EXPERIMENTAL MUSSEL CULTURE IN AUSTRALIA

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ABSTRACT

Raft culture of mussels was investigated to increase supply and quality while minimizing labor costs. Two types of spat catching rope and four types of growing rope were used. Mussel yields of 4-6 kg/m and lengths of 60-70 mm were obtained in the first year. Histological sections of gonads, planktonic samples and test settlement ropes were studied to facilitate settlement prediction. Spawning occurred with a fall in water temperature in late autumn and often continued to early summer. Major settlement occurred from winter to early spring. Harmful associates of mussels were investigated. Trematodes, polydorid polychaetes and pinnotherid crabs were most noticeable. Infestation levels, however, were very low. Mussels containing pea-crabs had significantly lower meat yields. Raft mussels had lower infestation levels than wild mussels. Fish predation was very severe on mussels of less than 30 mm, in certain estuaries.

INTRODUCTION

Previous studies on the ecology of Australian mussels (MacIntyre, 1959; Hum, 1970, 1971) led to a feasibility study of the raft culture of mussels around southern Australia. This joint project (12-045-05) between New South Wales State Fisheries and the School of Zoology, University of New South Wales, was funded by the Commonwealth Department of Primary Industry from the Fishing Industry Research Trust. The work was carried out by three graduate students with Technical help from H.T. Booth and field officers of the Fisheries Departments of New South Wales, Victoria, South Australia, Tasmania and Western Australia. The project was supervised by R.J. MacIntyre.

Physical and biological data were obtained from twelve mussel rafts established between New South Wales and Western Australia. The project aimed at increasing the quality and supply of mussels, minimizing labor costs, and determining the advisability of transfering stock from one site to another. Biological work concentrated on recruitment, growth, and parasites with observations on fish predation and fouling overgrowth.

MATERIALS AND METHODS

Mussel rafts were designed for simple low-cost production using readily available materials. They were of modular construction for flexibility, ease of transport and maintenance (Fig. 1). Each module was constructed from six 200 liter drums strapped to a timber framework measuring 3.5 m x 4.0 m. The modules were flexibly linked with motor tires and chain and were placed on single swinging moorings. Rafts were moored in sheltered estuaries and in more exposed marine bays (Fig. 2).

To understand gross timing of the reproductive cycle, histological preparations were made from monthly samples of adult gonads. Classification of gonad stages was based principally on that of Wilson and Hodgkin (1967). Plankton samples were taken whenever possible and the relative abundance of larvae estimated. Lengths of 15 mm diameter coir rope were used as test surfaces to assess time and intensity of settlement. Ropes were immersed for periods of 1 to 3 months.

Mussel spat was caught on two types of rope, 15 mm diameter coir and a 10 mm diameter rope made from polyethylene staple and coir at a ratio of 3:1 (Fig. 3). Where no settlement occurred on site, spat was transferred from other rafts, or from recently settled wild populations.

Mussels were reared by the Spanish method (see Ryther, 1968) on the mixed fiber rope which was pierced at intervals by hardwood skewers. The catch on coir rope was reset on plastic cone-ropes, pocketed welded-mesh tubes ("polynet"), and woven mesh bags ("polymesh") attached to ropes (Fig. 3). The growing ropes were 4 m long and were suspended at 0.4-0.6 mm centers. The rafts were sampled bimonthly; numbered series of ropes of each treatment were weighed and one rope of each treatment was removed for determinations of growth and yield. To reduce labor and costs, no fouling control or culling procedures were implemented.

Mussels from both raft and wild populations were dissected and examined for parasites with the aid of a binocular microscope. The foot, mantle, gonad, and posterior adductor muscle were teased. The stomach and intestine were opened. Meats were removed, drained and weighed on a Mettler E200 balance.

RESULTS

With the exception of Margate (Tasmania), all sites showed a similar pattern of gonad development and spawning. Gametogenesis began in mid to late summer and gonads were ripe by autumn. Initial spawning usually occurred with falling water temperatures (20-15°C) in late autumn. This was followed by 4 to 5 months of intermittent gonad redevelopment and secondary spawning. Not all animals in a population spawned twice; some went directly to the inactive stage (a period of nutrient storage). Gamete production in secondary spawnings was much less than that in the initial spawning.

At Margate the gonad cycle was similar to that of the mainland sites, but the timing was different; spawning did not begin until late spring, and continued through the summer and early autumn. The spawning activity at 6 sites is shown in Figure 4. The number of larvae taken in plankton tows showed no recognizable pattern; this was probably due more to sampling problems than to actual fluctuations in larval abundance.

