Pilot Project Technology Initiative

Future Sea Closed Containment Units

Saltspring Island
Marine Harvest Canada

Monitoring Report Draft
First Production Cycle

Submitted to:

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1.0 INTRODUCTION

This document presents an interim evaluation of environmental performance of the Future Sea *SEA System*™ closed-containment technology at the Marine Harvest Salt Spring Island site. Environmental performance of fish production using the Future Sea Technologies impermeable containment system is being compared to fish production using conventional steel cages. This technology test is being undertaken as part of the provincial Pilot Project Technology Initiative (PPTI) program.

Preliminary tests of Future Sea units at locations in British Columbia and eastern Canada had demonstrated an array of potential benefits from the containment system. Results of those preliminary trials suggested that the closed-containment technology tests would:

- minimize waste production as a result of improved feed conversion efficiency;
- minimize fish escapes;
- minimize fish health interaction between wild and farmed stocks; and
- minimize the frequency of interactions between farm operations and potential predators.

Data are being collected during the technology test at Salt Spring Island to assess environmental performance of the closed-containment technology in each of the above categories. Fish are being produced under full-scale commercial operating conditions over the technology-test period.

This document presents interim results of data collected for the first production cycle, between the start of the technology trials in Mid-June 2001 and final harvest in August/September 2002.

2.0 APPROACH AND METHODS

Six Future Sea closed containment units were used in the technology evaluation (Figure 2.1). Two large (30 m by 30 m) steel cage units were used as conventional-technology controls. Fish were grown in the closed containment units from the time of stocking in June 2001 until harvest during spring/summer in 2002. Fish harvest began in April 2002 and continued until September 2002.

2.1 FISH PRODUCTION SUMMARY

Fish used in the trials of the closed containment units were transferred from a lake smolt-production facility in early December 2000 to eight small net pens (10 m by 10 m) at average weights of approximately 80-150 g. In March 2001, these fish were transferred to two newly-placed large steel cages at approximately 200-300 g size. Fish from two of the steel cages were transferred to the six Future Sea closed containment units in June 2001 – approximately 15,000 to 17,000 smolts were placed in each of these units. Approximately 67,000 to 69,000 smolts remained in each steel cage at the start of the trial.

Approximate fish weights in rearing units over the trial grow-out period were:

Size at stocking (June 2001)	0.5 kg
Mid-October 2001	1.3-1.7 kg
Size at harvest (April-August 2002)	4.0-5.0 kg

Over the spring and summer of 2002, approximately 64 to 72 tonnes of fish were harvested from each Future Sea unit (total of 411 tonnes) and 280 to 300 tonnes were harvested from control cage units (total of 581 tonnes).

2.2 FISH PERFORMANCE MONITORING

2.2.1 Data Sets used for Evaluation

Several datasets were reviewed for preparation of this monitoring report. These were detailed site inventory and performance data collected by farm site personnel and recorded in Excel workbooks. Marine Harvest staff provided these data on two occasions: in November 2001 and October 2002. In addition, Marine Harvest Canada Campbell River head office staff supplied weekly production data for the period from November 2001 to June 2002. These data were summary outputs from data management software (Superior) being used by Marine Harvest to collate data from all farm sites.

