawling over the entire reseeding site and quantification of scallops resulting from each spat deployment by about October 2004. Completion of the third season's spat deployments by April 2005. Continuation of the project will depend on the conduct of a satisfactory review by the Steering Committee. Modifications to equipment and deployment methods will incorporate decisions made by the Steering Committee. Progress report.

31/03/2006

Test fishing for scallops in August 2005 and intensive trawling over the entire reseeding site and quantification of scallops resulting from each spat deployment by about December 2005. Draft Final Report.

30/06/2006

Final Report.

Following the successful breeding and rearing of scallop spat, the key issue for resolution in the first stage of the project was the establishment of a method for spat transport from the hatchery to the reseeding grounds and demonstration that the chosen transport and subsequent deployment methods delivered viable spat to the seabed.

Technical objectives in subsequent stages would depend on success in the first year, including testing of the viability of spat after transporting and deployment, and after the results of fishing on the reseeding site approximately 8 months after spat deployments.

4.0 METHODS

4.1 HATCHERY

West Coast Scallops sought to produce scallop spat in Elmwood Holdings Pty Ltd's scallop and pearl oyster hatchery in Geraldton using broodstock caught in the region where the spat were to be released. The supply of the spat was outside the objectives of the FRDC-funded project, the hatchery having successfully produced *Amusium balloti* spat in previous years.

Each spawning used up to 100 female and 50 male scallops to ensure the production of adequate numbers of spat and adequate genetic diversity of progeny - Plate 1. New broodstock were used for each spawning, all previous broodstock being destroyed after spawning as required by WA Department of Fisheries regulations and to maintain genetic diversity in the wild. The larvae were cultured in 4-tonne tanks in the hatchery until settlement (Plate 2), and settled spat were cultured in shallow tanks (Plate 3) containing fine mesh-bottomed trays (Plate 4). The larval phase in the hatchery is approximately 10 days (Pers. Obs.), while in the wild it has been reported as being between 12 and 24 days (Rose *et al*., 1988). The byssal thread is thought by most to be absent in this species, but the presence of a rudimentary short-lasting feature has been described has been described by Wang and Duncan, 2004.

The batches of spat produced in the hatchery are referred to by a simple alpha code generated chronologically beginning at "A" at the beginning of the spawning season and, if split into more than one batch, then an alpha-numeric code was applied, retaining the original alpha nomenclature and adding a "sub-set" numeric code - *e.g.* batch D became "D1, D2, D3.

Plate 1 Spawning table with female broodstock

Plate 2 Larval scallop culture tanks

Plate 3 **Scallop spat culture methods**

Plate 4 **Juvenile scallop culture trays**

4.2 GENERAL METHODS

4.2.1 Reseeding area

An area of seabed had been allocated to Elmwood Holdings Pty Ltd, which in turn allowed West Coast Scallops Pty Ltd use of the same, approximately 25 kilometres northwest of Geraldton in approximately 42 metres of water - Figure 1. The area had on only rare occasions produced scallops in the past 20 years, but this intermittent recruitment was sufficient to indicate that the area included areas of substrate suitable for scallops.

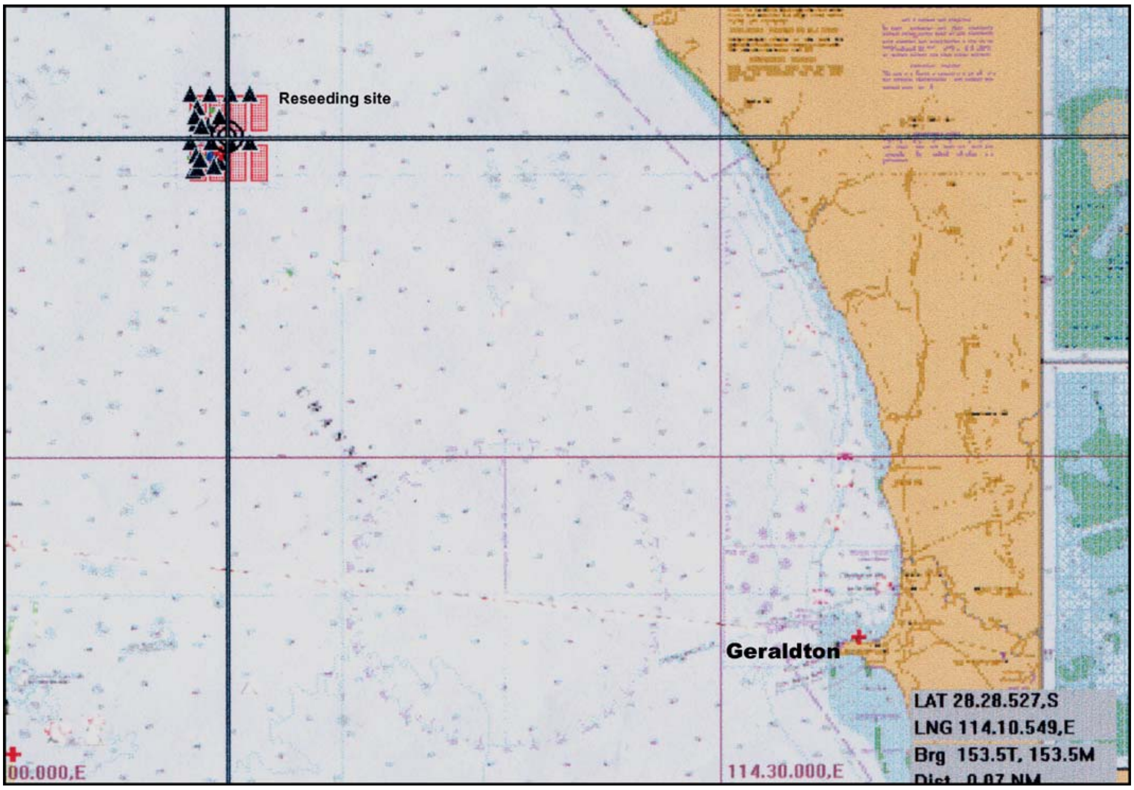


Figure 1 Location map

Prior to the first deployment of juvenile scallops, the reseeding area allocated to the enhancement project was trawled by a West Coast Scallops trawler to determine the presence, if any, of wild scallops. Trawling was done with 30mm mesh nets to ensure that all scallops over about 30 mm were caught and counted. Whilst it was recognised that it is not possible to remove all of the scallops from the area, and that small scallops do not lift above the substrate enough in response to a trawl to give a quantifiable estimate of numbers or density, the test trawling was designed to determine the presence/absence of scallops over about 30 mm in the area so that, if a reseeded spat cohort was successful, the size distribution and differences in size would indicate the origins of the different cohorts.

The reseeding area was divided into 8 separate areas (Figure 2) to allow for convenient separation of cohorts of deployed scallops.

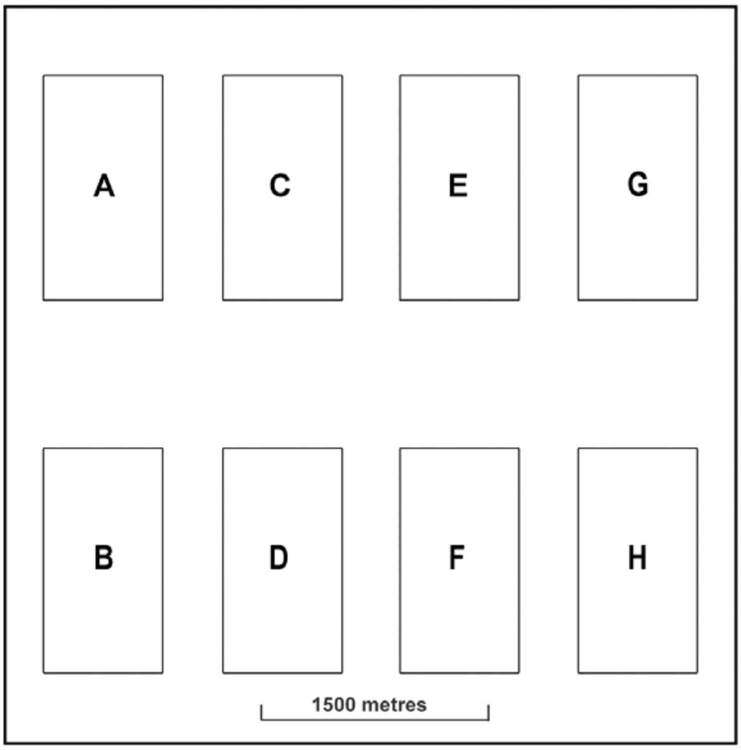


Figure 2 Deployment areas

4.2.2 Spat production

The production of spat was outside of the funded research program but was fundamental to the successful conduct of the research. Ten spawnings were planned for the first season, to supply up to 150 million settled spat, with smaller numbers planned for deployment due to natural attrition during the early stages of culture. Future spawnings and other hatchery procedures would depend on success in the first year of the project. A total of 25 spawning operations were actually carried out in the first season. Spat from each spawning operation were identified with an alphabetic code. They were developed through larval and early settled stages, using a mixed diet of *Pavlova lutheri*, *Chaetoceros sp, Isochrysis sp*, *Tetraselmis sp*, *Nannochloropsis sp, and Dunaliella sp,* settled onto 200µm nylon screens and ongrown for up to about 60 days before being transported to sea and released.

4.2.3 Disease Testing

The WA Department of Fisheries Hatchery and Translocation Regulations require disease testing of all animals prior to release into the environment. To facilitate the testing procedures and deployment program, and recognising the wish to deploy scallops which are smaller than that required for testing, the first cohort of spat were grown to at least 2mm before deployment. This size allowed the animals to be properly disease-tested by the Fisheries Department pathologists. A sample of the first cohort was retained in the hatchery for further health testing as required, while also allowing much smaller animals to be released on the basis that they were cultured in the same system and water as those larger ones which were sacrificed for the health assessments.

4.3 Spat transport methods

The first attempts at transporting spat from the hatchery to the reseeding site were operationally successful, so the same basic procedure was followed throughout the project's duration. The successful process involved transferring spat from the nursery trays to 20-litre plastic carboys (Figure 3) filled with seawater from the nursery. Between 15,000 and 50,000 spat were carried in each carboy, depending on their size. Once onboard the transport vessel, pure oxygen was supplied to each carboy at approximately 0.11 litres per minute, bubbled continuously through an air-stone until they were ready for deployment. Once beyond harbour limits, new seawater was slowly supplied to the carboys thus acclimatising the spat to local conditions prior to deployment.