The major period of larval settlement was from winter to spring, with very heavy settlements from July to September. It appears that the larvae spend approximately one month in the plankton before settling. Lighter settlements occurred through to late summer. Eden and Sydney (Middle Harbour and Georges River) were the only mainland sites where a significant (although light) settlement occurred in late summer. In Margate, the main settlement was in autumn, with a lighter settlement in spring.

Settlement densities of 300-500 mussels/cm of rope (over a one-month period) were recorded at Beaumaris and Woodmans Point, and up to 200 at Jervis Bay. Heavy growths of erect bryozoa and filamentous weed covered the test ropes at these sites and greatly increased the attractive surface area available for settlement. A maximum of almost 800 mussels/cm settled on a rope hung from July to September at Woodmans Point. At these densities, natural mortality was estimated to be between 50% and 80% in the first month. This still left high densities which caused overloading of the ropes as the mussels grew. Settlement densities at other sites were much lower. Margate and Eden had maximum densities of 20-30 mussels/cm; Sydney (Middle Harbour and Georges River), Batemans Bay, Merimbula, Lakes Entrance and Port Adelaide all had very light settlements, or none at all. In most estuarine areas, fouling by barnacles, compound ascidians, and an amphipod which builds a mud tube made the rope surfaces unattractive to mussel spat, and often smothered any spat that did settle.

Growth rates varied: they were greater in marine bays (Woodmans Point, Beaumaris, Eden, Jervis Bay) than in estuaries (see Table 1). Mussels grew to a size suitable for harvesting (60-70 mm) in one year in marine bays, while it required 18 months to achieve a similar size in most estuarine areas. Most rapid growth of mussels was obtained using the Spanish technique of culture, while in cones and meshes similar but less rapid growth occurred (see Table 1). Growth was continuous at all sites and not greatly influenced by temperature or latitude. Salinities at raft sites were usually between $20^{o}/_{oo}$ and $35^{o}/_{oo}$ (except during floods) but it has not been established that salinity was a major growth limiting factor. Growth patterns (Fig. 5) generally followed a simple decaying exponential relationship.

At Eden after one year's growth, yields of 4-6 kg/m of whole live mussels were obtained using cone, welded mesh and woven mesh ropes. Maximum yields of over 5 kg/m of marketable mussels occurred 10-16 months after settlement with mean shell lengths of 60-84 mm, but yields declined rapidly thereafter. Less than 6% of the mussels survived for 2 years. Yields were reduced in the Spanish method (0-5 kg/m) when skewer failure caused by marine borers allowed mussels to slide off the ropes. Experiments conducted later under ideal conditions however, yielded 12.5 kg/m of marketable mussels. At Woodmans Point and Beaumaris excessive settlements produced ropes weighing 50-63 kg after 10 months, but most mussels were lost due to smothering by additional spat settlement or breakage of the plastic cones and mesh by the excess weight.

Yields of mussels at estuarine sites were low as a result of severe predation of juveniles by fish, and competition and smothering by fouling organisms (mainly barnacles, tunicates, bryozoans and tube-building amphipods). Greatest estuarine returns were obtained using cone ropes at Merimbula: these yielded 3.0 kg/m after 18 months.

Only three serious pests have been found. The most obvious is the pinnotherid crab, *Fabia hickmani* Guiler. (The validity of this name is doubtful and will be discussed further in another paper). While it is common and found throughout the entire distribution of the mussel, it is only abundant in certain regions (see Table 2). Meat weights of experimentally infected mussels were approximately 20% lower than the control group (see Table 3).

The larvae of a fellodistomid trematode (*Cercariae praecox* Walker) occur only on the east coast of mainland Australia. They have no statistically significant effect on condition, but parasitic castration was evident. Infection was very low: infestation rate was less than 10%. The metacercariae of a trematode (*Gymnophallus* sp.) not only causes castration, but also prolific pearl formation. At one location the infestation was more than 60%.

Several species of spionid polychaetes bore into the shell, causing chamber-formation and mud blisters. While identification is not complete the genera *Polydora* and *Boccardia* appear to be represented. They are found throughout the mussel's range but infestation was less than 20%.

The raft mussels had lower infestation levels in all locations than did wild populations (see Table 2).