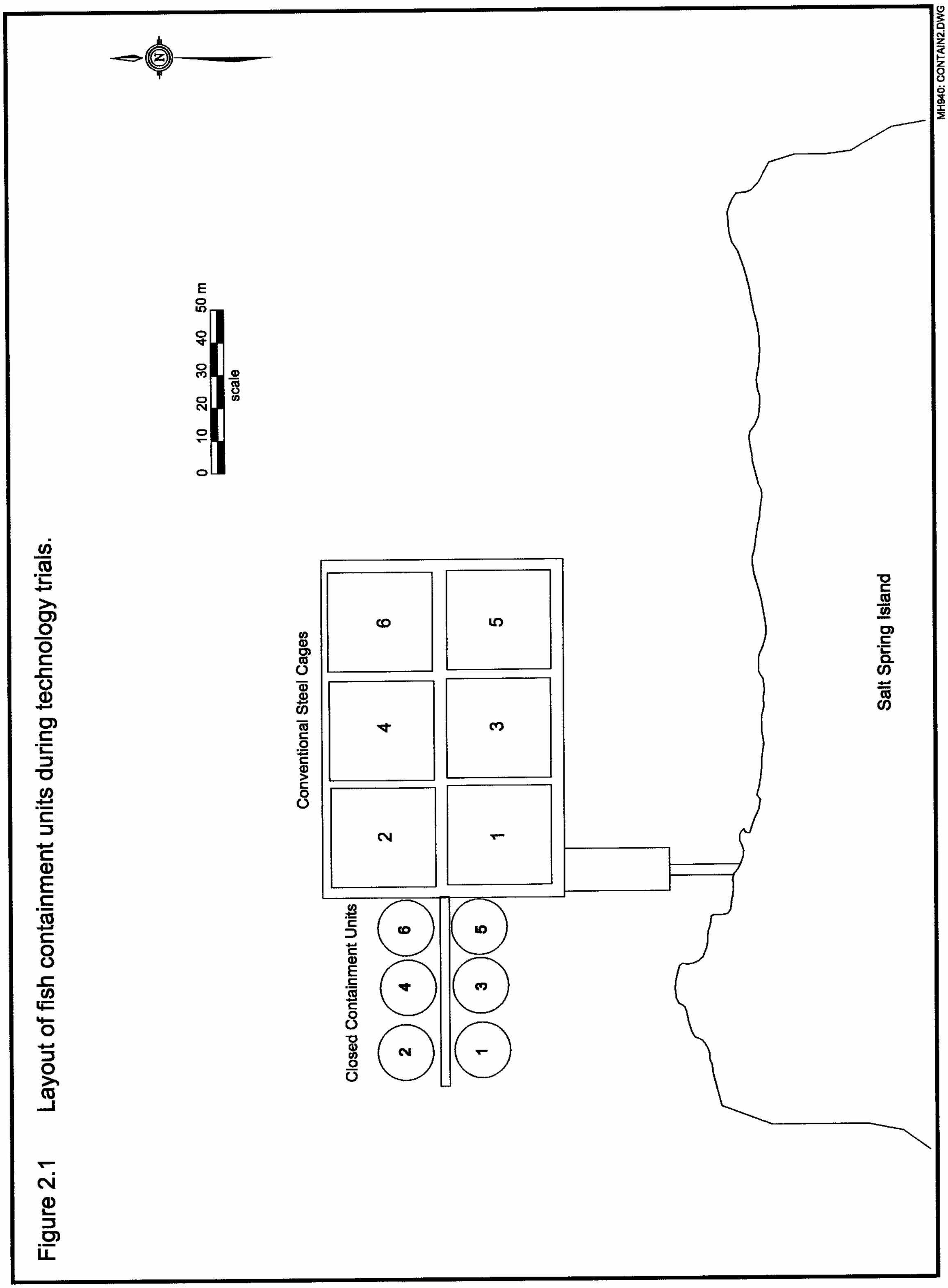


Figure 2.1 Layout of fish containment units during technology trials.

2.2.2 Fish Weight Measurement

Fish weight data used in this monitoring report are from two sources: periodic sample weight measurements collected at intervals over the production period, and harvest weights. Periodic sample weights were obtained using the non-intrusive Vicass remote camera sampling system. The Vicass system is operated by individuals who specialize in use of this system. During sampling a camera is placed in the sample pen and the camera is linked to a portable computer. The operator captures images of fish at different depths. A computer program then calculates weight of individual fish based on fork length and girth measurements. Approximately 250 images are used to calculate the average weight for the pen being sampled. Fish images are also examined for fish disease signs. Marine Harvest staff indicated that the Vicass provide approximate size data and more accurate data are generally not available until completion of harvest. Vicass data were collected from start of the trial in June 2001 to the end of April 2002. Average weights from harvest data were produced from mid-May, 2002, to the first week in September 2002.

