The Culture Performance of the Greenback Flounder (*Rhombosolea tapirina*) under Grow-out Conditions.

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OBJECTIVES:

1. To identify the suitability of various grow-out conditions including cage, tank, raceway intensive systems and pond extensive systems.

2. To assess the performance of juveniles in the above systems by measuring growth rates, survival, FCR and time to market size.

3. To determine additional parameters important to grow-out management such as feeding behaviour, feed wastage, disease susceptibility, degree of maturation.

4. To determine the market acceptance of the cultured fish.

NON-TECHNICAL SUMMARY:

Need for the Research

In 1993, a reasonable amount of information had been collected on the hatchery and weaning techniques, with small juveniles being grown at the University of Tasmania, Department of Aquaculture in Launceston and Tasmanian DPIF, Division of Fisheries at Taroona. This work was primarily based on the PhD studies of Piers Hart. The grant proposal was compiled because of encouraging data on the performance of juvenile flounder, interest generated by the project at the time, the declining flounder catch and the increasing development of flatfish such as turbot, halibut and Japanese flounder overseas.

The primary need for this project was to assess the level of suitability of greenback flounder for grow-out culture under a variety of culture conditions.

Summary of the results in relation to the original objectives:

* A variety of grow-out conditions were investigated, but the emphasis was on tank and raceway culture. Fish were introduced to an extensive pond system but this did not prove successful, with few juveniles being retreived. Due to the nature of the ponds (used for microalgal production to feed oysters) artificial feeds were not added, the fish relying totally on natural feeds such as crustaceans in the system. The cage trials were made logistically impossible because of the threat to the seacage salmonid industry from the pathogen, *A.eromonas salmonicida* (non-furunculosis strain) which has been detected in flounder in other systems. All infrastructure necessary for the cage trials is located on salmonid farms.

* Market size fish were produced within 20 months of hatch; these represented the upper grade of the grow-out fish. These may only be classified as fish of minimum size being 200 - 300 g.

* A depression in growth rate at Dunalley during May-November in 1995 may have been due to maturation/spawning, low water temperatures (<10^{o}C) or poor water quality. Although in their early stages, the performance trials at Pipe Clay Lagoon where the water quality is good, indicate improved growth rates in summer compared to the same period at Dunalley last year, but depessed growth was also experienced during winter. Growth in juveniles at St Helens was not depressed during winter but water temperatures were higher during this period.

* Prior to the depression in growth at Dunalley, juvenile fish grew from an average 35 g to 100 g in 4 months.

* Maturation levels of 83% were detected during one sampling during winter. The percentage of mature fish probably varies over a wide spawning season (April-October). Although maturation contributes adverse effects on production, a broad spawning season enables juveniles to be produced throughout most of the year once spawning and fertilisation techniques are refined.

* Groups of fish growing in a recirculating system at densities in the range 1-15 kg/m^2 did not show any substantial difference in growth.

* Feed wastage can be minimised by delivering numerous meals throughout the day. In addition the current should not be too strong as to sweep the pellets down the outlet i.e. the pellets must stay in the tank long enough to be consumed. High water flows may be required during heavy stocking levels where oxygen is a limiting factor. Supplementary oxygenation may be used as an alternative to increased water flows in relation to high stocking density.

* Flounder do not appear to be susceptible to pathogenic infections. Although *Aeromonas salmonicida* has been detected in two isolated cases, it has not been detected in this study even though moribund fish were sent to Mt Pleasant Fish Health Laboratories for analysis.

* Flounder appear to be susceptible to external parasitic infection from *Trichodina*; these infections affect the feeding behaviour and can kill fish. They appear to respond to treatment with malachite green/formalin baths, but an alternative treatment will be necessary in the future because of the nature of the chemicals.

* Feed conversion ratios (FCR) obtained during the trials have been variable but under controlled feeding (rather then feeding to excess) the FCR values have been around 1.5:1. Other figures during normal grow-out reached a maximum of approximately 2.5:1.

* A preliminary market assessment and a sensory assessment were conducted by the Centre for Food Technology in Brisbane, the results form separate reports prepared by Bronwyn Warfield and Roger Tomes, and Anne Ford and Rob Roberts respectively. Cultured greenback flounder may provide a replacement for the New Zealand imports into Australia. The best export markets appear to be Asia and perhaps North America. In Japan, high prices are obtained for a variety of right-eyed flounder species and this market should be further investigated. Flounder appears a good candidate for live tranport; live and large flounder attract the best prices in the market.

Further work needed

* Sub-optimal growth due to nutritional, feeding and maturation problems needs further investigation. A specifically formulated diet has not been developed for this species. In addition, little is known about its feeding behaviour, rhythms

and requirements. Low growth levels in winter appear to be due to maturation; triploidy techniques may be a possible solution to this problem.

* A significant level of mal-pigmented fish and spinal deformities have been observed in cultured fish, probably due to nutritional deficiencies and or larval developmental difficulties during metamorphosis. These problems require further investigation.

* Some sites are prone to flooding and the ability of flounder to osmoregulate and adapt to reduced salinities needs considering. Likewise, some ponds may be prone to evaporation resulting in elevated salinities.

* Although a preliminary market assessment has been undertaken, it is based on paper values and should be considered only as step 1. The next step requires the assessment of the actual cultured product in the market involving wholesalers, retailers and consumers. Sensory testing was undertaken in Queensland where a preference for large reef fish exists. This market is unfamiliar with flatfish, greenback flounder in particular. A further assessment conducted in the southern states where flounder is popular is recommended.

KEY WORDS:

Greenback flounder, grow-out performance, market assessment, sensory assessment

2. Background

Greenback flounder (*Rhombosolea tapirina*) shows the greatest aquaculture potential of the 'new' native marine finfish species currently being investigated in Tasmania. Research into this species started in the early 1980s with the work by Crawford (1984) but started seriously in relation to aquaculture objectives in 1989 with the PhD studies of Piers Hart on the development of hatchery protocols, followed by this initial FRDC grant on grow-out starting the end of 1993. At the same time, the Division of Sea Fisheries (DPIF) in Tasmania initiated a program of flounder culture in parallel with its striped trumpeter investigations. The overall assessment of flounder as a potential aquaculture species was originally outlined in Hart et al. (1993) and placed in context with other Tasmanian species in Searle and Zacharin (1994).

The FRDC program has concentrated on the grow-out performance of juveniles under a range of culture conditions: tanks, raceways, ponds and cages; the results being presented below. Of these, cage trials have not been undertaken to date because of the identification of potential disease transfer implications to salmon (Aquatas Pty Ltd were going to undertake these trials) and because of the lack of cage maintenance infrastructure on oyster leases where research was conducted. Small scale cage rearing of juveniles within tanks has been undertaken successfully by DPIF. Investigations in the overseas flatfish industries show that tank and raceway culture are favoured and sea cages are only used in experimental trials or where land for tank culture is in short supply or expensive (Hart, 1995).

Perceived market prices

Preliminary market enquiries indicate that the price of flounder is quite low for small, frozen fish but is relatively good in the speciality markets which demand large fish (500 gr+) and live fish. Prices in Asia for live flounder appear to be in the range A$10-15/kg (relatively high volume) and $12-25/kg in Australia. Wholesale prices for fresh fish appear to be around $6-10 / kg. Recent enquiries with a Korean processor visiting the University indicated that flounder without blemishes could fetch prices of A$30 /kg in

Korea. In Europe, the expanding turbot industry produces 3,000 tonne annually for a farm-gate price of A$10 /kg for 1 kg fish (Hart, 1995).

Experimental trials to date have shown that flounder can be transported live quite easily; the precise limitations are currently being examined at the University. There also appears to be a reasonably large and regular demand on the domestic market for chilled "plate size" fish of around 300-400 g but the supply and fish size must be consistent. There is also some indications that small fish with roe may be a specialty product in specific Asian markets. Enquiries concerning flounder culture and associated products have been received from Tasmania, mainland Australia, USA, New Zealand, Korea and Japan.

A secondary market assessment and sensory testing has been undertaken by IFIQ as part of this program - the results have been documented in separate reports, with a summary being included in this report.

Purpose and significance

The culture of flounder in shore-based facilities such as ponds, tanks and raceways actually improves the opportunity available to develop this species because of

(i) the limited availablity of cage leases in Tasmania and other south-eastern states,
(ii) the ability to integrate it into existing operations or establish polyculture situations and
(iii) the ability to treat effluent, reducing the objections in relation to environmental impact associated with aquaculture.

The oyster growers view flounder culture as a means of diversifying their businesses through the utilisation of sea leases, ponds or pump ashore facilities used in the culture of oysters. One oyster producer also has available extensive pondage which was once used for salt production. Expansion into flounder is seen as a good opportunity to diversify the business, using flounder as a species which is compatible with this under-utilised resource.

Despite the potential disease transfer implications to salmonids, many salmon growers also support the program because of the potential it displays; some of their infrastructure may be utilised in the future even if it is at a different site to the salmonids.

Some abalone growers have also made enquiries about the possibility of integrating flounder into abalone culture systems, however the tank design will be a influencing factor.

Flounder Characteristsics

In general, the flounder species and the program display the following desirable features:

* successful hatchery rearing; larval rearing using standard live feeds through to weaning onto artificial feeds have been conducted,

* can be grown under hatchery, nursery and grow-out culture conditions,

* a good candidate for on-shore culture where coastal seacage sites are limiting or are better utilised by other species (e.g. salmon, snapper),

* marketable product within a favourable timeframe,

* closed reproductive cycle; fertilised eggs have been obtained from cultured stock through hormone injection techniques and natural spawnings in tanks,

* long spawning season, April-December; it is possible that spawning periods may be manipulated by photoperiod control to extend this to year-round production,

* recognisable, marketable product, particularly in the southern states of Australia,

* favourable sensory test results; the cultured product compared well against wild flounder with no adverse off-flavours,

* flounder is a member of the flatfish group which is being extensively investigated worldwide for aquaculture,

* able to be integrated into shellfish (and finfish) operations,

* encouraging suggested market price, particularly for an aquaculture product of consistent size and quality, live in the market, which is distinct from the lower priced netted whole chilled product currently available,

* significant supportive research effort within other programs in Tasmania,

* significant industry interest and involvement.

Specific priority areas for further research

Some of the problems and areas for further research which have been identified are listed below. In most cases, a better understanding and improvement of procedures currently in place, is required.

* Nutrition - a formulated diet is required to overcome deformities and pale livers; this in turn will probably improve growth rates.

* Level and pattern of early maturation - need to assess its influence on growth but under ideal environmental conditions. Previous studies have been complicated by detrimental water quality conditions. The use of restricted rations and lights may be used to overcome early maturation in a similar manner to salmonids.

* Density - densities up to about 15 kg/m^2 have been trialed, densities higher than this and with lower water availability / oxygen supplementation need to be assessed.

* Deformities - close assessment of spinal and opercula deformities, may be linked with nutrition and/or sub-optimal environmental conditions.

* Feeding - feed delivery, pellet sizes (diameter, length), pellet texture, feeding behaviour (including hierarchies).

* Diseases - particularly *Aeromonas salmonicida*, *Trichodina*, microsporidian; effect on growth, mortality, transmission pathways, treatment; need a better understanding of these problems before preventative measures can be identified.

* Better resolution of spawning mechanisms; need an improved understanding of ovulation although eggs can be extracted from fish.

* Manipulation of spawning - in-tank spawning, extended season spawning; extended spawning periods allow almost year-round juvenile production.

* Grow-out parameters - better resolution of FCR, survival, growth, oxygen requirements, water requirements etc taking into account other factors above.

* Pond trials need further investigation. This was restricted by pond availability and absence of feeding structure in ponds.

* Cage culture requires investigation but is difficult at present with restrictions on the mixing of marine and salmonid fish on seacage leases.

3. Need

In 1993, a reasonable amount of information had been collected on the hatchery and weaning techniques, with small juveniles being grown at the University of Tasmania, Department of Aquaculture in Launceston and Tasmanian DPIF, Division of Fisheries at Taroona. This work was primarily based on the PhD studies of Piers Hart. The grant proposal was compiled because of the encouraging data on the performance of juvenile flounder, interest generated by the project at the time, the declining flounder catch and the increasing development of flatfish such as turbot, halibut and Japanese flounder overseas.

The primary need for this project was to assess the level of suitability of greenback flounder during grow-out under a variety of culture conditions.

4. Objectives

(i) To identify the suitability of various grow-out conditions including tank, raceway, cage intensive systems and pond extensive systems.

(ii) To assess the performance of juveniles in the above systems by measuring growth rates, survival, FCR and time to market size.

(iii) To determine additional parameters important to grow-out management such as feeding behaviour, feed wastage, disease susceptibility, degree of maturation.

(iv) To determine the market acceptance of the cultured fish.

5. Research Methods and Results

Experiment 1

The effect of stocking density on the performance of juvenile flounder

Introduction

The stocking density of the fish in the tank can have a major influence on growth and general performance. A high stocking density may inhibit growth through oxygen limitation, space interactions and competition for food. A low stocking density may provide space for the animals to grow but is usually uneconomical. At very low levels inefficient growth and poor feed conversion may be the result of a poor feeding response. As flounder occupy the floor of the tank rather than the water column it is probably more appropriate to refer to stocking density as kg/m^2 rather than kg/m^3. Identification of the maximum density for fish of specific sizes will enable the economics of an operation to be calculated as it relates to factors such as tank floor area, numbers of tanks and water usage.

Furthermore, oxygenation of the system may be used to improve growth or sustain a higher stocking density. Oxygen supplementation may also replace some of the pumping requirements in that the oxygen is supplied directly rather than via the water current.

In this experiment, various stocking densities were used to assess their impact on growth and general performance. This trial was established in a recirculation system and although it does not give absolute growth figures, the growth patterns may be viewed in a comparative manner. These trials were initially established in a flow to waste coastal site but suffered from severe temperature and oxygen fluctuation, compromising the results (see Trial A).

Materials and Methods

Eight circular Reln tanks with a useable volume of 270L/tank and an area of $1m^2$/tank were linked in a recirculating seawater system, housed in a temperature and photoperiod controlled room. The recirculation system was serviced by a pump, solids separation, sand filter, trickle biofilters, foam fractionators and pump.

A general rearing tank containing graded juvenile flounder with an average weight of 36-38g was used as a source of fish for the trial.

A stocking density of $20kg/m^3$, comparable with overseas flatfish culture systems, was used as the maximum initial density treatment. Other treatment levels were progressively halved giving the treatment densities of 20, 10, 5 and $2.5kg/m^3$ at the start of the experiment. Values were subsequently also converted to kg/m^2. Each treatment was undertaken in duplicate. The number of fish for each tank was calculated from the desired density divided by the average weight, rather than through mass weighing techniques. Fish were distributed randomly between the 8 treatment tanks with the actual densities being listed in Table 1.1.

As oxygen was a limiting factor in the experiment the water flows were set in proportion to the stocking density, so that the oxygen levels >5 ppm were constantly achieved. High water flows and their effect on feed flushing and fish swimming behaviour were considered during the design stage, and were avoided. Average tank flows equate to approximately 1.8-2.3 L/kg/min. Aeration was also provided in the tanks and within the support components of the system.

All tanks were fed 2% bodyweight/day, continuously via belt autofeeders during the light period. The ration was adjusted after each weight check. The photoperiod used was a 16:8 light:dark cycle. The temperature was maintained at $17 \pm 0.5^{\circ}C$. The light intensity of 3 $\mu E/m^2/sec$ at the water surface was used. The fish were acclimated for about one week prior to the trial.

Although few mortalities were recorded, these were removed when detected and weighed. Similar sized fish were sourced from the holding tank and used to replace the dead fish to maintain constant densities.

Initially a sample of 50 fish (where possible) were weighed and measured individually. Approximately every 14 days each tank was bulk weighed in groups of 22 (the lowest density holds 22 fish). All fish were weighed. At the end of the experiment all fish were weighed and measured individually. The experiment was conducted for 249 days.

Water quality parameters were monitored regularly throughout the trial.

Prior to the final weight check, 5 fish were randomly selected from each tank (4 treatments, 2 replicates), anaesthetised and within a maximum of 5 minutes a blood sample sample was extracted from the caudal blood vessel to be used for cortisol analysis. Cortisol may give an indication of the stress levels of the fish and may be used in conjunction with the growth patterns to describe performance under variable stocking rates.

Results and Discussion

Although the trial was conducted for 249 days, little depression in growth was obtained in any treatment. The growth curve for the average of each treatment is shown in Figure 1.1 Specific growth and FCR are illustrated in Table 1.1 As expected the growth rates were inversely correlated with stocking density. However, a plateau in growth was not observed; this plateau could be used to identify the maximum density tolerated by the fish before growth inhibiting factors severely influenced the performance.

Though the growth was slightly depressed the maximum density treatment reached 15.9 kg/m^2 or 61.1 kg/m^3. The second figure looks impressive but neglects the fact that the fish would not occupy any additional water above the existing 1 m^2 floor area.

The trial was terminated due to a moderate decline in water quality in the system; the system could not support the level of feed input. Feed was provided in excess, explaining the very high FCR levels shown in Table 1.1.

Although the water flows were adjusted in relation to the stocking density, the growth in the higher density tanks may have been compromised by the higher flows. Although consideration was given these issues in the design, the increase in density automatically raises the water flow, effectively terminating the experiment once the flow exceeds the limit at which fish can maintain station easily. As fish in the higher density tanks were forced to grow in a higher current, the growth may have been compromised as energy is expended on swimming.

Future experiments should take this into account with oxygen levels being maintained through the use of oxygenation in preference to increased water flow. Even so, the growth rates recorded in the higher density tanks are very encouraging.

The mean (and standard deviation) cortisol levels measured of the 10 fish sampled in each treatment are:

Treatment	Mean cortisol (ng/mL)	St. deviation
High density	1.76	1.90
Medium-high density	6.37	10.17
Medium density	5.05	9.29
Low density	7.43	18.20

As the sample size was low for each treatment and as this was considered a preliminary assessment, no statistical comparison was made between the treatments. The main result from the trial is the low cortisol levels associated with the high density fish, indicating that extended rearing under "crowded" conditions does not stress the fish. The higher cortisol levels in the other treatments also show a much higher variation; examination of the raw data reveals that most fish have low cortisol levels (comparable to the high density fish), with a few showing very high readings. The stress associated with these few fish may be the result of feeding hierarchies within the tanks as demonstrated previously by Shelverton (1995).

This trial has demonstrated that good relative growth, with low associated stress levels, can be maintained at a fish stocking density of about 16 kg/m^2 even in a recirculating system. This is a critical result in the assessment of flounder culture performance as the capital cost of constructing a land based farm hinges on the tank area required to rear specific tonnages. Future experiments should investigate the growth associated with higher stocking densities particularly where oxygenation is used instead of increased water flows.

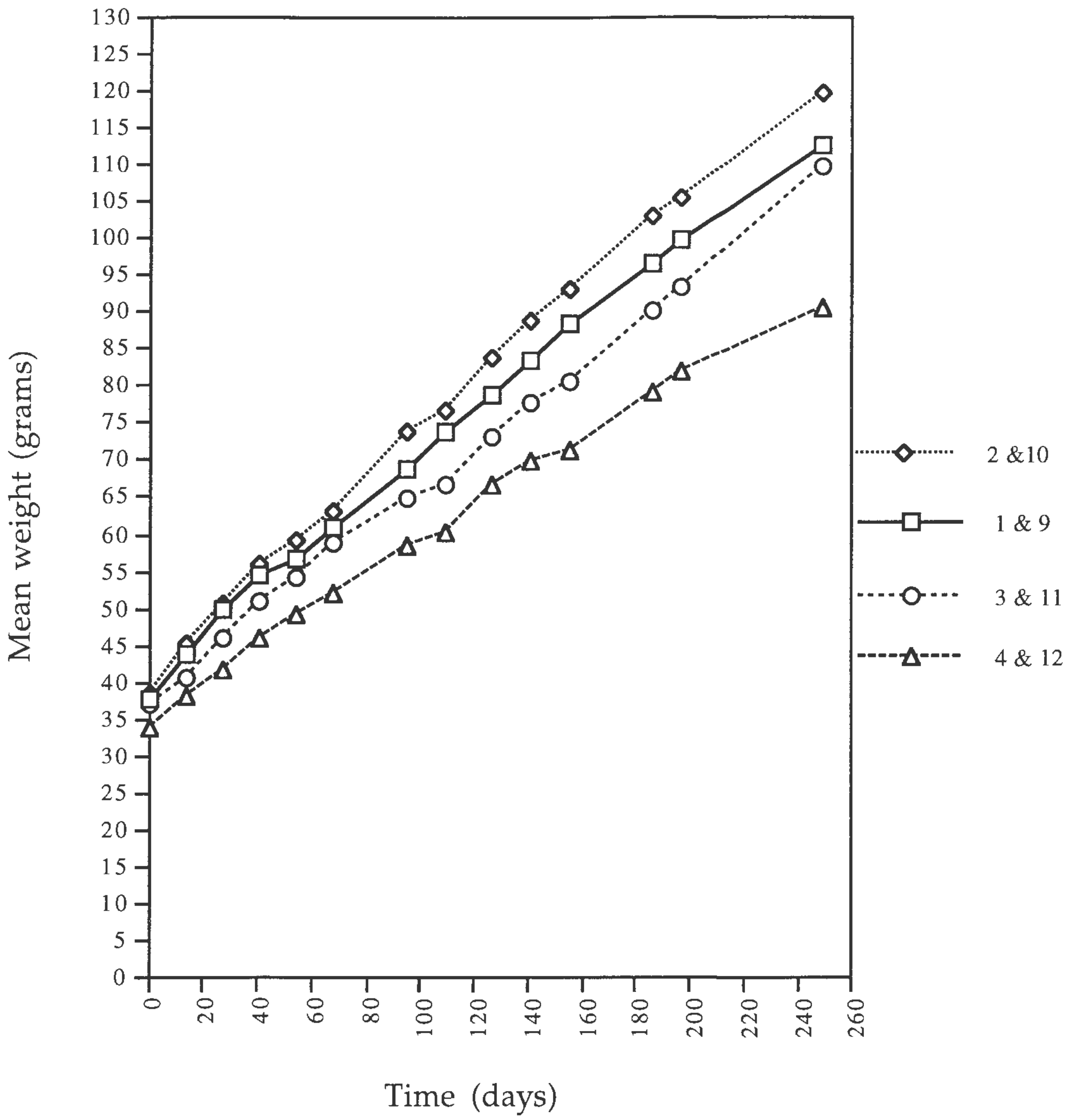


FIG 1.1. Growth rate of flounder (starting at age 298 days post hatch) in a recirculating system at 17.5 $\pm$ 0.5 ^{0}C where initial and final mean stocking densities were, Tanks 1 & 9 (0.80 to 2.38 kg/m^2), Tanks 2 & 10 (1.60 to 5.06 kg/m^2), Tanks 3 & 11 (3.14 to 9.30 kg/m^2) and Tanks 4 & 12 (5.75 to 15.24 kg/m^2). Fish were fed a daily ration of 2% body weight per day by belt feeders over 12-16 hours. Flow rates were set at a rate of 1.8-2.3 L/kg/min to maintain minimum dissolved oxygen levels of 5mg/L. Fish bulk weights were measured fortnightly for a period of 249 days from 7/7/95 to 19/3/96 at UTAS.