DISCUSSION

Mytilus edulis is primarily a winter/spring breeder in Australia, in contrast to the spring/summer breeding reported for northern hemisphere *Mytilus edulis*. In the colder waters of Tasmania, however, the cycle is shifted to spring/summer breeding. Breeding activity is characterized by an initial heavy spawning and a long period of secondary, lesser spawnings. In areas of heavy spatfall, secondary recruitment can provide adequate quantities of spat for cultivation. The most successful areas for spat collection were those characterized by a fully marine and partially enclosed water body. Truly estuarine areas were not suitable for spat catching, the main problems being fouling of the collectors and the occurrence of low salinities (either consistently low, such as Lakes Entrance where values were never greater than $22\,^{o}/_{oo}$; or intermittently low, such as Batemans Bay and Georges River, with ranges of 15 to $30\,^{o}/_{oo}$ and 10 to $22\,^{o}/_{oo}$.

Raft techniques were successfully used to culture mussels in Australian waters. The rapid growth to commercial size (60-70 mm within 12-18 months) ensures the prospective farmer a quick return on investment, but methods of increasing the yield must be developed, especially in estuarine waters, where fouling control measures and methods of protecting stock from predatory fish are needed. In more exposed sites, where rope failure occurred, stronger support materials will be necessary. Borer-resistant skewers for the Spanish technique and a more durable cone material must also be used. Although no attempt was made to control stock density by thinning or culling, these experiments have shown that in commercial culture, thinning will be necessary. Smothering of one-year-old stock by additional settlement is a serious problem which can be avoided by moving the adult mussels to waters where little settlement occurs. Both spat-catching and fattening sites will be necessary for commercial culture.

The crab represent the biggest parasite problem because of its abundance and its effect on production and marketing. Only the large female crab seriously affects mussel condition: this effect increases as the gonads fill, but it is not fatal to the mussel. A short-term solution is to culture mussels where the crab is not abundant, until a suitable control can be developed.

The trematodes and polychaetes are of little concern because of their very low abundance. The very high incidence of the gymnophallid in only one area is a puzzle. Although the polydorid infestation approaches 20% in some instances, the shell damage is minor. Serious chambering and blistering accounted for less than 6% of the occurrences. The few instances of higher infestation of polydorids were probably due to old and crowded populations (Middle Harbour) or bottom-dwelling populations (Perth area, Georges River area). The lower levels of infestation on the rafts can be explained by lower exposure to pests as a result of harvesting between 12 to 18 months, isolation from the bottom, and perhaps greater water movement.

Presently mussels are harvested by commercial dredge and by divers. Only one commerical mussel raft is in operation. The majority of mussels (taken by dredge) are pickeled and bottled. The remainder (those taken by divers) are sold live to retail shops and restuarants. A small amount is exported. Mussel landings in 1975-76 were estimated at 1,100 metric tons, an increase of 615 metric tons over the 1972-73 landings. Domestic consumption for 1975-76 was 1,555 metric tons with imports coming mostly from New Zealand, Korea and Taiwan.

The wholesale price varies considerably depending on location and condition Dredged mussels bring 6 to 7 cents/kg, while hand taken mussels bring 35 to 40 cents/kg in Melbourne and 50 cents to $1.00 /kg in Sydney (Rohan 1977).

There is no question that the market structure can handle an increased supply of mussels since they are always in demand in Sydney and under-supplied.

Briefly it is concluded that commercial-scale production of mussels can be achieved on rafts in spite of the influence of irregular spat-fall, fouling overgrowth and fish predation.

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FIG. 1. Four module mussel raft moored in sheltered waters.

FIG. 2. Map of Australia showing the known distribution of <u>Mytilus</u> from literature and direct observation, data collection points and 12 raft sites.

FIG. 3. Spat catching and growing ropes. The first two ropes are coir and mixed fiber rope. The others are welded mesh, woven mesh and cone ropes.