2.2.3 Mortality Removal

Fish mortalities, moribund fish and nonperforming fish were regularly removed from rearing units when observed on the surface and during a routine diving program. Crews noted the reason for removal and/or probable cause of mortality for each fish and recorded these data.

2.2.4 Starting Fish Groups

At the time of initial stocking, fish from Steel Cage 1 were placed in three closed-containment units (bags) and fish from Steel Cage 2 were placed in three different bags. Fish numbers and size in each rearing unit at the time of stocking are summarized in Table 2.1.

Fish from Steel Cage 2 were transferred to three closed-containment unit from June 14 to June 18. Fish from Steel Cage 1 were transferred to a second group of three closed-containment units from June 19 to June 21. Data indicate that prior to extraction of fish for placement in bags fish in Steel Cage 2 were smaller than fish in Steel Cage 1. This difference is evident among fish groups at the time of initial transfer from fresh water to the Saltspring site, among fish transferred to steel cages in March 2001 and at the time of fish transfer from the steel cages to the bag containment units; this size difference was evident until the end of the trial period. This has led to creation of two different trial groups and sample populations that are not fully randomized. Statistical comparison/tests of sample means that involve pooling of data from the two groups will not be valid, though separate analysis of the two groups is possible. Some data are combined for summary/illustrative purposes in the following analyses of fish performance, but these values should not be regarded as statistical population means.

Table 2.1 Fish stocking information at start of technology test.

Unit #	Stocking						Actual Weight Measurements			
	Date	Number	Est. Average Weight	Origin	Biomass	Density	Before Transfer		Post Transfer	
							Date	Ave Weight	Date	Ave Weight
Bags										
1	14/06/01	16,632	0.447	Steel 2	7,440	3.7	-	-	16/07/01	0.630
2	15/06/01	16,576	0.447	Steel 2	7,415	3.7	-	-	16/07/01	0.600
3	19/06/01	16,840	0.508	Steel 1	8,557	4.3	-	-	16/07/01	0.730
4	18/06/01	16,650	0.451	Steel 2	7,515	3.8	-	-	16/07/01	0.590
5	21/06/01	16,652	0.505	Steel 1	8,406	4.2	-	-	16/07/01	0.680
6	21/06/01	15,517	0.505	Steel 1	7,833	3.9	-	-	16/07/01	0.670
Steel cages - Controls										
1	21/06/01	67,607	0.508	Fish Remaining after some transferred to Bags	34,353	2.4	11/06/01	0.480	16/07/01	0.700
2	18/06/01	68,928	0.456	Fish Remaining after some transferred to Bags	31,421	2.1	11/06/01	0.440	16/07/01	0.620

2.2.5 Timeframe for Comparison of Steel Cage and Closed Containment Systems

The start of the trial period was after the last fish transfer, June 21. The next sizable handling of fish from one of the trial groups occurred on May 2, 2002, when half of the fish in one of the Steel Cage control pens (Cage 2) were moved to a separate Steel Cage unit (Cage 7). The trial period for comparison of fish performance in the closed containment systems and control units is comprised of:

Overall trial period – from the start of the trial period (June 21, 2001) until availability of accurate weight data at the completion of fish harvest (September 2002); and

Effective trial period – from the start of the trial period (June 21, 2001) until the time of first handling which may have affected onward fish performance in at least one of the control or bag units (this occurred on May 2, 2002 when half of the fish from one control cage, Cage 2, were moved to a separate cage, Cage 7).