Tank	Initial Weight (g)	Final Weight (g)	Δ kg/m^2	Δ kg/m^3	Δ Biomass (g)	Food Fed (g)	SGR (%/day)	FCR	Δ CV %	Mortality %
1	39.20±9.87	128.28±42.01	0.81-2.71	3.12-10.45	842-2822	5798	0.49	2.93:1	25.1-32.8	0 %
2	39.27±8.08	132.28±46.46	1.66-5.60	6.38-21.56	1723-5820	12904	0.49	3.15:1	20.6-35.1	0 %
3	36.85±8.92	125.34±46.39	3.24-10.61	12.48-40.85	3370-11030	23300	0.48	3.05:1	24.2-37.0	8 %
4	33.51±8.37	93.81±33.37	5.45-15.88	20.98-61.15	5665-16604	39043	0.43	3.60:1	25.0-35.6	11.4 %
9	36.9±6.72	96.68±32.05	0.79-2.05	3.06-7.88	825-2127	5727	0.38	4.40:1	18.2-33.2	0 %
10	36.92±8.88	106.53±31.27	1.60-4.51	6.18-17.36	1668-4687	11741	0.41	3.89:1	24.0-29.4	0 %
11	33.81±7.28	94.08±31.65	3.04-7.98	11.72-30.66	3165-8279	21736	0.39	4.25:1	21.5-33.6	3.4 %
12	35.67±9.43	87.01±31.51	6.05-14.64	23.30-56.40	6291-15227	39534	0.36	4.38:1	27.8-36.2	6.3 %

Table 1.1. Data summary for flounder (initial age 298 days post hatch) held in a recirculating system at 4 different stocking densities at Utas for a period of 249 days. Dissolved oxygen was maintained at a minimum of 5mg/L with temperature range of 17.5±0.5 °C. [FCR= Total food fed(g)/Δ Biomass; SGR (Specific growth rate= ((ln final Wt-ln Initial Wt)/days)x100 %.]

Experiment 2

Optimal feeding rates for juvenile flounder and the effectiveness of compensatory growth

Introduction

Little is known about the nutritional and feed requirements of the greenback flounder during grow-out. It is therefore difficult to extrapolate from nutritional data, the theoretical feeding ration for various fish sizes. Optimal feeding rates will optimise growth and minimise feed wastage. A range of feed rates using an available low fat salmon diet were trialed to determine the approximate feed rate suitable for a specific juvenile fish size grown at a particular temperature. At the end of this trial the fish were given food to excess to investigate the effectiveness of compensatory feeding strategies in restoring growth rates. This approach was used as a possible strategy in staggering juvenile production and grow-out to market size without causing adverse growth effects.

The trial was also used to determine the approximate maintenance ration level.

Material and Methods

The system used for the feed trials is described in the Materials and Methods section of Experiment 1. Duplicate treatment tanks were allocated across 8 Reln tanks, each with an effective water volume of 150L and a floor area of $1m^2$. Each tank received a water flow of 5-7 L/min while the recirculating system obtained a 20% water exchange every 2 days. Light levels and photoperiod were as per Experiment 1. The temperature of 18.5 ± 0.5°C was used throughout the trial.

Part A

A maximum initial stocking density of $1.1kg/m^2$, comprising 128 randomly allocated fish/tank with an average weight of 8.6 g, was used. The feeding rates used as treatments over the first 84 days were 0.5, 1, 2, 3% bodyweight/day. These rations were distributed to their respective tanks as a minimum of 4 meals/day using belt feeders. Toward the end of the feed trials, the pellets were delivered continuously during the daylight hours. All tanks were offered the same number of meals on any day.

Bulk weight checks (50 fish) were undertaken every 7-10 days. Initially, 20 fish were sampled but results proved too variable. These were subsequently omitted. Fish were anaesthetised using benzocaine prior to handling.

Part B

At the end of the 84 day feeding trial, all tanks were weight checked. Between day 84 and 120, the tanks were all offered 3% bodyweight/day as a feed rate. This level was determined in Part A as in excess to their requirements. This ration was delivered continuously over the day using a belt feeder on each tank.

Weight and length were measured on individual fish in a sample of 50 from each tank at days 0, 84 and 120.

Water quality parameters (pH, temperature, ammonia, salinity) were regularly monitored.

The proximate feed composition for both parts of the trial was: 53% protein, 9% fat.

Results

Part A

A summary of the performance parameters over the first 84 days is shown in Figure 2.2 while the average growth for each treatment is displayed graphically in Figure 2.1.

Growth rates are correlated with feed rate by FCR levels were best at the 2% rate. Higher rates at both the 1% and 3% level suggest inadequate feed and growth (1%) and excess feed (3%). The mortality level was highest at the 0.5% feed rate which also demonstrated an approximate maintenance ration level with little change in average weights. Stocking densities in the 3% feed rate increased from 1 - 1.1kg/m^2 to 4.3kg/m^2. Final condition factors were highest in the 2% feed treatment.

Figures 2.3 and 2.4 display the initial and final weight and length frequency distributions of the fish in the treatments (2 duplicates combined per treatment).

Figure 2.5 shows graphically the relationship between specific growth rate and ration, and corresponding FCR against ration. These graphs were used to theoretically calculate the optimum ration value at about 1.5% body wt/day for the temperature and light conditions used in this experiment.

Part B

Growth rates of the 0.5 and 1% treatments showed a marked improvement between days 84 and 120 when offered a 3% feed ration. In contrast, the rates of the 2 and 3% groups changed little. It is clear that some form of compensatory growth is possible. Specific growth rates of the reconditioned 0.5 and 1% groups are much better than the 2 and 3% groups, and the condition indices showed a similar improvement from 0.9 to 1.7 and 1.5 to 1.8, matching that of the higher rates (Figure 2.6). The size frequency distributions of the fish after feeding 3 % ration is shown in Figures 2.7 and 2.8.

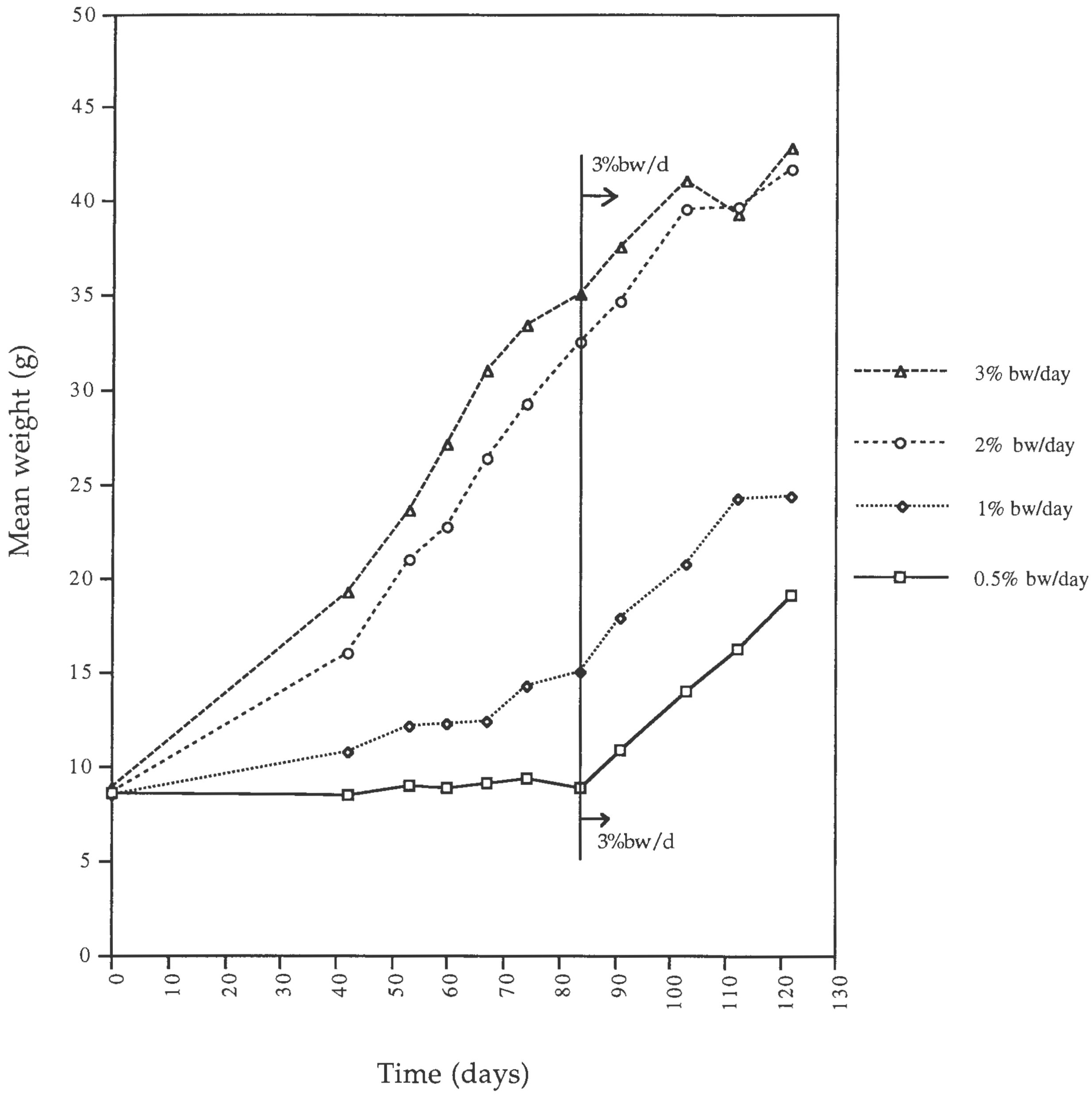


FIG 2.1. Growth rate of juvenile flounder (age 137 days post hatch) stocked in a recirculating system at 18.5 °C when fed daily rations of 0.5%, 1.0%, 2.0% & 3.0% body weight per day. Initially 128 fish were stocked into tanks at densities of up to 1.1 kg/m^2 and were fed by belt feeders over 24 hours. After 84 days all fish were fed 3.0% body weight per day to investigate compensatory growth.

Tank	Feed rate (%/day)	Initial Wt (g)	Initial Wt Standard Deviation	Final Wt. (g)	Final Wt Standard Deviation	Δ Biomass (g)	Total food fed (g)	SGR (%/day)	FCR
1	0.5%	8.55	2.45	9.22	2.55	(61.8)	492.3	0.1	--
2	1.0%	9.08	2.87	15.82	4.34	783.6	1331.6	0.7	1.7
3	2.0%	9.10	2.34	33.49	10.90	3021.5	3667.1	1.5	1.2
4	3.0%	8.54	2.70	34.86	14.88	3334.1	6106.4	1.7	1.8
9	0.5%	8.74	2.77	8.56	2.52	(160.0)	514.6	(0.0)	--
10	1.0%	8.02	2.00	14.43	4.48	676.2	1065.9	0.7	1.6
11	2.0%	8.22	1.96	31.67	13.19	3001.6	3857.9	1.6	1.3
12	3.0%	8.33	3.09	35.17	15.22	3435.5	6089.6	1.7	1.8

Tank	Feed rate (%/day)	CV %	% Mortality	K (Initial)	K (Final)	Initial Kg/m2	Final Kg/m2	Initial Kg/m3	Final Kg/m3
1	0.5%	27.7	12.5	1.7	0.9	1.0	1.0	6.2	5.8
2	1.0%	27.4	3.9	1.7	1.7	1.1	1.9	5.3	8.9
3	2.0%	32.5	0.8	1.8	2.0	1.1	4.0	4.2	14.9
4	3.0%	42.7	0.8	1.8	1.9	1.0	4.3	4.0	16.1
9	0.5%	29.4	12.5	1.8	1.5	1.0	0.9	4.1	3.5
10	1.0%	31.0	7.8	1.7	1.7	1.0	1.6	3.8	6.3
11	2.0%	41.7	0.0	1.7	2.0	1.0	3.9	4.2	16.2
12	3.0%	43.3	0.0	1.8	2.0	1.0	4.3	4.8	20.1

FIG 2.2. Data summary for flounder fed rations of 0.5%, 1.0%, 2.0% and 3.0% body weight per day for 84 days from 27/1/95 to 21/4/95.Food conversion ratio (FCR)= Total food fed(g)/ΔBiomass(g); Specific growth rate(SGR)=((Ln final Wt-Ln initial Wt)/days)100%; Condition index (K)=(weight (g)/length (cm)^3)100; n=100.

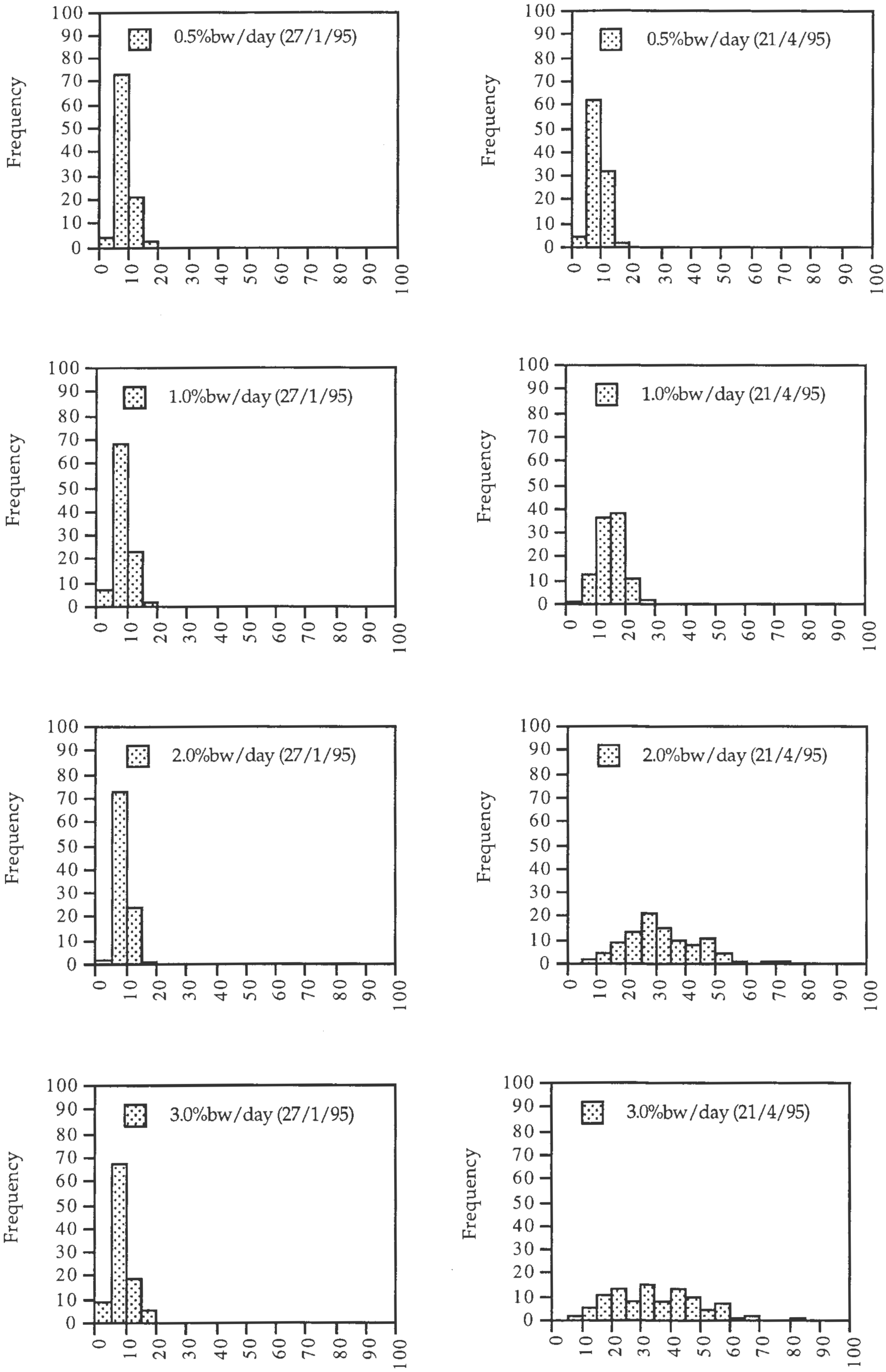


FIG 2.3. Weight frequency histogram for flounder fed 0.5%, 1.0%, 2.0% and 3.0% body weight per day feed rations for 84 days. Graph shows frequency weight distribution at start and at completion of experiment [y axis represents frequency, x axis represents weight expressed in grams; n=100].

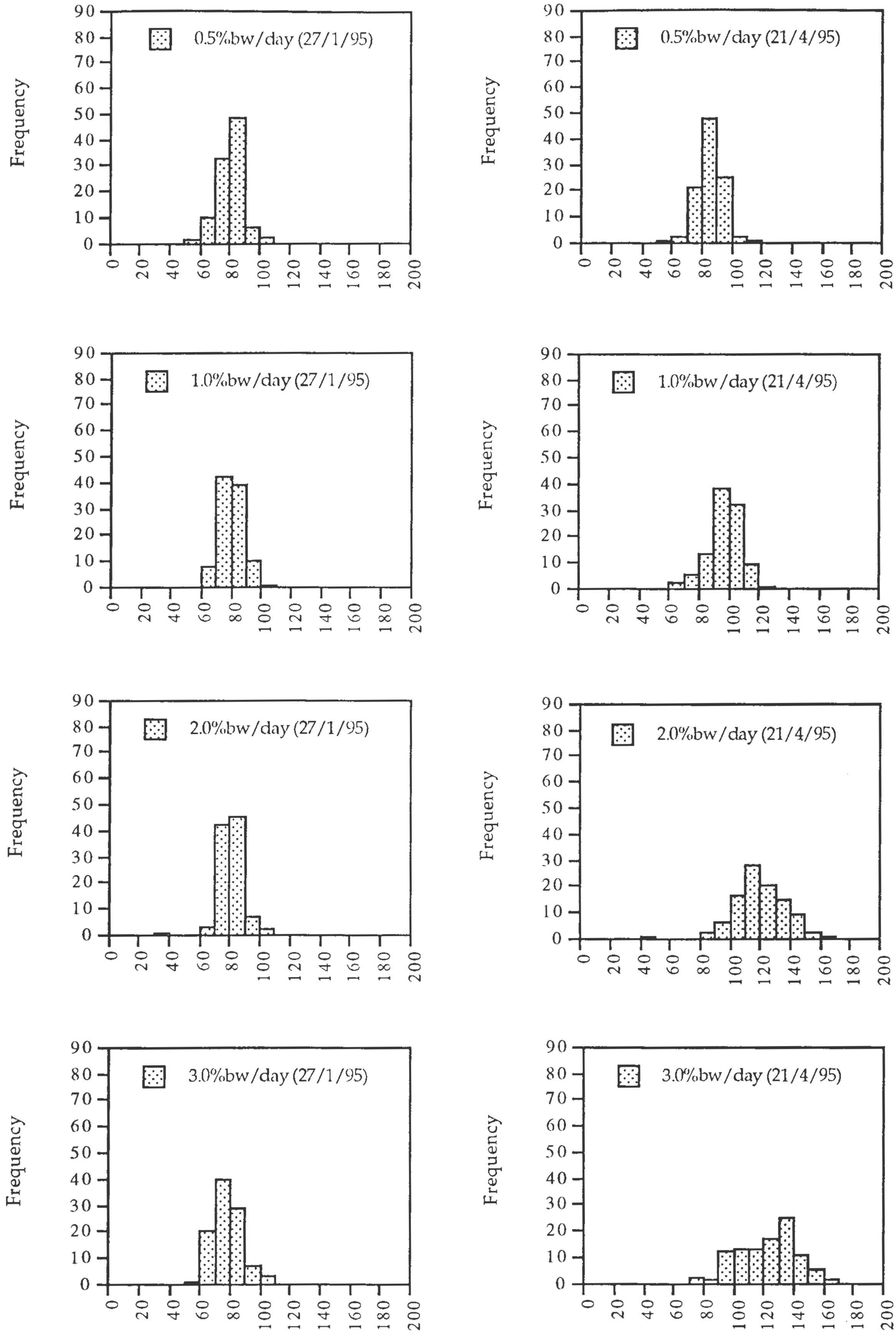
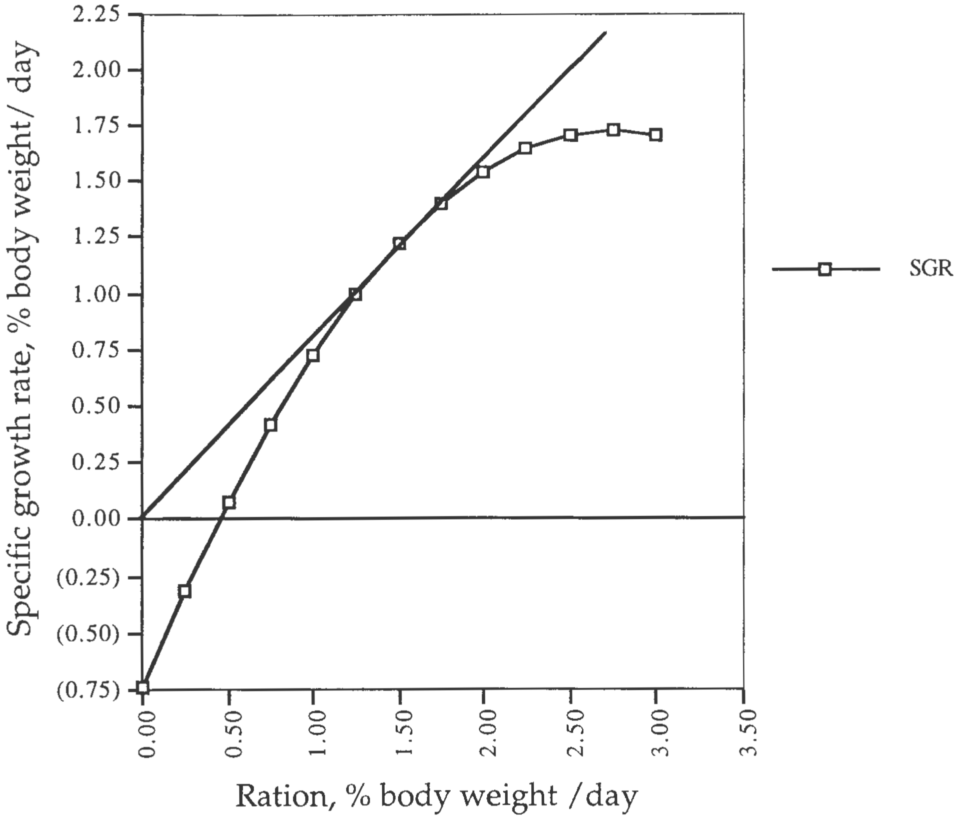


FIG 2.4. Length frequency histogram for flounder fed 0.5%, 1.0%, 2.0% and 3.0% body weight per day feed rations for 84 days. Graph shows frequency length distribution at start and at completion of experiment [y axis represents frequency, x axis represents length expressed in millimeters; n=100].



