Assessment of the Potential for Manila Clam *(Tapes philippinarum)* Cultivation on the Scottish West Coast

Crown Estate Commissioners

Seafish Report No. 400

February 1992

N.C.H. Lake
(Ardtoe)

SEA FISH INDUSTRY AUTHORITY

Marine Farming Unit, Ardtoe

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SUMMARY

The manila clam (Tapes philippinarum) is not an indigenous species in waters of the N.E. Atlantic and has its origins in S.E.Asia. Nevertheless it is accepted as a good substitute for the highly prized native European clam (Tapes decussatus) or palourde.

Seed for the manila clam has to be produced in a hatchery and the trials programme described in this report assesses the potential for manila clams grown by various methods in Scottish west coast waters.

The two main methods tested were the plot-or intertidal seabed culture, and tray culture in which the clams were placed in plastic trays filled with substrate. Two sub routines were followed, in that batches of manila clams were also first cultivated in pearl nets for 9 months. All the work was carried out in the vicinity of the Seafish Marine Farming Unit (MFU) at Ardtoe.

In terms of both growth and survival the tray cultivation of manila clams proved to be more successful than plots. There are clear benefits of tray cultivation in protecting the stock from predation.

Growth to market size is likely to be 3 to 4 years in Scottish waters which is considerably longer than in the warmer waters of southern Europe. The viability of tray culture however, is dependent on market price and the number of production cycles for which trays can be used. It is suggested that a minimum price of £3.80/kg is needed for tray cultivation to break even over 3 production cycles.

Plot cultivation may be economically viable allowing for the slower growth and the higher mortalities provided the price stablizes at a higher level than at present.

Site selection is critical and the results of this trial although a valid comparison of the methods investigated may well contain some site specific bias.

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1. INTRODUCTION

Interest in the cultivation of clams increased considerably during the 1980's due to their high market value. This situation was brought about by increased demand for live product in several European countries, coupled with a declining and variable supply from the existing fisheries.

Traditionally the most prized native European species has been the grooved carpet shell or butterfish (Tapes decussatus) termed variously the Palourde (France), Almeja fina (Spain) and Vongole veraci (Italy). In more recent years a similar species, the Manila clam (Tapes philippinarum) has been widely accepted as a suitable substitute for Tapes decussatus.

The reason for this acceptance is primarily because it is extremely similar in size and shape to the Palourde. However, it can have a more distinct pattern of dark shell markings. Internally the flesh of the Manila clam is more orange than that of the Palourde, while the syphons used for feeding are joined along their length unlike those of the Palourde. The Manila clam is a native of the Far East and was formerly found in the coastal waters of the Philippines, Japan and Korea. It has successfully spread by accidental introductions or through deliberate movement of broodstock and is now found throughout North America and Europe. In cold northern waters such as the UK, populations are not self recruiting and so seed for cultivation has to be hatchery produced, while in southern Europe self sustaining populations have become established.

Growth of cultivated Manila clams to market size($\approx$ 20g) in England and Wales has been found to be able to be achieved in 2-3 years, while the native Palourde takes $\approx$1 year longer. It is for this reason, together with its high market value, that the Manila clam was considered to be a suitable candidate for cultivation in the UK (Spencer et al., 1991).

Initial studies on the potential for Manila clam cultivation on the Scottish west coast were undertaken during the early 1980's (Paul, 1988) and centred around traditional plot cultivation. Conclusions from the work were that ambient temperatures allowed only a short growth season and that at least 3-4 years were required for stock to reach a commercial size. The survival rate of the stock was also considered to be vital to the commercial success of a cultivation operation.

Based on these findings the present study was instigated to determine if survival and growth of Manila clams could be significantly increased by offering the stock greater protection from the environment. This was achieved by the use of substrate filled trays placed on trestles on the foreshore, into which the clams were seeded. Conventional plot cultivation was also undertaken as a comparison and the two systems were assessed with respect to the growth and survival of the stock, and the commercial viability of cultivation on the Scottish west coast.

2. MATERIALS AND METHODS

Seed for the trial was obtained from Guernsey Sea Farms hatchery, Guernsey, Channel Islands, UK at the beginning of June 1988. The 12-17mm shell length seed was transported to Ardtoe in a moist environment within a polystyrene box. Total transit time was less than 24 h. Upon arrival the stock was placed in floating trays in a tank containing flowing seawater. After 2 days the seed was sorted by hand to remove mortalities, and the mean shell length and total wet weight of the survivors was determined.

The seed was divided into 3 batches for ongrowing using the following techniques:

Batch 1 (4000 animals) - Tray cultivation

Batch 2 (4000 animals) - Plot cultivation

Batch 3 (8000 animals) - Suspended cultivation

After 9 months of suspended cultivation batch 3 was sub-divided into two separate batches which were ongrown using the same techniques as batch 1 and 2.

Batch 3A - Tray cultivation

Batch 3B - Plot cultivation

Both tray and plot cultivation were undertaken within the North Channel of Loch Moidart, and suspended cultivation in Loch Ceann Traigh (Figure 1).

The North Channel site consisted of a gently sloping and sheltered foreshore of coarse sand and gravel. Maximum water depth over the plots and trays during a spring tide was approximately 4m. Surface water salinity in the area was not recorded during the trial, but previous studies have shown it to range from 23-35‰ on an annual basis (Edwards, 1976; 1978; Sherwood, 1976). The suspended cultivation in Loch Ceann Traigh was carried out 10m below the waters surface where the salinity was unlikely to have varied from that of the open sea (35‰).

Tray cultivation consisted of the use of plastic trays of 415mm x 715mm x 107mm internal dimensions filled with 40-50mm of substrate. The trays were secured to trestles of 0.5m height made from 12mm round steel bar and placed on the foreshore near mean low water spring (MLWS) tide level. The substrate within the trays was taken from the same locality as the plots, and consisted of particles ranging from coarse sand to small stones (2-20mm). Initial stocking density of the trays was 800 manila clams m^{-2}. The trays were covered with plastic netting of 6mm x 8mm mesh size in order to prevent predation and 10mm drain holes were placed in the base of each to prevent water stagnation.

Plots of $5m^2$ were selected as near to MLWS tide level as possible, ensuring that sufficient time was available between tides for sampling and harvesting. Plot preparation involved the removal of predators by hand raking, and digging a trench around the edge in order to secure the predator netting, which was of the same type as used for the trays. The plots were seeded at a density of 800 Manila clams m^{-2}.

The seed initially grown in suspended cultivation was placed in Japanese pearl nets of 9mm mesh size, at a density of 4300 m^{-2} (500 $level^{-1}$). These were placed at a sheltered site in Loch Ceann Traigh on a sub surface longline, 10m below the waters surface. Subsequently the stock was transferred to tray and plot cultivation and seeded at a density of $800m^{-2}$ as described above.

Sampling of each batch was carried out on a regular basis throughout the trial. For tray cultivation, stock from 2 trays was removed by sieving the substrate and the number of survivors per tray noted. The shell length and total wet weight of each of the survivors was recorded. The stock was returned to its respective tray, with different trays chosen for subsequent sampling. Similar procedures were carried out for suspended cultivation stock when transferred to trays. However, the lower stock numbers necessitated that only 1 tray was sampled per sampling.

Sampling of plot cultivation stock was carried out at the same time as the trays. Quadrats of $0.09m^{-2}$ were randomly placed within the plot and the substrate within the quadrat removed to a depth of approximately 15cm. The Manila clams were removed by sieving, with the total number per quadrat, shell length and total wet weight of the individuals recorded. At each sampling 5 quadrats per plot were examined and the stock returned after measuring. The above procedures were also carried out for the suspended cultivation stock when transferred to plot cultivation.

For the suspended cultivation stock survival was assessed within each pearl net, with 2 nets randomly selected for measurement of shell length and total wet weight of the individuals.

At the completion of the trial all stock from the trays and plots was recovered and overall survival assessed. Samples of at least 100 animals were taken from each batch and shell length and total wet weight measured. A further sample of 50 animals from each batch was also assessed for the same parameters together with wet meat weight. This was carried out by removing the entire soft tissue of each animal.

3. RESULTS

3.1. Growth

The growth in shell length of manila clams under tray and plot cultivation throughout the trial, together with the final percentage survival, is shown in Figure 2. After 2 months growth stock within the trays had attained a larger average shell length than those within the plots. This situation was maintained throughout the remainder of the trial. The mean ($\pm$ 1 Standard Deviation (S.D.)) shell length of the tray cultivated stock was found to be significantly higher at the end of the trial than for the plot cultivated stock at 37.8 $\pm$ 3.1mm and 35.0 $\pm$ 3.8 respectively (t-test, $P < 0.05$). The same significant differences also existed with respect to the total weight and meat weight (t-test, $P < 0.05$ for each) with values (mean $\pm$ 1 S.D.) for tray cultivation of 13.9 $\pm$ 3.4g and 4.7 $\pm$ 1.3g respectively, and for plot cultivation 11.6 $\pm$ 3.2g and 2.4 $\pm$ 0.7g respectively. Final survival also differed considerably between the two cultivation techniques with 53% recorded for the trays and 25% for the plot. Within individual trays the survival was highly variable and ranged from 48-90% throughout the trial (Figure 3).

The growth in shell length of the manila clams in suspended cultivation and subsequently transferred to trays and a plot, together with the final percentage survival, is shown in Figure 4. During the 9 months period of suspended cultivation the mean ($\pm$ 1 S.D.) shell length increased from 14.8 $\pm$ 1.4mm to 20.9 $\pm$ 2.7mm. However, by the end of the period the stock appeared mis-shapen in comparison to that in the trays and plots. The suspended cultivation animals showed signs of the shells "balling up" with the free edges of the valves beginning to curve inwards. The extent of the problem is indicated when individuals total weight in relation to length, for the suspended cultivation stock

(Figure 5) is compared to that for the tray cultivation stock (Figure 6). The relationship between shell length and total weight for the tray cultivated stock was well defined within a narrow band of weights in relation to length (Figure 5). However, for suspended stock of similar length range, there was far greater variability of total weight at any particular length (Figure 5). The mean shell length of the tray cultivated stock was significantly larger, at 24.2 $\pm$ 1.9mm, than for the suspended stock (t-test, $P < 0.05$). There was also a significant difference between the two stocks with respect to total weight (t-test, $P < 0.05$) with the tray animals achieving a mean ($\pm$ 1 S.D.) of 3.1 $\pm$ 0.7g and the suspended stock 2.1 $\pm$ 0.5g. The survival of the suspended stock prior to being placed in a plot and trays was extremely variable between individual pearl nets, and ranged from 37-70% with a mean of 51%.