2.2.6 Data Analyses

Site sample-weight data were used to calculate average weight data, specific growth rate and together with temperature data, thermal growth coefficients. Weight data were used with feed usage data to calculate feed conversion ratios. Both economic and biological feed conversions were calculated (biological feed conversion accounts for fish biomass removed from pens in the form of dead fish), however mortality was so low that often the same value was produced. Mortality data were used to calculate survival rates. Site data were also reviewed to identify potential differences in fish health, predator interaction and escapes.

2.3 MAINTENANCE OF CONTAINMENT UNITS

2.3.1 Steel Cages

Nets of the steel cage units were regularly inspected for damage and periodically changed. One net was changed during the initial four months (September 26) and fish were taken off feed for one day at that time.

2.3.2 Future Sea Seasystem Bag Containment Units

Different cleaning procedures were used for bag containment units compared to the steel cage units. Biofouling was substantial at times, particularly around the bottom portal, requiring lengthy cleaning times. Cleaning involved operating a suction-hose along the inner surface of the bag. Bag containment features that lead to differences in operational and maintenance procedures between the bag and cage units are the bag intake structure, use of electric motors to operate water pumps and use of supplemental oxygen.

Intake Depths

Intakes of the bag containment units were at a depth of 15m during the trial period.

Power/Pump Interruptions

Bag containment units rely on electrical power to operate the intake pumps and, after March 2002, to operate an oxygen generator. In late October the pump for bag unit number 2 failed, requiring fish to be taken off feed for a day. In early November 2001, a motor failed in one of the bag units leading to a build-up of waste material.

Use of Supplemental Oxygen

Supplemental oxygen was added to the bag units from shortly after stocking until harvest. Initially oxygen was from canisters brought in by barge; after March 2002 oxygen was produced by use of an oxygen generator installed at the site. Oxygen concentration was measured near the outlet of each bag unit for comparison with ambient/intake values.

2.4 FEED AND FEEDING

Similar feed and feed handling procedures were used in the bag and cage containment units. Fish and feed-particle movement in the bags differed from the cage units, so determination of fish satiation during feeding sessions may have differed during the initial months of the trial.

During the overall trial period, fish were fed comparable feeds, including medicated feeds administered in August 2001 to treat mouthrot. Fish were taken off feed for single days on several occasions during the initial months of the trial period, and before and during harvest. Feeding was stopped for all units in mid-August, 2001, prior to administration of medicated feeds. Additional single-day halts to feeding were: for Steel Cage 2 at the end of September during a net change; for Steel Cage 1 in mid-October on account of a sea-lion being present within the cage area; and for Bag 2 when a water pump ceased operating.

2.5 HEALTH MANAGEMENT

Fish were routinely examined for signs of disease. This included examination of dead fish and live fish observed using underwater cameras. Disease/parasite occurrence was low in both types of containment unit. Cage units were affected by mouthrot in August 2001 and accordingly were treated with medicated feed. Fish in bag units were treated for mouthrot disease at the same time as fish in the steel cages.

2.6 SEA BED OBSERVATIONS

2.6.1 Field Surveys

Surveys of the sea bottom under the FutureSea closed containment units and the control cages were undertaken on three occasions (October 2001, May 2002, and September, 2002) by personnel form Aquametrix Research Ltd. The sublittoral epibenthic surveys were conducted using a VideoRay Pro Remote Operated Vehicle (ROV). The VideoRay Pro, capable of dives to 100 metres, is equipped with approximately 120 metres of neutrally-buoyant tether and supports a high-resolution colour camera (vertical movement) and halogen lamps to view and photograph the sea floor. Onboard support includes the ROV controller, a colour monitor, VHS video recorder, and an 8 mm digital video recorder.

Controlled from the survey vessel the ROV is maneuvered using vertical and horizontal thrusters. Heading, depth, time, and date are displayed on the video screen and are recorded in digital format with the video. The start point of each transect is plotted using differential GPS and the desired direction of travel is noted. Recording of the transect is started when the ROV has attained the required depth. The desired heading is kept as the ROV is driven along the bottom in a continuous transect line extending the distance determined appropriate for the survey. Recording of the transect is terminated when the surface is reached.