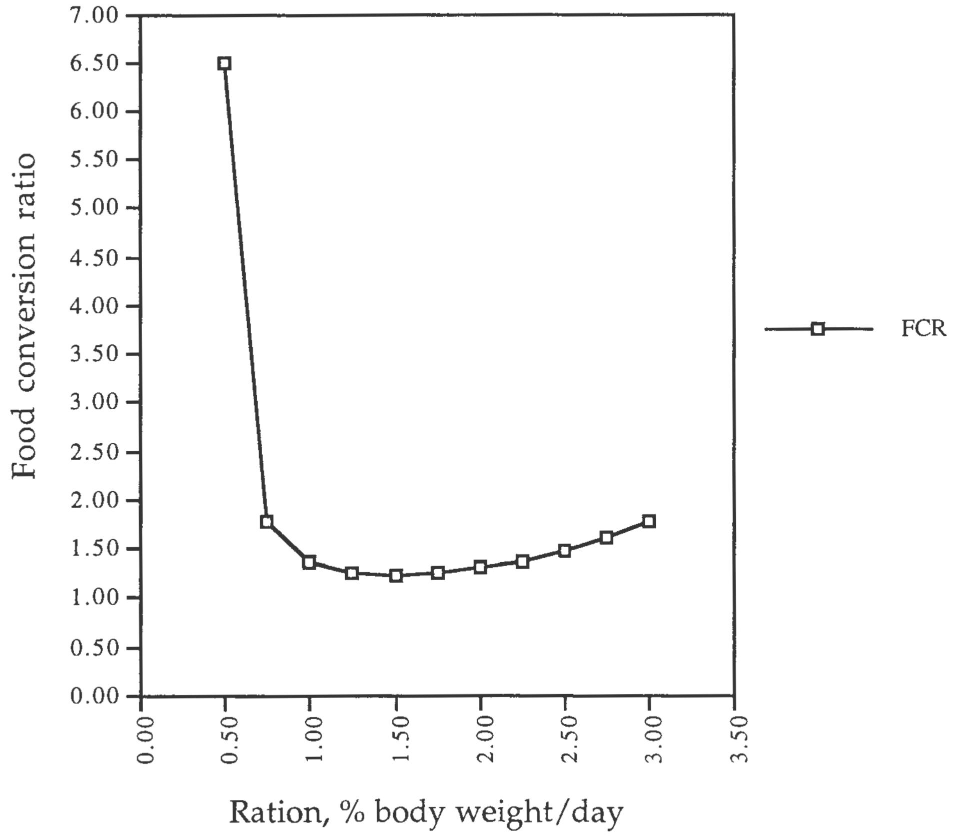


FIG 2.5 .Specific growth rate (SGR, % body weight per day) and food conversion ratio (FCR) versus ration (% body weight per day) for flounder of initial tank mean weight ranging from 8.0 $\pm$ 2.0 to 9.1$\pm$2.3 grams and age 137 days. Fish were held in a marine recirculating system at 18.5$\pm$ 0.5^{o} C for a period of 84 days.

Tank	Feed rate (%/day)	Initial Wt (g)	Initial Wt Standard Deviation	Final Wt (g)	Final Wt standard deviation	Δ Biomass (g)	Total food fed (g)	SGR (%/day)	FCR
1	3.0%	9.22	2.55	17.56	4.49	917.4	1446.5	1.7	1.6
2	3.0%	15.82	4.34	25.87	7.96	1216.1	2717.7	1.3	2.2
3	3.0%	33.49	10.9	41.38	18.53	986.3	4590.0	0.6	4.7
4	3.0%	34.86	14.88	44.31	18.68	1134.0	5388.6	0.6	4.8
9	3.0%	8.56	2.52	20.71	6.72	1360.8	1578.5	2.3	1.2
10	3.0%	14.43	4.48	22.95	8.82	1005.4	2314.5	1.2	2.3
11	3.0%	31.67	13.19	42.09	17.11	1323.3	5331.5	0.8	4.0
12	3.0%	35.17	15.22	41.38	18.63	757.6	5106.7	0.4	6.7

Tank	Feed rate (%/day)	CV %	% Mortality	K (Initial)	K (Final)	Initial Kg/m2	Final Kg/m2	Initial Kg/m3	Final Kg/m3
1	3.0%	28.1	1.8	0.9	1.7	1.0	1.9	5.7	10.9
2	3.0%	30.8	1.6	1.7	1.9	1.9	3.0	11.0	14.3
3	3.0%	44.8	0.0	2.0	2.0	4.0	5.0	14.9	18.4
4	3.0%	42.2	5.5	1.9	1.8	4.3	5.1	16.1	19.3
9	3.0%	32.4	0.0	1.5	1.8	0.9	2.2	3.5	8.4
10	3.0%	38.4	0.0	1.7	1.9	1.6	2.6	6.2	9.8
11	3.0%	40.7	0.8	2.0	1.9	3.9	5.1	15.0	21.4
12	3.0%	45.0	4.7	2.0	1.9	4.3	4.8	20.1	22.6

FIG 2.6. Data summary for flounder when all fed 3.0% body weight per day for 31 days from 28/4/95 to 29/5/95 investigating compensatory growth after feeding trials of 0.5%, 1.0%, 2.0% and 3.0% body weight per day. Food conversion ratio (FCR)= Total food fed (g)/ΔBiomass (g); Specific growth rate (SGR)=((Ln final Wt-Ln initial Wt)/days)100%; Condition index (K)= (weight (g)/length(cm)^{3}100; n=100.

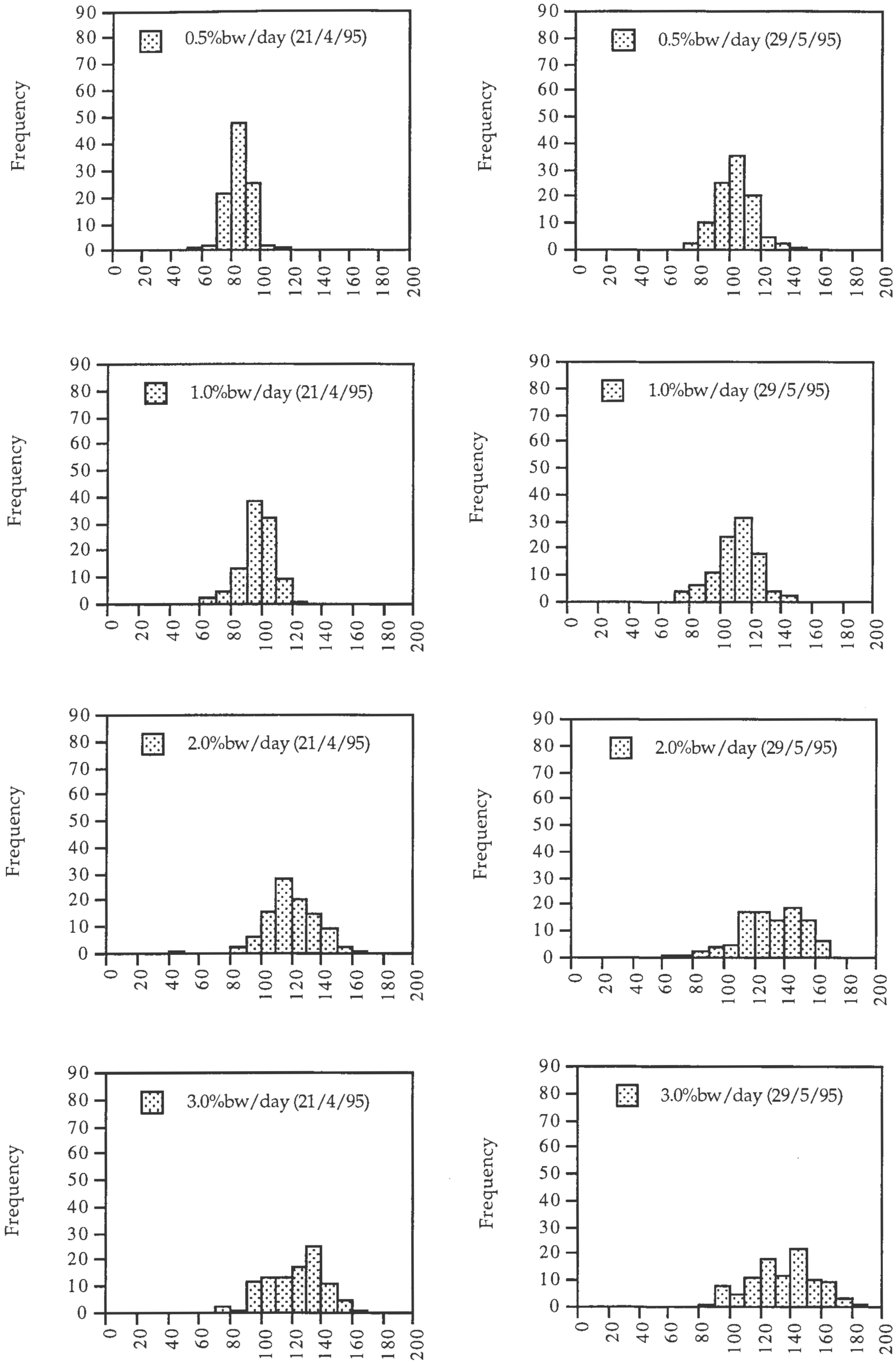


FIG 2.7. Length frequency histogram for flounder when all fed 3.0% bodyweight per day investigating compensatory growth after feeding trials of 0.5%, 1.0%, 2.0% and 3.0% body weight per day. Graph shows frequency weight distribution at start and at completion of experiment after 38 days [y axis represents frequency, x axis represents length expressed in millimeters; n=100].

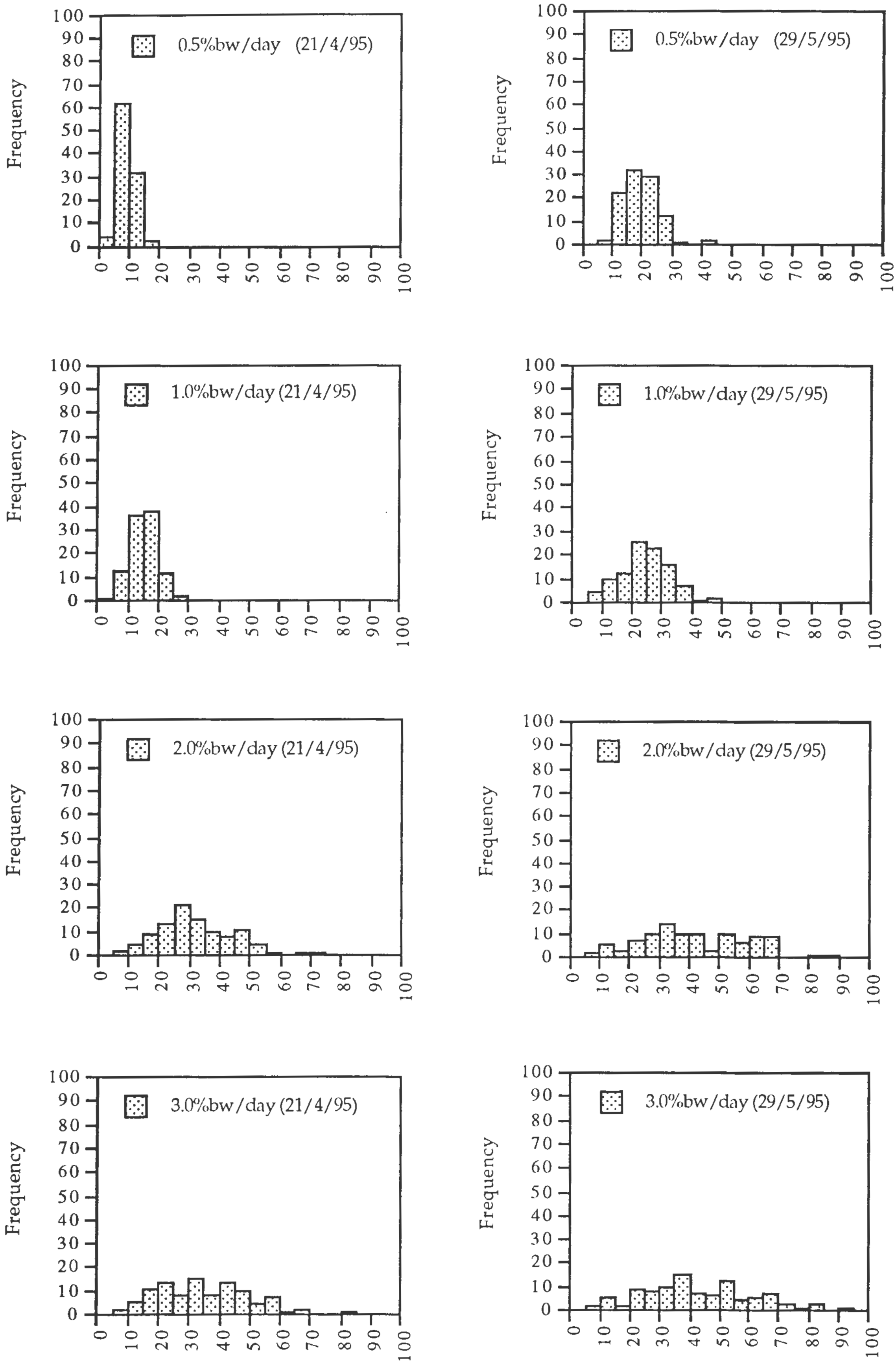


FIG 2.8 .Weight frequency histogram for flounder when all fed 3.0% body weight per day investigating compensatory growth after feeding trial rations of 0.5%, 1.0%, 2.0% and 3.0% body weight per day. Graph shows frequency weight distribution at start and at completion of experiment after 38 days [y axis represents frequency, x axis represents weight expressed in grams; n=100].

Experiment 3

Effect of grading on juvenile flounder growth and performance

Introduction

Variation in growth in juvenile flounder is visible even at the post-metamorphosis stage. Grading of fish is a standard management strategy aimed at optimising growth and performance. This is achieved by minimising hierarchy structures and optimising the pellet size to fish size ratio. Flounder grading has been undertaken successfully using square mesh screens rather than the conventional bar grader system employed on "round" fish. Visually, flounder have shown a moderate level of growth variation which would be unsuccessful under commercial conditions. The aims of this trial were to:

(i) measure the variation in growth
(ii) assess the influence of grading on growth
(iii) determine whether lower grade fish could improve this growth once separated from larger fish.

Materials and Methods

A cohort of juvenile flounder, reared under hatchery conditions using standard enriched live feed/weaning techniques were graded using screen bar sizes 7x7, 10x10, 13x13 mm. These juveniles were 70 days (post -hatch) old. Each of the three grades was placed in a 280L circular Reln tank connected together in a recirculation system serviced by solids removal, biofiltration and temperature control. Partial water changes were made daily amounting to about 20% system volume/week. The temperature of the system was maintained at 15-18.8^{o}C over the trial.

Growth was monitored in each graded tank, approximately every 10 days. A sample of 50 fish were individually measured for weight and length following anaesthesia (benzocaine). These fish were returned to the respective experimental tank following handling.

Mortalities were removed and counted at least once per day during the trial.

After 51 days each of the three tanks (A,B,C) were graded further into 2 groups giving graded groups A1, A2, B1, B2, C1, C2. Square meshed graders were used. These fish were on-grown for 54 days after an initial 7 day acclimation period in the tanks. Weight and length checks were undertaken on a sample of 50 fish on three occasions during this part of the trial.

Throughout the trial, salmon feed was delivered in excess during the light period over at least 5 meals. Automatic belt feeders were used over the tanks. Particle sizes used ranged from 0.6mm-1.5mm depending on fish size. The feed had a proximate composition of 53% protein, and 9% fat.

For each group, biomass, density, FCR, coefficient of variation and mortality were calculated. Size frequency histograms were compiled from weight and length data.

The environmental parameters salinity, ammonia, pH, temperature and photoperiod were recorded during the trial.

Results and Discussion

The growth curve over the trial period is shown in Figure 3.1 and performance details are summarised in Table 3.1. A high proportion of the fish fell into the smaller grades, however this was a function of the grader screen size (Table 3.3). Mortality levels were much higher in the smallest category (C + C2) during both sections of the trial, reaching 42.5% and 33.5% respectively (Table 3.1). Many of these mortalities appear to be due to poor conditioned fish i.e. fish not ingesting feed. The environmental conditions were acceptable throughout the trial (Table 3.2),

FCR figures are given but are not representative because the feed was delivered to excess.

The length frequency histograms (Figs. 3.2, 3.3) demonstrate that the spread of sizes increases over time from the narrow range obtained immediately following the grade. This trend suggests that additional grades are required to minimise size variation.

Although the graded fish were not compared with a non-graded group, the growth rate displayed by upper grade fish is much higher than lower grades (Figure 3.1).

In some cases the lower grade of one group overlaps with the upper grade of another e.g. B2 and C1. This has the advantage that these groups may be combined when transferred to ongrowing tanks rather than requiring an increasing number of tanks to accommodate graded groups. This pattern of overlap may also be due to screen sizes used.

In relation to the performance of the fish, one of the aims was to assess whether growth of smaller fish improves once the fish have been separated from the larger ones. This seems to be the case but more importantly this separation allows for better management of the fish in each group e.g. pellet size offered, in comparison to non-graded and mixed sized batches.

Another significant result is the poor performance of the bottom grade (C2). These fish would probably be discarded in a commercial situation as there appears to be very little growth potential in this group.

Overall there is large range in size between the highest grade (A1) and lowest (C2), an average of approximately 12g down to 1g after 182 days growth. This experiment did not aim at obtaining maximum growth but is comparative between groups given the culture condition outlined above, particularly given the uneven densities during the grow-out period which may have affected growth. These were not considered to be excessive.

Flounder appear to require fairly frequent grading at least in the early juvenile stages. This has obvious implications in relation to tank requirements, handling procedures and design of grading systems.