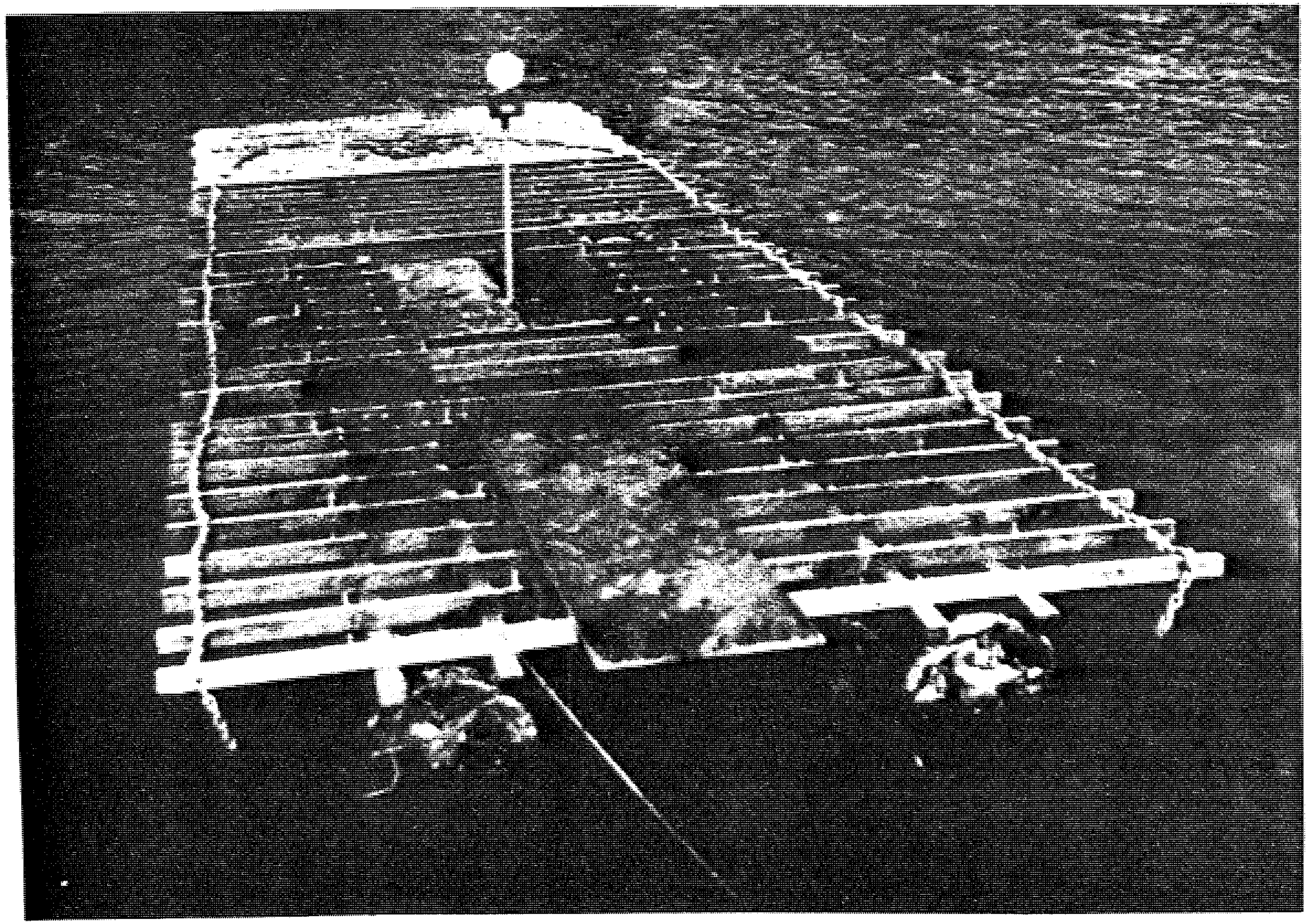
FIG. 4. Percentage of population in spawning condition at 6 sites. ■= heavy spawning, ▨= secondary spawning; X = no data.