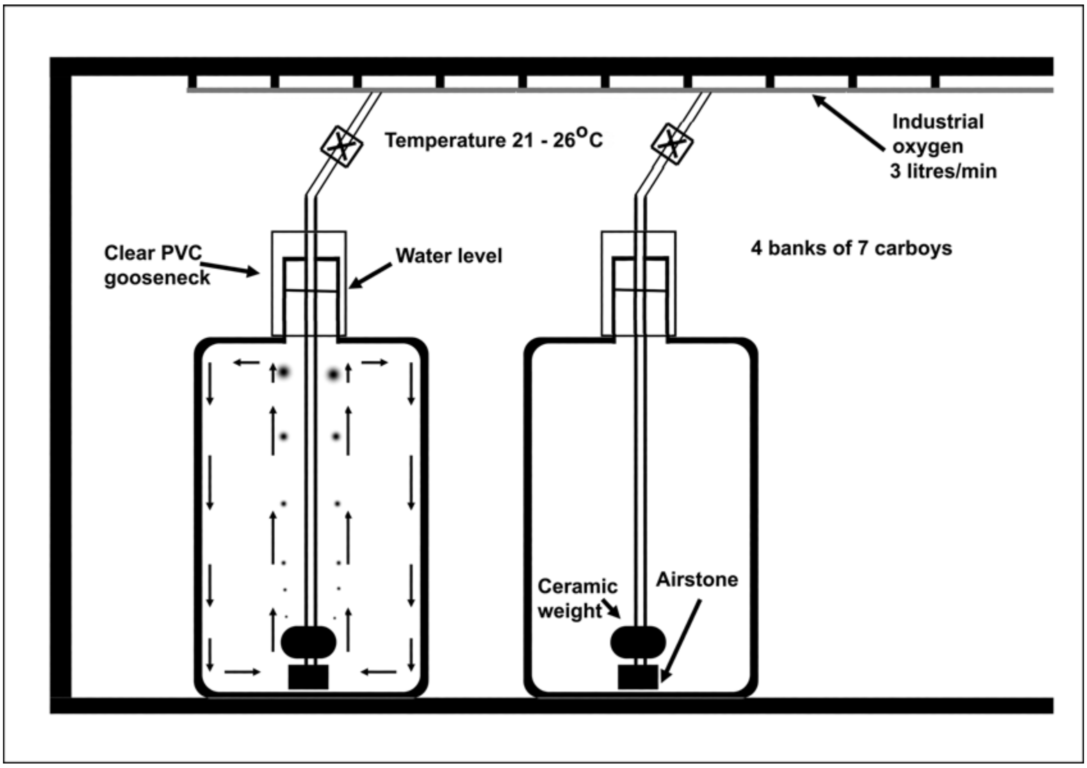


Figure 3 Spat transportation methods

4.4 TRIALS ON METHODS OF SPAT DEPLOYMENT

Given that spat deployment procedures were a primary objective of the project, and a subject about which we had no background experience, a range of methods was trialled. Each one was a development or adaptation on the previous one, designed to address problems experienced in earlier spat deployment operations. The operational objective of these trials was to deploy spat at relatively uniform density of up to approximately 20 animals per square metre and minimise mortality to the spat.

4.4.1 First Trial

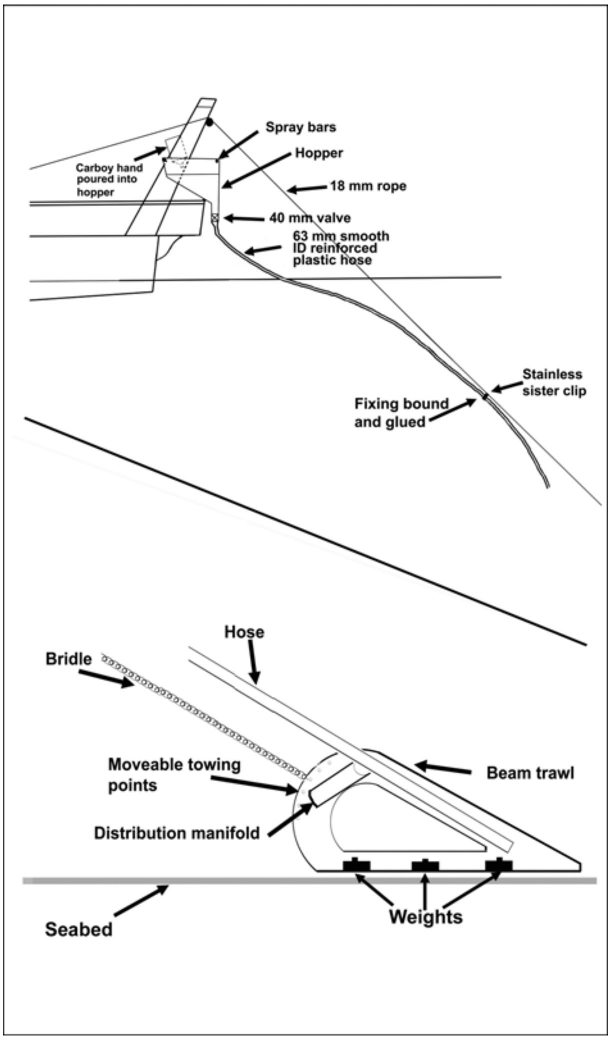
The first deployments took place on the 23rd of October 2002. A small hopper on the deck of the vessel was connected to the deck hose and a venturi attached to the main pipe which was a 50mm diameter polypropylene hose, approximately 150 metres long, which led to a beam trawl on the seabed. The hose outlet was attached to the beam trawl to achieve an outlet height above the seabed of approximately 150mm. The hose was attached every 10 metres to a supporting cable. The hopper was continuously filled with seawater from a second pump. Once the air was flushed from the system, the spat were added to the hopper, sucked through the venturi and deployed from approximately 150mm above the seabed as the vessel steamed at between 1 and 3 knots.

4.4.2 Second trial

The second deployment trial, on the 2nd of November 2002, used a small hopper connected directly to the 50 mm hose (with no venturi). Gravity was used to move the water containing spat down the hose to the bottom, which was attached to the beam trawl as used in the first trial. A gentle flow of water in the hopper moved all spat through the pipe. The last spat were washed out of the hose by a good flushing of seawater from the hopper. Deployment took place as the trawler steamed at between 1 and 3 knots, depending on wind and sea conditions.

4.4.3 Third Trial

The method which proved to be most useable and which was used for the bulk of the deployments, was first used on the 12th of November 2002 and is shown in Figures 4 and 5. It was necessary to ensure that the hose was not under load from the beam trawl to avoid damage to attachments and fittings. An aluminium hopper was fabricated and fitted over the stern of the vessel with the outlet for the delivery hose fitting facing directly downwards near the main line pulley - Figure 4. A deck hose was connected to the hopper to maintain a continuous flushing, with spat exiting through 2 openings on a manifold approximately 600 mm above the seabed – Figure 5.



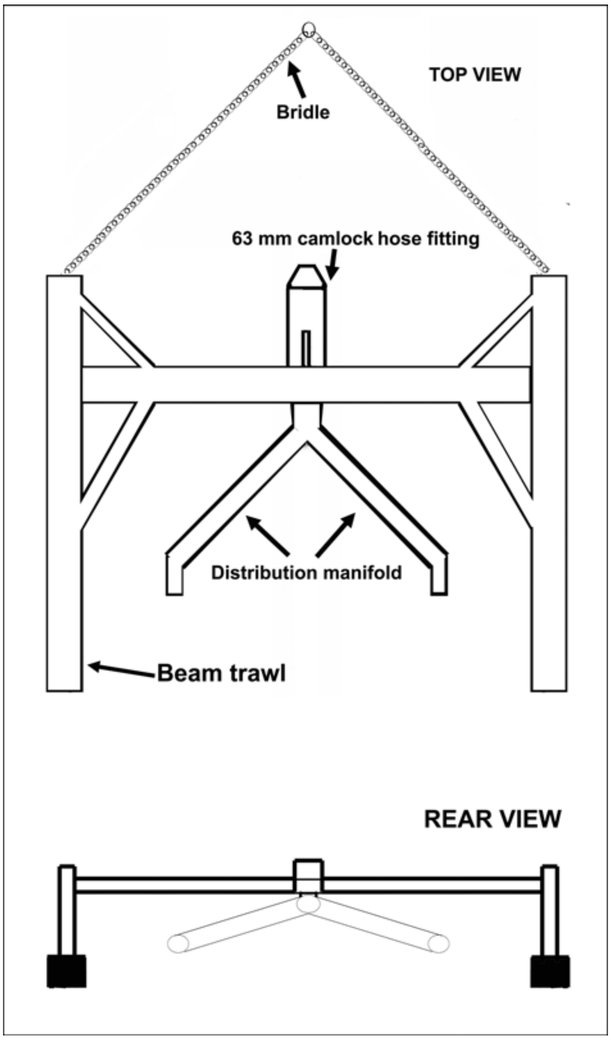


Figure 4 **Spat deployment equipment** **Figure 5** **Spat distribution frame**

4.5 EFFECTS OF DEPLOYMENT AND DEPTH CHANGES ON THE VIABILITY OF SCALLOPS

In addition to determining the consequence of transport and onboard handling, it was important to demonstrate that the spat were reaching the seabed in a viable state. Accordingly, on the 7th of January 2003, 1,400,000 juvenile scallops averaging 1.262mm (sourced from Batch X which was spawned 34 days earlier) were transferred from the hatchery to the reseeding site. Approximately 1,350,000 were deployed using the methods which had proved to be efficient and effective in delivering spat from the boat to the seabed. The deployment gear was then retrieved and reset with a 200 *um* mesh sock covering the exit aperture. The last carboy, containing approximately 50,000 spat, was added to the hopper and flushed down the deploy pipe according to the deployment method in place at the time which was clearly the best tested during the first season of deployments. The deployment equipment was then retrieved and the mesh sock rinsed back into a carboy and returned to the hatchery under normal transport methods. The water temperature at the sea surface of the site at the time of the trial was 22.5 º C compared to hatchery water which was maintained at 24° C.

Upon return to the hatchery, the spat were counted, checked for condition and replaced on a screen for 14 days with control spat in an adjacent tank. The spat were held in the same conditions as hatchery-based control spat for another two weeks and their viability assessed.

4.6 SPAT DEPLOYMENTS

Spat of discreet size-classes were allocated to separate locations within the deployment area in order to support analysis of information on an optimum size at which spat might be deployed. Four areas within the deployment site were each allocated spat from one of four size-classes, each size-class being an average size of spat for each deployment cohort but around which there was a substantial range of sizes – *i.e.* a range of up to +/- 30% was normal.

When the vessel was on location, the carboys containing the spat were individually emptied into the hopper on deck and a constant supply of seawater from a deck hose ensured a continued flushing of the hose to force the spat out near the seafloor. For each cohort of spat, the vessel steamed or drifted at between 1.0 and 3.0 knots over the deployment passes. The density of spat achieved on the seabed was difficult to determine due to the effects of weather and sea conditions on vessel speed and variability in the rate of delivery down the hose due to back flushing, but was designed to be a maximum of approximately 20 spat m^2. Noting that, however, it was inevitable that local concentrations far exceeded the objective on occasions due to uneven flow rates caused by sea conditions during deployment.