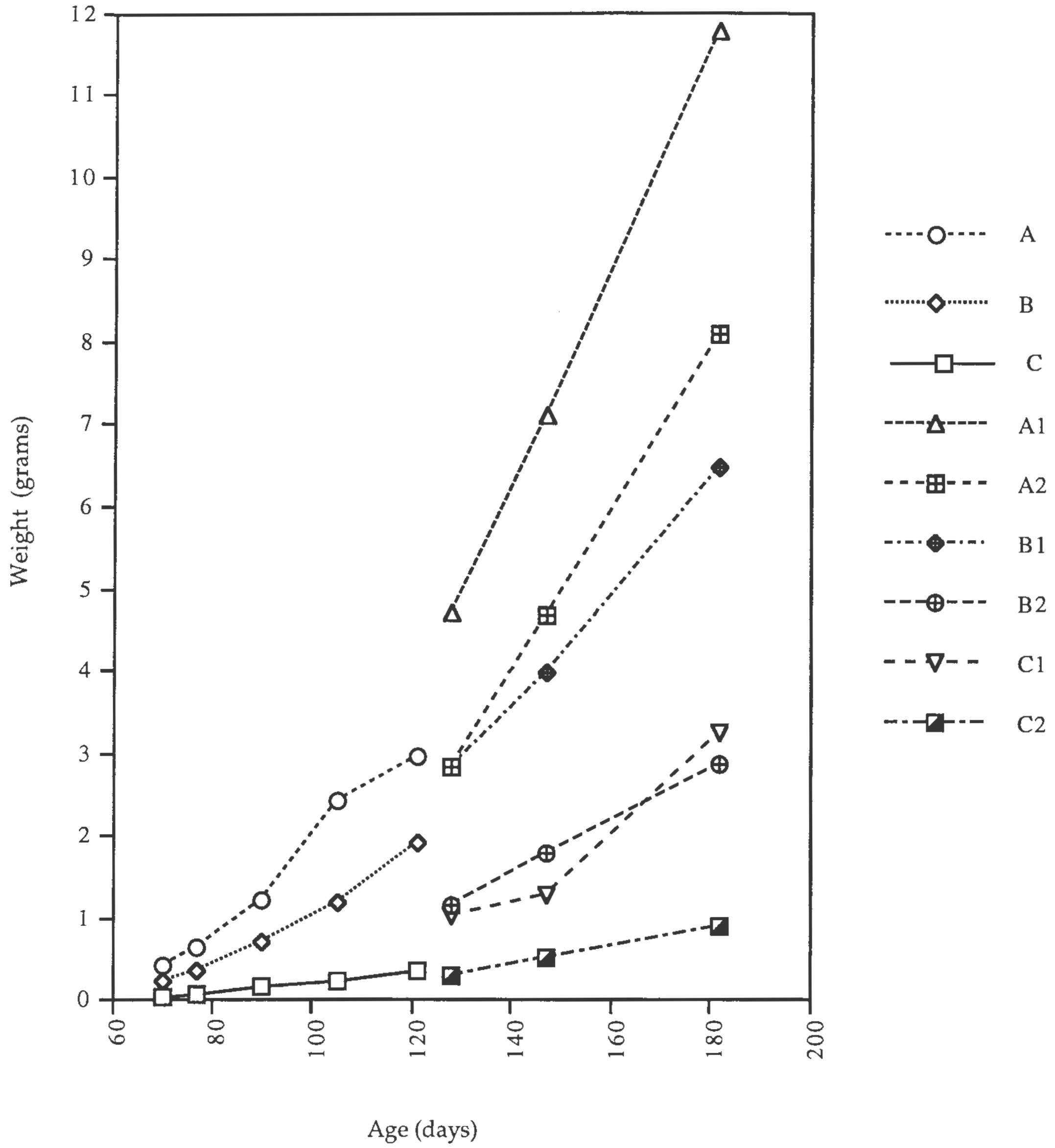


FIG 3.1. Growth of 70 day old juvenile flounder after grading into 3 size classes (A,B and C). After 51 days each size class was further graded into 2 size classes (A to A1 and A2; B to B1 and B2; C to C1 and C2) and on-grown for a period of 54 days. Experimental results have been recorded in table 3.1 and enviromental parameters in table 3.2. Fish were held in a recirculating system for the duration of the experiment.

TANK	Initial Weight (g)	Final Weight (g)	Δ Biomass (g)	Food Fed (g)	SGR (%/day)	FCR	Δ CV %	% Mortality	Δ Kg/m²
A	0.43±0.14	2.96±1.14	1744	2295	3.78	1.3:1	33-39	2.4 %	0.31-2.05
B	0.25±0.12	1.92±1.16	2389	2609	4.01	1.1:1	48-60	2.0 %	0.36-2.75
C	0.05±0.04	0.36±0.43	417	1645	3.97	3.9:1	80-120	42.5 %	0.12-0.52
A1	4.69±0.96	11.76±2.96	2840	3673	1.70	1.3:1	21-25	0 %	1.82-4.54
A2	2.84±0.98	8.08±3.15	1720	2075	1.94	1.2:1	35-39	0.6 %	0.91-2.56
B1	2.82±0.83	6.48±1.68	3070	4221	1.54	1.4:1	29-26	0 %	2.29-5.30
B2	1.16±0.64	2.88±1.45	720	1478	1.68	2.1 :1	55-50	9.3 %	0.59-1.32
C1	1.02±0.54	3.26±5.77	2256	3484	2.15	1.5:1	53-177	3.3 %	1.04-3.21
C2	0.31±0.24	0.89±0.74	265	699	1.95	2.6 :1	77-71	33.5 %	0.28-0.54

Table 3.1 .Data summary for 70 day old juvenile flounder graded into three size classes (A, B & C) held in a recirculating system at 15-18.8 °C at UTAS from the 21/9/94. After 51 days each size class was further divided into two size classes (A to A1,A2: B to B1, B2; C to C1,C2). Fish were ongrown for a further 54 days before the trial was terminated on the 11/1/95. Food conversion ratio FCR= Total food fed (g) /Δ Biomass (g); Specific growth rate SGR= ((ln final Wt- ln Initial Wt)/days) X 100 %.

Enviromental Parameters	Units
Temperature	15-18.8°C
Salinity	32-38 p.p.t
Total Ammonia	0.1-.04mg/L
pH	7.3-8.1
Photoperiod	16 L: 8 D

Table 3.2. Enviromental parameters maintained throughout the experiment.
Water quality maintained via regular partial (20 %) changes weekly.

Grade	Fish Numbers	% of Total Population
A	710	15 %
B	1460	31 %
C	2600	54 %
A1	402	9.7 %
A2	332	8.2 %
B1	845	20.2 %
B2	526	12.8 %
C1	1058	25.7 %
C2	952	23.1 %

Table 3.3. Number of fish in each grade and the % of the total population used in experiment.

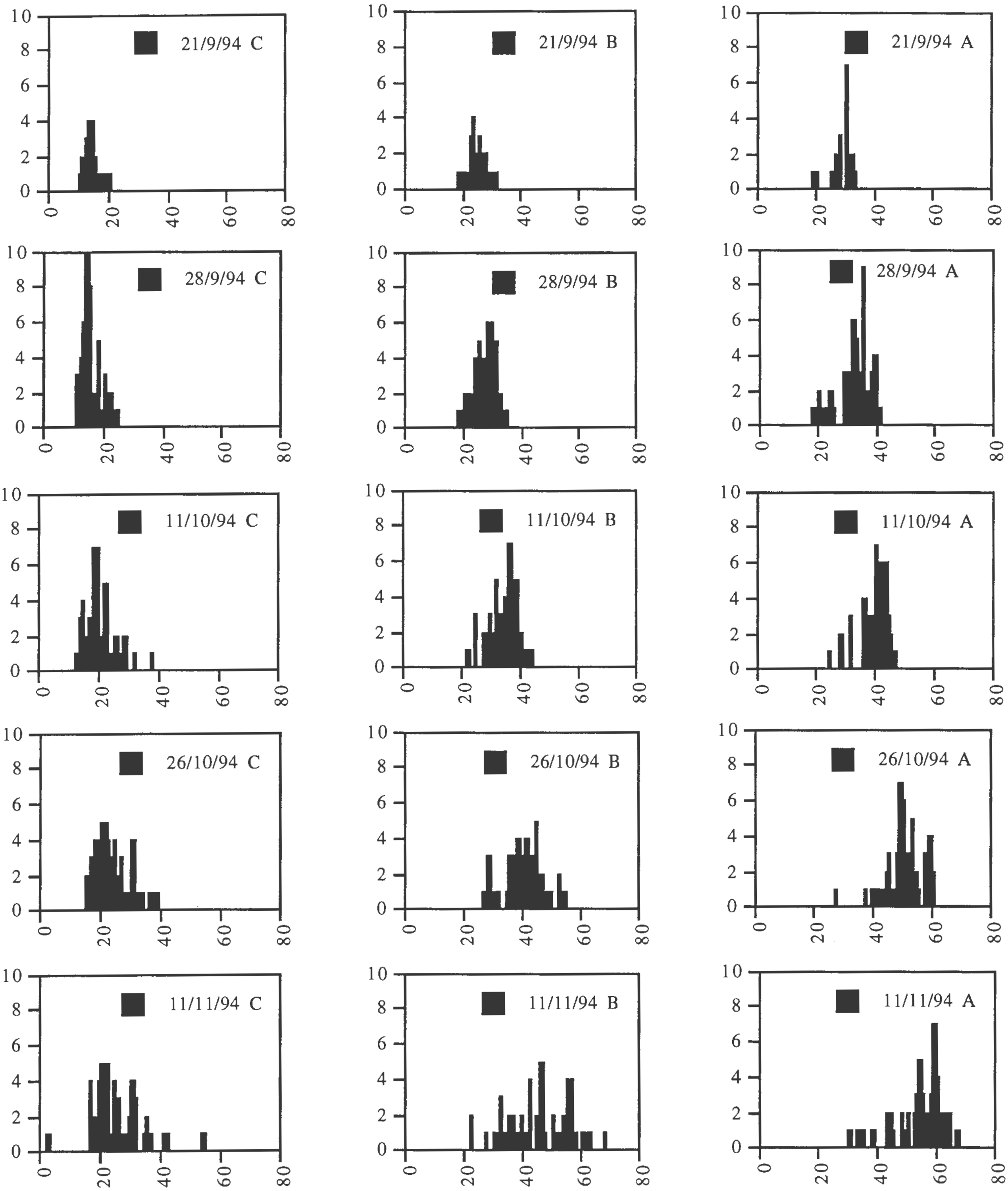


FIG 3.2. Length frequency histograms of 70 day old juvenile flounder after grading into 3 size classes (A, B and C) and on-grown for 51days. The horizontal axis represents length (mm) and vertical axis frequency.The sample size is 50 except for data 21/9/94 where n=20.

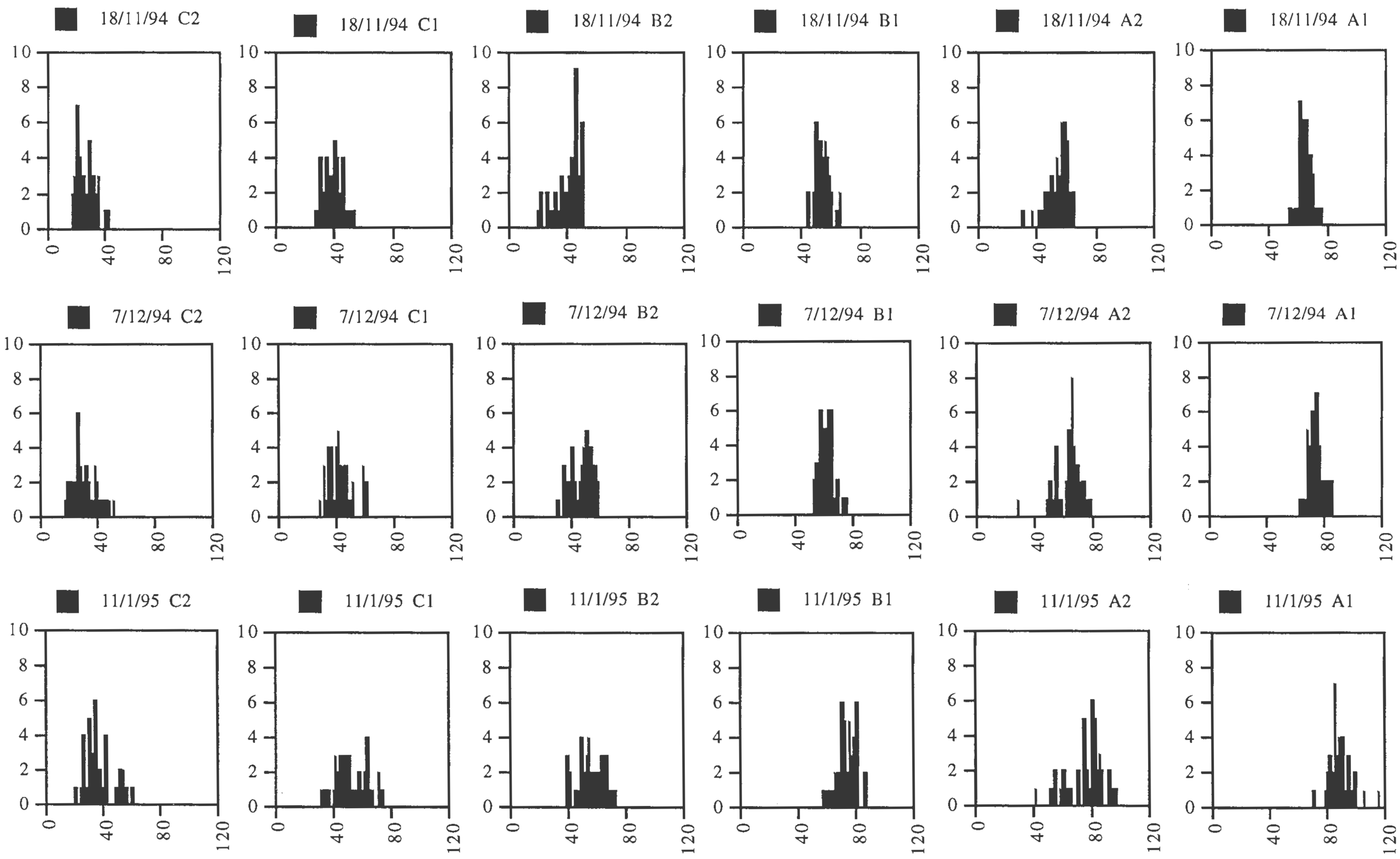


FIG 3.3. Length frequency histogram of 128 day old flounder after further grading from 3 size classes into 6 size classes (A to A1 & A2, B to B1 & B2, and C to C1 & C2) and on grown for a period of 54 days. The horizontal axis represents length (mm) and vertical axis frequency, sample size =50.

Experiment 4

The relationship between fish length, weight and area

Introduction

As the stocking density of flatfish is better related to tank floor area rather than water volume, it is expressed as kg/m^2 (as well as kg/m^3). Densities of approximately 25-30 kg/m^2 have been reported in Japanese flounder culture in Japan and 45 kg/m^2 in turbot culture in Spain (Hart, 1995). These figures relate mainly to species larger than greenback flounder. As there is a wide size range between these species it is difficult to compare density figures and to extrapolate the anticipated stocking of greenback flounder. Layering of the fish over a given area also is important; it not only relates to the stocking density but also to the tank usage by fish, inter-fish space requirements and dissolved oxygen characteristics near the tank floor.

This experiment aims to define the relationship between fish size and fish body area and to use these figures to calculate density, corresponding numbers of $fish/m^2$ and numbers of fish layers for given fish sizes and densities.

Materials and Methods

A wide range of fish sizes were sampled. These fish were anaesthetised using benzocaine, measured for weight and length and placed on a photocopier. The image of the fish was used to measure its area; an outline of the fish was cut out of the paper. Fins and tail were not included. The cut-out was weighed on a balance and the area calculated by comparing with the weight of a known paper area.

A linear regression between log weight and log area, and log length and log area was calculated. Tables of fish size, area, density, fish $numbers/m^2$ and number of fish layers at specific sizes and densities were compiled.

Results

The relationship between log area and log weight is shown in Figure 4.1 and may be described by the equation log area = 0.669logW + 0.557 ($r^2 = 0.997$). Examples of fish area in relation to weight are shown in Table 4.1. Similarly, the relationship between log area and log length is displayed in Figure 4.2 and may be described by the equation log area = 2.025logL - 2.682 ($r^2 = 0.997$). The relationship between weight and length may be illustrated by the equation log weight = 3.089. log length - 4.978.

Calculated numbers of $fish/m^2$ and layering in relation to fish weight, length and density are shown in Figure 4.3. These figures may be used, in turn, to describe tank floor usage and coverage by flounder during grow-out (Figure 4.3). The relationship between fish area and fish size is based on fish cultured at the time of undertaking the experiments. It is anticipated that these equations will change over time as cultured fish continue to display improved condition factors.

Discussion

Understanding the relationship between fish size and tank floor usage will provide information to calculate tank farm design, numbers of tonnes of fish/tank and potential oxygen requirements.

Figure 4.3. Examples of the relationship between fish size and surface area, and the ways in which it may be used to calculate fish layering.

Example 1: In Experiment 1, the highest density tank had the following features: average fish weight = 93.81 g, density = 15.88 kg/m^2, number of fish = 176.

From the equation log area = 0.669 logW + 0.557, the surface area of a fish averaging 93.81 g = 75.2 cm^2 (excluding fins and tail). Total area covered by 176 fish = 1.324 m^2. As the tank has an area of 1 m^2, the number of layers of fish = 1.324.

Similarly, the area taken up by the 22 fish averaging 96.68 g in the lowest density tank at 2.05 kg/m^2, is 0.169 m^2 equating to 0.169 layers of fish (only 16.9% of the tank floor is covered).

Example 2: Under grow-out conditions in a tank with diameter 4 m (surface area of 12.6 m^2), how many layers of 500 g fish are expected at a stocking density of 20 kg/m^2.

Number of fish at 20 kg/m^2 = 504
Surface area of a 500 g fish = 230 cm^2
Total surface area of 504 x 500 g fish = 11.6 m^2

Number of layers = 0.92 (or 92% floor coverage)

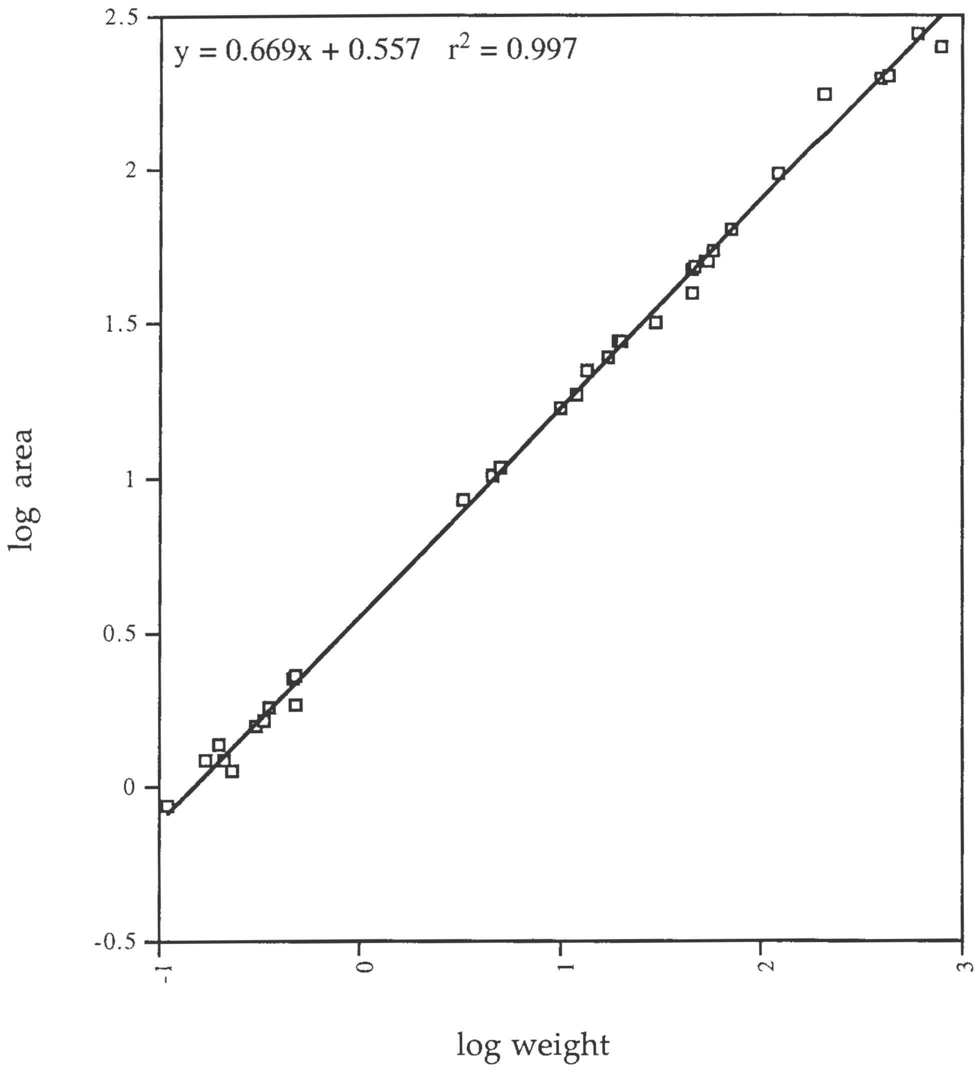


FIG 4.1. Log area (cm^2) to log weight (g) relationship of 34 Greenback flounder at Utas during 1994. Fish weights ranged from 0.1 to 600 g.