2.6.2 Data Analysis and Presentation

The video data is collected in digital format and later analyzed. Bottom composition, epibenthic species presence and comments on relative abundance were performed for the entire transect and summarized in a written format within this report. The presence of fish feed and fecal material was of particular interest, as these parameters were directly related to operational performance issues, and were thus the focus of the digital image review. Other related observations, including the presence of *Beggiatoa sp*., were also presented as an indication of cumulative impact effects associated with the production cycle.

3.0 ENVIRONMENTAL CONDITIONS DURING TECHNOLOGY TRIALS

General environmental conditions at the site during the technology trial period are outlined below. Conditions in the bag containment units were influenced by water conditions at the prevailing water depth at which the water intake was placed and by application of supplemental oxygen. Water intake depths of and use of supplemental oxygen in the bag containment units are described in Section 2.3.2.

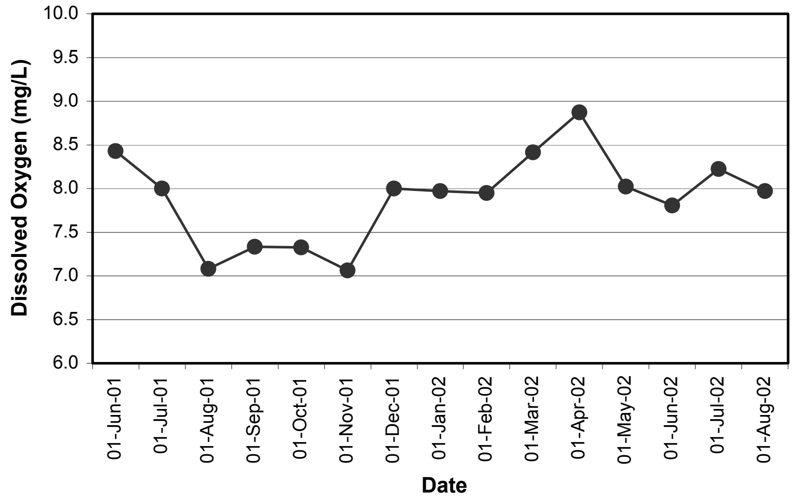
3.1 TEMPERATURE

Average near-surface (1m) weekly temperatures during the initial summer after transfer to containment units were 12-14ºC, decreasing to 7ºC during the following winter. Average monthly temperatures at the site during the overall trial period are summarized in Figure 3.1. Water is well mixed within the water column at the Saltspring site, resulting in little vertical temperature difference.

3.2 OXYGEN

Oxygen was monitored at one location outside of containment units at the site, and inside each of the six bag containment units. Oxygen concentration measured at bag intake depth outside the bags is summarized in Figure 3.2. Supplemental oxygen was used in the bags from July 2001 to harvest over May to August 2002, reaching maximum volumes as maximum biomass was reached just before harvest. From July 2001 to March 2002 oxygen was supplied to the bags from canisters that were regularly brought to the site by barge. After March 2002, oxygen was supplied to the bags using oxygen generators that were installed at the site.

Figure 3.2
Average monthly dissolved oxygen concentration during the trial period.



3.3 SALINITY

Water is generally well mixed by local water currents at the Saltspring site. Salinity were not recorded during the first trial production year but is typically 27-30 ppt at 5-10 metre depths throughout the year.

4.0 FISH PERFORMANCE IN THE CLOSED CONTAINMENT UNITS

4.1 FISH GROWTH

Fish growth in the bag containment units and control cages is summarized in Figure 4.1. Growth rates (Specific Growth Rate - SGR, and Thermal Growth Coefficient - TGC) are summarized in Figure 4.2. Growth performance over seasonal time periods is described in the following sections. These periods are based on available average weight data (Appendix A1):

Period 1 - First summer

Period 2 – Fall

Period 3 - Winter

Period 4 - Spring

Period 5 - Second summer

The first three periods make use of Vicass sample data, Period 4 uses Vicass and harvest data, and Period 5 uses harvest data and some extrapolated data points. Fish densities in rearing units over the trial period are summarized in Table 4.1.