Within 3 months of being placed into a substrate the suspended/tray cultivated stock had achieved a greater average shell length than the suspended/plot stock (Figure 4). This general relationship was maintained throughout the remainder of the trial. The average shell length of the suspended/tray cultivated stock was significantly greater than for the suspended/plot cultivated stock at the end of the trial at (mean $\pm$ 1 S.D.) 37.6 $\pm$ 3.2mm and 36.2 $\pm$ 4.4mm respectively (t-test, $P < 0.05$). However, there was no significant difference between the two stocks with respect to total weight at (mean $\pm$ 1 S.D.) 13.1 $\pm$ 3.4g and 12.5 $\pm$ 4.3g respectively (t-test, $P > 0.05$). The wet meat weight of the suspended/plot stock at the end of the trial was found to be significantly higher than that for the suspended/tray stock at (mean $\pm$ 1 S.D.) 4.5 $\pm$ 1.6g and 3.6 $\pm$ 0.8g respectively (t-test, $P < 0.05$).

3.2. Survival

The survival of the suspended cultivation stock for the period of plot and tray cultivation differed considerably between the two cultivation techniques with only 23% survival for the plot and 35% for the trays.

3.3. Ambient Conditions

The ambient seawater temperatures recorded at Ardtoe throughout the trial are presented in Figure 7. Mean monthly temperatures ranged from approximately 7-14°C with minimum and maximum values of approximately 5 and 16°C respectively. During 1988 mean monthly water temperatures only exceeded 10°C between June and October with a peak of 13°C in August. The following year a similar pattern occurred with the peak in July at 14°C. Mean monthly temperatures during 1990 were similar with a maximum of 14°C recorded in August and 10°C exceeded from May to November.

3.4. Size variations

The size frequency distributions for each of the stocks under cultivation at the end of the trial are presented in Figure 8. The proportion of the tray cultivated stock of > 39mm shell length was 29% in comparison to 8% of the plot cultivated stock. The tray cultivated stock also showed the lowest proportion of < 35mm shell length individuals at 13%, while the plot cultivated stock contained 41%. Similar relationships were apparent between the suspended/tray and suspended/plot cultivated stocks. However, the difference in the proportion of individuals of > 39mm shell length was smaller at 28% and 21% for suspended/tray and suspended/plot stock respectively. The difference for individuals of < 35mm shell length was also less at 13% and 32% respectively. Comparison of the tray cultivation and suspended/tray cultivation stocks shows them to be almost identical in terms of proportions of different size class animals with only a 1% difference between the 35-39mm and > 44mm shell length groups. Similar comparisons between the suspended/plot and plot cultivated stock show less conformity with the suspended/plot cultivation stocks having 13% more individuals of > 39mm shell length and 4% and 9% less individuals of 35-39mm and < 35mm shell length respectively.

3.5. Meat Yields

The relationships at the end of the trial between shell length and meat weight for each of the cultivation methods are shown in Figures 9-12. The relationship varied depending upon cultivation method, with the plot cultivation stock having a considerably lower meat weight yield for all size individuals in comparison to the other three stocks. For a standardised manila clam of 40mm shell length the mean meat weights were 5.1, 3.6, 4.1 and 5.3g for tray, plot, suspended/tray and suspended/plot cultivation respectively.

4. DISCUSSION

In terms of both growth and survival tray cultivation of manila clams was more successful than plot cultivation. However, initial suspended cultivation to produce larger seed, and hence attain superior growth and survival when placed in a substrate, was not successful.

The increased growth in shell length within 2 months of seeding shown by the tray cultivated stock, in comparison to the plot, indicates that conditions within the trays were more suitable for the stock to become established. However, this position was maintained, rather than extended, for both the tray/plot and suspended/tray/plot stocks. This indicates that while an initial advantage in terms of growth in shell length was conferred by the trays, this was not enhanced throughout the trial, with consequently only a small difference in shell length between the stocks at the end of the trial (≈ 3mm).

The major advantage of tray cultivation appears to be the protection afforded to the stock and resultant far higher survival levels. However, in terms of survival considerable differences occurred between trays, which serves to indicate inherent variability which is likely to occur regardless of cultivation technique. The exact reasons for the enhanced survival of tray cultivation stock are not known but it seems likely that reduction in predation pressure could have been a major factor. Potential predators of manila clams include crabs, starfish, benthic living fish and wading birds (Spencer, 1991). The placing of the trays on trestles and hence raising them above the seabed by ≈ 0.5m would deter the attention of fish, crabs and also wading birds. The fact also that the plastic netting covering the trays was ≈ 6cm above the substrate within the trays, would have prevented predators gaining direct access to the stock through the mesh as observed by Spencer et al. (1991). In comparison the protective netting was placed directly onto the substrate for plot cultivation. When submerged and feeding the siphons of the manila clams would have protruded through the protective mesh and would have been vulnerable to both fish and crabs.

At low tide when uncovered or partially submerged the stock would also have been susceptible to attack from wading birds.

Other factors relating to survival include stability of the substrate and smothering of the stock, together with environmental variables of temperature and salinity. With respect to substrate stability the need for careful site selection in relation to hydrographic factors and sediment type has been recognised to be of prime importance for the success of plot cultivation (Dravers, 1987, Kraeuter and Castagna, 1989, Malouf and Bricelj, 1989, De Valence and Peyre, 1990, Spencer et al., 1991). While the site chosen for the plots was inherently stable, tidal and wave action caused localised movements of the surface deposits. No smothering of the stock occurred but the small scale movements are likely to have been an additional stress in terms of disturbance. The substrate within the trays would have been subjected to far less disturbance, being protected from wave action by the tray walls. One major advantage of tray cultivation is that smothering of the stock by the substrate should never occur. However, survival in relation to ambient temperatures may tend to favour plot cultivation as opposed to trays. During the period the stock is uncovered at low tide, fluctuations within the trays are likely to be greater than for the plots, as the trays are exposed on all sides and not just from the surface. This is particularly important with respect to the winter months when air temperatures of <5°C and frosty conditions prevail. Conversely during the summer months air temperatures of >20°C, and direct heating of the substrate by the sun are likely to occur. Such problems in northern areas termed "winterkill" have been noted by Kraeuter and Castagna (1989). Plots by being part of the foreshore will in comparison have a far more stable temperature regime. Extreme substrate temperatures during the night in winter and afternoon in summer have been found to be lethal (Chew, 1989). During the present study there were no recorded instances of extremely cold and frosty weather coinciding with spring tides, and so the effect of such conditions on the tray and plot cultivated stock was not able to be assessed. However, it seems likely that survival in trays is likely to be adversely affected in comparison to plots.

There has been found to be a definite relationship between survival in plots and size at first seeding with the larger the seed the higher the survival (Paul, 1988, Spencer et al., 1991). The larger the seed however, the higher its nursery cost to the grower and so this needs to be balanced against the advantages of increased survival. In order to increase growth and hence survival the technique of initial suspended culture of seed was investigated.

The main problem associated with extended periods of growth with no substrate is shell malformation (Richards et al., 1980). Over the 9 month period in nets, such problems occurred and resulted in the suspended stock at seeding being smaller than that grown over the same period in both plots and trays. Survival of the suspended stock prior to seeding was also poor. The exact influence of shell deformation on this is not known but the conditions are considered to have been detrimental. It should be noted however, that a proportion of the mortalities were directly attributed to crab predation, the larvae of which had settled into the nets during the summer. Consequently the suspended cultivation of 15mm seed over a 9 month period was detrimental to the production of marketable stock, as even after re-seeding the stock showed higher mortality levels than the original tray and plot grown seed. It may still be beneficial however, to use some form of suspended cultivation to increase the stock size prior to seeding, but this should possibly only be undertaken with smaller seed and/or for a shorter duration. It should also be borne in mind that active predator exclusion/removal is likely to be needed.

With respect to temperature it has been found that manila clams show little growth below 10°C but good growth at 18°C (Utting 1987, Chew, 1989) with growth continuing at up to 25°C (Dravers, 1987). Monthly seawater temperatures at Ardtoe were found to exceed 10°C and 13°C for only 6-7 months, and 3 months, respectively each year, with a maximum mean monthly temperature of 14°C. Consequently scope for growth in terms of temperature was extremely limited and seasonal. The best growth was achieved under tray cultivation with 29% of the stock of marketable size (> 39mm) after 30 months. Growth in shell length slowed during the second twelve months in comparison to the first which is indicative of natural reduction in growth rate with age, as opposed to the direct effects of temperature. Based on predicted growth rates for the stock a further twelve months of tray cultivation would be likely to be required to achieve 80% of the stock at > 39mm. Consequently between 36-48 months seems likely to be required to ensure that the majority of stock achieve a minimum size of > 39mm. This is far longer than achieved at other more southerly sites within the UK and Europe. Manila clams have been stated to reach this size in 18-24 months on the south coast of England (Wordsworth, 1990 pers. comm.) with 24-30 months required at other English sites (Spencer, et al., 1991). In France, growth from 17mm seed has been achieved in 12 months (De Valence and Peyre, 1990) although 16-20 months is more common.

In terms of meat weight yield the value of 5.1g for a "standard" 40mm shell length tray cultivated Manila clam is similar to the findings of Paul (1988) for plot grown stock from the same area. Consequently the trays are considered not to restrict the supply of food to the stock to any appreciable extent.

The reasons why the plot cultivated and the suspended/plot cultivated stocks showed the lowest and highest mean meat weight yields are not known. Both treatments were within 50m of each other on the foreshore and the final stocking densities were similar at $\approx 200\ m^{-2}$. Only 7% of the plot stock had achieved > 39mm by the end of the trial while for the suspended/plot stock it was 21%. This serves to indicate that even within small areas considerable growth variability can occur.