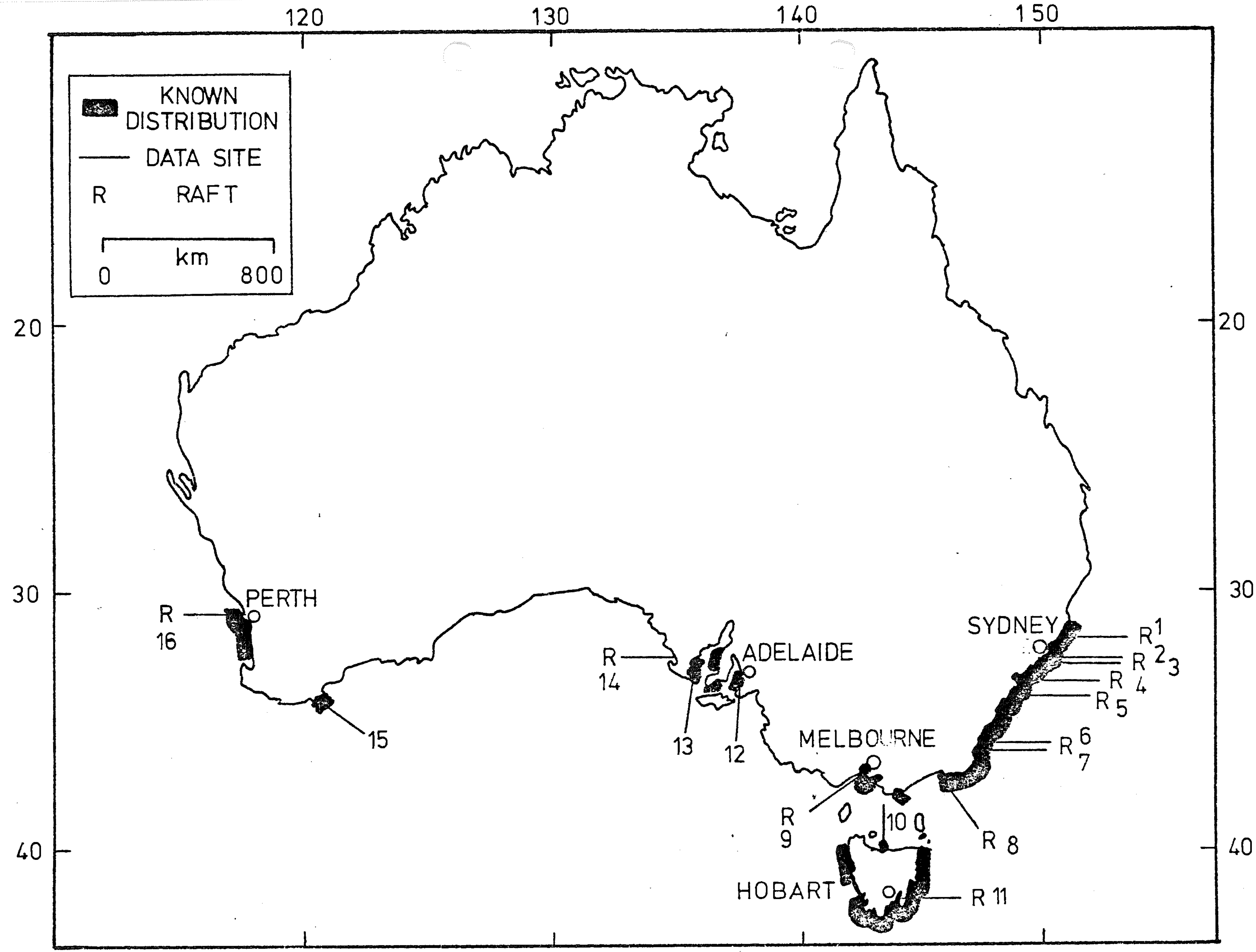
FIG. 5. Growth pattern of cultured mussels. Percentage length frequency histograms and fitted von Bertalanffy growth curve. The figures shown are sample size and the growth equation parameters for lengths in mm and age in months are also given. Data are from cone ropes at Eden.

TABLE 1. Growth of mussels at 9 sites using 4 culture methods.

TABLE 2. Percentage infestation of 3 organisms in populations of wild and cultured mussels.

