BLUE MUSSELS

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Introduction

This project had three aims, first, the establishment of mussel-oyster polyculture, second, using hatchery techniques to provide a reliable supply of mussel spat since NSW had not had a significant mussel spatfall, north of Eden, in almost two decades; the third aim was to demonstrate the use of open sea longlines in NSW. Separate winter and summer spat rearings were carried out in successive years by R. Hand and S. Hunter at the NSW Fisheries, Brackish Water Research Station at Port Stephens while on-growing was carried out on longlines and rafts at Lake Macquarie, Botany Bay and Jervis Bay by M. Pastore. Mussel ropes were also grown on trays 30 cm. deeper than oysters in a fattening lease in Botany Bay. Some trial ropes were given to oyster farmers at Batemans Bay, Georges River and Port Macquarie.

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R. Hand's work at Port Stephens aimed to rear mussels to settlement on ropes on a commercial scale and to compare laboratory cultured algae with natural filtered "brown water" (Ogle, 1982) as larval foods.

Spawning

Broodstock were held out of water for either one or two days before cleaning and placing on a recirculating table in seawater (Salinity=34, T=17^{o}C.). In 20 minutes, when most mussels were open, the temperature was raised to 22^{o}C. over 2 hours. Extra spawning inducements included sperm and algal dosing and short salinity lowering. As females spawned 65-micron eggs they were segregated in separate containers for egg inspection while male spawn was pooled. Here the mean egg yield (fecundity) was 2 million each, in a published range of 1 to 10 million. Within an hour of release, eggs were fertilised in 20 l of near-ocean water (S=31, T=20^{o}C.) with 150 ml of sperm suspension which gave 100% fertilisation rate.

Twenty minutes later the zygotes were placed in a 20,000 l. fibreglass reinforced plastic tank of aerated sea water of the same temperature and salinity. Larval rearing water was a 50/50 mixture of ocean and estuary water, sand filtered and settled for 2-3 days before use. A chelating agent (EDTA) was added at 1mg/l and temperature was held at 19±1 degrees C.

Larval Feeding

After 48 hours the D-stage veliger larvae were fed at 1000 and 1700 hrs with unicellular algae, a mixture of *Pavlova lutheri* (30%), *Chaetoceros calcitrans* (30%) and small celled Tahitian *Isochrysis galbana* (40%). Consumption rates were based on figures used at BWFCRS for *Saccostrea* but by day 9 inadequate consumption led to accumulation and lowered larval activity. After washing and transfer the remaining 22% of larvae recovered and the feeding rate was lowered by 10-25%, depending on water clearance rates.

Daily samples of 50 larvae were measured and examined for activity, gut colour and lipid droplets. Water changes were made each 3 days up to day 9 and each 2 days thereafter. At each water change larvae were sieved and counted. Selective screening maintained an even size distribution, by culling undersized individuals.

Nine hundred 4-metre polypropylene mussel ropes were lowered into the larval tank with concrete weights, on day 17, after the larvae had been measured and the proportions of eyed and pediveliger larvae determined. During settlement aeration was increased and feeding was maintained. After 10 days the ropes with attached spat were deployed on longlines.

Table 1: Development

Day	Size (µm)	Survival (%)	Development
0	65	100	Eggs.
2	117	72	D-veliger.
11	220		Eye spot.
13	258	35	Pediveliger.
15	283		95% eyed, with 50% crawling.
18			Settled.
24		9	9 $x10^6$ settled on 900 ropes.
27			Ropes deployed.

Brown Water Culture

This differs only in the method of feeding and the fluctuating ambient temperature: the zygotes were produced the same way in both experiments but here they were removed from the laboratory as D-stage veligers and placed outdoors in 10,000 l. aerated tanks of local estuary water, coarse-filtered through 5-micron GAF (General Analine Film Corp.) filter bags to remove zooplankton and large phytoplankton. Salinity and temperature were monitored daily and each two days the tanks were drained off through appropriate sieves from which larvae were placed in a clean tank of filtered estuary water; in this process phytoplankton was noted and the larvae were counted and rinsed and undersized individuals were continually culled.

Outdoor tank temperatures were lower and less stable (9-17^{o}C.) than those in the laboratory and salinity fluctuated and was raised, as required, with additions of commercial sea salt. Two batches of broodstock were used: batch 1 comprising 32 males and 20 females, in poor to good gonad condition, produced 52 million 67-micron eggs (19-21^{o}C) after 90 minutes: these gave 99% fertilisation using 50 ml of sperm suspension. This batch was supplemented 4 days later by 198 million zygotes of batch 2: this mixing of two cohorts should be avoided. Both batches produced large (114-micron) D-veliger larvae in 48 hours after fertilisation.