Based on average growth and survival data the total weight of Manila clams produced from 1 kg of seed has been estimated for each of the 4 treatments investigated (Figure 13). It can clearly be seen that tray cultivation results in the highest level of production which is greater than 2.5 times that of plot cultivation. The low production from both the suspended seed, tray and plot cultivation techniques is directly attributable to the high mortality levels associated with suspended cultivation. Consequently based on the results from the present study the cultivation of Manila clams in substrate filled trays is the best option to achieve maximum production.

One other advantage of the tray cultivation technique is the ease and efficiency of harvesting which can be achieved. While plot cultivation relies on the removal of stock by digging or dredging, the entire contents of each tray can be sieved to remove the clams, with the substrate returned to the tray. In this way 100% harvesting efficiency should be achieved, and the substrate within which the clams are grown can be chosen regardless of the characteristics of the foreshore. While small scale growers may choose to undertake sieving operations by hand the uniform nature of the trays easily lends to the use of simple machinery, which for large scale operations is likely to be a necessity.

It is extremely important to note that the present trials were undertaken on a very limited scale at a single site. One of the most important factors in determining the success or failure of a cultivation operation is the suitability of the site. This is particularly important with respect to plot cultivation and the nature of the foreshore in terms of the substrate type, wave exposure and tidal scouring. Other factors such as height above MLWS tides and the salinity regime, will also considerably affect the growth and survival of stock. With these factors in mind it should be realised that the present study serves to indicate the relative difference between two cultivation techniques at one site. The results from this study therefore need to be considered with those of other studies at different sites before the potential for Manila clam cultivation in Scotland can be fully assessed. However, this study has served to show that marketable size Manila clams can be produced in Scottish waters within a 4 year production cycle.

5. PRODUCTION COSTS AND VIABILITY

While the present study has indicated that production can be considerably increased by using substrate filled trays in comparison to plot cultivation, the economic viability of such a system needs to be considered as outlay is appreciably higher.

Obviously one of the critical factors for viability of cultivation is the market value of the product. The main market for clams from the UK is Continental Europe with France, Spain and Italy being major consumers. In the case of Manila clams this is particularly relevant as considerable wild clam fisheries exist in the Mediterranean Sea.

The level of supply of both wild and cultivated clams to these major markets can dramatically effect the value of the product. An example of price instability and supply of Manila clams from commercial fisheries is given by De Franssu (1990) for the Italian market. Live imports of the Palourde (Tapes decussatus) into Italy totalled about 3-3500 MT annually during the mid 1980's, coming mostly from Tunisia, Albania and Turkey. Imports from Turkey however, declined from 3500 MT in 1987 to only 1100 MT in 1988 causing a sharp rise in price. Substitution of other similar clam species including Tapes philippinarum caused a price increase for the species. Conversely since 1989 clam prices steadily declined due to the increased success of commercial fisheries in several Mediterranean countries. One example of this is the situation in Italy itself. During 1983 some farmers began cultivation in one small area using imported French seed. This resulted in the escape and settlement of spat with the formation of naturally sustaining beds in the River Po Delta. By 1987 a commercial fishery had begun to exploit the resource which caused a sharp decline in clam prices during 1989.

The Italian situation is indicative of the markets in both France and Spain and so values of £4-5 kg^{-1} for Manila clams relevant to 1987/88 need to be considered in relation to the low values of £2-3 kg^{-1} apparent during 1991/92.

With respect to potential markets within the UK the value of the product can vary dramatically. There is no large wholesale market for clams and consequently sales are typically small scale and local. Hotels, public houses and restaurants are the most likely purchasers, but volumes are only likely to be small (<20 kg). Consequently there may well be scope for individual growers to supply such outlets on a regular basis with the clams attracting a premium price (£5-6 kg^{-1}).

The following production cost figures are based on the 1991 costs for materials and an assumption of labour being available at £3/hour. No account has been taken of the cost of borrowing capital, transport costs or general overheads. From January 1st 1993 the sale of bivalve molluscs within the EEC will be regulated by the EEC directive 91/492 which stipulates hygiene requirements (Anon, 1991). Shellfish grown in waters other than those of class (a) will be required to be purified prior to marketing which will be an additional cost which has not been taken into account.

Plot and Tray Cultivation Production Costs

Table 1 indicates the relative inputs of capital and labour to establish, and maintain to harvest, a 10 m^2 plot and an equivalent area of trays. The following assumptions have been made based on experience to date. (i) Seeding density of 800 m^{-2} using 15mm stock at £17/1000. (ii) Protective plastic netting at £0.40 m^{-2}. Requires changing once during production cycle for plot cultivation. (iii) Plastic tray at £7.50 provides a surface area of 0.3 m^2. (iv) Steel trestle at £22 for 6 trays.

TABLE 1

	Cost $10m^{-2}$ (£)	
Resource	Plot Cultivation	Tray Cultivation
Seed	136	136
Predator net	15	8
Trestle/Trays	-	382
Labour		
Set up	3	6
Maintenance	21	12
Harvesting	8	6
Total Cost	183	550

It can be seen that the capital cost of the trestles and trays is excessive in comparison to the capital required for plot cultivation. However, it needs to be noted that both the trestles and trays should be serviceable for at least 3 production cycles (12 years) and consequently this should be taken into account in the long term production costs.

Based on the percentage survival and marketable yields achieved during the present study, and assuming a seeding density of 800 m^{-2}, Table 2 indicates the relative market values which Manila clams would have to achieve in order for cultivation to financially break even.

TABLE 2	Plot Cultivation	Tray Cultivation
% Survival	25	53
% marketable	65	91
Total Production (kg $10m^{-2}$)	26.0	77.2
	Revenue Break Even Value of clams (£kg^{-1})	
Over 1 Production cycle	7.04	7.12
Over 3 Production cycles	7.04	3.77

In relative terms the cost of tray cultivation decreases with each production cycle as the equipment has already been purchased. However, these figures, as previously stated, do not include the cost of borrowing or take account of inflation. Consequently it can be seen that at the very minimum the market value of Manila clams would have to be £3.80 kg for tray cultivation to break even over 3 production cycles.

The value of Manila clams is controlled by market forces and consequently it is more realistic to consider factors which the grower has some control over in order to assess the economic viability of a cultivation technique. Table 3 indicates the percentage survival of stock required in order for either plot or tray cultivation to break even. The proportion of the stock of market size at harvest for each cultivation technique is based on results from the present study.

TABLE 3	Plot Cultivation		Tray Cultivation	
Manila Clam Value Kg^{-1} (£)	2	5	2	5
% Survival required to break even over 1 Production cycle	88	35	>100	76
% Survival required to break even over 3 Production cycles	88	35	100	40

Based on a market value of Manila clams of £2 kg^{-1} survival levels during a production cycle for plot cultivation would need to be far in excess of those recorded during the present study in order to break even. However, with a market value of £5 kg^{-1} the level of survival required is far more realistic. A similar situation exists with respect to tray cultivation over 3 production cycles, although slightly higher survival is required to reach a break even point.

It has been found that survival and growth rates of Manila clams do not vary appreciably in plots seeded at up to 1200 clams m^{-2} (Paul, 1988, Spencer et al., 1991). Based on the assumption that survival and marketable yields would not be considerably altered at 1200 m^{-2} in comparison to the 800 m^{-2} used in the present study, this may be one way in which profitability could be increased. However, upon examination such changes are actually only likely to marginally increase returns. For example the difference in survival level required to break even between a plot seeded at 800 and 1200 m^{-2} is only 8% based on a market value of £2 kg^{-1}. Consequently the manipulation of seeding density could be used to optimise the return from a particular site but is unlikely to significantly affect the overall profitability.

With respect to tray cultivation the high cost of the plastic trays is prohibitive to commercial use. In order to reduce this cost wooden boxes could be constructed. However, with a 4 year production cycle it is unlikely that they could be used more than once. Such a short lifespan would in fact make such an alternative more costly.

With respect to tray cultivation and survival levels achieved during the present trials, a market value of £5 kg^{-1} for Manila clams would at best only allow a cultivation operation to break even. While the use of trays has been shown to be able to appreciably increase stock survival the extra capital investment in equipment negates the value of the extra production. Consequently even with a relatively cheap tray system, cultivation is unlikely to be economically viable.

Based on current findings cultivation using conventional plots means that with a market value of £2 kg^{-1} survival levels in excess of 80% would be required to break even. This assumption relates to the fact that only 65% of the stock would be of marketable size at harvest. In warmer waters where a far shorter production cycle is possible it is likely that a higher proportion of stock would be marketable at harvest. Consequently with a figure of 90% marketable at harvest the break even point is reduced to ≈ 60% survival. It can therefore be seen that while plot cultivation in Scottish waters is unlikely to be economically viable based on the current market value of Manila clams, at a site in warmer waters it could be.

If the market value of Manila clams again rise to those previously reported (Dravers, 1987, Paul, 1988) plot cultivation in Scottish waters may become economically viable. However, considerable care will need to be taken in site selection and the maintenance of stock in order to secure high survival levels.

6. CONCLUSIONS

(i) The use of substrate filled trays has been shown to appreciably increase the survival of Manila clams in comparison to conventional plot cultivation.

(ii) In Scottish waters growth to market size is estimated to take 3-4 years, with tray cultivation yielding a higher proportion of marketable size stock at harvest in comparison to plot cultivation.

(iii) The use of trays while affording greater protection of stock in comparison to plot cultivation, is unlikely to be commercially viable in Scotland due to the higher capital investment required.

(iv) Based on current market values for Manila clams, plot cultivation in Scottish waters is unlikely to be viable as over a 3-4 year period high stock survival levels are required. If however, market values rise considerably and are likely to remain stable for at least the duration of a production cycle, the potential for Manila clams to be commercially cultivated in Scottish waters does exist.

(v) Plot cultivation is likely to result in lower marketable yields of Manila clams in comparison to the use of trays. However, far less capital is required to set up the plots and so this may well prove to be a more viable option under certain circumstances.