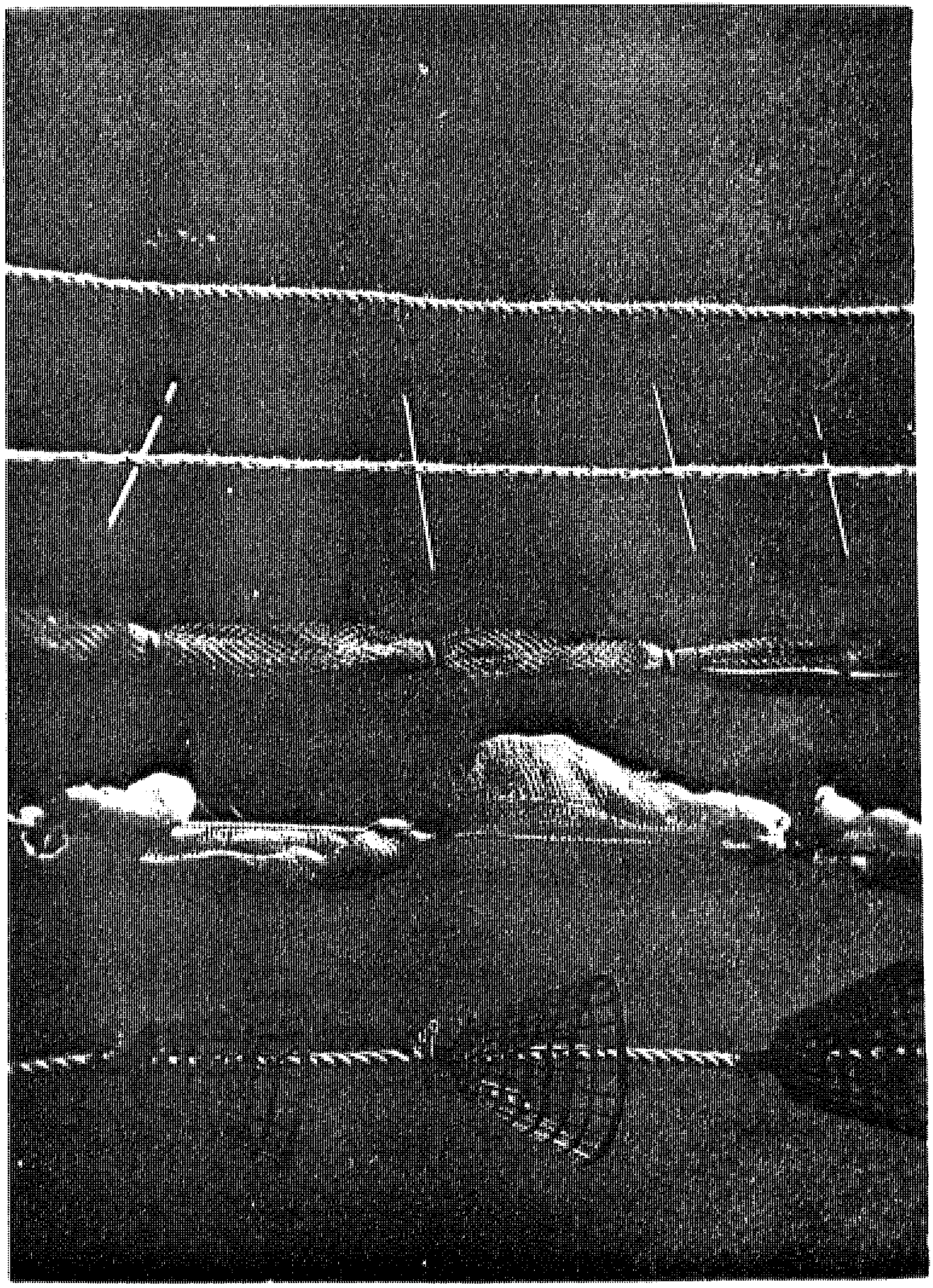
TABLE 3. A comparison of meat weights of control and mussels experimentally infected with Pinnotherid crabs.