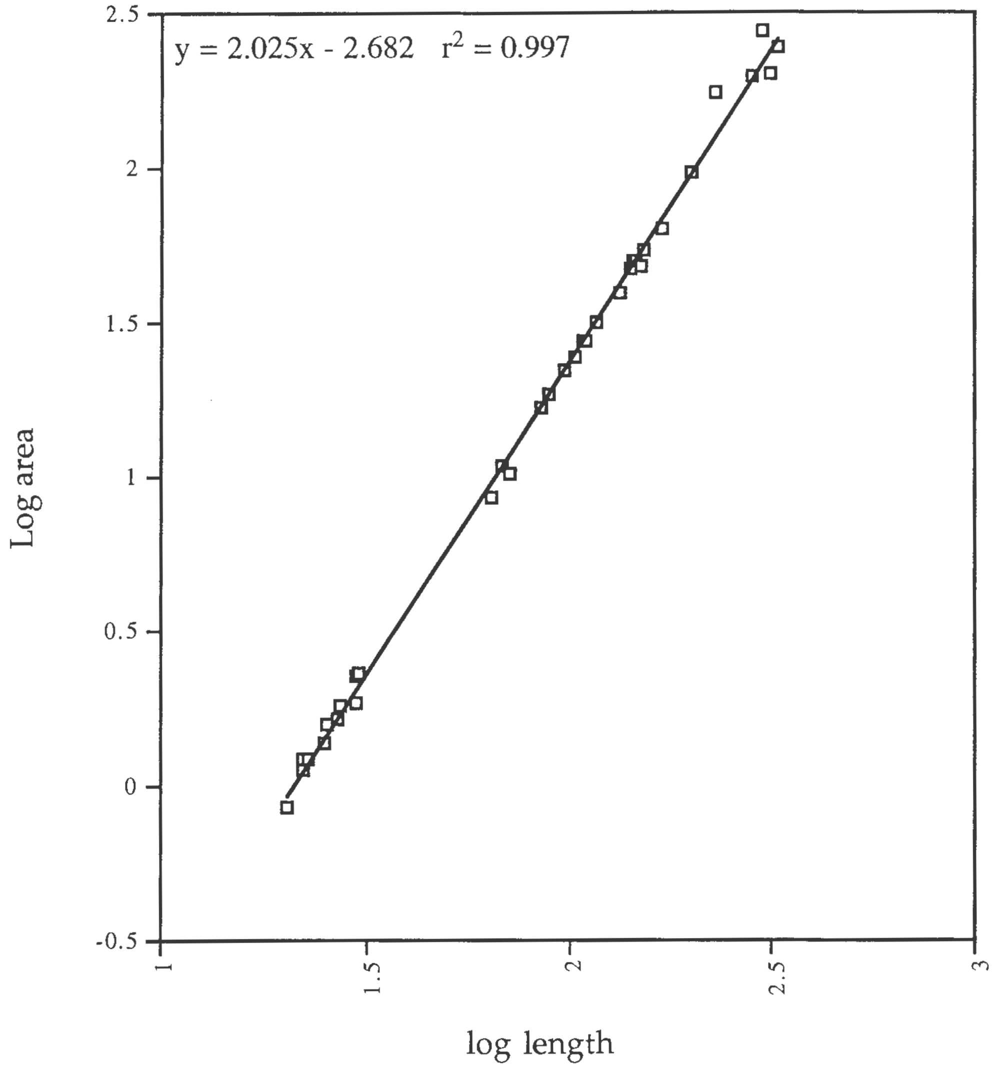


FIG 4.2. Log area (cm^2) to log length (cm) relationship of 34 Greenback flounder at Utas during 1994. Fish ranged in length from 2.3 to 33 cm.

Fish Weight (g)	Fish Surface Area (cm^2)
5	10.5
10	16.8
50	49
100	79
250	145
350	182
500	230

Table 4.1. Fish surface area based on weight where area (y) = $\log^{-1}$ (0.669 (log weight) +0.557).

Trial A

Growth and performance trials at Cameron of Tasmania, Dunalley and Taranna

Introduction

Dunalley was used as the principal location to collect information on grow-out performance. The tanks were located here because of company interests in flounder culture to diversity system operations, access to pumped seawater, personnel on site with experience in handling fish, support from the company and access to an air blower and farm laboratory.

The ponds at Taranna (about 1 hectare each in area) used for culturing microalgae to feed oyster spat/juveniles were considered appropriate as an extensive culture site. These ponds are filled, fertilised and the resultant algal bloom directed through spat upwellers near the pond. Ponds may be drained annually or left for a longer period. Prolific zooplankton and invertebrate growth is experienced in this system, with these items considered a potential feed source for the flounder. A large number of flounder juveniles were released in one pond in early 1995, at much the same time the fish were introduced into the tank system. However, as the pond has not been drained (at the time of writing this report) it is not possible to assess the success of the exercise.

This section will therefore only discuss the results from the tank trials.

Materials and Methods

(1) Tank Specifications for Grow-out

Three Aqualok tanks were assembled at Dunalley, within the oyster hatchery and nursery complex operated by Cameron of Tasmania. Each tank had the following specifications: diameter = 4.2m, effective volume = $10m^3$, floor area = $13.8m^2$, serviced by a water flow of 100-180L/min, introduced at an angle on the water surface, and three aeration points around the tank. The floor of the tank was initially sloped at an angle of about 2-3^{o}. The water level was maintained by an in tank stand-pipe; an outer sleeve created a suction from the floor of the tank to remove solids. Oxygen cylinders fitted with micropore stones were positioned near the tank for emergency oxygenation in the event of low oxygen conditions or pump failure. The tanks were shaded with shade cloth with a rating of about 50%.

A 3kW submersible pump supplied water to the tanks via a 100mm lay-flat hose.

An Amiad filter (1500µm) was positioned in-line to remove seaweed and animals. A pressure sensitive alarm switch was positioned on the incoming line and was in turn connected to a central alarm and pager system.

(2) Fish details in grow-out tanks

Two of the Aqualok tanks were initially stocked with juvenile flounder produced by DPIF Division of Sea Fisheries (Taroona). The third tank was used as a backup in the event of an emergency but was also designed to be used during any grading or spreading of stock if required.

The juvenile flounder were stocked in December 1994. The 1871 fish in tank A averaged 35.3g and 1111 fish in Tank B averaged 12g at stocking. Remaining fish from the density trial were added after a few weeks giving a total of 1421 fish. The age of the fish at stocking was approximately 209 days old. Salmon pellets (1.5-4mm) were fed to the fish over the trial period at a rate of 2% body weight per day or in response to feed intake when water clarity was good. Hand-feeding was used initially but autofeeders were used after about 4 months. Pellets were offered to the following approximate fish size: 1.5mm (start), 1-5-2.5mm (60-100g), 3mm (100g), 3-4mm (130g+).

Grading was not undertaken during the study so that the size range of a cohort during tank growth could be assessed. A sample of 50 fish were measured individually for weight and length on a monthly basis. On occasions only gross weight was determined. After 8 months growth, a sample of 400 fish were measured for weight and length, and assessed for deformities, maturation (sex where possible) and malpigmentation in an atttempt to quantify % maturation in the groups and to determine approximately the level of "marketable" fish and what problems were experienced during development.

Mortality was also recorded when tanks were cleaned.

As density levels were perceived to be quite high for the water conditions being experienced in October 1995, 300 fish were transferred from tank A to tank B. The density at this time was 11 kg/m^2.

At the final weight check prior to the sensory testing, a sample of 150 fish from each tank were individually measured for weight and length.

(3) Tank specifications for density trial

To assess the effect of density on the growth of the fish in a flow-through system, a set of 8 circular Reln tanks (volume = 270L) were assembled and serviced by water delivery system, aeration and emergency oxygenation. Duplicate treatment tanks were established; the treatments used were based on size of fish (area) and number of layers of fish on the tank floor. The densities (and numbers) used were calculated on the basis of tank floor coverage: 100% coverage = 1 layer (544), 50% cover = 0.5 layer (272), 25% cover = 0.25 layer (136) and 12% cover = 0.12 layer (68), effectively halving the density for each progressive treatment. The fish (total = 2,040) were removed from Tank B and distributed randomly between these tanks. Oxygen cylinders and microspore stones were positioned next to these tanks in case of emergency situations.

Results

(1) Grow out performance

The growth curves of the fish in Tanks A and B, and the temperature recorded during grow-out period is shown in Figure 5.1, The temperature experienced at Dunalley, in contrast to St. Helens, shows lower and higher extremes with a range of about 8-22.5°C. The site also showed temperature changes of up to 6°C in a 2 week block.

The growth demonstrated a steady increase from the 35g average weight to about 100g over 5 months. However, a dramatic slowing in growth occurred in May with little change, and even a weight loss, up until November. The onset of growth depression co-incides with a water temperature below 10°C and observations of maturation in the tank. The weight increase prior to this time may have included gonad development as well as somatic growth. Interestingly, growth depression occurred in both tanks at about the same size though tank B depression was delayed by about 1.5 months, indicating a possible relationship between fish size and maturation during a relatively broad spawning period.

The FCR experienced during the grow-out period ranged between 1.2 and 2.85:1 depending on the position on the growth curve. Specific growth varied between -0.26 and 1.32%/day. The density in Tank A ranged from 4.8kg/m^2 at the start to 10.7kg/m^2 in October when 300 fish were moved to Tank B, in an attempt to improve growth rate. The density of 10.7 kg/m^2 equates to a 66% floor coverage.

(2) Maturation assessment

Tables 5.1, 5.2, 5.3 summarise the figures from the maturation assessment, while Figures 5.2, 5.3 display the size frequency histograms in relation to sex and maturity. Generally, there is a higher percentage of mature males than females at the time of the assessment. Although this may be an accurate representation, indicating that males tend to mature at a younger age than females, it may only provide a picture as a point in time over a long cycle. As flounder can mature over a range of months from May to October (usually) the lower percentage of mature females could under-represent females which have already spawned or which will spawn toward the end of the season (& assessed as "indeterminate"). Although there is little difference in the length frequency distribution of the groups, the females tend to weigh heavier. This could indicate that the larger fish in the cohort tend to be females or it could reflect the significant gonad weight that occurs during egg development, particularly close to ovulation.

(3) Deformity assessment

Table 5.3 shows the proportion of the sample that is deformed in some way, either with an abnormality or malpigmentation or both. The main types of abnormal development are shortened/deformed opercula (particularly the upper side) and scoliosis/lordosis (bent spine). The later condition can occur anywhere along the backbone but is mainly near the caudal peduncle. Malpigmentation takes a number of forms from "blotchy" underside or upperside, to white fish, to minor pigmentation spots on the blind side. All conditions have the potential to affect marketability and are probably caused by suboptimal conditions during early development in the hatchery.

(4) Density Trial

Problems were experienced in this trial from the first day. High temperatures and moderate oxygen saturation produced some mortalities during the distribution of the fish into the tanks. Oxygen levels fell from 7 ppm to 4 ppm within 5 minutes despite aeration. The fish which succumb to the low oxygen levels all displayed deformities of the gill opercula which probably compromised respiration. High water flows were introduced into the tanks during the following weeks to overcome the lower oxygen levels. However, feed pellets were swept to the outlet before the fish had an opportunity to ingest them. Consequently many of the mortalities experienced after a few weeks of the trial were in poor condition. The trial was subsequently abandoned and moved to controlled conditions at the University. The results of that trial are reported in Experiment 1. The remaining fish from the trial were moved to Tank B giving a total at the time of 1421 fish.

Discussion

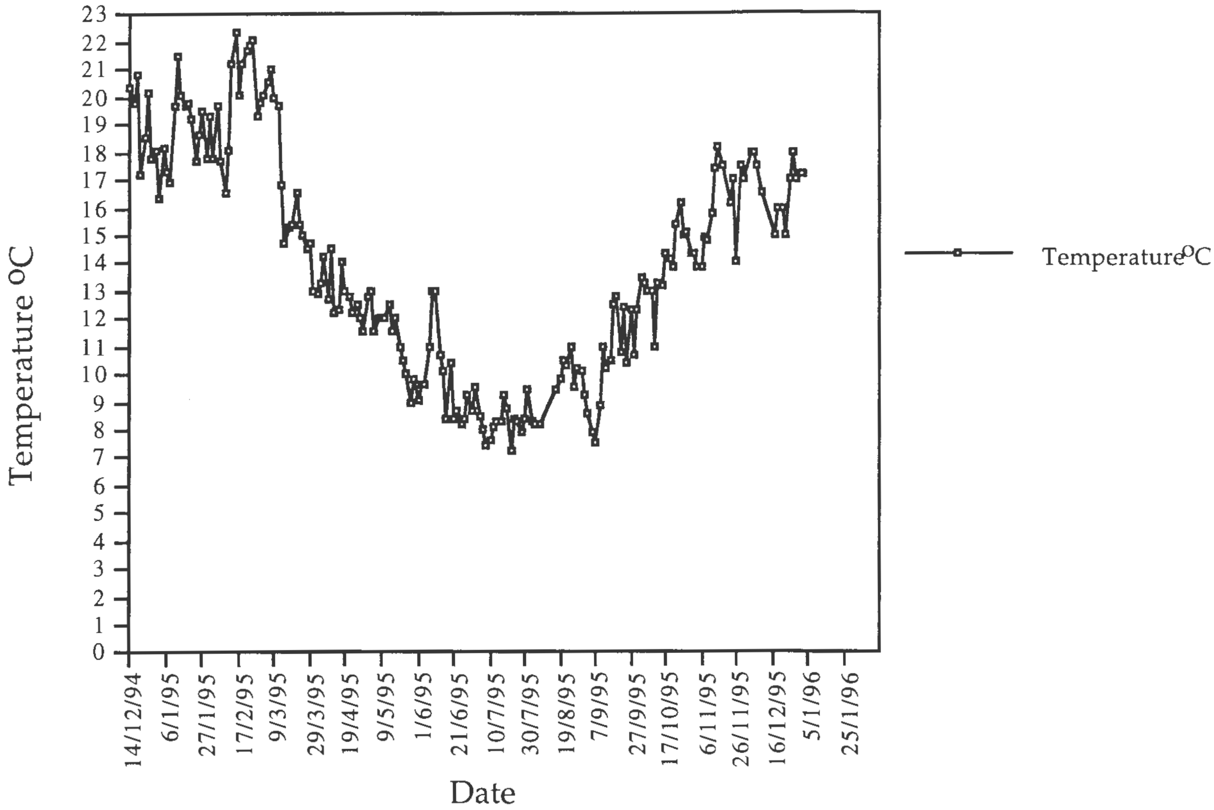
The reduced growth rate experienced in both tanks over the winter/spring months were unlikely to be due to density effects (based on other experiments) but most probably due to low water temperatures and/or the onset of maturation. Growth in fish reared at St. Helens was not significantly affected over winter but water temperatures did not fall below 10^{o}C. At Dunalley, water temperatures fell to 8^{o}C (below 10^{o}C) for a period of 4 months.

At the time of the maturation assessment on 9 August 1995, 83.5% of the sample were classed as mature. Such a high level of maturation at one year of age and at a small size does raise concerns about culture, however interest in roed small fish has been shown by Japanese companies. Of the fish assessed 32% were classed as mature females. Triploidy procedures are currently being trialed by the investigators as part of an ARC grant and these may be used to overcome maturity effects.

The effect of maturation on growth over a relatively long period of time is likely because flounder may spawn between May and October, with lower numbers of individuals showing maturation features throughout the year. Therefore, unlike many other species which have set spawning periods usually over a relatively short period of time, flounder display spawning potential throughout the year with individuals moving through this cycle at various times. This provides distinct advantages for broodstock management but the effect on growth and marketability requires closer attention. A monthly assessment of maturity levels would provide better pattern resolution.

The level of abnormality/deformity in the fish is of some concern to the program but may be associated with inadequate Vitamin (particularly C and E levels) in the feed. If Vitamin C levels have been inadequate, the condition demonstrates the high requirement in flounder for this vitamin, compared with salmonids.

The malpigmentation may be caused by a variety of conditions such as unsuitable light levels or photoperiod, or other stresses experienced during early larval/juvenile development particularly during metamorphosis.



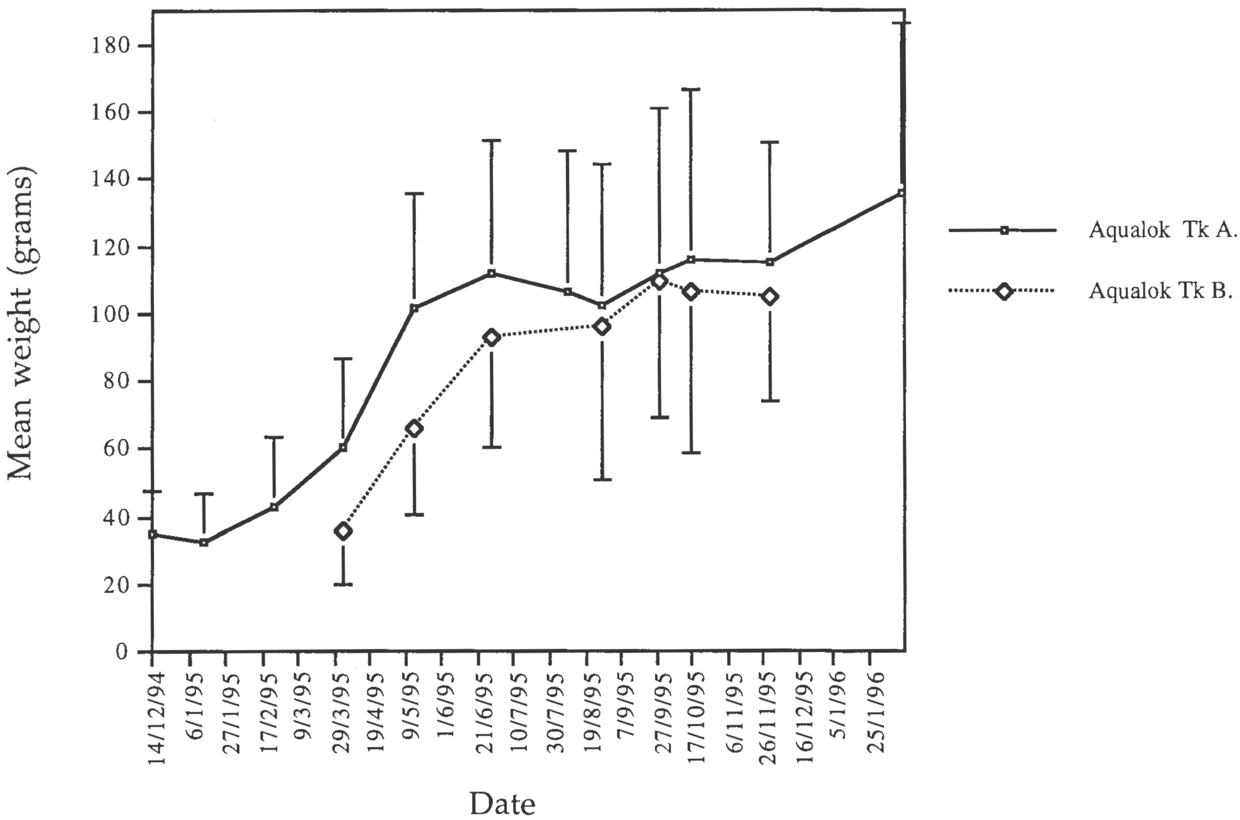


FIG 5.1. Growth and temperature profiles for Greenback flounder at Cameron of Tasmania at Dunalley from December 1994. Growth is represented by sample mean weights and associated SE.

	Male	Female	Indeterminate	Total
% of Population	51.8%	31.8%	16.5%	100%
Mean Length (mm)	167.1±19.5	176.8±23.7	166.7±21.6	166.4±21.9
Mean weight (g)	89.4±27.3	138.7±47.7	96.16±31.1	106.1±41.9
% Abnormalities	15.0%	22.8%	10.6%	16.8%
% Malpigmented	54.6%	37.2%	54.3%	49.3%

Table 5.1 . Table shows diferences between male fish, female fish and fish of indeterminate sex from Tank A at Cameron of Tasmania at Dunalley in relation to % of population, mean length (mm), mean weight (g) and the proportion of abnormalities and malpigmentation.

	Male	Female	Indeterminate
0-50 g	3.75%	1.25%	1.0%
51-100 g	31.25%	5.5%	8.5%
101-150 g	15.5%	12.0%	6.75%
151-200 g	1.0%	10.0%	0.75%
201-250 g		2.5%	
251-300 g		0.25%	

Table 5.2 . Table shows the percentage of total population of male fish, female fish and fish of indeterminate sex from Tank A at Cameron of Tasmania at Dunalley in relation to different weight classes.

	Abnormal only	Malpigmented only	Abnormal & Malpigmented	Normal
0-50 g	1.9%	1.7%	0.8%	2.2%
51-100 g	3.6%	19.5%	1.9%	20.3%
101-150 g	3.6%	17.5%	3.6%	9.7%
151-200 g	0.3%	5.0%	0.6%	5.6%
201-250 g		0.3%	0.3%	0.3%
251-300 g		0.3%		

Table 5.3. Table shows percentage differences between abnormal fish, malpigmented fish , abnormal and malpigmented fish and normal fish in relation to different weight classes from Tank A at Cameron of Tasmania at Dunalley.