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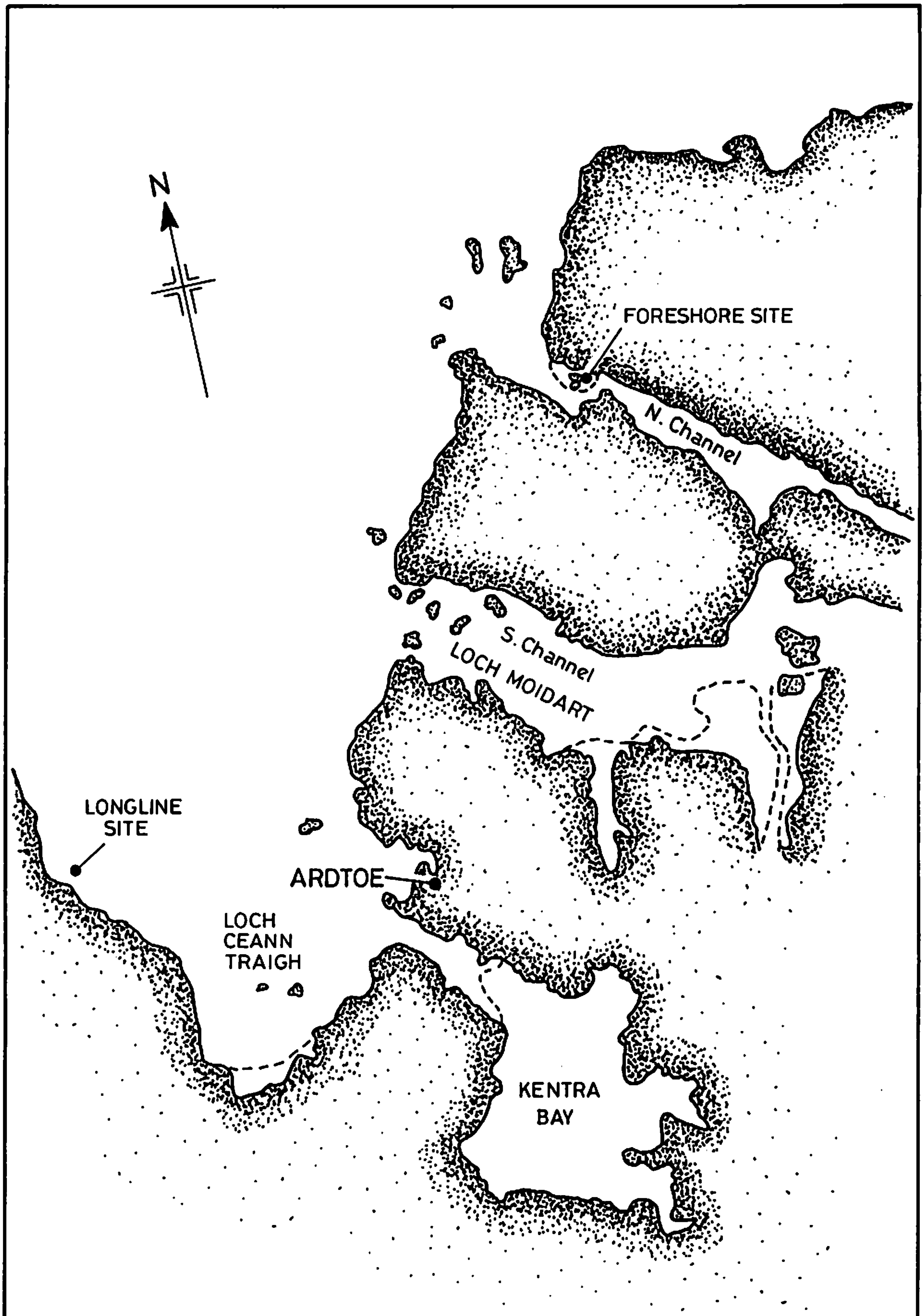


Map showing approximate position of ongrowing sites for scallops. Fig.1

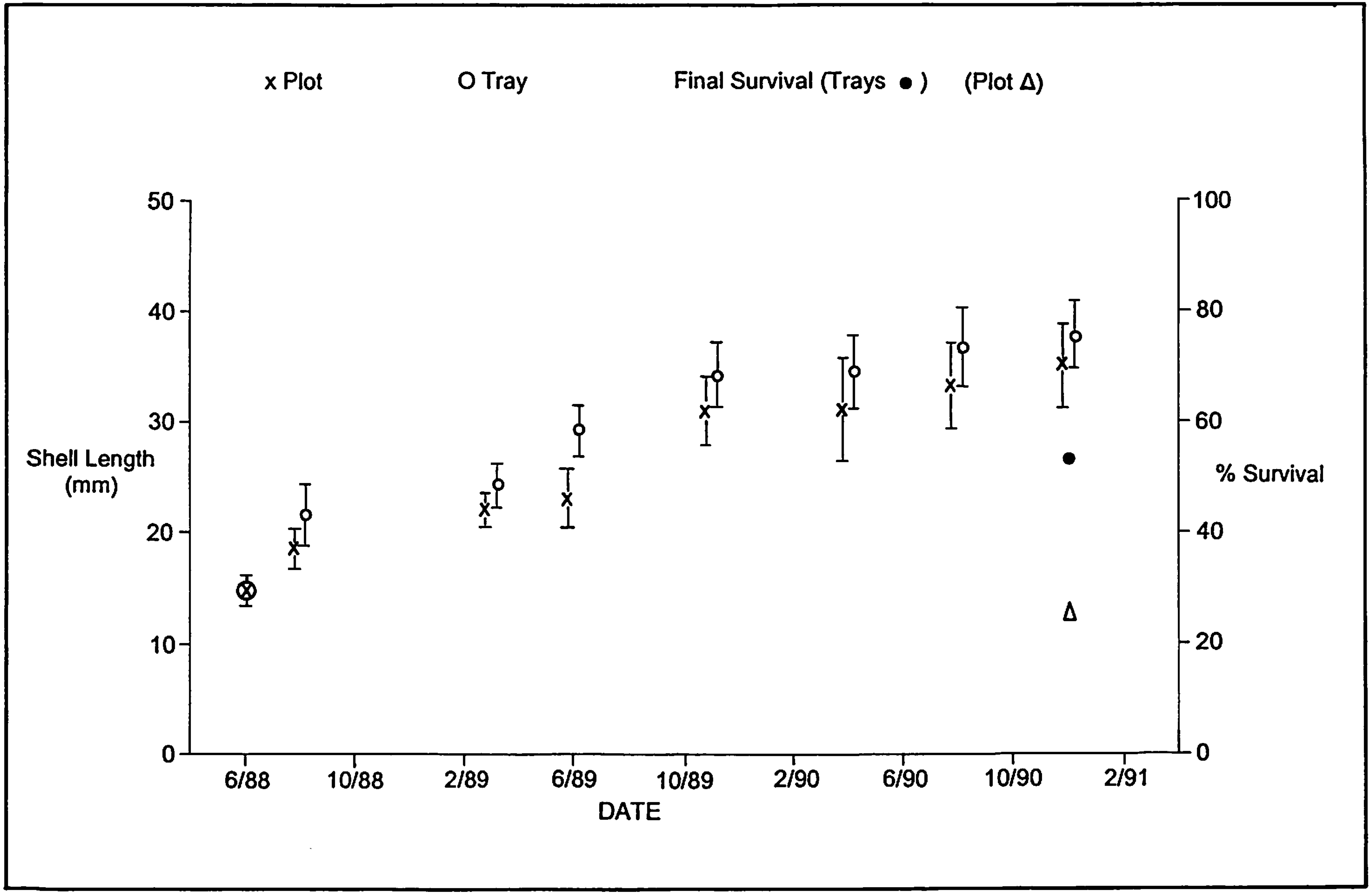


Figure 2

Growth in length (Mean ± ISD) measured throughout the trial for Manila clams in trays and a plot together with final percentage survival.