When all of batch 1 larvae were eyed and reached 265 microns and over half were pediveligers, they were screened off into a settling tank with 100 bundled mussel ropes which had been soaked in salt water for a week. Batch 2 larvae were placed in a settling system 5 days after batch 1. Each 2 days 3/4 of the settling tank water was strained off and replaced with fresh 5µm-filtered sea water: swimming larvae were counted. After settlement, spat were sampled by soaking rope samples in 5% sodium hypochlorite for 24 hours to detach the spat. After 6 weeks damp spat ropes were transported to longlines in plastic bags.

In a second series of tanks, the water was enriched with 500g of "Aquasol" soluble garden fertiliser per 10,000 l and held for 4 days to promote extra algal growth but this fertilizer, which contains a balanced mixture of nitrate and phosphate, caused blooms of chain-forming diatoms so thick that they blocked the larval transfer screens so this fertilized series was discontinued.

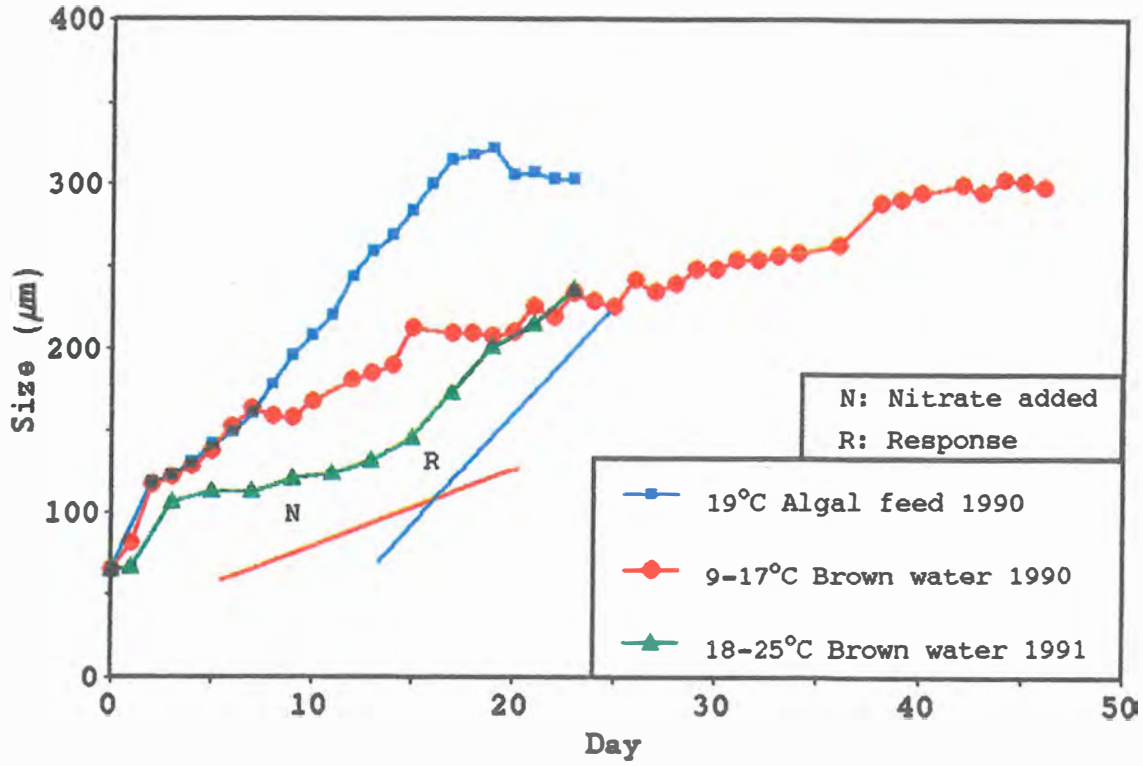
When S. Hunter repeated the brown water experiment a year later, in November 1991, higher summer temperatures ranged from 18-25° (mean 22.8) and with a steady salinity of 35.7, she did not use "Aquasol" but used ammonium nitrate to boost flagellates from 2 to 2000/ml.

Here mean fecundity was 7.1 million eggs/female and the larvae reached maximum size in 24 days and settled after 28 days, compared with 35 days in Hand's experiment. Mortality was however high due probably to the high temperature and to loss through the use of too coarse a screen at the 2-day transfers.