Whilst it was planned that each pass would be separated from the previous pass by at least 100 metres to ensure a spread of the spat over a wide area within each size-class and deployment, the weather proved to be influential in determining where each deployment pass occurred. The locations of each deployment track (Figure 6) were essentially randomly located within each deployment area for each size-class.

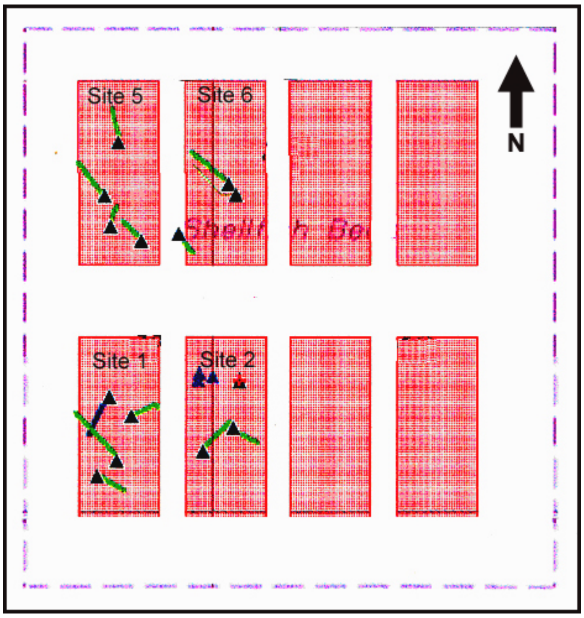


Figure 6 Locations of spat deployments in 2002-03

4.7 Test Fishing

In early August 2003, approximately six months after the first spat deployments concluded, sample trawls were conducted over each of the deployment sites to determine whether any spat had survived. The trawls were done initially using a small mesh tri-net, deployed from a modified rock lobster vessel purchased and modified for the project, to ensure that any spat over 30 mm were caught. Subsequent trawls were conducted using a standard scallop trawler using commercial scallop nets. The trawls were originally planned to run perpendicular to the course taken during deployment to ensure maximum chance of scallop recovery, but weather and sea conditions on site prevented this, so trawls were done, as close as possible, along the deployment track as stored on the onboard navigation system. Sizes and numbers of scallops taken during all trawls were recorded.

4.8 Analysis of Results from Test Fishing

Abundance and size composition of scallops from the 4 separate reseeding locations and were compared, using data from August and September 2003 fishing trials. Further data were obtained from a survey of the scallop fishery in the region by the Western Australian Department of Fisheries, in which the authors participated. Analysis of Variance (ANOVA) was used to compare catch size composition and, where differences were indicated, pair-wise comparisons were performed using Fisher's Least-Significant-Difference Test. In the absence of any reliable replication at this level of reseeding operation, it was not possible to conduct detailed statistical tests on the abundance data sets. Catch rates from test fishing operations were used to give semi-quantitative assessment of abundances.

Distinguishing between natural recruits and reseeded scallops that settle contemporaneously was anticipated as a significant challenge for project staff. The pre-reseeding catch information provided evidence of the presence of scallops of a predictable size at the time of harvest. The size composition of existing, naturally spawned, scallops was such as to exclude confusion with any of the recruits from the hatchery. A widespread contemporaneous settlement of wild scallops was considered to be the only significant event that could affect identification of successful hatchery-reared spat in the field. The absence of an effective labelling method and uncertainty in interpreting shell check-marks (Joll, 1988) meant that a difference in catch rate between reseeded and adjacent non-reseeded areas was the only available way to identify presence and abundance of a cohort of spat from the hatchery.

5.0 RESULTS AND DISCUSSION

5.1 HATCHERY ACTIVITIES

5.1.1 Spat production in 2002

In excess of 25 spawnings were carried out between August 2002 and January 2003. But for water quality problems in Geraldton Harbour due to dredging and consequent suspension of fine material and contaminants in the water column, that number would have been substantially greater. The reasons for the larger-than-planned number of spawnings included losses of batches of larvae during the period during which water quality problems took place, growth rates which allowed or required batches to be deployed more rapidly than originally planned, and the generally better than expected availability of broodstock in good spawning condition which permitted the hatchery manager to be more selective with batches of eggs and larvae. Between 200 million and 250 million fertilised ova were produced from these spawning events. Survival from fertilised ova to settled spat averaged approximately 10%. This included “losses” of up to 37% during water changes in the larval culture tanks.

5.1.2 Spawnings in 2003 - 2005

The availability of naturally mature broodstock determined the beginning and end of the first season of spawning. Based on observations in the early part of the 2002 spawning season and the hatchery operator’s past experience, hatchery operations commenced in late July 2003 to take advantage of an earlier-than-expected spawning season. This extended the potential production and deployment season by at least six weeks over the first season. Spawning and hatchery operations were undertaken between August and November 2003, and between August 2004 and January 2005 for the last season of hatchery operations.

5.1.3 Spat growth rates

Observations on growth rates were made over multiple batches of larvae and spat during the hatchery phase. Figure 7 shows a summary of the first season’s growth data. The data points are means of multiple batches of spat.

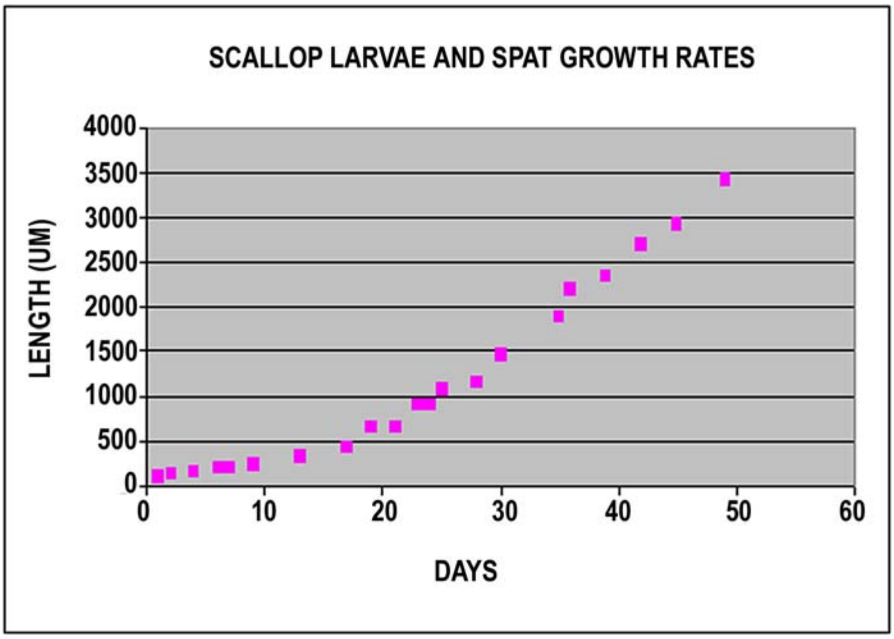


Figure 7 Scallop larvae and spat growth rates

5.1.4 Disease Testing

Samples from the first and a subsequent cohort of spat were sent to the Head Fish Pathologist at the Department of Fisheries for disease and health testing prior to the first deployment of juvenile scallops. No health or disease concerns were raised from either test, allowing all cohorts to be deployed as required. The health certificate was stated to be current for four weeks, providing significant latitude in the deployment program

5.1.5 Rate of Larval Development

Observations in the hatchery across all cohorts of larvae indicate that the larval development cycle takes as little as 10 days. This is substantially shorter than any reported in the scientific literature; O'Brien *et al*. (2005) report the larval phase of *A balloti* in Queensland to be as long as 18 days, and Rose *et al*. (1988) reported it as taking between 12 and 24 days. The health and viability of settled spat appears to be linked to the speed of larval development. It was possible to maintain larvae well beyond the minimum/optimum time for settlement, but the longer the larvae took to settle, the less well they appeared to develop and mortalities generally increased with time. The relatively low success rate and growth rates achieved in larvae/spat which were slow to settle did not justify their retention; it was judged better to terminate such batches and re-start a spawning operation in the expectation of producing a faster-growing batch.

5.2 SPAT DEPLOYMENT METHODS

5.2.1 First Trial

A small hopper on the deck of the vessel was connected to a venturi and to the deck hose, which was in turn connected to a 50mm diameter polypropylene hose, approximately 150 metres long, which led to a beam trawl on the seabed. The hose outlet was attached to the beam trawl to achieve an outlet height above the seabed of approximately 150mm. The hose was attached every 10 metres to a supporting mainline.

Some problems arose with this first system, specifically with regard to controlling the flow rates. Any air locks or rises in the hose trapped spat and, if the flow rates were not checked or controlled, the turbulence through the venturi might have been detrimental to spat health and survival. In addition, uneven flow would have lead to an uneven distribution of spat on the seabed. This system took approximately 2 hours to deploy 1,220,000 spat on the 23rd of October 2002.

5.2.2 Second trial

The second deployment trial used a small hopper connected directly to the pipe (with no venturi). Gravity was used to move the spat to the bottom. A gentle flow of water in the hopper moved all spat through the pipe, followed by a good flushing of seawater upon completion.

The only difficulty observed was that any slack in the pipe – i.e. any section in the pipe which forms a "shelf" for spat to gather on - could cause a build up of spat. It appears to be essential that the pipe be kept as close to the main line to assist in spat delivery, without allowing it to take any weight of the beam trawl. This system took approximately 90 minutes to deploy 1,170,000 spat on the 2nd of November 2002.

5.2.3 Third Trial

Before the third deployment, the main line and pipe were re-calibrated so that the pipe attachments were 150mm longer than main line clips to ensure that the pipe was not under load from the beam trawl while at the same time preventing the formation of a "shelf" on which spat could build up.

An aluminium hopper was fabricated and fitted over the stern of the vessel with the outlet for the delivery hose fitting facing directly downwards near the main line pulley - Figure 4. A deck hose was connected to the hopper to maintain a continuous flushing through spray bars on either side of the hopper.

This system worked better than the previous two methods. It was easier to operate, there was less chance of a malfunction or handling errors, and it was workable in up to 30 knots of wind. Deployment took place as the trawler steamed at up to 3 knots, and took approximately 20 – 30 minutes to deploy 1,118,000 spat on the 13th of November 2002; deployments on other dates were not timed.

It was planned to extend the beam trawl in the following next year to accommodate an underwater video system to assess the release of the spat, particularly the dispersion and to determine the presence of predators, but the failure of the hatchery to supply meaningful numbers of spat precluded this phase of the project being completed.