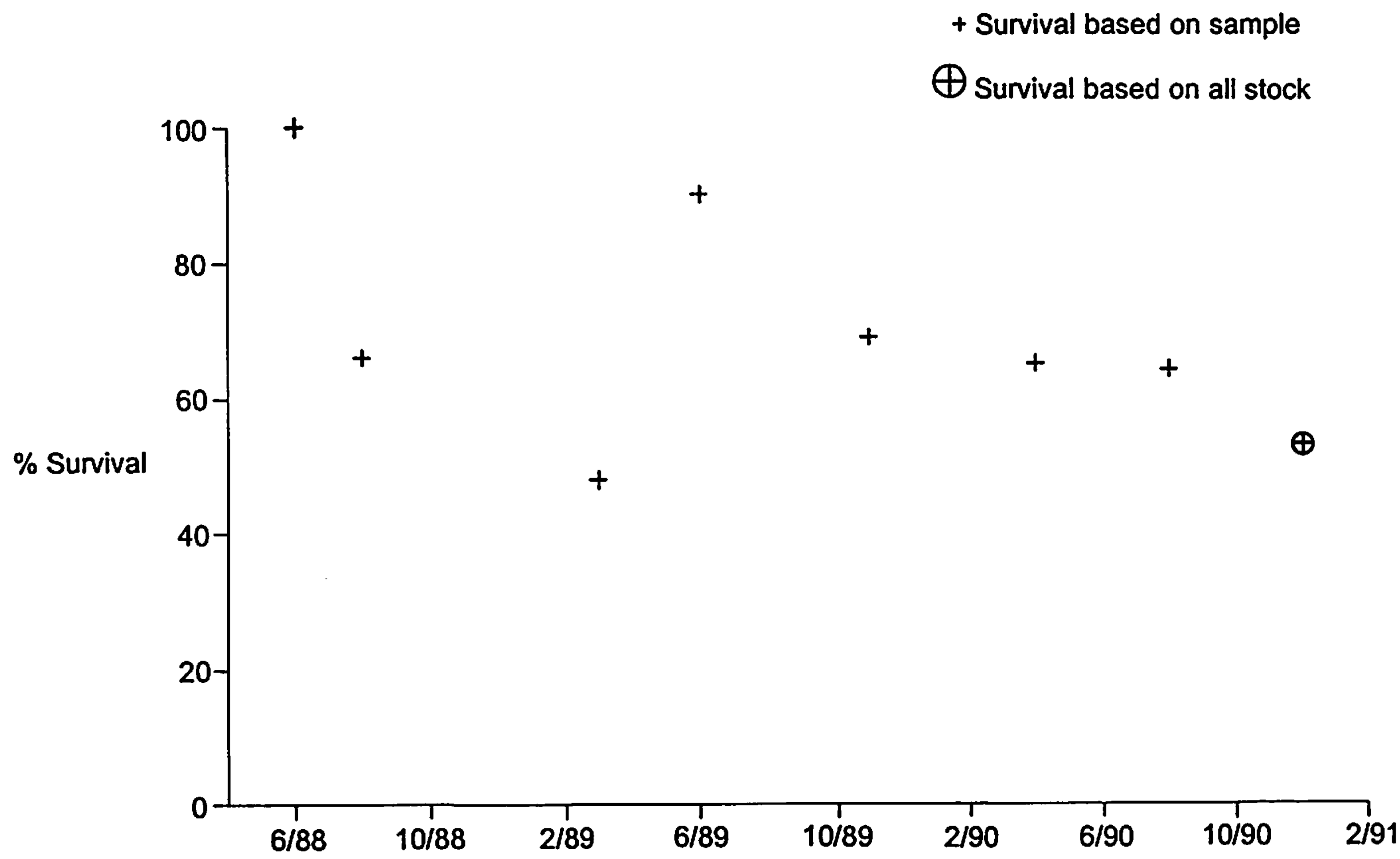


Figure 3

Survival of tray cultivation stock throughout the trial

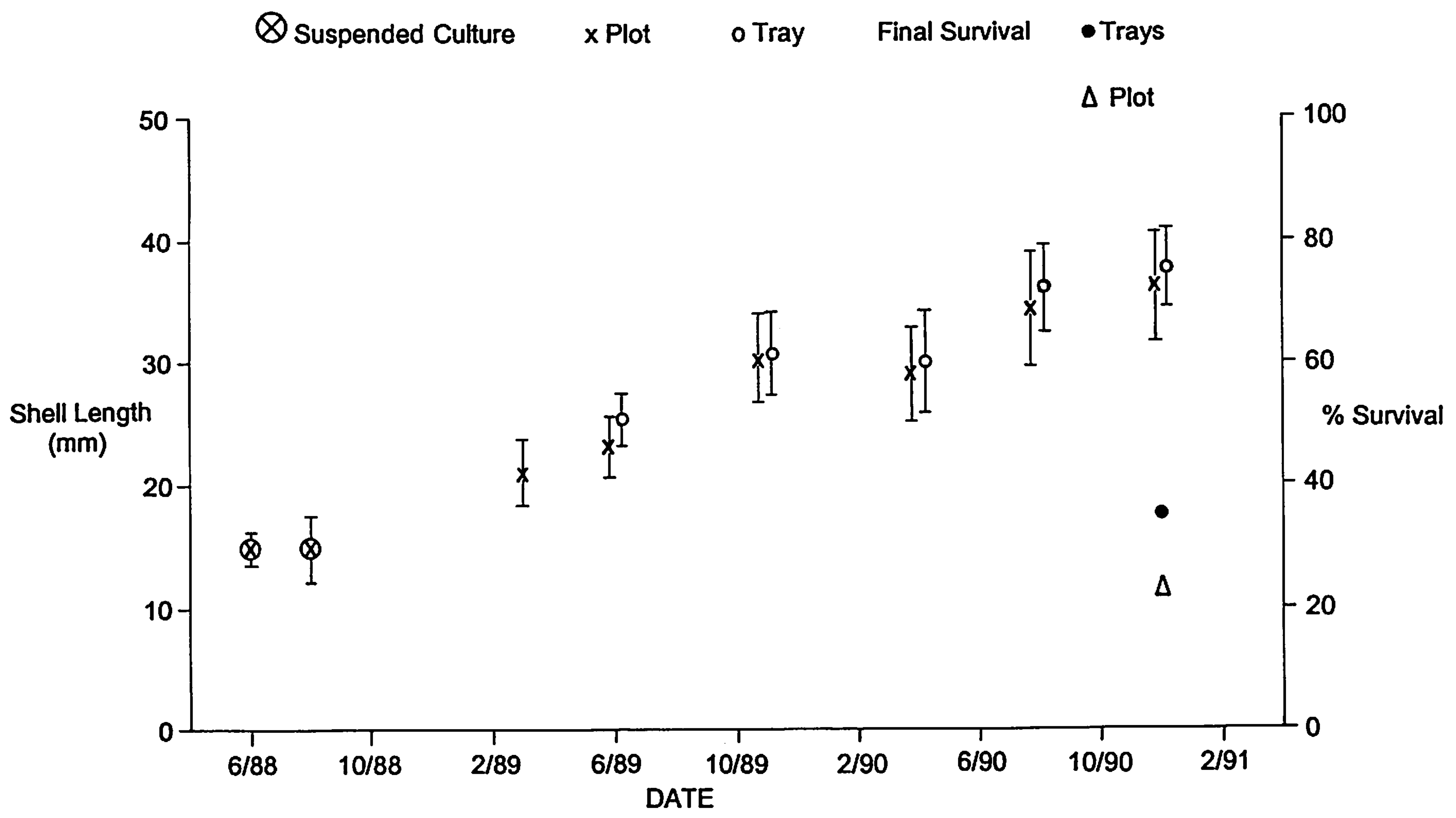
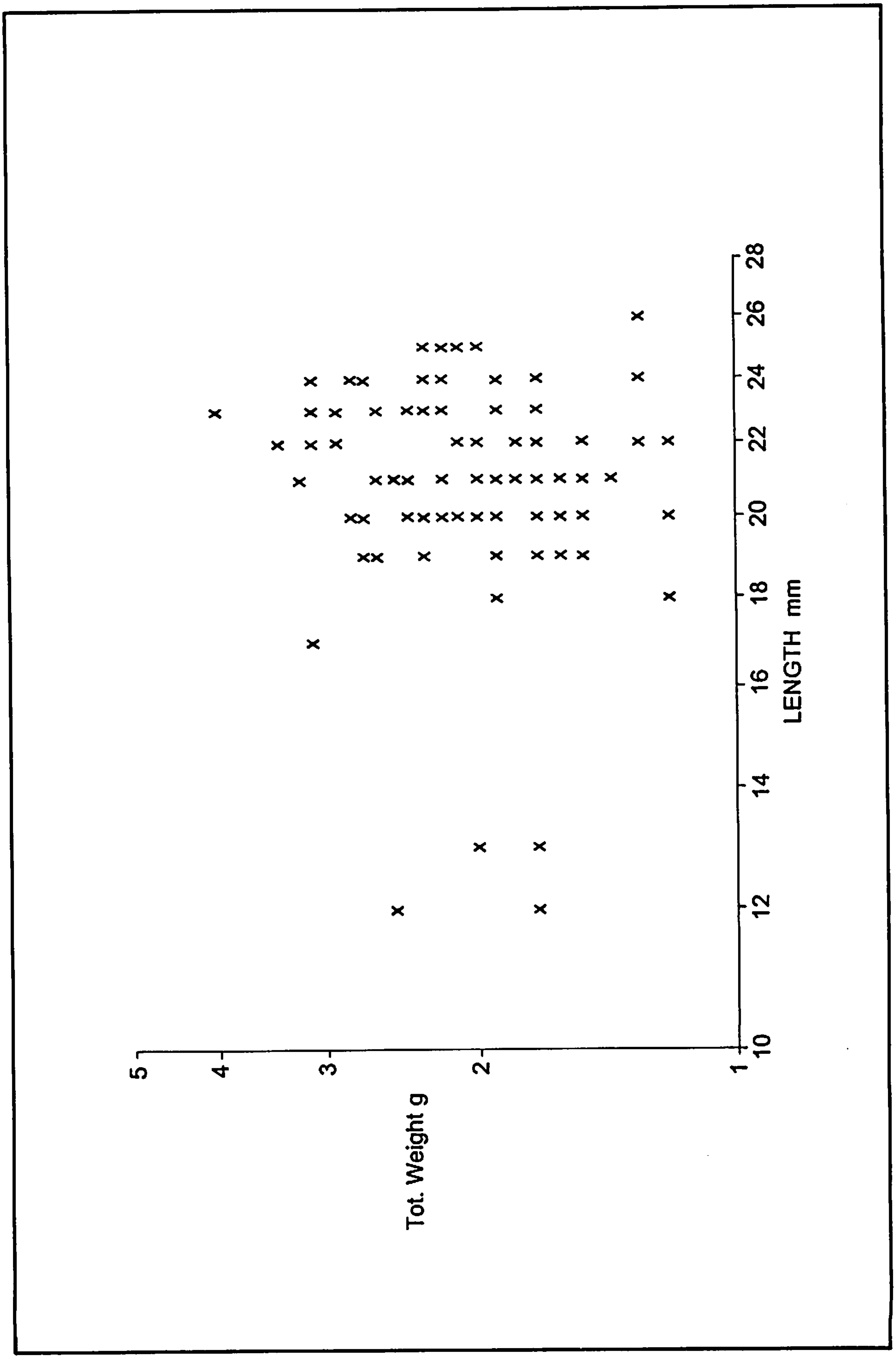
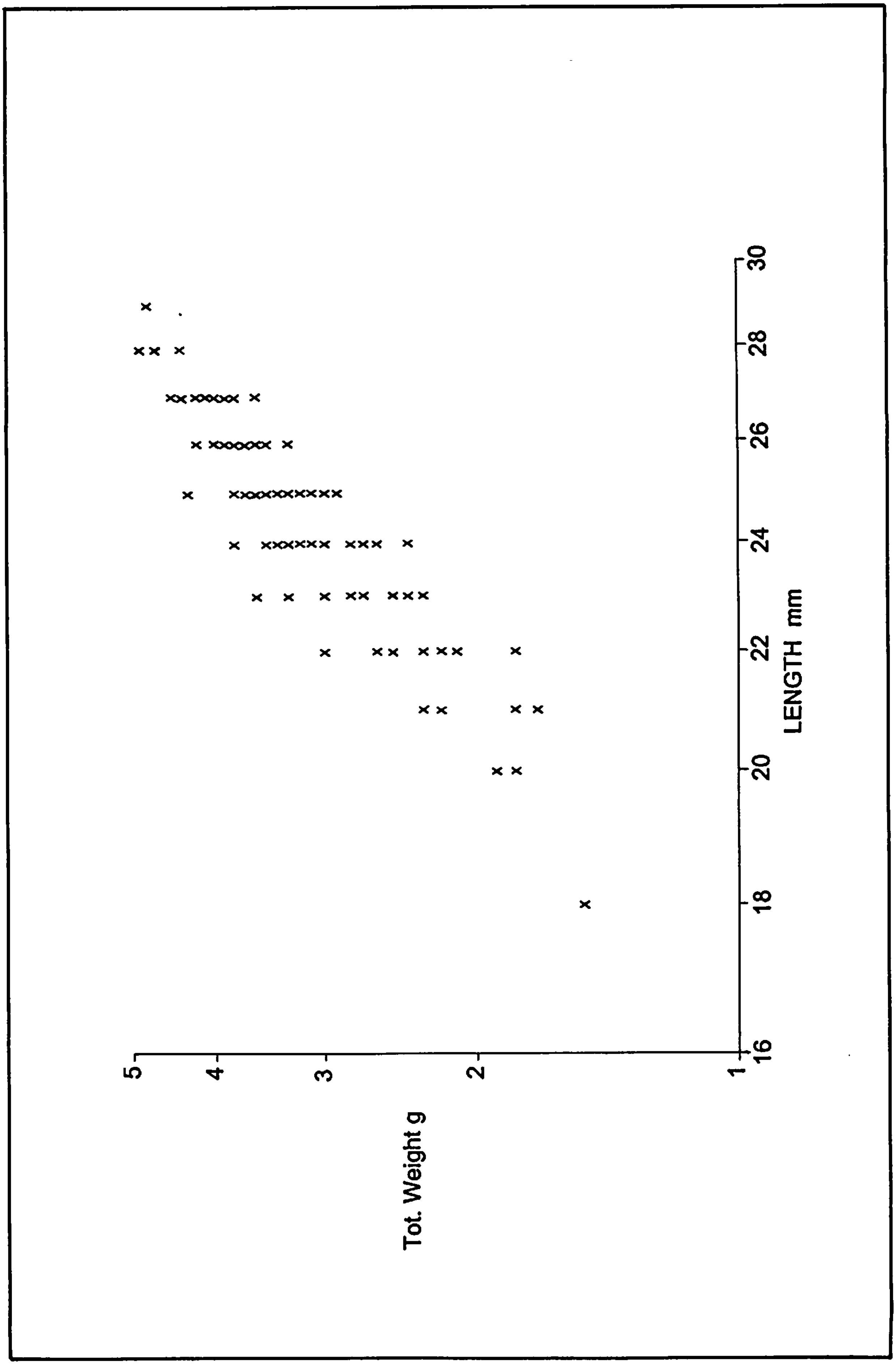