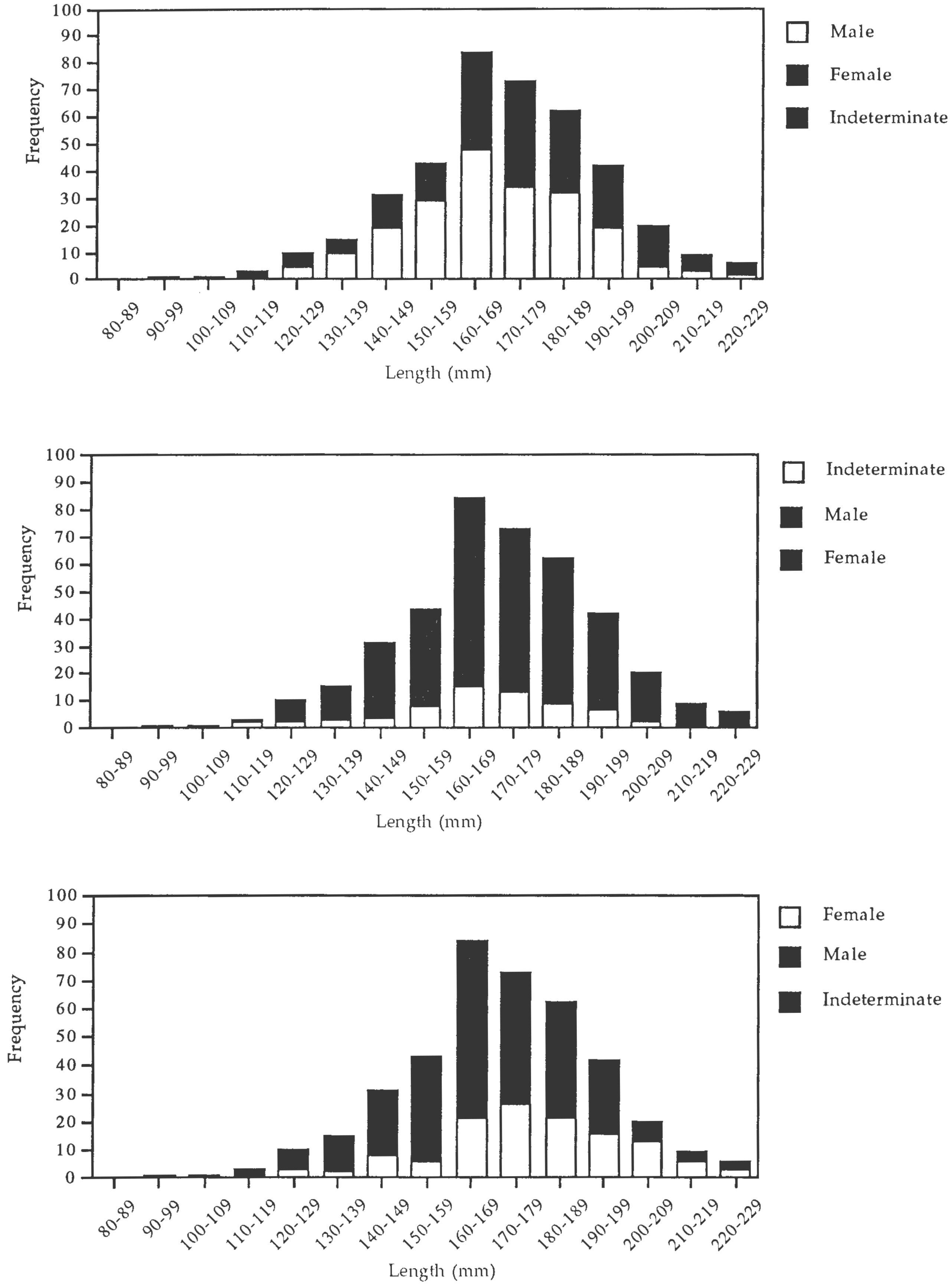


FIG 5.2 . Length frequency histogram of flounder (15 months old) from Cameron of Tasmania at Dunalley showing differences of length between sexes. Fish were transferred to the farm at age 7 months and totalled 1392 at the time of sampling on 9/8/95; sample size=400.

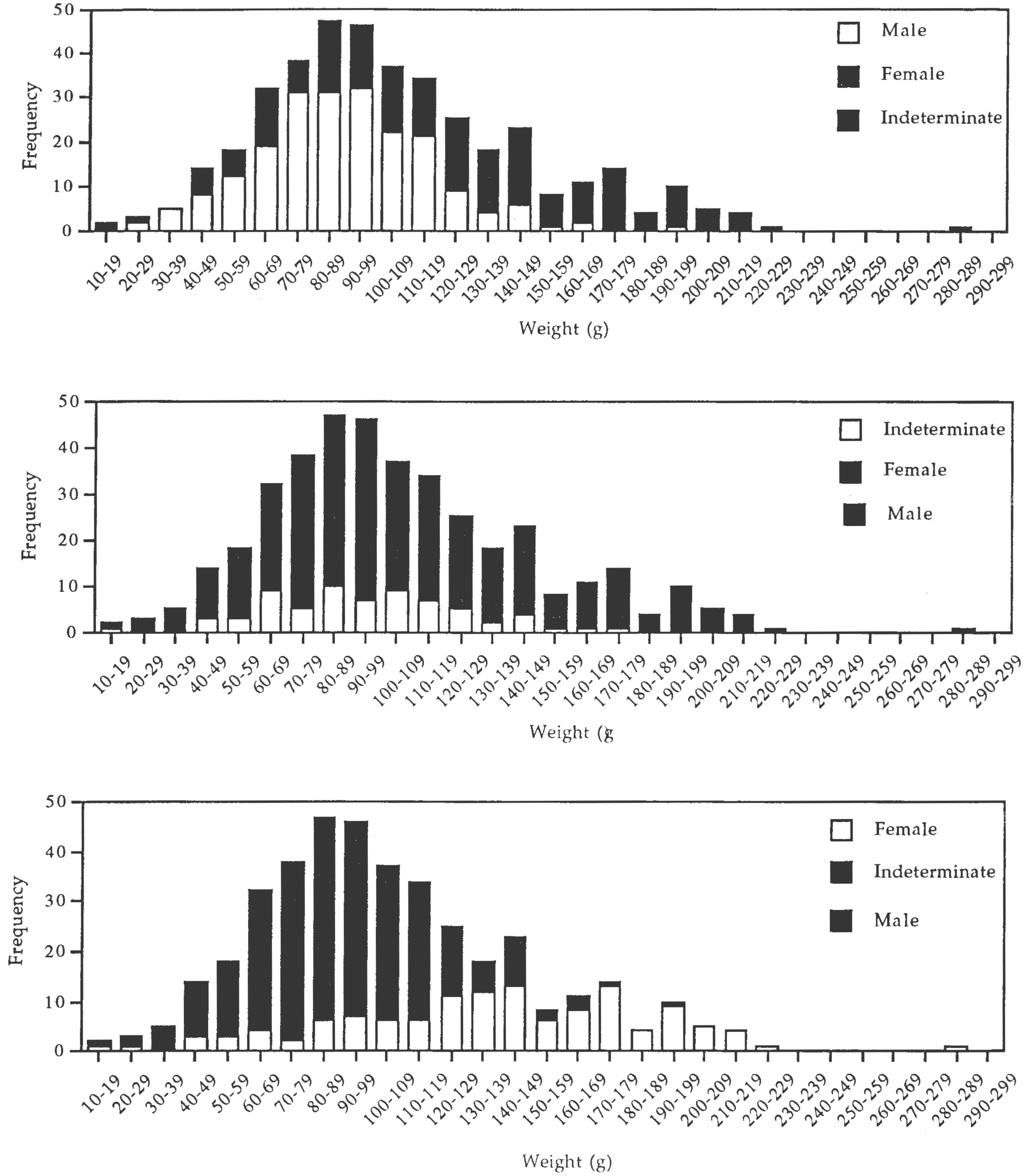


FIG 5.3 . Weight frequency histogram of flounder (15 months old) from Cameron of Tasmania at Dunalley showing differences of length between sexes. Fish were transferred to the farm at age 7 months and totalled 1392 at time of sampling on 9/8/95; sample size=400.

Trial B

Growth trials at St. Helens Aquaculture

Introduction

Small concrete raceways were trialed at St. Helens as part of the comparison between holding systems: raceways, tanks and cages. These small raceways were originally constructed to hold crayfish prior to packaging and shipment.

The trial was also undertaken as a preliminary assessment of the effect of ambient temperature on the growth of the fish, particularly the extremes in summer and winter.

Materials and Methods

Approximately 200 juvenile flounder were transferred at an age of 212 days and an average weight of 1.92g to a concrete raceway system at St. Helens Aquaculture. These raceways measure 5.5m x 1.4m x 0.35 m and were each supplied with 8-12 L/min seawater pumped from the nearby bay. The fish were originally introduced into one raceway with the intention of spreading fish to other units as they grow. Feed was delivered by hand at a rate of about 2 % body weight /day over a minimum of 3 feeds during the day. Feeding behaviour was rated on a score of 1-10 with 1 as poor and 10 as excellent. Ambient temperature was recorded daily.

A second recirculating tank system, containing fish of the same age and located on campus at the University of Tasmania (UTAS) was used to compare progress at St. Helens. The recirculating system was maintained at a constant temperature of 18±1°C. The effect of the fluctuating ambient temperature could then be compared in a general way with the constant temperature system at UTAS.

Results

Although the growth of the fish at St. Helens initially lagged behind the growth of the fish at UTAS (Fig. 6.1), the ambient temperature growth overtook the constant temperature growth after about 150 days. The results indicate little or no growth depression in fish even though temperatures fell to 10°C in winter.

Discussion

This preliminary trial suggested that winter temperatures experienced at St. Helens produced little if any growth depression. The minimum temperature experienced was 10°C. Although growth may have been compromised by water quality in the recirculation system (e.g. chronic low level ammonia) the temperature was held at a constant level considered close to optimal for fish on-growing.

Problems were associated with the design of the raceway and these may be summarised as follows:

(1) Pumping difficulties were experienced due to personnel switching between pumps without first clearing water delivery lines. Consequently, water contaminated with hydrogen sulphide was introduced into the system. Fish losses were associated with this problem.

(2) As the raceways were originally constructed for crayfish, the design was not strictly suitable for small fish. Even though the units are shallow and the water introduced across the breadth of the race, food and faecal material was not efficiently removed through the outlet at the end of the unit. Modifications were

undertaken to the floor to overcome this problem. A sloping floor from one end to the other and from the side to the middle was constructed. This proved effective for most material by smaller particles remained a concern.

(3) Biofouling in the form of algal growth on the sides and floor of the raceway impeded the clearing action of the currents. Food and faecal material added to the growth and fish found it difficult to feed and move around (being bottom dwellers). Cleaning also proved difficult because of the rough concrete surface (compared to glass or fibreglass) and potentially very labour intensive. Shade cloth and and a frame were positioned over a number of units and although it reduced the problem it did not remove it completely.

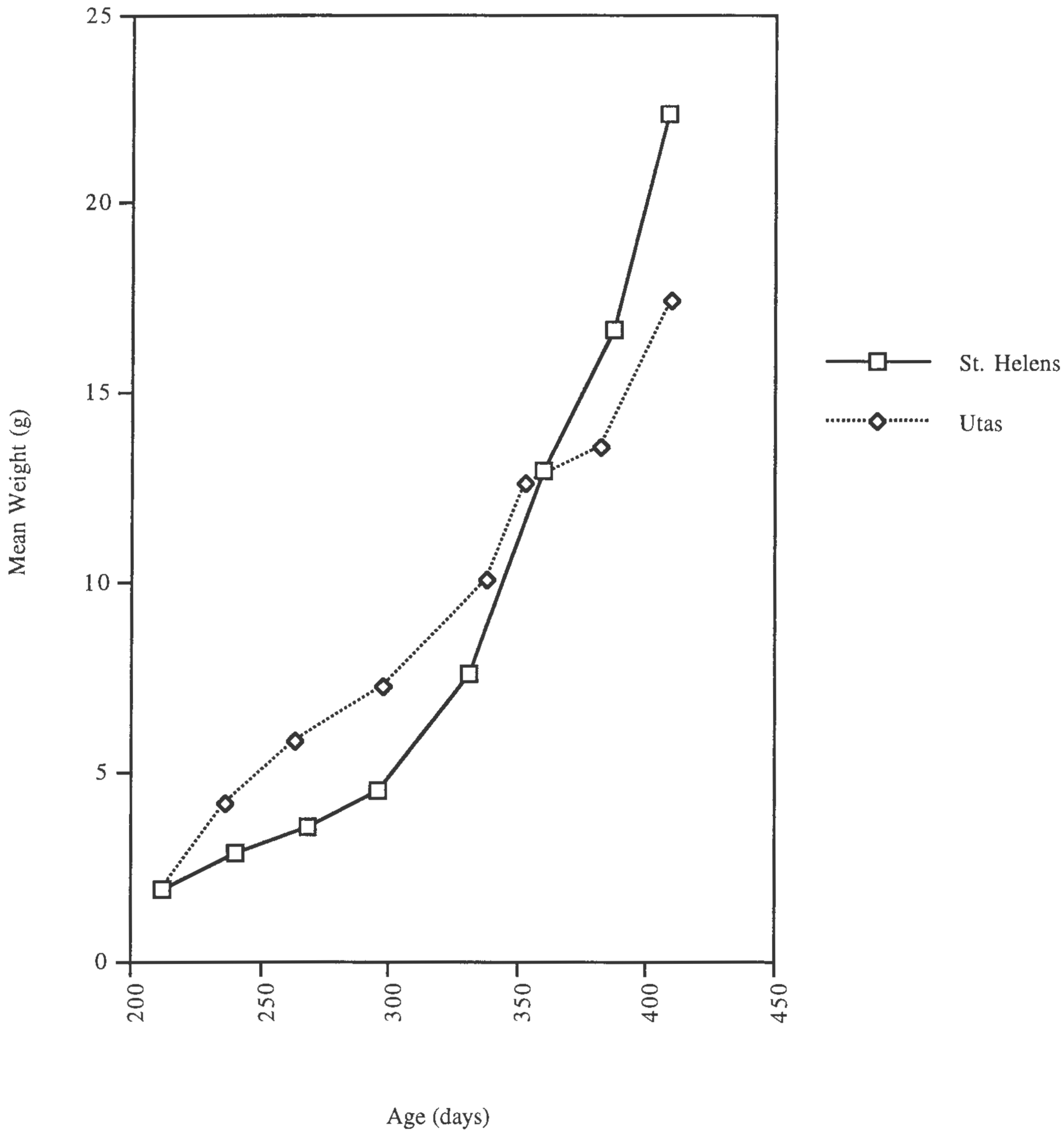


FIG 6.1. Growth comparison of Greenback flounder at a ccoastal marine site (10-18 °C) with flow through water (St. Helens Aquaculture) and flounder held in constant temperature (18 ± 1°C) marine recirculating system (Utas, Launceston). Fish were 212 days old at commencement of study with mean weight and length of 1.92g and 45mm; a total of 198 fish used at marine site and 200 in recirculating system.The study was conducted from 15/3/94 until 6/10/94.

Trial C

Growth trial at Purves Fisheries, Bridport

In 1995, 15,000 small juvenile fish (0.7-3.9 g) were transferred from DPIF Sea Fisheries to the Purves Fisheries site at Bridport and placed in circular tanks (diameter approximately 6m) for grow-out. Unfortunately, the majority of these fish suffered from lordosis/scoliosis, deformed opercula, anorexia and cataracts. A high percentage of these fish died because of the deformities.

This site would be used for future trials because of the interest in the species shown by the company, investment in developing flounder culture and the environmental nature of the site. During winter this site experiences lower salinity conditions and is restricted on a daily basis in the way that seawater is pumped; pumping can only occur effectively at high tide (incoming tide).

In late 1995, 7,200 juvenile flounder (average 2 g) were transferred from DPIF Fisheries to 2 tanks on this site. Grow-out trials continue, with little difference in growth data between this site and the others. Water visibility is an issue during rains. Water is pumped on the high tide. Green water larval culture is currently being trialed on this site.

Trial D

Growth trials at Pipe Clay Oysters

Nursery and grow-out tank systems were constructed on this site in 1995. Facilities on this site include 12 nursery tanks, 4 x 4 m diameter fibreglass grow-out tanks serviced by a pumping system, aeration and water reservoirs. Grow-out trials commenced late 1995 with the transfer of 4,000 juvenile fish (averaging 5 g) from DPIF Sea Fisheries to this site. Fish size has been measured and growth will continued to be monitored approximately every month. Growth results to date show little difference to the other sites, with the same trend emerging of growth interrupted by lower winter temperatures and the onset of maturation.

In addition, broodstock are also being held on this site.

6. Comments on various culture aspects

Transportation

Fish with an average weight ranging from 2g to 100g have been transported successfully in plastic bags and fibreglass transport tankers during this program. Densities of about 17-23 kg/m^2 were used.

Transportation of the fish has raised a number of points for consideration:

- Flatfish appear to have different requirements for transportation compared with "round" fish.
- They require a flat floor on which to rest although at low densities a rounded floor is acceptable. The water column in the tanker is rarely used by the fish although the tank sides are used. Smaller fish tend to be more active than larger fish.
- As the density is increased the number of layers of fish on the floor of the tanker increases, effectively eliminating oxygen supply to the lower layers unless water movement is created in the tanker.
- High supersaturation levels (≈20 ppmDO) created accidentally in tanks (due to malfunction of DO meter, the readings were incorrect) appeared to have caused gas bubbles in the eyes of some fish.
- Low DO levels (<3 ppm) can be tolerated over short periods but proved lethal to some fish in the tanker.
- Fish are difficult to crowd and net from the tanks to load into tankers as they stay close to the floor.

Grow-out Conditions and Management techniques

- Fish may be damaged when walking into tanks during capture if crowding devices are not used.
- Although fish at times seem to seek out sunlight in the tanks, grow-out probably requires some form of shading.
- Tank shading promotes feeding and minimises biofouling.
- Biofouling on tank walls probably reduces nutrient levels in the water, and may be important in recirculating systems, but causes water quality problems during cleaning operations. Tank cleaning needs to be undertaken daily and is labour intensive.
- Non-toxic antifoulants are being investigated and will be trialed in 1997 at Pipe Clay Oysters.
- As the tank stocking is based on floor area rather than volume, ways of increasing densities or tank production levels should be investigated. Multi-layering of tanks (or other culture vessels such as raceways and cages) has been proposed but has not been developed. Management issues such as feed distribution, observation of behaviour, detection of mortalities and disease, and maintenance of efficient tank hydro-dynamics are considerations associated with multiple layering systems for fish.

- Tank depth needs to be adequate to provide some light reduction (if shading is not directly used) but does not need to be as deep as tanks used for pelagic fish.

- Flow dynamics of tanks and raceways and important; water currents should provide a self-cleaning action and adequate oxygen but should not be excessive. High currents tend to flush pellets from the tank too quickly and force fish to "cling" to the tank floor. Both of these conditions compromise growth.

- Descriptions of flatfish tanks and raceway systems are available in the literature e.g. Cripps and Poxton (1992), Lygren (1994) and Oiestad (1996); design considerations raised in these papers should be combined with the results from these flounder trials when planning to design any culture systems.

- Cage culture of flatfish is described by articles such as Anon. (1996), Won Tack Yang (1994) and Gillespie (1996).

- As flounder are fairly slow, clumsy feeders they benefit from regular meals dispersed widely to minimise hierarchies rather than a few large meals during the day.

- Although flounder appear to tolerate quite low oxygen levels, dissolved oxygen should be maintained near saturation to provide optimal growing conditions.

- Pump failure during the trials have caused high mortality levels due to the loss of water movement and declining dissolve oxygen levels.

- Aeration should be used in tanks to support moderate to high densities although oxygenation systems may need to be used to support high to very high densities. Back-up generator and pumping facilities would also be essential under these conditions.

- Partial recirculation or full recirculation systems may be a way of reducing pumping costs. Fish have performed favourably in these systems during the growth trials.

- During low oxygen conditions significant losses were experienced in some batches but are usually only small poor conditioned fish, many possessing deformed opercula. These fish would have had trouble ventilating their gills because of these deformities.

Nutrition

No nutrition work has been undertaken as part of this grant but the following observations have been made:

- Juvenile flounder ingest pelleted and crumble feeds manufactured for salmon and trout. Low and high fat diets are consumed although lower fat diets are probably preferred.

- Fish find it difficult to consume hard pellets, particularly some of the extruded diets which retain their integrity for longer periods than the pressed pellets. Steam pressed diets are taken by the fish but are not manufactured in the same quantity as extruded diets.

- Some fish display pale livers which may be a symptom of high fat diets.

- A high level of lordosis/scoliosis (bent spines) and deformed opercula (particularly top side) suggest inadequate vitamin C levels in the diet. Vitamin C requirements therefore may be much higher than those of trout and salmon.

- Formulation of a flounder diet is one of the most important research areas to be undertaken.

Fish Health

- Fish health assessments were undertaken by the Fish Health Unit at Mt Pleasant DPIF prior to the fish being transferred from DPIF Sea Fisheries or University of Tasmania to farm systems.

- *Aeromonas salmonicida* has been detected in flounder at two sites in Tasmania (out-with this study). Although it has been identified as the non-salmonid (non-furunculosis) strain, precautions have been taken to keep flounder culture isolated from salmonid facilities to protect the local salmon industry. These precautions are essential but have meant that cage trials, previously outlined in the grant application, can not be undertaken on salmon leases where the necessary infrastructure to support such trials is located.

- *A. salmonicida* has not been detected during routine screening in this program.

- Samples of moribund fish on farms or research facilities were regularly sent to the Fish Health Unit, Mt. Pleasant for disease detection.

- Consideration should be given to separating cultured and wild flounder on farms to reduce any possibility of disease transfer, particularly *A. salmonicida.* Wild flounder may be used for broodstock.

- *Flexibacter* has been detected in samples. The infections have been mainly detected around the mouth and on some skin lesions. Infections around the mouth occurred mainly in winter and may have been caused by abrasions on food, tank floor or diatom irritation, and have resulted in necrosis of the mouth area. Poor water quality (particularly solids build up in the tank) may contribute to the condition.

- A condition similar to fin rot (may be *Flexibacter*) was also detected at low levels.

- A reddening around the fins, detected mainly on the underside of the fish, was seen at low levels fairly frequently; its cause is largely unknown.