5.3 SPAT SURVIVAL

It was an early requirement to determine whether the handling and transport methods affected viability of the juvenile scallops up until the time of their arrival at the reseeding site before taking the next step of assessing the viability of the spat after deployment to the seabed. Accordingly, on the 12th of November 2002, 10 carboys, each containing approximately 9,400 spat (average size of 5 mm), sourced from Batch D, were transported to the site. The contents of one carboy were returned to the hatchery after seven hours while the rest were deployed. Those spat which were returned were divided onto 2 x 600 *um* screens – Plate 4. Another group of spat from Batch D, which had not been transported, was also split onto 2 x 600 *um* screens. All spat were left in the same tank together and fed according to normal hatchery protocols for a further 14 days. Natural mortalities occurred in both groups of spat, but no significant difference was observed between those that had travelled and the control spat.

Beyond determining the neutrality of the transport and onboard handling, it was important to demonstrate that the spat were reaching the seabed in a viable state. Accordingly, on the 7th of January 2003, 1,400,000 juvenile scallops averaging 1.262mm from Batch X were transferred from the hatchery to the reseeding site. Approximately 1,350,000 were deployed using the methods established in the third deployment trial. The deployment gear was then retrieved and reset with a 200 *um* mesh sock covering the exit aperture. The last carboy, containing approximately 50,000 spat, was added to the hopper and flushed down the deploy pipe according to the deployment method in place at the time. The deployment equipment was then retrieved and the mesh sock rinsed back into a carboy and returned to the hatchery under normal transport methods. The water temperature at the sea surface of the site was 22.5 º C compared to hatchery water which was maintained at 24° C.

Upon return to the hatchery, the spat were counted and checked for survival, condition and health and replaced on a screen for 14 days with control spat alongside (as per the previous experiment on transport methods). Most of the spat subjected to transport and deployment re-attached to the screens within 3 hours, indicating unaffected health and vigour.

A sample count revealed that approximately 48,000 spat had been recovered, indicating that the deployment gear had delivered most or all of the spat to the sea floor during deployment.

The spat were held in exactly the same conditions as the hatchery control spat for another two weeks. There were no major differences in mortalities between the sample and the Control. Any minor mortalities appeared to be conventional losses as experienced in other batches. After a 14-day period of observation, the Control spat and the returned deployed spat were re-deployed on the 21st of January 2003 (140,000 x 3mm spat). Repeats of the tests were planned for the 2003-4 season using a more structured approach with several size classes in order to confirm the findings. This experiment did not eventuate due to the unexpected problems with the development and apparent poor health of spat in the hatchery in the 2003-4 and 2004-5 spawning seasons.

On the basis of the above first observations of low impact of transportation and deployment on spat survival, we concluded that the transport and deployment methods used did not adversely affect the viability of juvenile scallops of the sizes tested.

5.4 SPAT DEPLOYMENTS

Experimental protocols developed for the first season (2002-3) called for approximately 50 million deployed spat. This planned deployment level was not completely achieved, due in part to water quality problems which halted hatchery operations for about a month. Other limitations including the timing of the program relative to the natural spawning season of the scallops, and some limitations to production due to physical space in the hatchery and the time taken to grow the spat to the desired size for deployment.

Batches of spat were deployed at a range of ages and sizes, between an average size of 0.5 mm and 5 mm (Table 1). The location of the reseeding area is shown in Figure 1 and the location coordinates are in Table 1. The traces show the course taken for each deployment, all of which took place during the day.

The planned method involved deploying a number of size classes of spat, beginning at 0.25 mm pediveligers. This was modified before the first deployment as a result of information gathered subsequent to submission of the final grant application document which indicated a low likelihood of significant success from deploying such small animals. The average size of spat from the youngest batch releases was 0.62 mm. These were 21-day spat (from spawning), deployed approximately 11 days after settlement.

A total of approximately 12.5 million spat were deployed on 11 separate release dates during the first stage of the program, deployments being completed in mid-January 2003 (Figure 6). Multiple batches were generally deployed on any single date, onto different locations depending on their size. Four batches of spat released on two dates were in the 0.5 to 1.0 mm size range, 12 batches on 6 dates were between 1.0 and 2.0 mm, five batches on 2 dates were between 2.0 and 3.0 mm, two batches on two dates were between 3.0 and 4.0 mm, and two batches on one date were between 4.0 and 5.0 mm. A small number of spat in the size range of 20 to 40 mm, sourced from the fourth spawning and run in some preliminary nursery studies were also released on the final day of deployments.

Owing to problems with the development and apparent health of scallop spat in the second and third years of the program, no spat deployments were completed in 2003-04 or 2004-05. These setbacks resulted in the curtailment of a series of experiments designed to examine survival and growth of hatchery-reared spat released into open water.

Table 1 Spat deployments Year 1

Date	Batch	Size (ave mm)	Age (days)	Number	Latitude	Longitude	Comment
23/10/02	C6	1.75	38	410.000	28.29.161S	114.09.231E	
23/10/02	C5	1.75	38	450.000	28.29.161S	114.09.231E	
23/10/02	C4	1.95	38	180.000	28.29.161S	114.09.231E	
23/10/02	C2	1.85	38	180.000	28.29.161S	114.09.231E	
02/11/02	C3	3.42	49	250.000	28.28.033S	114.09.140E	
02/11/02	H	1.90	37	920.000	28.29.699S	114.09.750E	
12/11/02	C	4.67	59	84.000	28.27.700S	114.10.123E	
12/11/02	D	5.00	56	84.000	28.27.700S	114.10.123E	9,400 out & back
13/11/02	I	2.95	48	350.000	28.29.595S	114.09.285E	
13/11/02	I2	2.95	48	390.000	28.29.595S	114.09.285E	
13/11/02	C & D	2-3	60	210.000	28.29.595S	114.09.285E	Culled out small C & D
21/11/02	L1	2-3	35	800.000	28.29.286S	114.09.390E	
21/11/02	L2	2.3	35	336.000	28.29.286S	114.09.390E	
21/11/02	I	3.3	56	78.000	28.29.286S	114.09.390E	
22/11/02	N	1.48	30	360.000	28.27.989S	114.09.230E	
22/11/02	O	1.02	23	66.000	28.27.989S	114.09.230E	
23/12/02	V	0.84	24	1.600.000	28.29.370S	114.10.158E	
23/12/02	W	0.62	21	1.080.000	28.29.370S	114.10.158E	
24/12/02	W1	0.65	22	720.000	28.29.527S	114.09.931E	
24/12/02	W2	0.65	22	2.050.000	28.29.527S	114.09.931E	
07/01/03	X1	1.26	34	700.000	28.28.082S	114.09.473E	
07/01/03	X2	1.32	34	450.000	28.27.776S	114.09.191E	
07/01/03	X3	1.20	34	250.000	28.27.776S	114.09.191E	Deploy & bring back
08/01/03	Y1	1.02	34	360.000	28.27.415S	114.09.290E	
08/01/03	Y2	1.72	34	360.000	28.27.415S	114.09.290E	
21/01/03	X2	3.00	49	140.000	28.27.772S	114.10.177E	
21/01/03	D	20-40	>90	320	28.27.772S	114.10.177E	Released at end
TOTAL			**Approx.**	**12,860,000**			

5.5 FISHING RESULTS

5.5.1 Pre-reseeding trawling 2002

Pre-reseeding trawling was conducted over the reseeding site on the 21st of August 2002 using a commercial scallop trawler and two 10-fathom 30 mm mesh nets to determine whether there were any naturally spawned recruits in the area. Eight 20-minute trawl shots were made over a wide area of the reseeding site, producing 110 scallops. Individual shots produced between 0 and 46 scallops, the majority measuring between 80 mm and 95 mm, suggesting that they were approximately 12 months old. No scallops smaller than 67 mm were caught, demonstrating that a new cohort from the 2001-2002 recruitment season was not present in any significant numbers, if at all, on the site.

A further set of test trawl shots were conducted over parts of the test area in early March 2003, approximately two months after completion of the first set of spat deployments. Three sample shots were conducted from the rock lobster vessel purchased for this project, using a 2-fathom try-net fitted with 30-mm mesh. This trawl was deployed at intervals to cover approximately 2.5 nautical miles between deployment locations. The recovery of small numbers of other benthic animals indicated that the net was operating effectively. No scallops were taken, indicating that there was a low likelihood of there having been a natural recruitment event in the previous six months.

5.5.2 Test Fishing

5.5.2.1 August 2003

The first set of seven test trawls was conducted over the reseeding site on the 21st of August 2003. Test trawls were run over selected sections of the reseeding area, covering, where possible, the courses followed during the spat deployments. All trawls were of 40 minutes duration and at an average speed of 3.0 knots. The locations of the test trawls are shown in Table 2. High resolution trawling over the site was then postponed because scallops recovered during these initial test trawls were small (average 75 mm +/- 3 mm) it was decided to delay final recovery fishing until they were of adequate size to be processed, estimated to be January or February 2004. The locations of reseeded scallops from the 2002-03 deployments can be seen in Figure 6.

Table 2 Trawl locations

Trawl #	Location
1	Block 1
2	Block 2
3	Block 5
4	Block 6
5	Between blocks 3,4,7, & 8
6	West of Blocks 1 & 5
7	South of Blocks 1,2,3, & 4

Trawls 1, 2, 3 and 4 occurred in the sites which were reseeded between August 2002 and January 2003. In an attempt to cover as much of the reseeded ground as possible, the courses followed were necessarily circuitous, with the potential for the nets to be less effective than a straight trawl shot, due to either closure of the inside nets during a tight turn, or to "flying off the bottom" by the outside nets. Trawls 5, 6 and 7 were within the licenced area but outside of the reseeded sites, and were conducted in straight lines, with a greater potential effectiveness and trawl time.

Results and Discussion

The results of the seven trawls are contained in Table 3.

Table 3 Catch statistics from test trawls

	TRAWL #						
	1	**2**	**3**	**4**	**5**	**6**	**7**
LOCATION	Block 1 [a]	Block 2 [a]	Block 5 [a]	Block 6 [a]	East of 3 & 7	West of 1 & 5	South of 1 to 4
TOTAL CATCH	167	28	168	865	198	318	232
# MEASURED	167	28	168	120	120	120	120
MEAN LENGTH	78.26	76.82	74.92	73.43	77.75	73.01	75.08
VARIANCE	128.54	128.67	95.29	83.73	133.58	100.70	123.98

([a] denotes trawls within reseeded areas)

There is an apparent difference between the catch rates of some trawls, with one area, Block 6 (trawl 4), producing 865 scallops, more than 2.5 times the catch of any other trawl.

An Analysis of Variance of size (DVM) showed that there is also a highly significant difference between the size composition of scallops recovered from some of the trawls ($P < .001$). Pair-wise comparison of shots using Fisher's Least-Significant-Difference Test showed that a significant difference exists between some pairs of trawl shots. The number of scallops taken in Blocks 1 and 5 is similar, but their sizes are significantly different ($P = .039$). The spat deployed in those blocks averaged 2 mm and 1 mm respectively. The spat deployed on that site were the largest size of any of the large-scale spat deployments (average 4.84 mm).