Figure 4

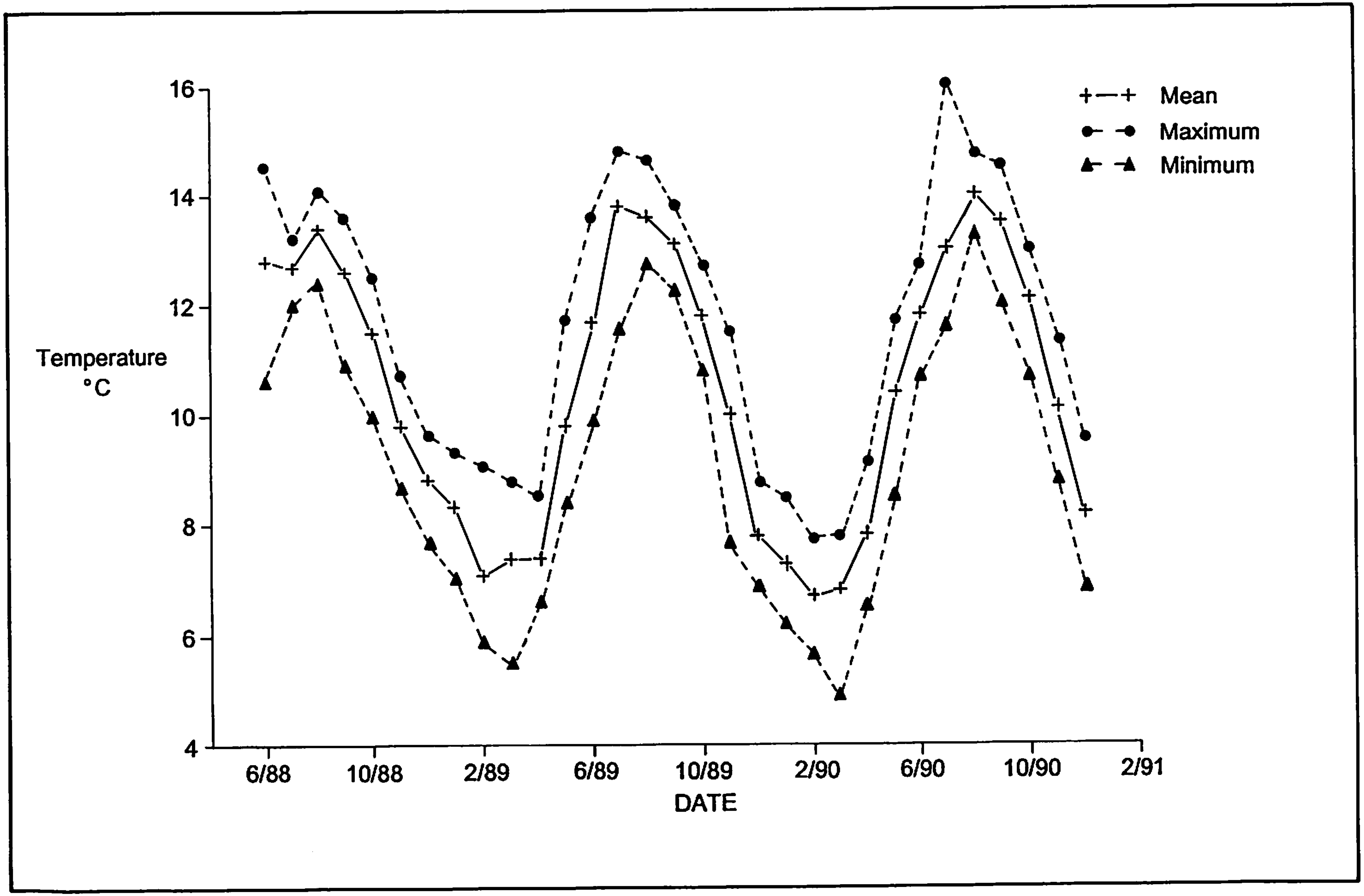
Growth in length (mean ± 1SD) measured throughout the trial for Manila clams in suspended culture and subsequently placed in trays and a plot, together with final percentage survival