- The external protozoan parasite *Trichodina* appears to be the major disease problem encountered. Fish feeding was suppressed by these infections and mortalities encountered. Infections occurred on the skin and in the gills, and were successfully treated using a bath of malachite green and formalin. This type of treatment will require attention in the future.

- Quality of the intake water has been a concern on a number of occasions at Dunalley, affecting the behaviour, feed intake and health of the fish. Problems were encountered with algal blooms (gill irritation, lower oxygen levels, mouth damage), high suspended solid load, high turbidity (gill irritation, difficult to observe fish), lowered salinity due to torrential rain and extreme temperatures where the tide moved water off shallow sand flats (high temperature in summer, low in winter).

- Nutritional diseases such as pale livers (high fat), bent spinal column (deficiency in Vitamin C) and malpigmentation (possibly nutritional but may be environmental) have been experienced and are more of a concern than pathogenic diseases.

- Spinal curvature may be caused by vitamin C, E deficiency, Mg or tryptophane deficiency, vitamin A toxicity.

- A few cataracts were detected in the fish; these may be caused by physical damage or some nutritional deficiency. The incidence was reasonably low but worth noting. A greater problem is the bulging of the eyes due to what appears to be a gaseous build-up. This has been seen during transportation and in some pumping situations, and may be caused by gas supersaturation. Over a longer term it may be caused by a bacterial infection in the eye.

- Microsporidian infections of the liver have been detected in cultured fish. More work needs to be undertaken to determine the transmission pathway as the disease can cause mortalities particularly in conjunction with stress. It does not appear to have any significance in relation to human consumption, as it has only been detected in the liver.

7. Product Assessment

Product reared as part of the grow-out program was used in sensory testing at IFIQ and determination of gutted recovery rates. In addition, a market assessment on flounder and flatfish was contracted to IFIQ to estimate market sizes and prices based on wild-caught product.

(i) Sensory testing

The Sensory Evaluation unit at the Centre for Food Technology (DPI) was contracted to undertake the sensory testing of cultured flounder. Although a comprehensive assessment would be based on tests in all states (due to the cost) the initial test was undertaken in Brisbane where the Institute is based. Although the location to some extent may bias the results, because flounder are relatively unknown except in southern states, the results may be used in a comparative way. It is comparative because the culture greenback flounder was assessed against wild caught greenback flounder and frozen New Zealand flounder (*Rhombosolea plebeia* , sand flounder).

Fifty fish from each group were sent to Brisbane for assessment. All three groups were of a similar size, around 180-300g. This size is considered small and about the minimum marketable size. The wild and cultured greenback flounder were sent as fish gutted chilled fish while the New Zealand product was frozen (as sold in commercial outlets).

The results were very favourable with the cultured product rating more favourably than the wild greenback flounder. The only negative comments were that the fish were on the small side and some displayed a greenish colouration in the flesh rather than white.

The sensory market analysis report is separate to this document; pertinent points are listed in the Technical Summary, and copies of the contents pages and executive summary are included in the Appendix 1.

(ii) Recovery rates

During the product preparation of the cultured fish for sensory testing the recovery rates of gutted product from whole fish were determined. A sample of the fish was assessed; the results are shown in Figure 9. The average recovery rate is 94%. Gills and gonad are left in the fish, unlike salmon and trout which are processed to gilled and gutted product (with gonad also removed). Roed flounder may be considered one product form.

(iii) Market Assessment

The Rural Enterprise Development unit at the Centre for Food Technology (DPI) was contracted to conduct an assessment of the current market size and price structure for flatfish and for flounder in particular. Various flatfish species are sold in the markets around Australia; many are local while some are imported from New Zealand. These flatfish include a variety of flounder species, sole, brill and turbot; greenback founder is only one species within this group.

The market size for flatfish gives an approximation of the volume of flounder and other species moving through fish outlets. Wholesale and retail prices provide a baseline from which to work in assessing cultured product. At present there is no cultured flounder in the market; accurate figures on cultured fish are therefore not possible. The price for wild caught product is a starting point but it is suggested the cultured product will be different in the following ways:

(i) Cultured products can be harvested at particular sizes as ordered by the customer, probably 300g+ (with a maximum of about 700g).

(ii) Orders may be based on planned harvests rather than inconsistent capture in the wild. Harvests may occur year-round.

(iii) Cultured fish may be sold as live product in premium quality.

(iv) Roed product may be sold at specific times during the year.

(v) Fish displaying higher meat: frame ratios may be grown through the development of suitable diets.

As the aim of the about points is to promote quality, product flexibility and year round markets, the prices obtained in the market place should be higher than trawled or seine-netted fresh and frozen product.

The preliminary market assessment report is separate to this document; pertinent points are listed in the Technical Summary and a copy of the contents page and executive summary are included in Appendix 2.

8. DPIF Division of Sea Fisheries - data

The production protocol that was developed by and used in the DPIF Finfish Aquaculture Development Program has been published as an internal report (Butler et al., 1996). The protocols do differ from those used at the University particularly in relation to the system used, the live feed enrichment and weaning regimes. A summary of the factors in the protocol is as follows (as supplied by DPIF):

Egg incubation - 14°C, no aeration or light

Stocked in larval tanks at 50 eggs/L

First feeding day 4 on rotifers at 5/ml both morning and afternoon

AF introduced day 9

Rotifers withdrawn day 10

Enriched metanauplii day 11

AF withdrawn day 12

Metamorphosis on day 22, once all fish have settled then transferred to weaning cages (day 27)

Weaning diets = Nippai, Ewos, Gibson's (< 2mm)

Temperature = 14°C, Dissolved oxygen > 6ppm, Total ammonia < 0.3 ppm

Growth:
Weight at 155 days = 9.25 g, at 237 days = 45.25 g

9. Technical Summary

Brief Summary

The research and development of flounder production displays the following characters:

Strengths

* Industry involvement
* Additional supportive research
* Successful culture of broodstock, larvae, juveniles and market size fish
* Closed production cycle (breeding from cultured stock)
* Long spawning season
* Market sized fish produced in about 2-3 years
* Good growth except during maturation
* Triploidy can be induced, may be used to combat maturation
* Cultured at moderate densities without elevated stress levels or retarded growth
* Can grow on available salmonid diets but needs a specifically formulated pellet
* Feed conversion ratio of 1.2:1 - 2:1
* Condition factor of about 2
* Survival of 89-100% (juveniles) under experimental grow-out over 250 days
* May be integrated into shellfish hatchery production (diversification)
* Processed gutted recovery rate of 95%
* Favourable sensory test results, no off-flavours
* Wild caught live flounder have fetched $15-25 /kg in Australian markets
* Flounder appear to be good candidates for live transportation
* Tolerant of low dissolved oxygen concentrations
* Popular market product in southern Australian states
* Restaurants have asked to trial product
* Low wild catch level of 47 tonne/year (total flatfish = 92 t)
* Australian flatfish market estimated at 735 t /year
* Flatfish is popular overseas; right-eyed flounder fetch up A$50 /kg in Japan
* Flatfish market in Japan estimated at 166,880 t/year

Weaknesses

* Range of diseases identified, *Aeromonas salmonicida* is of most concern
* Can not use salmonid infrastructure because of *A. salmonicida* disease transfer threat
* Slow feeders
* High maturation and slow growth during winter
* Moderate levels of juvenile spinal column deformities and malpigmentation
* Low prices for frozen and small chilled wild caught flounder

* Relatively unknown in northern Australian states
* Pumping costs involved in shore based production

Detailed summary

Summary of the research findings relevant to the development of flounder as an aquaculture species. Dot points are listed under the strengths and weaknesses of the fish, markets and systems.

Strengths

Industry Involvement

* At present in Tasmania, 2 growers are involved in pilot scale growout assessment trials with a further 2 expected to start in 1997. A further 10 calls of interest have been received. In Victoria, one company is presently establishing a small hatchery and grow-out operation. In South Australia, about 5 calls of interest have been registered.

Supportive Research

* There is a significant number of research projects on flounder apart from that funded by FRDC. This means that the research and development component has a critical momentum which enables work to be tied together over a relatively short period of time.

Sensory testing - Center for Food Technology Report

* In sensory tests (flavour, texture, aroma, appearance) at the Centre for food Technology in Brisbane, cultured greenback flounder rated as highly as imported New Zealand *R. plebeia* and better than fresh wild caught greenback from Tasmania. No off-flavours were detected. It was commented that the cultured product displayed a "greenish" colour compared with the whit/cream/pink colouration of the frozen and wild fish. The effect of the artificial feeds and method of killing need to be examined.

* Overall the cultured product was well accepted by participants.

* As participants in Brisbane favoured tropical reef fish, and as they were not very familiar with flatfish, it was suggested by the Centre to run the tests in the southern states where this product is more recognisable.

Market assessment - incl. summary from Centre for Food Technology Report

* Wild caught fish delivered live in Australian markets have fetched $15-$25 /kg.

* Very encouraging preliminary live transport experiments have shown that flounder can be chilled and survive for 24 hours with 100% survival when subsequently revived at 15°C.

* Wild caught chilled flounder can fetch prices of $6-10/kg wholesale. Cultured fish would need to be a premium product. It is difficult to extrapolate wild caught prices to cultured because of inconsistent supply, variable sizes and little species-specific marketing in the former.

* Recognisable, marketable product, particularly in the southern states of Australia.

* It is considered to be the only flatfish species which can be considered commercial and which can compete with imported flatfish.

* Flounder is a well known product group in Asia, Europe and North America. Flatfish are classified as right-eyed or left-eyed. Greenback flounder is right-eyed. In Japan prices for particular species in each group (hirame and karei) fetch up to A$50/kg (wholesale). Four species of right-eyed flounder fetch prices over A$20/kg.

* "Mures" in Hobart wishes to introduce cultured flounder to their restaurant menus, and has placed orders with one grower. They also plan to film the whole production process and incorporate the segment into a television program on Tasmanian foods.

* Australian catch of greenback flounder is declining and stands at about 47 tonne/year out of a total flatfish tonnage of 92 tonne. Difficult to obtain high quality fresh flounder of consistent size and supply.

* Australian flatfish market is estimated at 735 t valued at $4.4 m. New Zealand imports comprise 90% market; mostly trawled frozen product.

* Market wants large plate size flounder (about 400g+) fresh or live with a 30% flesh to bone ratio. Cultured fish display a better condition factor than wild caught.

* Japan's flatfish market in 1994 was 166,880 t of which half was imported.

* New Zealand flounder exports into Taiwan in 1992 increased from 160 kg to 10,376 kg in 1994. Between 1993 and 1994 it increased 19 times in quantity and 6 times in value.

* Report recommends that the higher price structures are found in Japan, Singapore and United States and that these markets should be investigated further.

* Australia exports about 52 t of flatfish/year, all of which is re-exported New Zealand product; averaging a price of $10/kg.

Culture Techniques

* Flounder is a member of the flatfish group which is being extensively investigated worldwide for aquaculture. Greenback flounder culture can benefit from some technology transfer from overseas.

* Closed reproductive cycle: fertilised eggs have been obtained from cultured stock through hormone injection techniques and natural spawnings in tanks.

* This species shows a relatively long spawning season of April-December; it is possible that spawning periods may be manipulated by photoperiod control to extend this to year-round production,

* Successful larval rearing using standard live feeds through to weaning onto artificial feeds has been conducted.

* It has been demonstrated that flounder can be grown under hatchery, nursery and grow-out culture conditions.

* The species is a good candidate for on-shore culture where coastal seacage sites are limiting or are better utilised by other species (e.g. salmon, snapper).

* The culture techniques can to be integrated into existing shellfish (and finfish) operations.

Maturation

* Triploidy appears to be a feasible method of overcoming gonad development and slow growth during winter. Although grow-out performance trials have not been conducted as yet, high triploid rates (85%+) have been obtained experimentally.

Market size fish, growth

* Market size fish (smaller sizes about 300 g) were produced within 20 months of hatch; these represented the upper grade of the grow-out fish. Australian markets desire fish 300-700 g. The minimum legal size is 250 mm (about 280 g).

* Prior to the winter depression in growth juvenile fish grew from an average of 30 g to 100 g in 4 months. The following specific growth rates have been measured during the study: 1.7-2.3%/day (10-40 g juveniles), 0.35-0.50 %/day (35-120 g juveniles) and 0.8 %/day for larger fish.

Density

* Groups of fish growing in a recirculating system at densities in the range 1-15 kg/m^2 (floor area) did not show any substantial difference in growth. The higher density is comparable with some flatfish species produced overseas.

Feeding

* There is some evidence that flounder will feed 24 hours/day through light and dark cycles. This requires further investigation; all feeding undertaken in this trial was conducted during the light cycle.

* Pellet size (diameter) to fish size, approximate feeding rates and maintenance feeding rations have been identified.

* Compensatory growth mechanisms appear to be present and these may be used to control growth in juvenile fish. This approach may be used to stagger grow-out and fish availability into the market place.

* Feed conversion ratios (FCR) obtained have been approximately 1.2-1.5:1 for juveniles around 10-40 g using salmon diets. FCR values during the grow-out phase are approximately 1.5-2:1 although it is difficult to quantify wastage. These are good considering that the nutritional requirements of flounder have not been identified.

Behaviour

* The fish will congregate on the surface if hungry and approach personnel. Fish adapt easily to tank environments and generally display low stress levels.

* They do not appear to like high light intensities such as direct sunlight all day. Some shading is necessary.

Survival

* Survival figures have been complicated by losses due to pump failure etc but are in the order of 40% in the larger systems. Survival of around 89-100% (over 250 days) was achieved in the smaller experimental systems where greater control over water quality was possible.

Recovery rates

* Recovery rates from whole fish to whole gutted (gill and gonad in) fish are around 95 %.

Weaknesses

Disease

* A range of diseases has been identified in the fish during culture: *Trichodina* (external protozoan parasite), *Flexibacter*, *Vibrio* (bacteria), myxosporidia, microsporidia (internal protozoan parasites), none of which have caused mass mortalities or are a concern in the market. *Aeromonas salmonicida* also has been detected (wild flounder) and has caused some concern to salmon growers - the trials have been undertaken in non-salmonid areas to prevent disease transfer.

Behaviour

* Pellet consumption rates are slow because they are bottom feeders rather than pelagic feeders, and therefore feeding in cages with open weave floors would waste feed. They will take pellets in the water column when hungry.

Maturation

* Maturation levels of 83%, in one year old fish, were detected during sampling in winter. The percentage of mature fish probably varies over a wide spawning season (April-October). Maturation (and low temperatures) slow growth.

Product Quality

* A proportion of fish in each batch display deformities (bent spinal chord, shortened gill covers) and/or mal-pigmentation. Nutritional imbalances or sub-optimal environmental parameters are suspected as causal factors. These are unacceptable traits in market fish.

* Some fish during the taste testing appeared to show a green colouration in the flesh and the bones, perhaps due to the killing method, artificial feed or astaxanthin. This condition would affect the saleability of the product and requires further investigation.

Market assessment

* Low prices for whole frozen and chilled product can be in the order of $2-$6 /kg wholesale, but is governed by quality and size.

* No aquaculture product is currently sold in the market; all figures are based on wild caught fish.

* Although greenback flounder is well known in the southern states, it may need to be promoted in the market in the north of Australia.

Systems

* Flounder are probably not a cage culture species except in solid floor cages in very sheltered coastal areas. Pumping would form a significant production cost component in on-shore systems but this may be reduced by the development of efficient recirculation systems.

10. Benefits

The original benefits and beneficiaries were listed as:

The program will

(i) identify the most suitable grow-out system to determine whether flounder may be easily incorporated into salmon farms (cages) or whether it represents a new land based industry (tanks or raceways);

(ii) identify the time taken to reach market size as this will relate significantly to the economic viability of the culture of a new species;

(iii) assess the suitability of available salmon diets, specifically in terms of growth and flesh condition. Should it be found to be unsuitable a new diet would need to be developed;

(iv) provide data on the culture of flounder under intensive systems. If the program appears economically viable these data will be used as a starting point for the development of a 'flounder industry' with the techniques being refined over time.

At this stage of the development of flounder, any intensive culture is most likely to be undertaken in land-based tank or raceway systems while the semi-intensive preference is ponds. Cages may be a possible option but its development may be hampered by the lack of sheltered inshore sites, conflict with other coastal users, the need to develop cage culture techniques and possible disease transfer implications near other established finfish (e.g. salmonids) facilities. Potential beneficiaries include

(i) new aquaculture developers,
(ii) oyster farms where sheltered sites do exist and where micro-algal cultures and other facilities exist for hatchery rearing,
(iii) abalone farms where some tank designs may be suitable for duo-culture or where water from the abalone may be re-used through flounder systems,
(iv) salmon farmers who have fish culture knowledge and existing infrastructure such as processing areas, marketing, distribution outlets etc.

Indirectly the beneficiaries could also include

(i) restaurants which require a consistent product size, quality and supply,
(ii) export companies which trade in south east Asia,

through the development of a new aquaculture product.

The time to market has been identified as approximately two years from spawning, but only for the top grade of fish and only for a relatively small proportion of the population. Retarded growth during winter due to maturation, feed nutrition inadequacies and low temperature extends the growth period to over two years.

Removal or reduction of these problems would significantly improve growth and reduce the growth time to market size.

The existing salmonid diets were used during the trials. Three problems were experienced: the lack of consistency in the available diet, lack of understanding about the specific dietary requirements of this species and growth problems such as reduced growth and spinal deformities observed during the trials. A balanced diet based on the nutritional reqirements of greenback flounder needs to be formulated to benefit the development of this species.

Preliminary grow-out parameters have been identified and these have been listed in the summary under strengths and weaknesses. Overall, flounder appears to be a promising culture species, particularly if problems associated with maturation, nutrition and feeding are overcome.

11. Intellectual Property and valuable information

The intellectual property arising from the research involves the data outlined in the experiments detailed above; specifically information about stocking density, size variability, grading effects, maturation frequency/composition, effects of density on cortisol, growth data, tank floor coverage and effects of ration size on growth.

12. Further development

Because of the nature of the program, it is difficult to patent or sell the results of the project. They should be, however, beneficial for any investor wishing to establish a flounder grow-out facility. The industry participants acknowledge the valuable contribution that FRDC has made, through this project, to the development and better understanding of this species. Should this report generate wide-ranging interest in the results, the chief investigator would suggest that the results could be better disseminated by conducting a training program on the grow-out techniques used in flounder culture.

13. Staff

List of personnel who at various times particated directly in the program

University of Tasmania

Dr John Purser
Mr Craig Thomas - employed by FRDC funding
Dr Piers Hart
Mr Mark Johnston

Tasmanian DPIF, Sea Fisheries

Mr Lance Searle
Ms Polly Butler
Dr Arthur Ritar
Mr Brent Hill - short-term employment via FRDC funds
Mr Alan Beech
Mr Bill Wilkinson

Cameron of Tasmania

Mr Ian Cameron
Mr Michael Cameron
Mrs Debbie Cameron
Mr Graham Cameron
Mr Brian Webster
Mr Ashley Gatehouse
Mr Ian Duthie

St Helens Aquaculture

Mr Ivan Bailey
Mr Ian Coatsworth

Purves Fisheries

Mr Alec Purves
Mr Ian Cameron

Pipe Clay Oysters

Mr Peter Chew
Mrs Jan Chew
Mr David Wright
Mr Scott Wright

14. Final cost

Cash Contribution by FRDC:	$ 120,850
Estimated In-kind Contributions by:	
University of Tasmania	$ 71,000
DPIF Division of Sea Fisheries	$ 30,000
Cameron of Tasmania	$ 25,000
St Helens Aquaculture	$ 7,500
Purves Fisheries	$ 15,000
Pipe Clay	$ 7,500
TOTAL	$ 276,850

15. Acknowledgements

I would like to thank memebers of the FRDC board and TasFRAB for their support of the program and the significant financial assistance provided over the last 2 years, the companies (Cameron of Tasmania, Purves Fisheries, St Helens Aquaculture, Pipe Clay Oysters) who have participated in the program and contributed very significantly, the University of Tasmania for its administrative and infrastructure support and the Fish Aquaculture section of the Division of Sea Fisheries, DPIF for their considerable assistance and contribution in the production of juvenile fish and their technical support.

In addition, I wish to thank Anne Ford and Bronwyn Warfield and their staff at the Centre for Food Technology in Brisbane for undertaking the sensory testing and market assessment trials, Bob and Lorraine Andrew (Tasmanian Fish Markets) for advising on techniques of fish packaging and gutting, Michael Cripps for supplying the wild-caught flounder, Ansett Air Freight, RMAX and Spicers for assistance with product packaging.

I would like to express my sincere thanks to Craig Thomas for his dedication to the program and endless hours of looking after the experimental fish; also to Dr Piers Hart for his assistance and advice particularly with reference to larval rearing. Finally, I wish to thank Professors Nigel Forteath and Andrew Osborn, and the other staff and students of the Department of Aquaculture, University of Tasmania for their support in the development of flounder as an aquaculture species.

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APPENDIX 1.

Sensory Market Analysis -
Copy of report contents page and executive summary

FINAL REPORT

Sensory Market Analysis of Aquacultured Greenback Flounder

Prepared for Department of Aquaculture
University of Tasmania
Launceston TAS 7250

Ann Ford and Ron Roberts
Centre for Food Technology Sensory Evaluation

DEPARTMENT OF PRIMARY INDUSTRIES

EXECUTIVE SUMMARY

Greenback flounder which had been cultured under pilot scale grow-out conditions in Tasmania were oven baked, and the fillets were served to a group of Brisbane consumers who regularly eat fish in restaurants or at home. They rated the acceptability of various attributes of the cooked flesh and the appearance of the whole fish, in comparison with flounder which had been "wild caught" off the Tasmanian coastline and imported frozen flounder from New Zealand. (Total imports of fresh and frozen New Zealand flounder constitute 90% of the flounder purchased in Australia.)