Zygotes were placed outdoors in brown water immediately after fertilisation and allowed to grow for a week until it was decided that they were under fed, although the growth rate had been comparable to Hand's 1990 9-17° brown water trial. A week after adding ammonium nitrate the larval growth rate increased to approximate that of Hand's pure algal culture run (see Figure 1).

At 19° both pure algal culture and ammonium nitrate fertilised brown water gave larval growth rates four times faster than those of runs done at 9-17° or at 18-25° without fertilizer. This result is most important because it indicates that the brown water technique with all of its bacteria in place and costing little more than a pump and two or three tanks can be as satisfactory as the sterile pure cultured algae technique developed in the 1950's and requiring a full laboratory to prevent a bacterial explosion from taking place if there is an infection in a pure culture. The older brown water technique has been overtaken in popularity largely because of the higher percentage of survivors in the laboratory method, but with an animal with a fecundity from $1\text{-}10\times10^6$ this is not important as it is survivors, not percentage of survivors, which counts.

Figure 1: Growth of Mussel Larvae



Lake Macquarie

Mussels were grown on longlines in the inlet bay of Eraring power station where they experienced a steady stream of food and cool water. Unfortunately this habitat also supports large populations of predatory fishes which on two occasions stripped the mussels from the ropes almost overnight. When the ropes were covered with mesh this rapidly clogged with fouling organisms and the mussels were smothered. This habitat is very hard for mussel growth as the fishes are completely dominant.

Port Macquarie

Here mussel ropes loaded with hatchery spat were grown under mesh protection on a submerged oyster lease and like the neighbouring oysters they were subjected to periodic aerial exposure to control competitive fouling organisms. While this is well north of Port Stephens, the geographic limit of the species, the aim of the experiment was to establish the mussels in

winter and grow them to a small special market size by the time that the water became too warm to support them, if in fact temperature is limiting.

Table 2: Port Macquarie Mussels

Date	Wild Stock	Hatchery
23/6/90	Arrived	-
24/7/90	-	Arrived
6/8/90	-	Not visible
3/11/90	64mm	16mm
5/1/91	70mm	41mm

These notes provided by the oyster farmers show that in the 6 months between July and January the hatchery spat had grown to 41mm while the wild spat grew only 6mm in the 2 months, November to January, when the smaller hatchery spat grew 25mm. Clearly the young mussels can reach a superior restaurant size in only half a year.

Botany Bay

Within Botany Bay mussels were held on a raft in Quibray Bay before transfer to trays 30cm deeper than the oyster fattening trays of a farm in Wooloware Bay: mussels left unprotected on the raft were subsequently eaten by fish. On the fattening trays mussels were initially protected in envelopes of galvanised chicken wire. The growth rate was lower than that of the suspended culture as feeding was interrupted by the tide: the shells however were muddy and remarkably free from fouling organisms.

Table 3: Wooloware Bay Mussels

Date	Size (mm)
5/4/91	39
6/11/91	46
30/4/92	61
21/10/92	65

These measurements indicate that mussels settled in mid 1990 and on-grown in Jervis Bay for 5 months to November before transfer to Wooloware Bay at approximately 30mm, grew steadily for almost 2.5 years. While their growth rate was slower than that in suspended culture their survival was greater than expected and they were an added bonus to the farmer as they grew on the same ground as the oysters.

Jervis Bay

Here two 60m longlines were installed in a 4 ha. experimental area, with two riser ropes on the seaward end of the longline and one facing the shore. Each line carried 120 mussel ropes each attached with a dropper one metre below the longline and the 20 l. floats were suspended one metre above it. A mussel raft was also used to support longlines and to provide above water antifouling exposure.

Continuous immersion allows the development of a smothering coat of fouling organisms, most of which (barnacles excluded) are less tolerant to exposure to air and sunlight than mussels. With this in mind Hunter carried out a series of experiments in which she tested the optimum exposure time for mussels by laying ropes on a mussel raft for various periods before replacing them in the water and noting the faunal and floral changes so induced: 12 hours is the optimum exposure time to control most fouling organisms and this has no effect on the mussels.

The ocean longline used was modified from Johns & Hickman (1985) but 20 l. black chemical containers were used as main flotation and each was attached by a 1m. dropper which submerged the longline, allowing small boats to cross it without damage and making pilfering and vandalism more difficult. Minimum buoyancy was employed to minimise strain in rough weather. Hatchery spat were deployed on the two longlines moored over a clear sand bottom far from reef areas which shelter predatory fishes. The only shelter provided for the mussels was the hanging of ropes in bundles in the early stages of growth.