The spat deployed into Block 2 averaged 0.5 mm. Subsequent catch rates at that site were low. These low catch rates may, however, have been caused by poor trawl gear performance as much as low spat survival. The track followed during this shot involved a number of tight turns, which are known to diminish otter trawl gear effectiveness.

The catches from the non-reseeded areas give information that requires further consideration. Assuming that the area covered by the nets is similar for all trawls, the catches from the straight-line trawls differ between the western and eastern sides of the site. The coincidence of the higher catches coming from areas adjacent to two reseeded blocks cannot be ignored, but there is not adequate data to be certain of the origins of those scallops at this stage.

The difference between the catch rates and size variances from the seven test trawls suggests that there may have been a wild spat settlement coincident with some of the spat deployments, or that spat from different hatchery batches were growing at different rates and dispersing, to some degree, from the release sites. Data that could be used to support either of these hypotheses were obtained by exploratory trawling outside of the reseeded area. Permission was sought from the Western Australian Department of Fisheries to conduct some try-net trawls outside the current reseeding area, to determine whether scallop densities and size structure change with distance from the reseeded site and that work is reported on below.

Of further relevance to the information above, a try-net fishing trip for broodstock on the 27th of August 2003, on an area approximately 4 nautical miles west of the licenced reseeding site, caught very small numbers of scallops compared with the catches experienced within the reseeding site as detailed above. The size of the few scallops caught was all above 90 mm, *i.e.* mature scallops over a year old. No small scallops such as predominated in the trawls within the reseeding site were caught. This indicates that, if there was a wild spat-fall, it was of a very localised distribution, an unlikely event in the opinion of the experienced scallop fishermen and scientists associated with this project.

5.5.2.2 December 2003

In early December 2003, a comprehensive survey was conducted by the WA Department of Fisheries as part of the wild scallop fishery management program using the same trawler and nets as those used in the previous test trawls. The reseeded area was sampled by 9 20-minute shots in straight lines – i.e. not directly along the spat deployment tracks – covering between 1.0 and 1.3 nautical miles, and the rest of the scallop fishery was sampled with 28 20-minute shots covering similar distances. Figure 8 shows the size frequencies of all catches

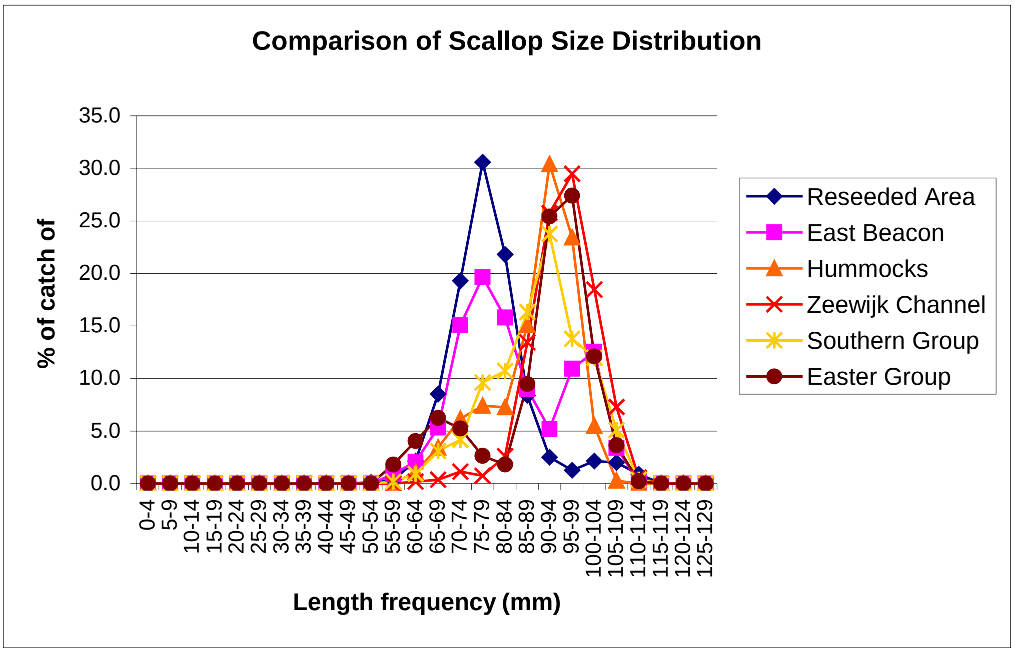


Figure 8 Scallop sizes in different parts of the fishery, December 2003

(Data source: E Sporer, WA Department of Fisheries, 2004).

Discussion

The size frequency and distribution of scallops recovered from the reseeded area differs significantly from all other locations sampled during the survey which covered the major known fishing areas in the Abrolhos Islands and adjacent scallop fishery (other than the East Beacon area), suggesting that the date of recruitment was different from all other locations, or that the growth of scallops in the reseeding area was markedly different from that elsewhere, which is thought to be unlikely. Whilst the average catch per trawl shot was lower than elsewhere in the survey, the location has not had a significant recruitment in many years, and that, combined with the size distribution, suggests that there may have been a successful recruitment from one or more of the spat deployments.

5.5.2.3 September 2004

The reseeded area was fished again on the 31st of August and 1st of September 2004 using standard scallop nets from a commercial trawler. Any surviving scallops from reseeding would have then been 18-20 months old and in the expected size range of 95-110 mm DVM. The data were analysed for abundance and overall size frequency of scallops taken in tri-shots and commercial scallop net shots from individual sites. Only data from single reseeded locations were used for specific site analysis. Data from trawls that overlapped two reseeded sites were only used to demonstrate the overall population size-structure against which size composition data from individual sites could be compared.

Figure 9 shows the composite data from all trawl shots in the reseeded area. There are three clear modes of scallop size, indicating a strong likelihood of three distinct ages of scallop on the reseeding area, one probably being from one spawning season *(2002-3)* and two from the next year (*2003-04)*. Based on the known size at age relationship of *Amusium balloti*, only those in the size class above about 92 mm dorso-ventral measurement (DVM) could have originated from hatchery-sourced animals spawned from August to December 2002 and deployed between October 2002 and January 2003. The smaller scallops with modes around 75 and 85 mm, are clearly younger than those which might have survived from hatchery deployments in August 2002 to January 2003 and thus must have been sourced from natural recruitment in the subsequent year which produced significant catches, and so some larvae might have dispersed in this instance as far as the reseeding area which traditionally has not received any significant recruitment in many years.

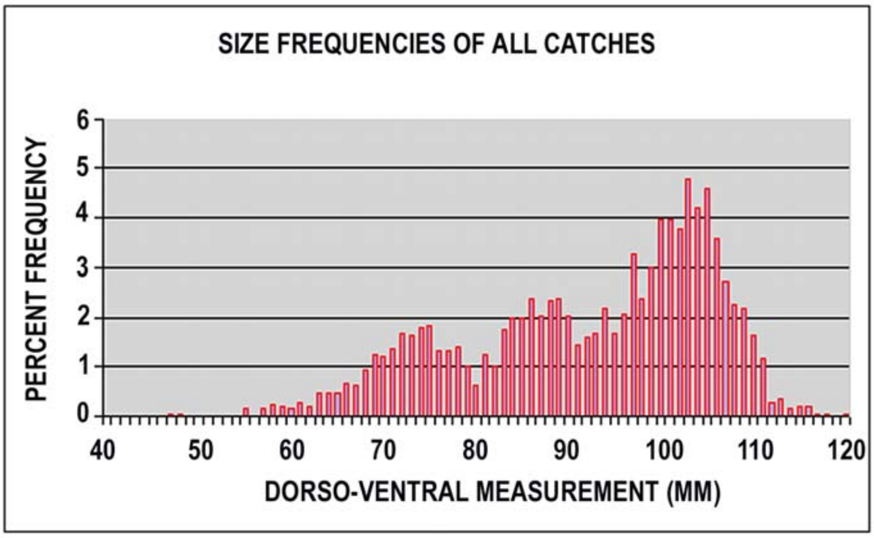


Figure 9 Composite catch data from all trawl shots

The three size-frequency graphs below (Figures 10, 11 and 12) show data from the three sites which were trawled during the survey on 31st of August and 1st of September 2004.

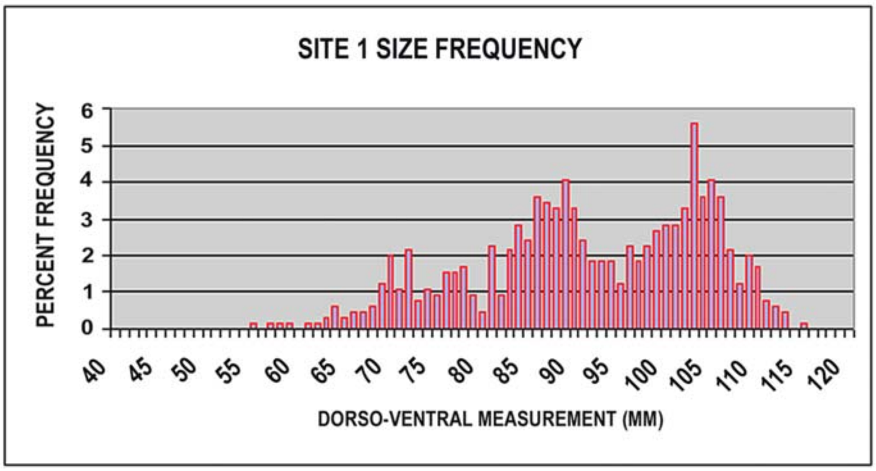


Figure 10 Site 1 September 2004

The size distributions in Sites 1 and 6 appear reasonably similar, although there is a higher proportion in the largest size-class (>92 mm) in Site 6. This suggests a different age structure between the two sites.