MANILA CLAMS Suspended Stock 3/89 Figure 5



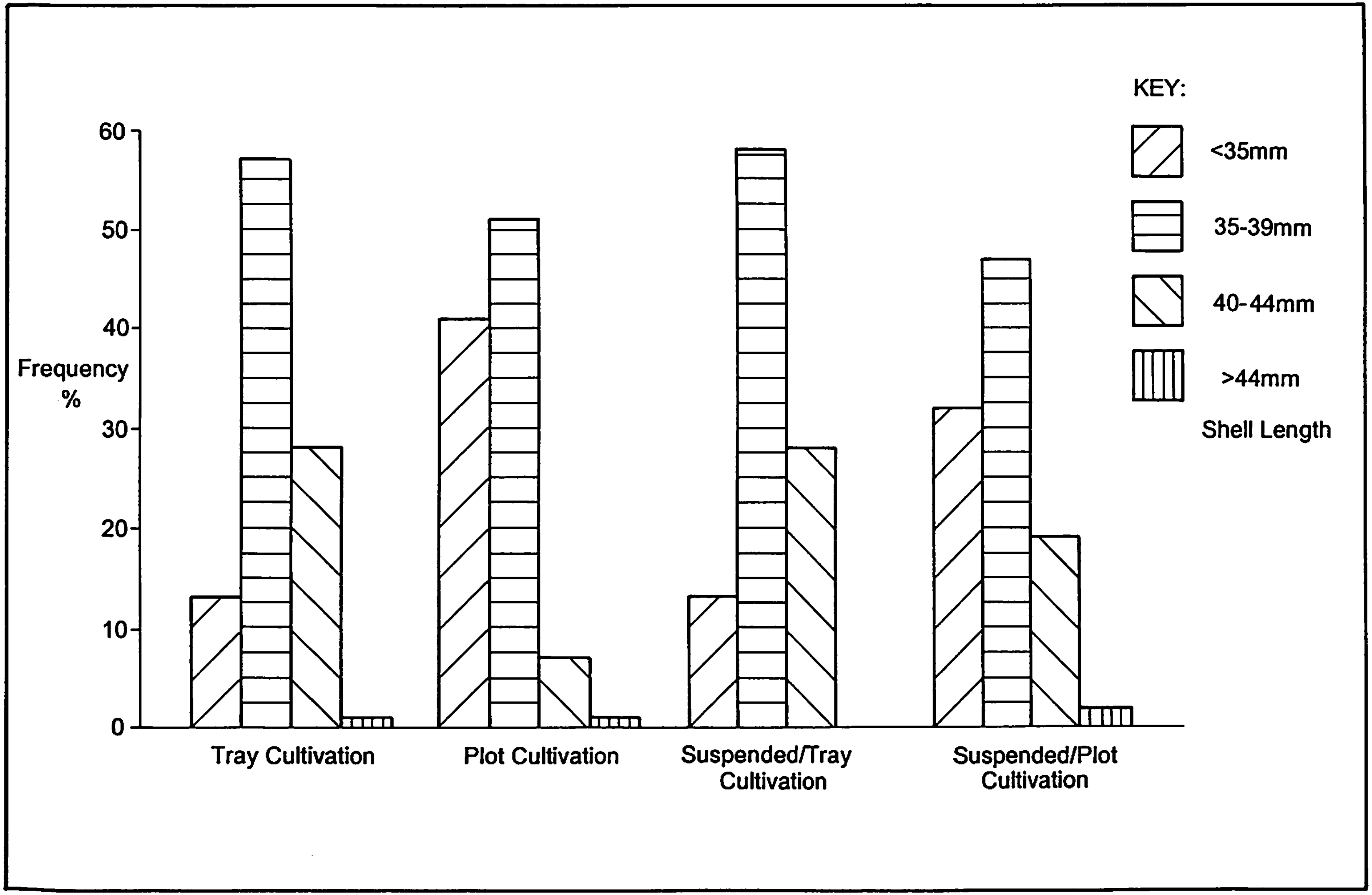
MANILA CLAMS Tray Stock 3/89 Figure 6

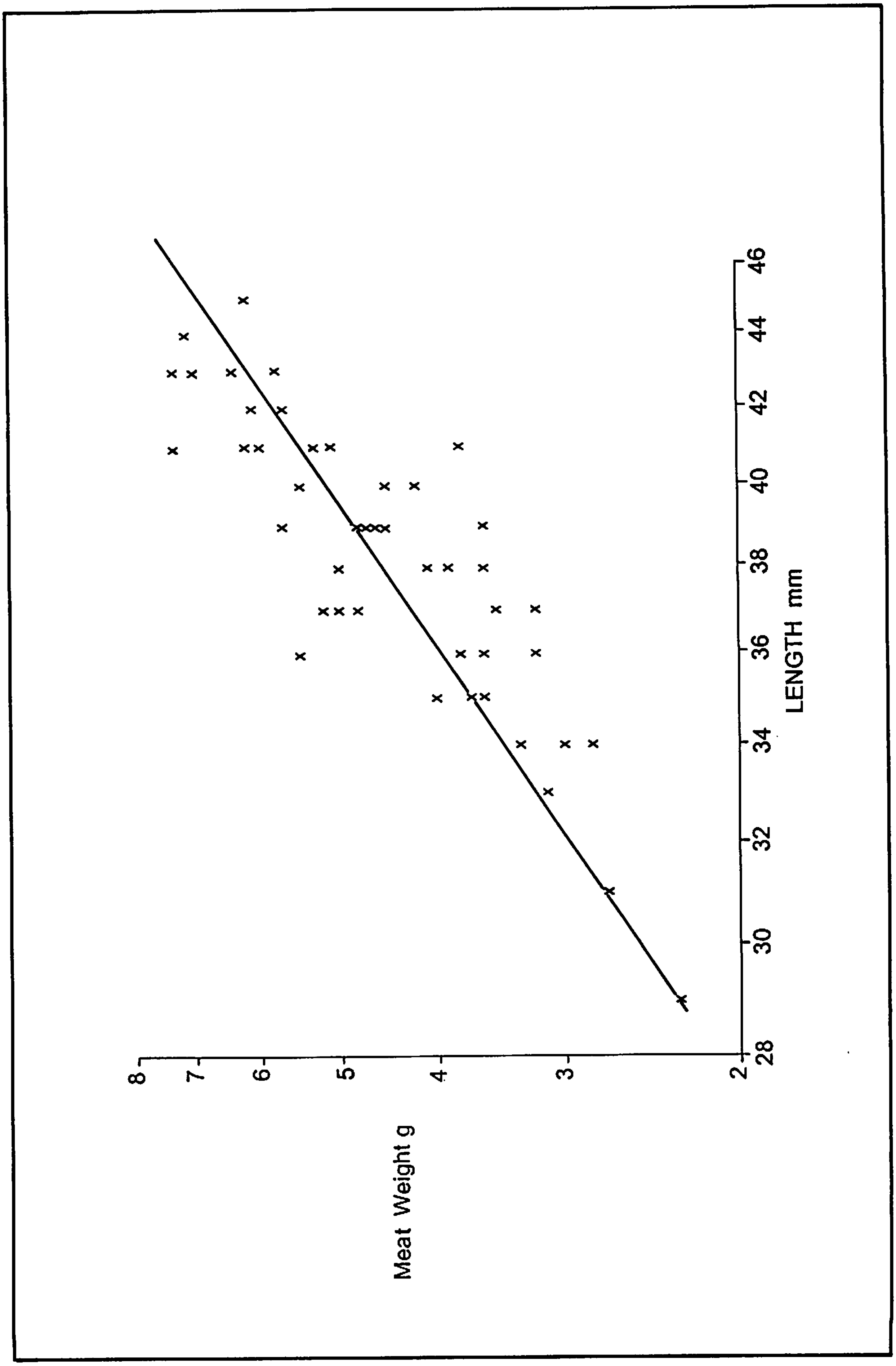


Monthly ambient seawater temperatures recorded at Ardtoe during the trial Figure 7

Figure 8

Shell length frequency distributions for each of the cultivated stocks at the end of the trial