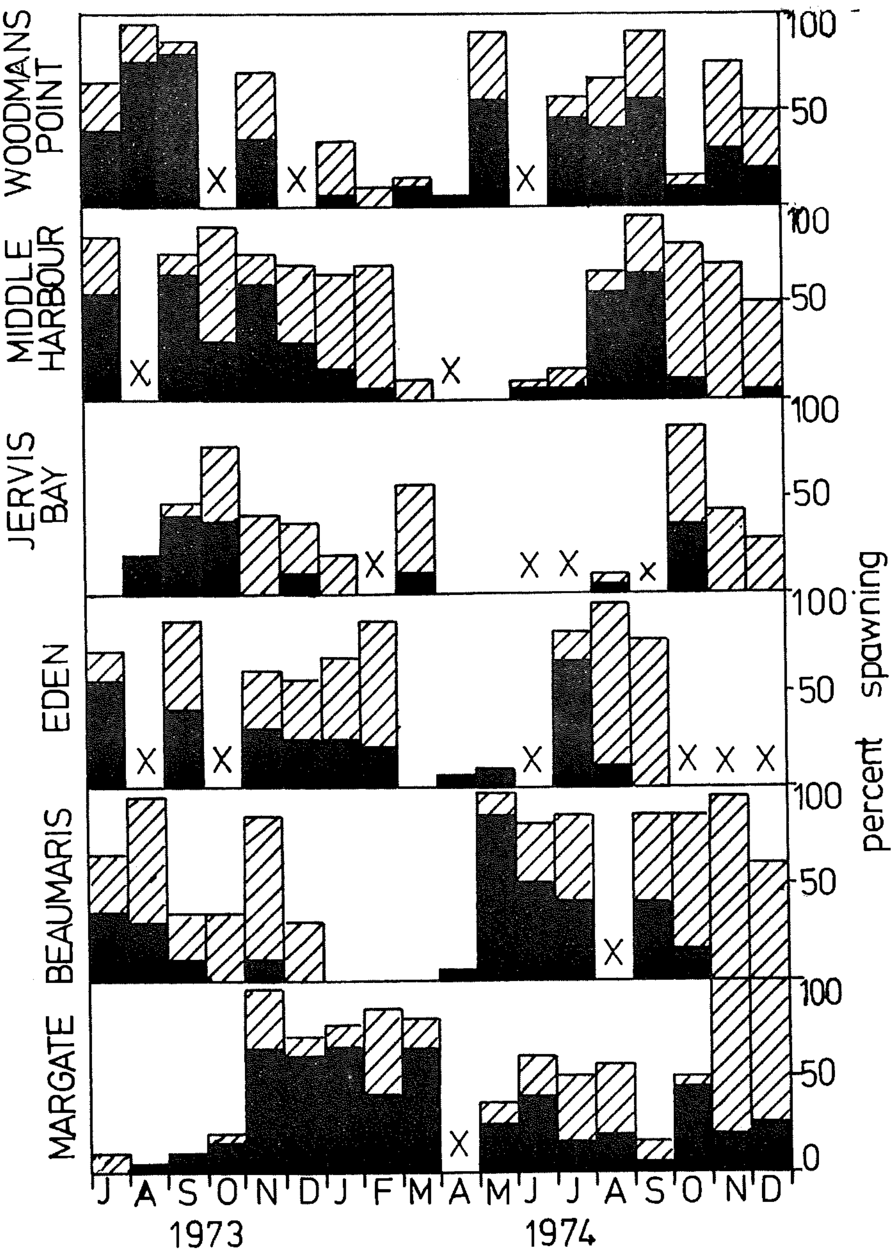




KNOWN DISTRIBUTION
DATA SITE
R RAFT
km
0
800
120
130
140
150
20
30
40
PERTH
ADELAIDE
MELBOURNE
SYDNEY
HOBART
R 16
15
R 14
13
12
R 9
10
R 11
R 8
R 1
R 2
3
R 4
R 5
R 6
7

125




WOODMANS POINT
MIDDLE HARBOUR
JERVIS BAY
EDEN
BEAUMARIS
MARGATE
100
50
0
percent spawning
J A S O N D J F M A M J J A S O N D
1973
1974