Figure 4.1a Summary of fish growth over the trial period.
A. Group 1

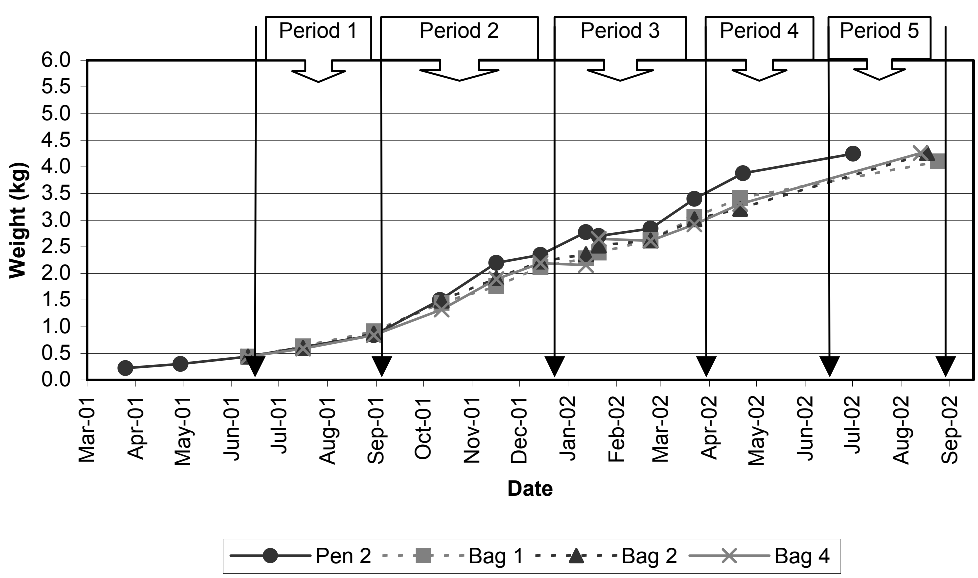


Table 4.1 Summary of fish density in rearing units, June 2001 to September 2002.

Date	Density								
	Steel 1	Steel 2	Steel 7	Bag 1	Bag 2	Bag 3	Bag 4	Bag 5	Bag 6
21-Jun-01	2.4	2.3	---	4.0	4.1	4.4	3.8	4.3	3.9
1-Jul-01	2.6	2.5	---	4.4	4.5	4.9	4.2	4.8	4.3
1-Aug-01	4.0	3.6	---	6.3	6.2	7.4	5.8	7.0	6.3
1-Sep-01	4.6	4.1	---	7.7	7.6	9.0	6.9	8.8	7.9
1-Oct-01	6.5	5.9	---	10.6	10.6	12.0	9.5	11.9	10.7
1-Nov-01	9.6	8.4	---	13.6	14.3	15.5	12.1	15.1	14.2
1-Dec-01	12.6	11.4	---	15.8	17.6	20.3	16.4	18.2	18.3
1-Jan-02	14.1	12.2	---	19.2	20.6	22.3	19.2	21.5	21.2
1-Feb-02	13.9	13.3	---	20.7	22.4	23.9	22.1	23.3	22.2
1-Mar-02	14.1	13.8	---	22.3	22.9	24.6	21.3	25.2	23.1
1-Apr-02	17.3	16.6	---	26.1	26.5	27.5	24.1	27.5	25.9
1-May-02	19.3	18.9	---	29.4	28.5	36.4	27.5	32.0	31.3
2-May-02	19.4	9.7	9.2	29.5	28.7	36.5	27.7	32.1	31.4
1-Jun-02	10.0	10.2	10.2	29.7	29.3	32.4	28.5	32.2	32.1
17-Jun-02	1.8	11.1	11.0	31.4	30.1	0.8	29.0	23.1	24.5
1-Jul-02	---	10.2	10.4	31.1	31.7	---	30.8	24.6	26.0
12-Jul-02	---	1.3	10.4	32.6	33.0	---	32.3	25.9	27.2
1-Aug-02	---	---	0.4	33.3	33.7	---	33.4	26.3	27.4
3-Aug-02	---	---	0.4	33.7	34.0	---	33.8	26.5	27.8
5-Aug-02	---	---	---	34.0	34.4	---	34.1	26.8	12.3
12-Aug-02	---	---	---	35.3	35.6	---	33.7	7.3	---
16-Aug-02	---	---	---	35.4	35.6	---	8.8	---	---
23-Aug-02	---	---	---	34.3	12.3	---	---	---	---
1-Sep-02	---	---	---	13.0	---	---	---	---	---
2-Sep-02	---	---	---	13.0	---	---	---	---	---