The acceptability of aroma, flavour and texture of flesh from the aquacultured fish was similar to that of the New Zealand flounder and significantly higher than the "wild caught" fish. The flesh was ranked lowest for appearance, and this coincided with a perceived "greenish" tinge in the flesh compared to "pinkish/cream" and "greyish" in the New Zealand and wild caught groups respectively.

However, overall the aquacultured flounder was well accepted by the participants in the test and shows potential as an alternative to the species from tropical waters which they stated were their "favourite fish", and with which they are more familiar.

We believe further investigations are needed into the potential of the fish, by firstly surveying restaurants owners, chefs, and executives of family restaurant chains throughout Australia, and secondly by repeating the tests run in Brisbane in the southern states, where consumers are familiar with this type of fish.

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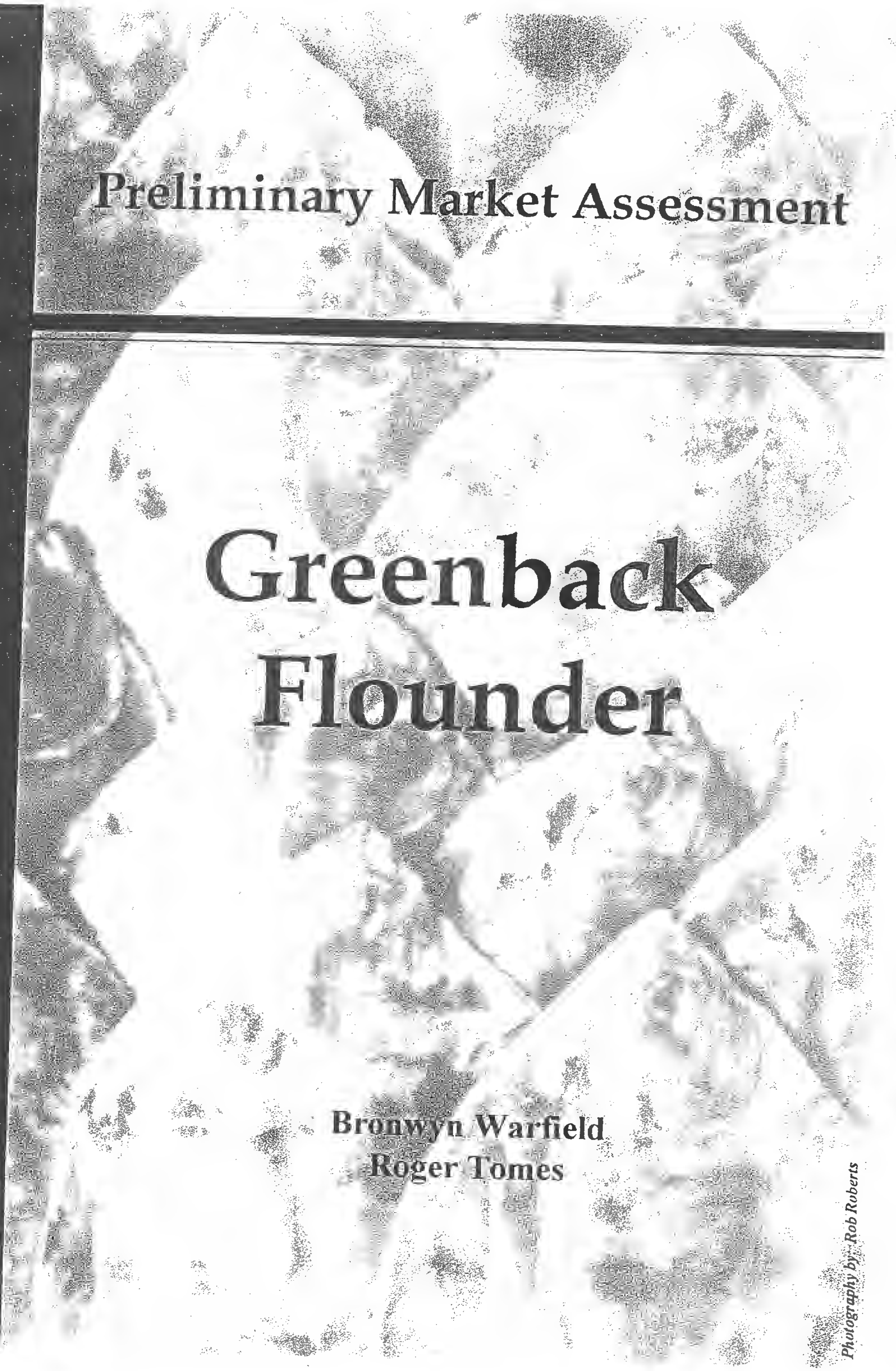
APPENDIX 2.

Preliminary Market Assessment - Copy of report contents page and executive summary



Preliminary Market Assessment

Greenback Flounder

Bronwyn Warfield
Roger Tomes

Photography by: Rob Roberts

PRELIMINARY MARKET ASSESSMENT
GREENBACK FLOUNDER

APRIL 1996

Bronwyn Warfield (Marketing Officer, Rural Enterprise Development, DPI)

Roger Tomes (Regional Economist, Rural Enterprise Development, DPI)

DPI QUEENSLAND

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EXECUTIVE SUMMARY

This report was commissioned by Dr John Purser from the University of Tasmania to be undertaken in February 1996. The brief was to determine the market for flatfish, flounder and in particular, greenback flounder, in Australia, Taiwan, Japan and Korea based on published information and statistics (secondary research).

Presented in this report are the findings from our secondary research, which provides a preliminary market assessment for cultured greenback flounder. As there was no published market information on cultured greenback flounder, it is strongly recommended that this report be regarded as stage one. It should be followed by stage two - interviews (primary research) in Australia and selected overseas markets to provide specific market information relating to cultured greenback flounder.

Species

Flatfish is the generic name for a wide range of fish which includes many of the world's tastiest and most valuable food fishes, such as the flounder, sole, plaice, halibut, turbot and brill (there are a number of species belonging to each of these types). This report looks at the total flatfish market including flounder and in particular greenback flounder. It should be noted that commercial species of flatfish vary in size from 365 cm (Atlantic halibut) to 27 cm (harrowed sole) and can be either left eyed or right eyed. The greenback flounder being cultured in Tasmania is a right eyed flatfish and in the wild grows to a maximum length of approximately 38 cm. In overseas markets, flatfish of different sizes and right and left eyed appear to compete in different market sectors. In assessing potential overseas prices it is important to look at right eyed flatfish of a similar size to the greenback flounder.

Australian market

Greenback flounder is the only species of flounder caught in Australia that could be considered "commercial" (Perkins, DPI) and that has the potential to compete with imported New Zealand flounder.

In 1994/95, the greenback flounder catch in Australia was estimated to be 47 tonnes. Greenback flounder is predominantly caught in Tasmanian, South Australian and Victorian waters. It was estimated that the average market size for all species of flounder in Australia is 735 tonnes valued at $4.4m. New Zealand flounder dominates the Australian domestic flounder market, supplying more than 90% of the market.

Wholesale prices quoted in Sydney, Brisbane and Melbourne for chilled greenback flounder varied between $6 and $10/kg. The prices quoted by wholesalers selling New Zealand chilled flounder in Australia are an indication of the prices a well grown cultured greenback flounder would fetch as an import replacement.

The trade (wholesalers in Sydney, restaurateur, chef) did not differentiate between species of flounder. The only distinction made was between domestic and New Zealand flounder. Nor did the trade speak about different species of New Zealand flounder (see Table 1) but simply called them all New Zealand flounder. New Zealand flounder (term used by trade) was perceived to be larger (500 g to 800 g) and therefore better than domestic flounder (term used by trade to describe all Australian flounder). As the sand and greenback flounder are similar in appearance it is possible that the larger NZ flounder being referred to by the trade is sand flounder. The fact that different species of flounder all looking similiar and the buyers are not distinguishing between different species is an imporant marketing and promotional issue.

Based on the trade research, the market requires larger, plate sized flounder with a 30% flesh to bone ratio. A larger greenback flounder with a high flesh to bone ratio may be achievable in a cultured fish. A cultured greenback flounder grown to a similar size to New Zealand flounder would therefore be more competitive than wild caught greenback flounder.

New Zealand -competitive activities

New Zealand's main export markets for flounder (excluding Australia) are Hong Kong, Japan and the United States of America (USA). The USA pays a higher price ($5.11/kg) for flounder than the other major export markets (Hong Kong $4.70/kg, Australia $3.78/kg and Japan $3.76/kg) . All of these markets are established, as New Zealand has been exporting flounder to these countries for at least three years. The total quantity of New Zealand flounder exports has been relatively constant. However, the total value of flounder exports increased by 16% over the last three years.

Overseas markets

The import statistics for the category "other flatfish" are the focus of analysis, as it was assumed that flounder would be classified in this category. The import statistics for halibut, plaice and sole were used only to calculate Japan's total flatfish market and total flatfish imports for each overseas market.

In 1994, Japan's market size for flatfish (including halibut, sole, plaice and other flatfish) was 166,881 tonnes valued at $2,475m. Although Japan imports most of its flatfish frozen, a significantly higher price was paid for chilled flatfish. The average price for chilled flatfish in 1994 was $11.11/kg compared with $3.28/kg for frozen flatfish. Right eyed flatfish are classified as the karei market in Japan. It was thought that the right eyed greenback flounder would compete in the karei market. This market was perceived to be lower priced compared with the left eyed hirame (includes - bastard halibut, US fluke and California halibut) market. Despite this, the wholesale prices for some right eyed flatfish in 1994 were comparable with the hirame market, with prices varying between $2.45 and $58.24/kg. As very high prices were obtained in 1994 at the Tokyo Central Wholesale Market for certain chilled small (30-40 cm) right eyed flatfish, the Japanese market warrants further investigation.

Taiwan's main imports of flatfish are frozen halibut. Only a small quantity (11 tonnes) of other flatfish (excluding halibut, sole and plaice) valued at $21,490 was imported in 1994. New Zealand is the main exporter of other flatfish to Taiwan. In the last three years New Zealand's exports increased significantly (1994 - 10,376 kg) from a low base (1992 - 160 kg).

Korea mainly imports other flatfish and significantly smaller quantities of halibut, plaice and sole. In 1994, Korea imported 22,749 tonnes of other flatfish valued at $26m. The import price paid for other flatfish was lower than that paid by the USA and Japan.

Future research

As a result of our research to date, stage two would need to determine if a higher price than $10/kg could be obtained in a niche market in Australia for cultured greenback flounder in a form (chilled or live) that meets that market's requirements. The small, declining Australia catch of greenback flounder and the high imports of flounder from NZ indicate an opportunity exists to supply the local market with similar sized flounder to NZ's on a consistent basis. In addition, the research in Japan needs to investigate further the karei market and determine if some of the very high prices being obtained for right eyed flatfish of a similar size to the greenback flounder could be achieved. The Taiwanese and USA markets also present potential opportunities, with NZ's exports of flatfish to Taiwan increasing and the USA paying the highest unit price for NZ flounder.

APPENDIX 3.

Data from DPIF Sea Fisheries

DATE	AGE	TEMP	DO	MORTS	FEED	FLOW	NH3-N	COMMENTS	TANK
10/7/95	27	13.8	7.6		250um Nippon	10L/m	0.03	Moved from tank 8 hatchery	7
11/7/95	28	13.7	7.6		40g 250um Nippon	10L/m			7
12/7/95	29	14	7.6		50g	10L/m	0.06		7
13/7/95	30	13.3	7.6		60g	10L/m			7
14/7/95	31	12.3	7.9		60g	10L/m			7
15/7/95	32	12	8.1		60g	10L/m			7
16/7/95	33	11.1	8.3		60g	10L/m			7
17/7/95	34	12.4	8.3		60g	10L/m	0.04		7
18/7/95	35	12	7.9		60g	10L/m			7
19/7/95	36	12.8	8		60g	10L/m			7
20/7/95	37	12.8	8		60g	10L/m	0.06		7
21/7/95	38	12.6	7.9		60g	10L/m			7
22/7/95	39	12.9	7.5		60g	10L/m			7
23/7/95	40	14.3	7.2		60g	10L/m			7
24/7/95	41	13.9	7.6		60g	15L/m	0.14		7
25/7/95	42				240g of 250:400um	15L/m	0.06		7
26/7/95	43	15.2	7.2		240g of 250:400um	15L/m		Only afternoon artemia feed	7
27/7/95	44	14.6	7.2		240g of EWOS:250:400	15L/m			7
28/7/95	45	14.7	7.2		240g of EWOS:250:400	15L/m	0.14		7
29/7/95	46				240g of EWOS:250:400	15L/m			7
30/7/95	47	12.8	7.7		240g of EWOS:250:400	15L/m			7
31/7/95	48	14.1	7.2		240g of EWOS:250:400	15L/m			7
1/8/95	49	14.8	6.9		240g of EWOS:250:400	25L/m	0.18		7
2/8/95	50	14.8	6.8		330g of400:EWOS	25L/m	0.35		7
3/8/95	51	13.1	7.5		330g of400:EWOS	25L/m			7
4/8/95	52	13.3	7.3		330g of400:EWOS	25L/m	0.13		7
5/8/95	53	13.9	7.3		330g of400:EWOS	25L/m			7
6/8/95	54	13.7	7.1		330g of400:EWOS	25L/m			7
7/8/95	55	13	7.5		330g of400:EWOS	25L/m		New net	7
8/8/95	56	13.8	7.2		330g of400:EWOS	25L/m			7
9/8/95	57	14	7.4		330g of400:EWOS	25L/m			7
10/8/95	58	13.8	7.6		330g of400:EWOS	25L/m	0.31		7
11/8/95	59	12.6	7.8		330g of400:EWOS	25L/m			7
12/8/95	60	13.8	7.5		330g of400:EWOS	25L/m			7
13/8/95	61	13.7	7.3		330g of400:EWOS	25L/m			7
14/8/95	62	13	7.5		330g of400:EWOS	25L/m			7
15/8/95	63	12.7	7.6		330g of400:EWOS	25L/m			7
16/8/95	64	13.1	7.5		330g of400:EWOS	25L/m	0.15		7
17/8/95	65	13.6	7.1		330g of400:EWOS	25L/m			7
18/8/95	66	13.6	7.1		330g of400:EWOS	25L/m			7
19/8/95	67				330g of400:EWOS	25L/m			7
20/8/95	68				330g of400:EWOS	25L/m			7
21/8/95	69	13.4	6.9		330g of400:EWOS	25L/m			7
22/8/95	70	13.4	6.7		330g of400:EWOS	25L/m	0.26		7
23/8/95	71	14.1	6.1		330g of400:EWOS	25L/m		No artemia	7
24/8/95	72	13	6.5		330g of400:EWOS	25L/m			7
25/8/95	73	13.3	7		390g of 400:EWOS	25L/m		Out of weaning cage	7
26/8/95	74	14.1	7.4	80	390g of 400:EWOS	30L/m		Transferd to T.9 and Formalin treatment	9
27/8/95	75	12.4	7.8	200	390g of 400:EWOS	30L/m			9
28/8/95	76	12.8	7.7	80	390g of 400:EWOS	30L/m			9
29/8/95	77	13.6	7.5	100	390g of 400:EWOS	40L/m	0.33		9
30/8/95	78	13.5	7.4	250	390g of 400:EWOS	40L/m			9
31/8/95	79	13.7	7.3	250	390g of EWOS:.6 Gibsons	40L/m			9
1/9/95	80	13.2	7.5	200	390g of EWOS:.6 Gibsons	40L/m			9
2/9/95	81	13.8	7.4	300	390g of EWOS:.6 Gibsons	40L/m			9
3/9/95	82	14.1	7.2	270	390g of EWOS:.6 Gibsons	40L/m		Morts small fish	9
4/9/95	83	13.5	7.3	200	390g of EWOS:.6 Gibsons	40L/m			9
5/9/95	84	12	7.8	110	390g of EWOS:.6 Gibsons	40L/m			9
6/9/95	85	12.3	7.8	80	390g of EWOS:.6 Gibsons	40L/m	0.18		9
7/9/95	86	12.6	7.7	50	390g of EWOS:.6 Gibsons	40L/m			9
8/9/95	87	12.3	7.8	20	390g of EWOS:.6 Gibsons	40L/m			9
9/9/95	88	14	6.9		390g of EWOS:.6 Gibsons	40L/m			9
10/9/95	89	12.8	7.2	46	390g of EWOS:.6 Gibsons	40L/m			9
11/9/95	90	12.5	7.5	15	420g 80% .6 Gib:10%EWOS:10% 1.0 Gib	40L/m	0.15		9
12/9/95	91	13.1	7.6	10	420g 80% .6 Gib:10%EWOS:10% 1.0 Gib	40L/m			9
13/9/95	92	13.6	7.3		420g 80% .6 Gib:10%EWOS:10% 1.0 Gib	40L/m			9
14/9/95	93	13.8	7.5	20	420g 80% .6 Gib:10%EWOS:10% 1.0 Gib	40L/m	0.17		9
15/9/95	94	13.5	7.4		420g 80% 0.6 Gib:20% 1.0mm Gib	40L/m			9
16/9/95	95	13.6	7.3		420g 80% 0.6 Gib:20% 1.0mm Gib	40L/m			9
17/9/95	96	13.3	7.2		420g 80% 0.6 Gib:20% 1.0mm Gib	40L/m			9
18/9/95	97				420g 80% 0.6 Gib:20% 1.0mm Gib	45L/m		Graded/Medium	1
19/9/95	98	13.9	7.6	45	420g 50%.6Gib :50% 1.0mm Gib	45L/m			1
20/9/95	99	14	7.3	20	420g 50%.6Gib :50% 1.0mm Gib	45L/m			1
21/9/95	100	13.8	6.9		510g 50% .6Gib: 50%1.0mm Gib	45L/m			1
22/9/95	101	13.7	7.1		510g 50% .6Gib: 50%1.0mm Gib	45L/m			1
23/9/95	102	13.6	7.6		300g as above	45L/m			1
24/9/95	103	13.9	7.4		300g as above	45L/m			1
25/9/95	104	13.9	7.6		360g	45L/m			1
26/9/95	105	12.7	8.3		330g as above	45L/m			1
27/9/95	106	14.2	8		330g as above	45L/m			1
28/9/95	107	12.7	8.3		300g as above	45L/m			1
29/9/95	108	14	8.1		300g as above	45L/m			1
30/9/95	109	13.9	8.2		300g as above	45L/m			1
1/10/95	110	14.5	7.8		300g as above	45L/m			1
2/10/95	111	13.9	7.9		300g as above	45L/m			1
3/10/95	112	14.1	7.9		300g as above	45L/m			1
4/10/95	113	14.3	7.6		300g as above	45L/m			1
5/10/95	114	14.3	7.8		300g as above	45L/m			1
6/10/95	115	14.5	7.9		330g as above	45L/m	0.07		1
7/10/95	116	14.2	7.9		330g as above	45L/m			1
8/10/95	117				330g as above	45L/m			1
9/10/95	118	14.2	7.7		330g as above	45L/m			1
10/10/95	119	14.4	7.5		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m			1
11/10/95	120	14.3	7.6		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m	0.19		1
12/10/95	121	14.5	7.6		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m			1
13/10/95	122	14.4	7.4		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m	0.11		1
14/10/95	123	14.5	7.5		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m			1
15/10/95	124	14.6	8		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m			1
16/10/95	125	14.4	7.6		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m			1
17/10/95	126	14.8	7.8		330g 80% 1.0mm: 20% 0.6mm Gib	45L/m			1
18/10/95	127	14.8	7.5		330g 1.0mm Gib	45L/m	0.1		1
19/10/95	128	15.2	7.4		330g 1.0mm Gib	45L/m			1
20/10/95	129	14.5	7.5		330g 1.0mm Gib	45L/m			1
21/10/95	130	15	7.5		330g 1.0mm Gib	45L/m			1
22/10/95	131	15.2	7.5		330g 1.0mm Gib	45L/m			1
23/10/95	132	14.6	7.5		330g 1.0mm Gib	45L/m	0.18		1
24/10/95	133	15.6	7.4		330g 1.0mm Gib	45L/m			1
25/10/95	134	14.8	7.3		360g 80% 1mm:20% 2mm Gib	45L/m			1
26/10/95	135				360g 80% 1mm:20% 2mm Gib	45L/m			1
27/10/95	136	15	7.4		360g 80% 1mm:20% 2mm Gib	45L/m			1
28/10/95	137	14.2	7.6		360g 80% 1mm:20% 2mm Gib	45L/m			1
29/10/95	138	14.2	7.5		360g 80% 1mm:20% 2mm Gib	45L/m			1
30/10/95	139	14.8	7.3		360g 80% 1mm:20% 2mm Gib	45L/m			1
31/10/95	140				360g 80% 1mm:20% 2mm Gib	45L/m			1
1/11/95	141				360g 80% 1mm:20% 2mm Gib	45L/m			1
2/11/95	142	14.8	7.5		360g 80% 1mm:20% 2mm Gib				1
									1
3/11/95	143	15	7.5		360g 80%1mm:20% 2mm Gib		ave 1.75g	Med/small 2267 total	1
4/11/95	145	15	7.5		360g 80%1mm:20% 2mm Gib				
5/11/95	146				360g 80%1mm:20% 2mm Gib				
6/11/95	147	14.1	7.7		360g 80%1mm:20% 2mm Gib				
7/11/95	148				360g 80%1mm:20% 2mm Gib				