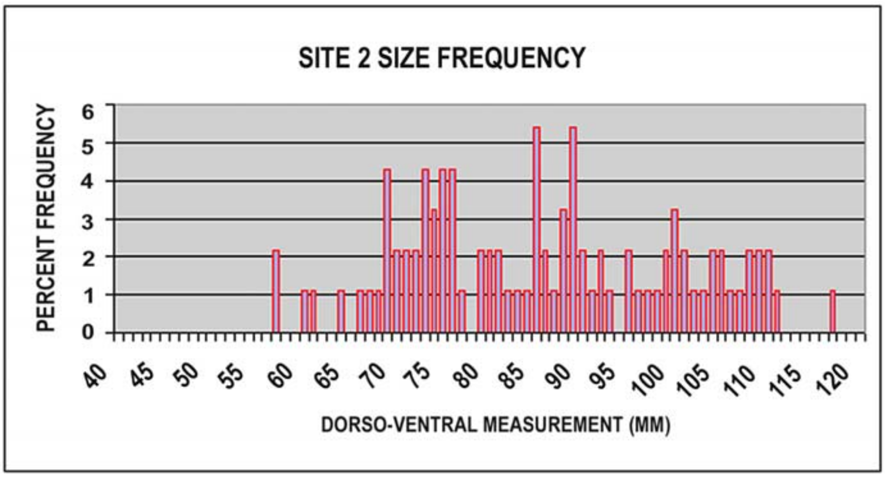


Figure 11 **Site 2 September 2004**

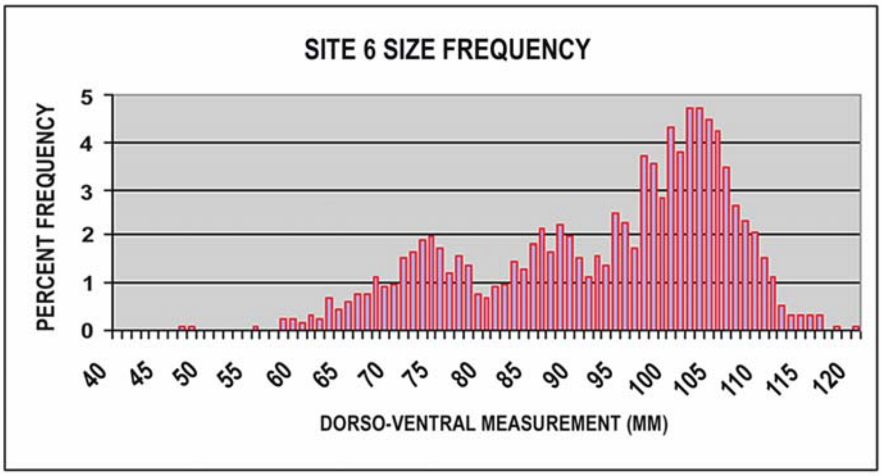


Figure 12 **Site 6 September 2004**

The raw catch data shown in Figure 13 and Table 4 also present a different view which cannot be ignored, although the relatively small number of samples in Sites 1 and 2 result in a large variance of catch rates. It suggests that there may be more scallops over 92 mm in Site 1 than in Site 6, although the variability in the data and inherent patchiness of catches would require more samples to resolve that issue. It may also be relevant to note that Site 6 had been trawled quite extensively by the time this sample was completed, potentially reducing the number of reseeded scallops available to catch.

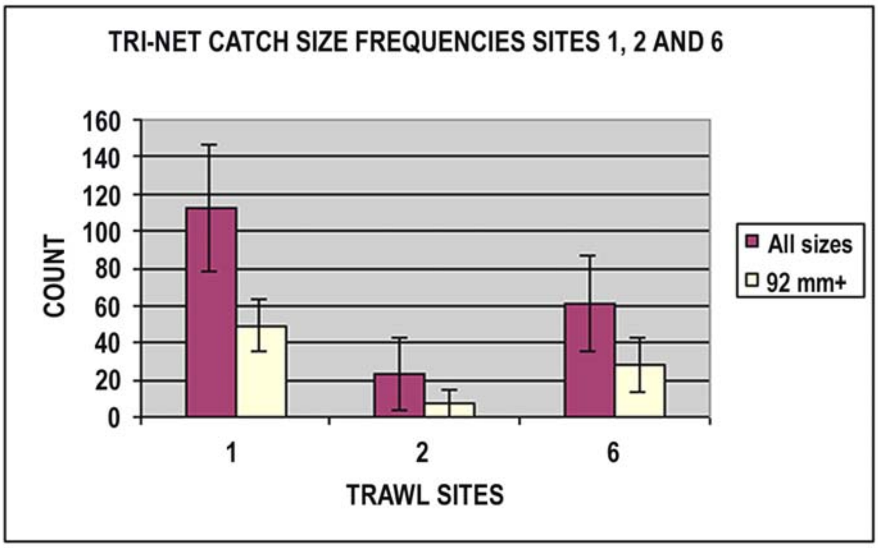


Figure 13 Consolidated size data

Bars are Standard Errors of Means of catches

Table 4 Summary trawl data

Percent Occurrences			
	Site 1	**Site 2**	**Site 6**
DVM			
<81mm	18.70	40.86	22.06
81-92mm	32.58	27.96	18.65
>92mm	48.72	31.18	59.29

5.5.2.4 Subsequent years

No further test fishing was conducted over the reseeding site in subsequent years due to the inability to produce any significant numbers of healthy spat in the hatchery beyond the end of the 2002-03 season.

5.6 DISCUSSION

Whilst it is not possible to claim with complete certainty that hatchery-reared spat generated beds of juvenile scallops, there is considerable circumstantial evidence that at least one batch of hatchery sourced spat (those from Batch D, released in Block C at a mean size of about 5 mm) gave rise to a small bed of scallops that were still reasonably abundant some 10 months after their release. The facts that no wild-sourced scallops were observed in pre-release sampling, and a relatively uniform sized group of scallops was identified in the samples from August 2003, of a size consistent with 8-12 month-old animals (*i.e.* of an age equivalent to hatchery-sourced spat), suggests that there was a good likelihood that the hatchery sourced animals did survive and become vulnerable to sampling gear some 10 months after release. It is proposed, if all reseeded sites had produced similar numbers and size distributions of scallops 6 months or more after reseeding, that a wild spat fall had probably occurred, but that, because significantly more scallops were recovered from one of the reseeding sites than from some others, then it may be argued (not necessarily correctly) that the site producing the higher catches was successfully reseeded.

The smaller scallops with modes around 75 and 85 mm recovered from the reseeded area are clearly younger than those which might have survived from hatchery deployments in August 2002 to January 2003 and thus must have been sourced from natural recruitment, from spawnings in late 2003; wild spawnings from that period produced a relatively high catch from the entire fishery in 2005 of about 1260 tonnes of meat. The scallops over about 92 mm DVM are clearly predominantly from the spawnings in August to December 2002 and which were fished in the 2004 fishing season, during which only about 30 tonnes of meat was taken from the entire fishery. This low catch from the fishery makes a chance and historically rare recruitment from wild spawnings onto the reseeding area extremely unlikely.

The issue of certainty of identity of scallops recovered during fishing operations is currently being addressed through another FRDC research project. There are early indications that such marking is achievable. If this turns out to be the case it will be possible to apply a minor amount of a fluorochrome to the culture water of juvenile scallops, resulting in a discreet band or spot in the shells of mature scallops which can provide close to 100% certainty that the scallops recovered are either of wild or hatchery origins. Early indications are that the scallop is able to take up and deposit several different dyes into the shell, with the result that it may be possible to deploy multiple batches of spat over the same area, each bearing a unique “label”. This would not only mean that the hatchery or wild origin of recovered mature scallops could be readily determined, but also that the precise history of each recovered group would be known, leading to greater efficiencies in further research and progress towards commercial success more likely. Such marking technology is critical for rigorous testing that enhancement or restocking is achieving its desired outcomes.

The time of day at which the spat are released is thought to have the potential to affect rates of loss due to predation. Whilst it was not possible to test this during the only season of successful hatchery operation, it is worth considering for any future reseeding trials. The deployment of spat during daylight, as was practiced during the current study, potentially places the spat at a greater risk of predation compared with night-time deployments, due to their greater visibility compared with a night-time deployment, although deployment near the bottom, as was the case in the current study, reduced that exposure to some extent.

The distance above the seabed at which the spat are released also has the potential to affect loss to predation and local overcrowding. Deployment close to the seabed, as was practiced during the current study, is likely to cause localised dense aggregations of spat which might attract predators before they have the opportunity to hide in the sediments, while widely dispersed individuals would be less likely to do so. The creation of dense aggregations of spat could also lead to higher post-deployment mortalities than widely spread individuals due to competition for space or other resources. Whilst the spat are mobile, their ability to move far enough away from adjacent individuals to allow them to have all of their needs satisfied without compromising the survival of their neighbours is unknown. If deployed near the surface, whilst there is a greater opportunity for predators to capture the spat as they fall through approximately 40 metres of water column than if they are deployed near the seabed, they are also given a greater opportunity to spread out into more uniform density than when deployed near the seabed, resulting in reduced opportunity for predation by demersal fish species and lower local densities.

These last two issues could be addressed by night-time deployments from near the surface to ensure wider spread of spat at a time when predation on small animals is considered likely to be less than during the day.

6.0 BENEFITS AND ADOPTION

The objective of this project was to achieve commercial recoveries of scallop meat through reseeding an area of seabed. Whilst it failed to give absolute signals about the success of a scallop enhancement operation, there were encouraging indications that hatchery-produced spat may have high enough survival rates to support an enhancement operation. The data from the fishing operations suggested the possibility that the cohort of the largest spat deployed, approximately 5 mm, may have resulted in a significant recruitment, although the absence of a tangible label prevented the confirmation of this. The associated “minor objective” of developing technology and systems to deliver spat to a reseeding site and release them onto the bottom at reasonably uniform density and in a state from which survival was reasonably assured was achieved.

Queensland Sea Scallops Pty Ltd (QSSP) is engaged in a scallop reseeding project near Bundaberg, Queensland. That project will benefit from the development of demonstrably successful techniques used in this project for the transport and deployment of juvenile scallops. Should another reseeding project be developed in Western Australia, the successful transport and deployment methods will be available for immediate use by that project. This will save substantial effort and opportunity cost for any project, noting that the transport needs of *Amusium balloti* were completely unknown prior to the commencement of the current project and it was not until quit elate in the first season of deployment that the operators were certain that the transport and delivery methods were acceptable.

This project has contained elements of a pioneer venture and, as such, has encountered a series of unforseen challenges and problems. This has lead to identification of a series of information needs and systems improvements, the most important being the need for consistent hatchery production of scallop spat and the need for capacity to identify hatchery-reared scallops. These information needs were reviewed and developed by the project’s steering committee. They are discussed in Section 7.

7.0 FURTHER DEVELOPMENT

A number of issues have been identified as requiring resolution if reseeding of *Amusium balloti* is to succeed. Experiences over the current project, many of them occurring in the hatchery which was not part of the FRDC-funded research, have helped to develop a list of "Research Needs", answers from which will help to advance the cause of reseeding. Knowledge gained from trying to solve the problems in the hatchery using a range of approaches, as well as observations made in all phases of the project, has contributed to an improved understanding of what the key issues for reseeding are or might be and how they might be approached to most efficiently deliver the knowledge required to help scallop reseeding to progress.