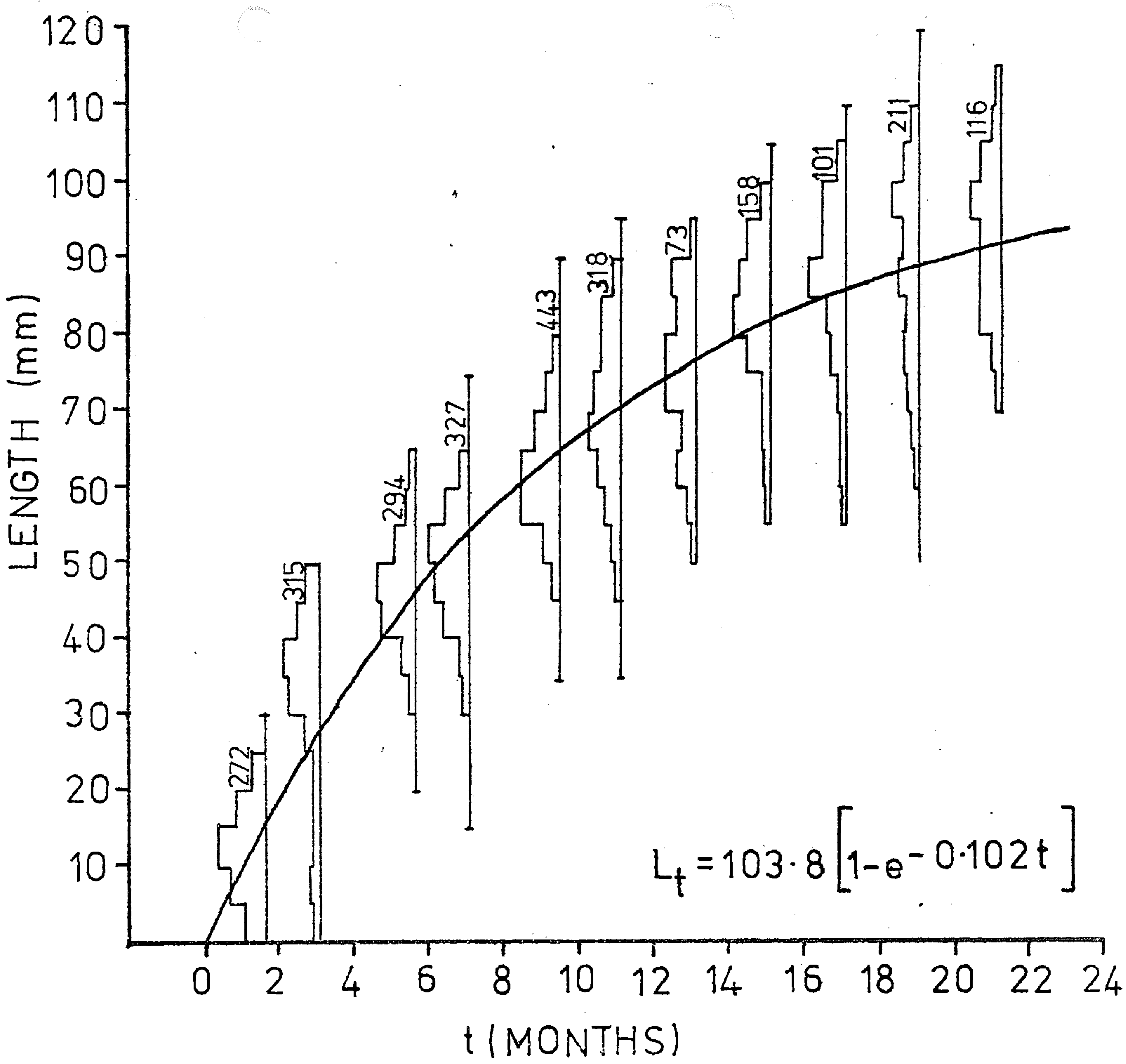

LENGTH (mm)
120
110
100
90
80
70
60
50
40
30
20
10
272
315
294
327
443
318
73
158
101
211
116
$L_t = 103 \cdot 8 \left[1 - e^{-0 \cdot 102 t}\right]$
0
2
4
6
8
10
12
14
16
18
20
22
24
t (MONTHS)

TABLE 1

GROWTH OF MUSSELS AT 9 SITES USING 4 CULTURE METHODS

SITE	WOODMANS POINT			BEAUMARIS		EDEN				MARGATE		JERVIS BAY		MERIMBULA				GEORGES RIVER			MIDDLE HARBOUR			PORT STEPHENS			
DURATION (MONTHS)	6	12	18	6	12	6	12	18	24	6	12	6	12	6	12	18	24	6	12	18	6	12	18	6	12	18	24
LENGTH (mm)																											
METHODS																											
C	42	66	80	36	56	48	73	86	94	-	-	35	60	30	53	70	84	26	45	60	-	-	-	32	56	70	81
WD	40	66	-	-	-	38	68	88	96	-	-	34	-	28	50	65	-	26	48	59	34	60	-	32	54	67	-
WM	42	65	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	28	52	64	-	-	-	-
S	46	72	-	43	68	42	70	91	100	34	68	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

C = CONES, WD = WELDED MESH, WM = WOVEN MESH, S = SPANISH-STYLE.

TABLE 2

PERCENTAGE INFESTATION OF 3 ORGANISMS IN POPULATIONS OF WILD AND CULTURED MUSSELS.

LOCATION	CRABS	TREMATODES	POLYDORIDS
PORT STEPHENS RAFT	0.5	0.0	7.4
MIDDLE HARBOUR RAFT	6.0	1.1	19.4
GEORGES RIVER AREA	46.0	3.0	21.9
GEORGES RIVER RAFT	36.0	0.0	5.7
BATEMANS BAY AREA	0.0	1.9	8.5
MERIMBULA AREA	0.6	3.6	2.5
MERIMBULA RAFT	0.0	0.0	1.6
EDEN AREA	0.4	0.0	1.3
LAUNCESTON AREA	5.9	0.0	13.9
HOBART AREA	57.3	64.8	4.7
MARGATE RAFT	5.9	0.0	0.6
LAKES ENTRANCE AREA	12.4	2.3	1.0
BEAUMARIS AREA	80.5	0.0	7.9
BEAUMARIS RAFT	68.2	0.0	0.9
ADELAIDE AREA	0.0	0.0	1.2
PORT LINCOLN AREA	8.9	0.0	2.1
PERTH AREA	0.2	0.0	19.9
WOODMANS POINT RAFT	0.0	0.0	6.2

TABLE 3

A COMPARISON OF MEAT WEIGHTS OF CONTROLS AND MUSSELS EXPERIMENTALLY INFECTED WITH PINNOTHERID CRABS

	Experimental mussels	Control
mean meat weight	3.78 g	5.11 g
standard deviation	.94	1.30
number	19	43
"t" test value	3.96	

Reject H_o at $p > .001$