Table 4: Jervis Bay Mussels

Time 1990	July 9	July 24	August 7	August 24	September 7
Density/cm	21	9	6	6	5
Size mm	0-1	8	-	20	30

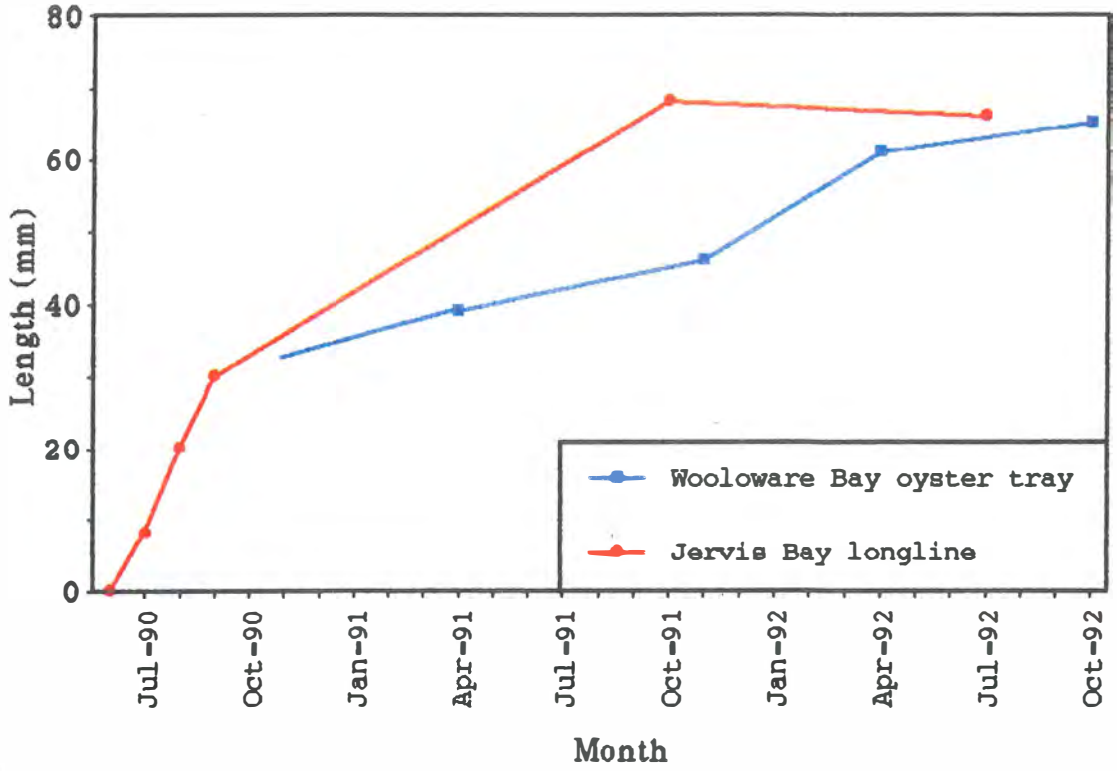
Over this 3-month period there has been a fourfold reduction (21-5/cm of rope) and at the same time they have grown thirty times in length (1-30) on average, but they spread widely from 4 to 80mm. This stock was measured twice more: on 2/10/91 (68mm) and 8/7/92 (66mm) but by this time the population also reflected recruitment from wild spatfall. A comparison of these and later measurements with those from Wooloware with growth in Wooloware Bay is given in Figure 2.

An analysis of the components, shell, cooked meat, raw weight and the difference in juices is given in Table 5.

Table 5: Sample from Jervis Bay Longlines
2/10/91

Live Weight	2200g
Cooked Meat	500g
Shell	810g
Difference	890g

Figure 2: Growth of adult mussels



Conclusion

The Blue Mussel *Mytilus edulis* feeds itself and can be grown on inconspicuous structures which can be arranged so as not to inhibit recreational navigation. It has been demonstrated that it can be reared commercially under either pure algal culture or brown water techniques. It can be grown well outside its natural distribution range to a small market size in six

months, and it can readily be grown as a second crop on the same ground as oysters. Control of fish predation, particularly in the early stages, is a crucial factor for any mussel industry. As much as a quarter of the live weight is available as cooked meat which can be frozen and sold world wide. Normally regarded as a one year crop many more small mussels can be sold at 6 months and fewer large specimens can be had in two years so the animal is very flexible as a market commodity; it is only unsaleable for two months after spawning or if it becomes infected by the "Pepper Taste" syndrome. Predators, parasites, competitors, spatfall and storm and tempest remain to temper a farmer's enthusiasm.

References

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Ogle JT, 1982, "Operation of an oyster hatchery utilizing a brown water technique." J. Shellfish Res. 2 (2):153-156.