7.1 RE-EVALUATION OF THE POTENTIAL OF RESEEDING USING CURRENTLY-KNOWN PARAMETERS

The models presented in the Dredge Report do not consider all financial components, or in some cases they did not have access to the detail and quality of information produced during the current study, with regard to the costs of a scallop reseeding operation in coming to a conclusion that reseeding has substantial potential for Australia. For example, the costs of spat deployment and fishing to harvest survivors can now be estimated with some degree of realism not previously possible now that the current project has had three years of such experiences. This information should be incorporated into a modelled reassessment of the potential viability of reseeding. That model should also include inputs discussed above which are either known or much better understood from work in the hatchery, and from three seasons of attempts and some success in culturing the animals under early nursery conditions. This work is probably best done before any decision is made on whether to proceed to further research in the hatchery and nursery, because the improved state of knowledge might identify a gap between the costs and potential benefits that make commercial success so unlikely as to make further expenditure unattractive.

The needs of a commercial hatchery and nursery of a size required to support a reseeding operation with a required recovery could now be modelled with more known inputs and fewer uncertain or widely varying assumptions, and these figures could be used to better model the overall feasibility of scallop reseeding.

7.2 IDENTIFICATION OF SCALLOPS RECOVERED FROM THE RESEEDING SITE

The research to date has not succeeded in absolutely confirming that scallops produced in a hatchery have been able to survive and to be caught in commercial numbers following a lengthy period on the seabed. Whilst some results from the first year's deployments suggest that enough scallops survived to generate local increases in catches in locations where the largest spat were deployed, it has not been possible to be certain that the scallops comprising those increased catches originated from the hatchery. Improved identification methods must be used to be certain about the origins of scallops recovered during fishing operations.

Unless the numbers and recovery of surviving spat in the form of mature scallops are at least several times that of any natural recruits in the reseeding area and its surrounds, it will not be possible to distinguish between natural and hatchery recruits without a unique identifying mark. Whilst a commercial reseeding operation will not require all released spat to bear a label, the research phase does require that a large proportion of the released juvenile scallops carry such a label so that the survival can be estimated, allowing the true cost-benefits of reseeding to be determined.

The Bribie Island Aquaculture Research Centre (BIARC) has successfully applied to the FRDC for funds to research the chemical labelling of scallop shells. The project seeks to identify a fluorochrome which is taken up by the juvenile scallop shell and which remains for long enough to permit the identification of hatchery-produced scallops at the time when they can first be caught by a scallop trawler – i.e. at about 50 mm. The Principal Investigator is Dr Liz O'Brien, with Rick Scoones being the Co-Investigator. The project is currently running and is using scallops from the Queensland Sea Scallops (QSSP) project at Bundaberg. Early results indicate that possibly all three chemicals tested are incorporated into the calcified tissue of scallops approximately 15 mm DVM. The longevity of such chemical tags and medium term effects on the scallops are yet to be determined, and smaller scallops also can now be tested as they become available.

In the event of the hatchery at QSSP failing to continue to produce viable spat for the testing of the labelling chemicals, young scallops will be collected on board scallop fishing vessels on the major fishing grounds off Gladstone in November and onwards when the wild scallop grounds are trawled.

7.3 HATCHERY PRODUCTION

The hatchery was able to produce large numbers of apparently healthy and fast-growing spat as required during the first year of the project. Subsequently, the spat produced were not of a quality which was considered adequate to release, on the basis that their survival and growth rates during the larval phase or in the first few days following settlement were well below that observed in the first year of the project and that to deploy them would have introduced a potential confounding of results should there be no evidence of significant survival after trawling over the reseeding grounds.

The poor survival and slow growth of larvae and juvenile scallops indicates that there are some key issues which need resolving before hatchery production of *Amusium balloti* can be considered routine. A range of factors could be responsible, although the results from the hatchery at two independent locations suggest that water quality was not the main cause. The condition of broodstock and the quality of their gametes and their resultant larvae is worthy of investigation. This might be assessed through, but not limited to, research into diet, including a gut analysis of mature scallops from the fishing grounds, and to extend into the effects of diet on biochemical composition of eggs and how any observed variations are reflected in the performances of batches of larvae.

7.4 SPATIAL REQUIREMENTS

Amusium balloti spat require space for optimum growth. They appear not to tolerate being kept in close proximity, resulting in a need for large areas of culture space due to the fact that the spat do not have byssal attachments which would otherwise allow them to be grown attached to ropes or similar and make three-dimensional use of water volume in a hatchery. Whilst this conclusion is based partly on subjective observations, the requirement for space between individuals became clear over a period of time dealing with the spat in the hatchery and nursery stages. The requirement for space appears to increase with size, but the precise requirement needs to be determined experimentally. Further, the cost of providing such space while allowing the spat to grow, and so become more robust for their life immediately after deployment, also needs close examination to determine whether the higher cost of culturing the spat for longer periods, and the costs in doing this provides a benefit in the recovery of mature scallops. It is currently concluded that, if spat culture cannot make significantly better use of the floor area of the hatchery and nursery areas, it is probable that reseeding will not be economically viable. Investigations into culture methods that would allow substantially higher density of spat per unit of hatchery floor area than has been achieved to date could result in greater stocking efficiencies in the hatchery and better use of the expensive facility.

7.5 SURVIVAL RATES IN THE HATCHERY

The survival of larvae and spat in the early stages of culture has been highly variable and needs to be more reliable before reseeding can be successful. Whilst the variability of the larvae and spat survival may be due to reasons previously discussed, issues such as water quality, stocking density relative to water exchange, food quality as pertains to individual algae starter cultures and the like should be considered.

8.0 PLANNED OUTCOMES

This project sought to resolve the key technical issues which currently prevent the successful enhancement of *Amusium balloti* on natural scallop grounds. The application noted: *Successful resolution of the key issues identified by Dredge et al. could result in increases in the production of scallop meat from the Western Australian and Queensland scallop fisheries by several hundreds of tonnes. It will reduce the natural, seasonal variability in production, allowing greater certainty in supply. This in turn will allow more stability for producers and marketers of the product. Substantial increases in export earnings will result and local employment will be a major beneficiary with each tonne of scallop meat produced employing 13 people for a day and injecting $23,000 into the economy. The improvement in GVP from enhanced scallop fisheries will also flow back to The WA Government and the FRDC in the form of a proportion of the licence fee devoted to R&D*.

The project achieved some success in determining that the juvenile scallops could be successfully transported to a remote reseeding site and deployed to the seabed without significant detriment to the viability of those animals. The transport and deployment methods developed in the first year of the project probably do not need any significant further development or testing.

Whilst the production of commercially viable catches of scallop meat was not achieved, the inability to identify the origins of recovered scallops may have contributed to that result. Significantly higher catches of scallops were recovered from an area onto which the largest scallops were deployed, but the differences in catch rates between the reseeded location and those from immediately adjacent waters was not adequate to validate a claim to the certainty that the hatchery scallops were the cause of the higher catch rates.

Whilst not a formal Planned Outcome, the project also identified a number of areas that require further research before reliable production of scallops for reseeding of *Amusium balloti* can occur. This information is crucial to the continuation of the concept of reseeding. Failure to benefit from the past experiences of well-qualified practitioners would set back any further efforts significantly and would result in unnecessary duplication of past costs in achieving the state of knowledge currently held by those involved to date.

9.0 CONCLUSIONS

The objective of recovering commercially viable recoveries of scallop meat from a site which was seeded with hatchery-produced spat was not achieved. The catch data suggest that some spat, particularly those in the larger size classes, may have survived in large enough numbers to reflect in the trawl catches from the reseeding site approximately 18 months and more after reseeding, but the absence of a chemical marker in the scallop shells prevents categorical identification of any scallops. The catches were not adequately higher in the reseeding area compared with those from surrounding waters to be certain that the higher catches were due to the survival of reseeded scallops.

The transport and deployment methods developed during this project are simple and work well. Spat transported to the reseeding site and deployed and recovered from near the seabed survived for an extended period once back in the nursery. This subject probably does not need significant further effort.

The reliable performance of a hatchery is fundamental to the success of a reseeding program such as that envisaged by this project. The hatchery's successful performance in the first year was not repeated in subsequent years, with all batches of larvae and early settled scallops showing attenuated development, resulting in the decision to terminate their culture rather than risk the success of the project on the deployment of scallops which were clearly compromised. A major priority in any project which seeks to continue the objectives of this current work must be to achieve improved reliability in the production of juvenile scallops through to deployment size.

The technology for nursery culture of juvenile scallops needs to be investigated with a view to its potential commercial viability. The technology used in the nursery stage of the current project would not be adequate for a commercial reseeding project. The size of juvenile scallop at deployment at which reseeding might be commercially viable, and the spatial needs of scallops of that size mean that there is a need to develop a nursery technology which uses three dimensions rather than the two used in the current project.

For commercial scallop reseeding to succeed now requires substantial inputs from a broad industry base and further assistance from research funding bodies. There also needs to be an input from the WA Department of Fisheries via their research division, just as Agriculture WA does in conjunction with the farming industries. Working hand in hand with grass roots industries should assist in defining correct procedures to be undertaken and allow future industry participants a recipe for success rather than leaving industry to “sink or swim”. The financial inputs by a small sector of the industry have demonstrated that success could be achieved, if a few significant issues can be resolved. Most of these issues are considered to be of a fundamental biological nature in the first instance, followed by some of a more technical nature relating to efficiency of husbandry.

When considering the potential benefits of increasing the production of scallops from a wild fishery, with one tonne of meat being worth in the region of $23,000 and providing employment for 13 people for a day, it is now the role of the whole of industry to take up the challenges identified by this project. The project partners and authors believe that the issues identified can be solved and that there exists an opportunity to succeed where other reseeding projects have failed. But to achieve that success, noting who will benefit, the entire industry and non-industry partners must be prepared to spend significantly on the next stage to take advantage of the substantial investment and commitment made over the last 4 years by West Coast Scallops Pty Ltd, the Fisheries Research and Development Corporation and other agencies and individuals who have invested resources into scallop population enhancement.

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APPENDIX 1

PROJECT STAFF

Principal Investigator – Rick Scoones

Co-Investigator – Mr Peter McGowan

Co-Investigator - Dr Lindsay Joll

STEERING COMMITTEE

Mr Hamish Ch'Ng – Far West Scallops Pty Ltd

Mr Peter McGowan – Elmwood Holdings Pty Ltd

Mr Tim Duggan - Elmwood Holdings Pty Ltd

Dr Patrick Hone - Fisheries Research and Development Corporation

Mr Matt Barwick - Fisheries Research and Development Corporation

Mr Mike Dredge – Retired fisheries biologist, part time Fisheries & aquaculture consultant from Queensland

Dr Lindsay Joll - WA Department of Fisheries

Mr Richard Stevens - Research and Development Consultant to the WA Fishing Industry Council

APPENDIX 2

INTELLECTUAL PROPERTY

West Coast Scallops Pty Ltd and the authors consider that there are no intellectual property issues for this project. The described methods for the transport and deployment of juvenile scallops are considered best released for the benefits of any other project that seeks to examine the potential of reseeding of scallops.