MANILA CLAMS Tray Cultivation Figure 9

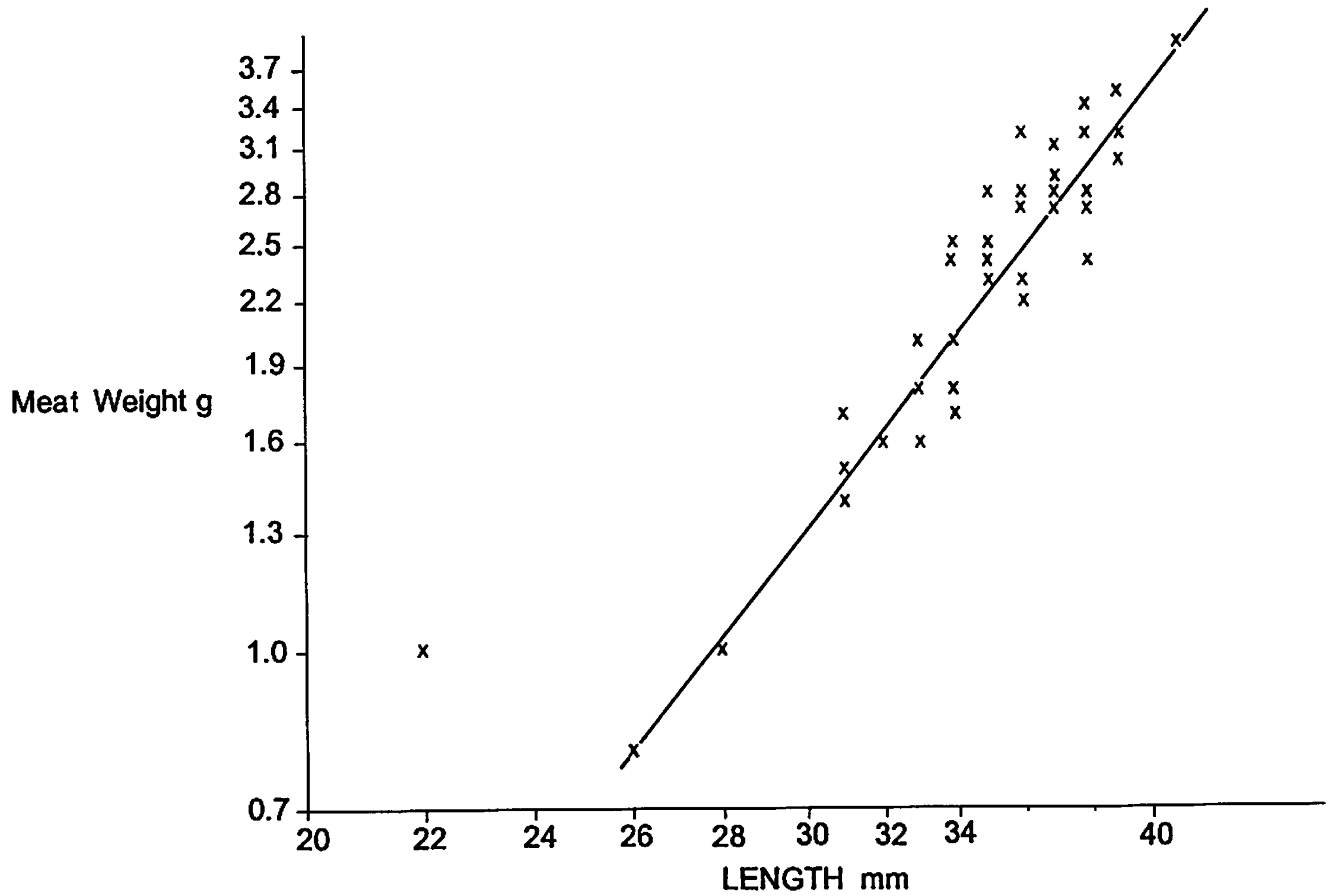
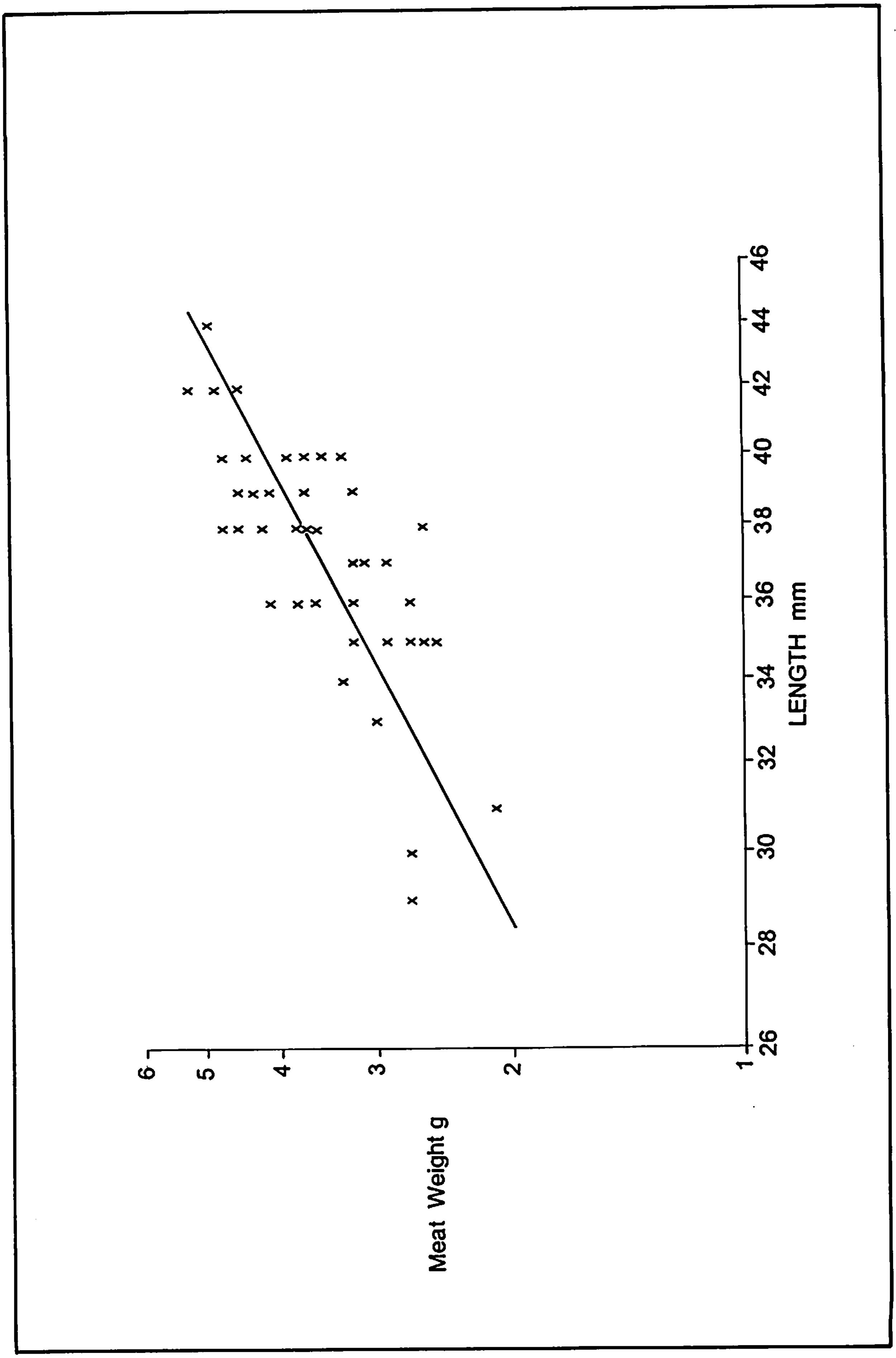
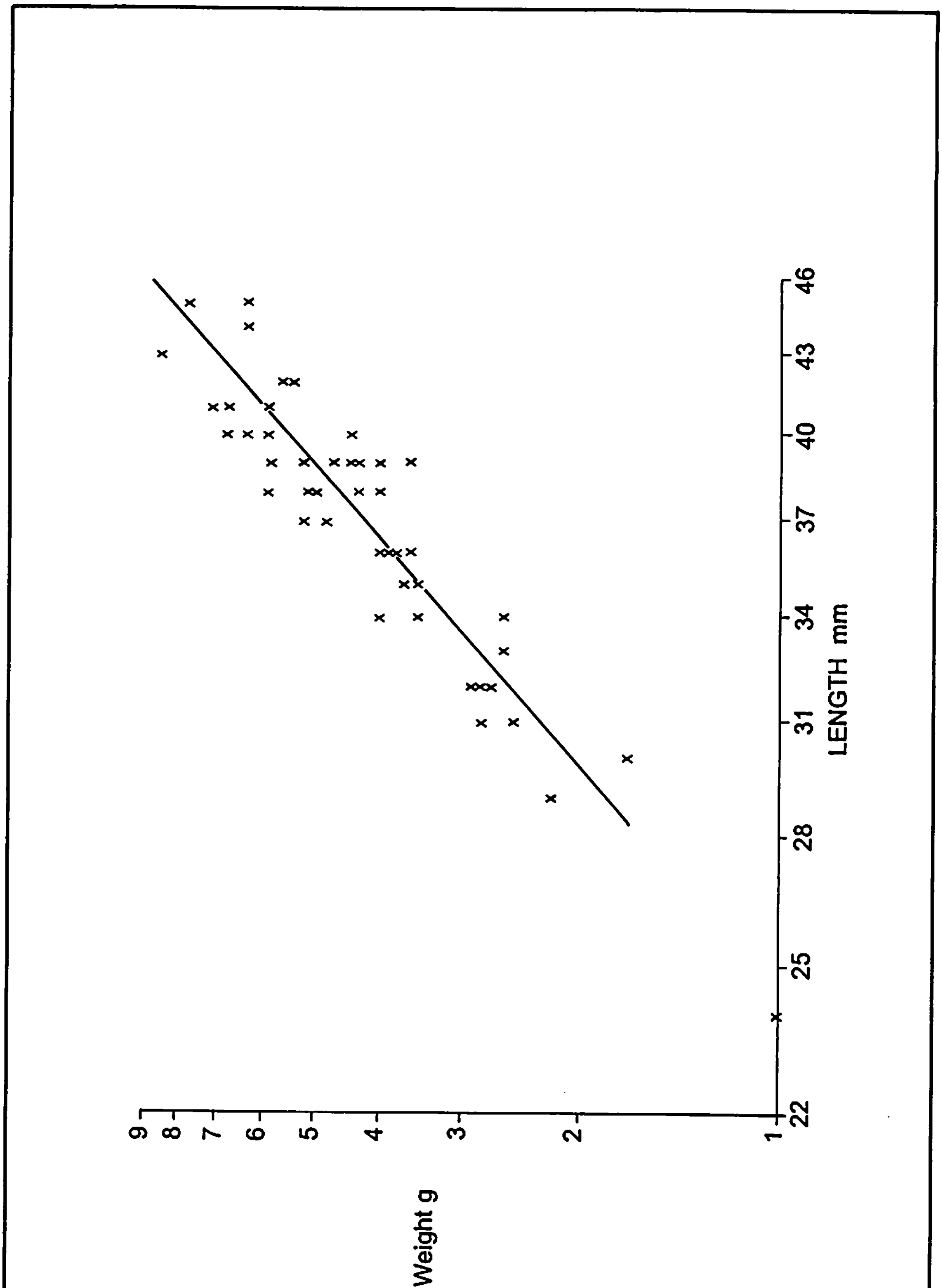


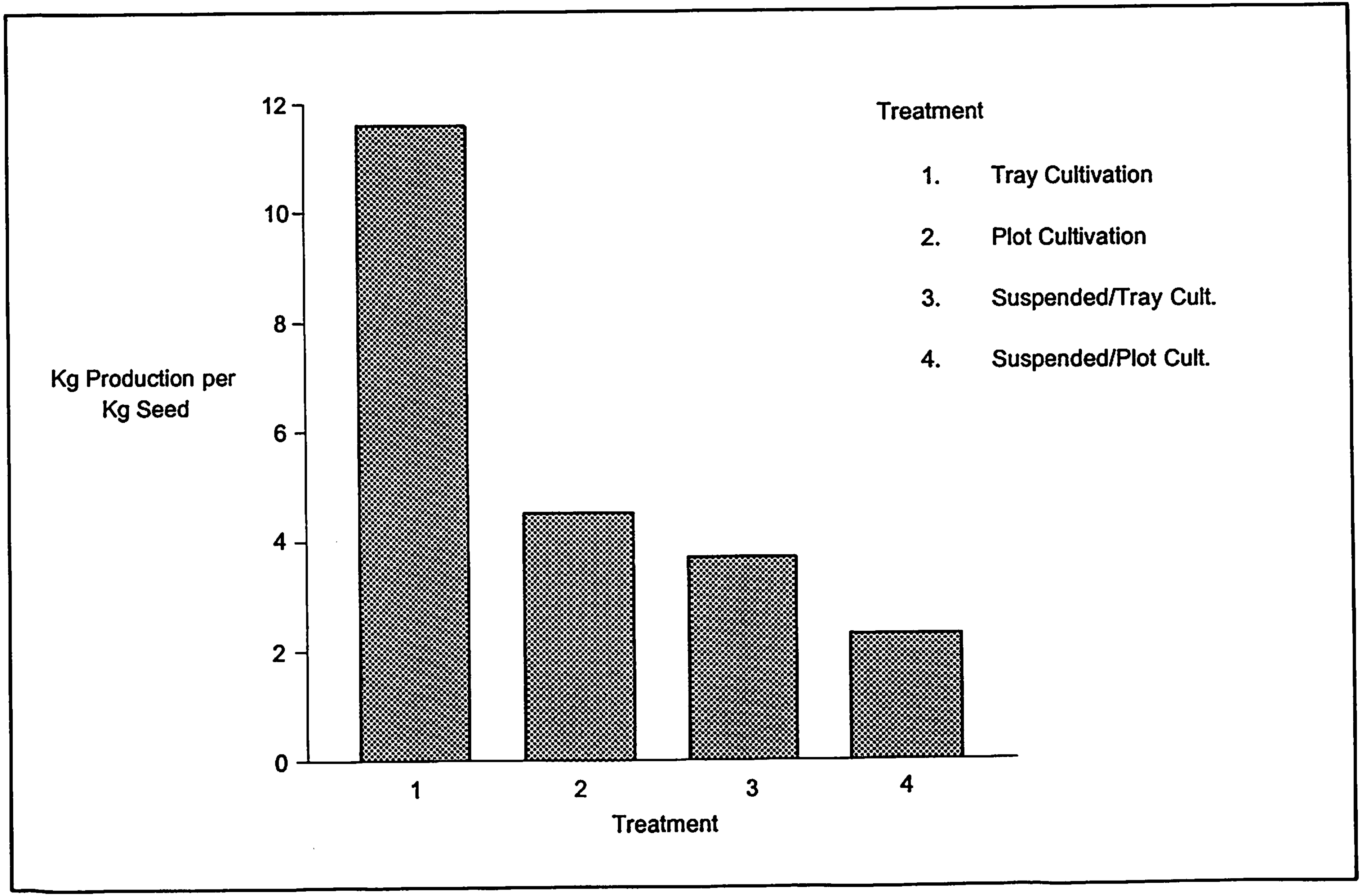
Figure 10 MANILA CLAMS Plot Cultivation



MANILA CLAMS   Suspended Seed Tray Cultivation   Figure 11



MANILA CLAMS   Suspended Seed Plot Cultivation   Figure 12



Estimated production from 1Kg of seed for each cultivation treatment based on recorded growth and survival (for relative production costs refer to Table1).
Figure 13