APPENDIX 3

DATA

TRAWL DATA AUGUST – SEPTEMBER 2003

DVM	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7
45						1	
46							
47							
48							
49							
50							
51							
52				1			1
53							
54				1	1		
55						1	
56				2		2	
57							
58							
59	1					2	1
60	1	1	3		1	2	2
61	2		2	1	1		1
62	1	1	2	4		2	
63	1		1	2	1	3	1
64	1		5	2		2	3
65	5		5	5	1	8	10
66	1		3	3	2	4	4
67	8	3	7	2	3	5	4
68	1	2	9	5	2	4	3
69	8	1	8	4	4	8	5
70	12		17	8	10	5	11
71	7	3	8	7	8	8	7
72	7	3	7	16	10	10	7
73	7		9	9	12	7	5
74	6	1	15	10	3	5	5
75	13		10	6	9	6	8
76	10		3	5	7	3	2
77	5	2	6	0	5	2	7
78	9		5	3	1	3	3
79	6	2	5	1	3	2	2
80	8	2	8	6	7	3	
81	1	1	3	1	3	5	1
82	5	1	3	1	2	3	2

DVM	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7
83	2		2	2	3		2
84	4		6	2	1	2	4
85	1		2		1	5	3
86	2		2			1	1
87	1	1		1	1		1
88	4				1	1	2
89	1			2			
90	7		1	1	1		1
91	1				2		
92	3			1	1		
93			1				1
94			1		2		
95	1	1			1		
96				1	1		
97		1					1
98							
99	1		1	1			1
100	1					1	1
101	2		1			1	
102	1		1			1	
103	1	2	1				2
104			1				
105	1			2			
106	1			1	2		1
107					2	1	1
108							
109	2				1		1
110			4		1		
111	1						
112	1				1		
113							
114					1		
115	1				1		
116						1	
117	1						
118							1
119							
120							
	167	28	168	119	120	120	119

Western Australian Department of Fisheries West Coast Scallop Survey Data (Source: E Sporer).

Length (Count)	Seed Area	East Beacon	Hummocks	Zeewijk	Southern group	Easter Group		Length (%)	Seed Area	East Beacon	Hummocks	Zeewijk	Southern group	Easter Group
0-4	0	0	0	0	0	0		0-4	0.0	0.0	0.0	0.0	0.0	0.0
5-9	0	0	0	0	0	0		5-9	0.0	0.0	0.0	0.0	0.0	0.0
10-14	0	0	0	0	0	0		10-14	0.0	0.0	0.0	0.0	0.0	0.0
15-19	0	0	0	0	0	0		15-19	0.0	0.0	0.0	0.0	0.0	0.0
20-24	0	0	0	0	0	0		20-24	0.0	0.0	0.0	0.0	0.0	0.0
25-29	0	0	0	0	0	0		25-29	0.0	0.0	0.0	0.0	0.0	0.0
30-34	0	0	0	0	0	0		30-34	0.0	0.0	0.0	0.0	0.0	0.0
35-39	0	0	0	0	0	0		35-39	0.0	0.0	0.0	0.0	0.0	0.0
40-44	0	0	0	0	0	0		40-44	0.0	0.0	0.0	0.0	0.0	0.0
45-49	0	0	0	0	0	0		45-49	0.0	0.0	0.0	0.0	0.0	0.0
50-54	1	0	0	0	0	0		50-54	0.1	0.0	0.0	0.0	0.0	0.0
55-59	3	6	0	0	1	9		55-59	0.4	0.9	0.0	0.0	0.2	1.8
60-64	17	14	8	1	5	20		60-64	2.1	2.1	1.1	0.2	0.9	4.0
65-69	68	36	25	2	17	31		65-69	8.5	5.3	3.4	0.4	3.1	6.3
70-74	154	102	45	6	23	26		70-74	19.3	15.1	6.2	1.1	4.2	5.2
75-79	244	133	54	4	53	13		75-79	30.6	19.6	7.4	0.7	9.6	2.6
80-84	174	107	53	14	59	9		80-84	21.8	15.8	7.3	2.6	10.7	1.8
85-89	67	61	110	72	90	47		85-89	8.4	9.0	15.1	13.4	16.3	9.5
90-94	20	35	222	138	131	126		90-94	2.5	5.2	30.4	25.7	23.8	25.4
95-99	10	74	171	158	76	136		95-99	1.3	10.9	23.4	29.5	13.8	27.4
100-104	17	85	40	99	66	60		100-104	2.1	12.6	5.5	18.5	12.0	12.1
105-109	16	23	2	39	28	18		105-109	2.0	3.4	0.3	7.3	5.1	3.6
110-114	7	1	0	3	2	1		110-114	0.9	0.1	0.0	0.6	0.4	0.2
115-119	0	0	0	0	0	0		115-119	0.0	0.0	0.0	0.0	0.0	0.0
120-124	0	0	0	0	0	0		120-124	0.0	0.0	0.0	0.0	0.0	0.0
125-129	0	0	0	0	0	0		125-129	0.0	0.0	0.0	0.0	0.0	0.0
Total	798	677	730	536	551	496			100	100	100	100	100	100

Table 1 . Shots by ground and catch summary for the 2003 Abrolhos Island Scallop Survey

AREA	SHOT NO	SHOT LOCATIONS START	SHOT LOCATIONS FINISH	DURATION (MIN)	DISTANCE (NM)	basket	SHOT CATCH	CATCH (NO/NM)	CATCH RATE (NO/HR)
Hummocks	1	28°46.5 114°02.73	28°45.803 114°02.884	20	0.71		1491	2089	4473
	2	28°44.6 114°01.70	28°43.6 114°02.10	20	1.08		88	82	264
	3	28°44.2 114°00.50	28°45.209 114°00.405	20	1.01		480	474	1440
	4	28°45.6 114°00.01	28°46.7 114°00.00	20	1.10		120	109	360
	5	28°47 114°01.30	28°46.8 114°02.40	20	1.12		720	644	2160
Gee Bank (east)	6	28°48.1 114°00.00	28°48.4 113°58.70	20	1.33		231	173	693
			TOTAL	120	6.36		3130		
			MEAN	20	1.06		522	595	1565
Southern Group	7	28°51.4 114°56.4	28°51.4 114°55.3	20	1.10		231	210	693
	8	28°51.5 113°52.6	28°50.8 113°51.5	20	1.30		626	480	1878
	9	28°50.2 113°52.2	28°49.05 113°52.3	20	1.15		920	797	2760
Wooded island	10	28°48.8 113°52.2	28°48.5 113°53.4	20	1.24		380	307	1140
			TOTAL	80	4.80		2157		
			MEAN	20	1.20		539	449	1618

	SHOT	SHOT LOCATIONS		DURATION	DISTANCE	basket	SHOT	CATCH	CATCH RATE
AREA	NO	START	FINISH	(MIN)	(NM)		CATCH	(NO/NM)	(NO/HR)
Zeewijk	11	28°47.3 113°53.5	28°46.1 113°53.1	20	1.26		3000	2372	9000
	12	28°47.6 113°52	28°47.5 113°53.2	20	1.20		1740	1445	5220
	13	28°44.3 113°53.2	28°44.33 113°52.2	20	1.00		310	310	930
	14	28°44.53 113°53.98	28°45.50 113°53.17	20	1.08		1080	1003	3240
			TOTAL	80	4.55		6130		
			MEAN	20	1.14		1533	1282	4598
Easter Group	15	28°39.8 113°46.7	28°40.7 113°46.4	20	0.95		425	448	1275
	16	28°38.2 113°48.2	28°37.9 113°49.3	18	1.14		255	224	850
	17	28°37.9 113°50.1	28°38.3 113°51.2	20	1.17		126	108	378
South Wallabi	18	28°31.7 113°54.4	28°30.8 113°55.2	20	1.20		330	274	990
			TOTAL	78	4.46		1136		
			MEAN	19.5	1.12		284	263	873
East Beacon	19	28°28.6 113°50.5	28°27.5 113°50.4	20	1.10		110	100	330
	20	28°26.4 113°50.7	28°25.3 113°50.7	20	1.10		15	14	45
	21	28°25.9 113°47	28°24.9 113°46.9	20	1.00		467	465	1401
	22	28°24.1 113°47.2	28°22.9 113°46.9	20	1.24		491	397	1473
	23	28°22.5 113°46.1	28°23.7 113°45.8	20	1.24		32	26	96
Wallabi Group	24	28°24.27 113°46	28°25.02 113°46.77	20	1.07		721	671	2163
			TOTAL	120	6.76		1836		
			MEAN	20	1.13		306	279	918

	SHOT	SHOT LOCATIONS				DURATION	DISTANCE	basket	SHOT	CATCH	CATCH RATE
AREA	NO	START		FINISH		(MIN)	(NM)		CATCH	(NO/NM)	(NO/HR)
Northern Area	25	28°17.18	113°53.1	28°16	113°53.1	20	1.18		26	22	78
					TOTAL	20	1.18		26		
					MEAN	20	1.18		26	22	78
Geelvink	26	28°22	113°56.2	28°22.95	113°57.3	20	1.45		100	69	300
					TOTAL	20	1.45		100		
					MEAN	20	1.45		100	69	300
Kidney Patch	36	28°33	114°13.8	28°33.9	114°14.2	20	0.98		970	985	2910
	37	28°34.4	114°14.1	28°34.7	114°13	20	1.14		325	285	975
					TOTAL	40	2.13		1295		
					MEAN	20	1.06		648	635	1943
Seed area	27	28°26.8	114°8.4	28°27.8	114°8.4	20	1.00		91	91	273
	28	28°28.8	114°8.3	28°30.1	114°8.3	20	1.30		142	109	426
	29	28°29.72	114°9.27	28°28.5	114°9.2	20	1.22		128	105	384
	30	28°28.1	114°9.2	28°26.9	114°9.3	20	1.20		15	12	45
	31	28°26.4	114°8.8	28°26.4	114°9.9	20	1.10		128	116	384
	32	28°26.9	114°9.9	28°28.1	114°10	20	1.20		197	164	591
	33	28°28.8	114°10.7	28°27.7	114°10.8	20	1.10		15	14	45
	34	28°28.7	114°10	28°30	114°10	20	1.30		38	29	114
	35	28°30.6	114°10.1	28°30.6	114°11.3	20	1.20		44	37	132
					TOTAL	180	10.63		798		
					MEAN	20	1.18		89	75	266

LARVAE AND SPAT GROWTH MEASUREMENTS

DAY	LENGTH (um)
1	105
2	120
3	
4	150
5	
6	195
7	200
8	
9	230
10	
11	
12	
13	330
14	
15	
16	
17	420
18	
19	660
20	
21	655
22	
23	905
24	895
25	1070
26	
27	
28	1160
29	
30	1460
31	
32	
33	
34	
35	1875

DAY	LENGTH (um)
36	2200
37	
38	
39	2330
40	
41	
42	2700
43	
44	
45	2930
46	
47	
48	
49	3420
50	