Shading indicates approximate harvest timing.

4.1.1 Period 1: First Summer

Fish Size

Fish in bag units were the same size as or slightly larger than counterparts in control cages in weight samples at the end of August (Table 4.2). Weight sample data collected in mid-October indicated that fish in bags were slightly smaller than those in control cages.

Table 4.2 Fish weight in test and control groups, June to October, 2001.

Containment Unit	Sample Date				
	June 11, 2001	June 21, 2002[1]	July 16, 2001	August 30, 2001	October 12, 2001
Group 1					
Bag- Units Mean	***440***	***470***	***607***	***570***	***1420***
Steel Cage 2	**440**	**470**	**620**	**840**	**1500**
Group 2					
Bag-Units Mean	***480***	***508***	***693***	***1030***	***1616***
Steel Cage 1	**480**	**508**	**700**	**970**	**1780**

1. Estimated values for trial start-date.

Growth Rate

Overall, growth rate (Specific Growth Rate and Thermal Growth Coefficient) appeared to be the same or slightly higher for fish in bags compared to fish in control pens over July and August, but lower over September to December (Figure 4.3); these values are summarized in Table 4.3.

Table 4.3 Growth rates in test and control groups, June to December, 2002.

	June 21 to August 30		*August 30 to December 14*	
	Cages	Bags	Cages	Bags
Specific Growth Rate	0.88	0.95	0.99	0.84
Thermal Growth Coefficient	1.99	2.16	3.67	3.08

4.1.2 Period 2: Fall

Fish Size

Weight data collected in October, November and December show fish in bag units to be consistently smaller than fish in control cages (Table 4.4). Growth divergence appeared to commence over September/October, and may have been relate to difficulties with oxygen supply to bag units at that time.

Table 4.4 Fish weight in test and control groups, June to October, 2001.

Containment Unit	Sample Date			
	August 30, 2001	October 12, 2001	November 16, 2002	December 14, 2002
		Group 1		
Bag Mean	***570***	***1420***	***1530***	***2170***
Steel Cage 2	**840**	**1500**	**2200**	**2350**
		Group 2		
Bag Mean	***1030***	***1616***	***2147***	***2440***
Steel Cage 1	**970**	**1780**	**2490**	**2800**

Growth Rate

In general growth rate was lower for fish in the bag containment units over fall though this difference was greatly diminished in data collected over winter (Figure 4.2). Growth rate data over that period are summarized in Table 4.5.

Table 4.5 Growth rates in test and control groups, December 2001 to March 2002.

	August 30 to December 14		*December 14 to March 22*	
	Cages	Bags	Cages	Bags
Specific Growth Rate	0.99	0.84	0.32	0.30
Thermal Growth Coefficient	3.67	3.08	2.13	1.94

4.1.3 Period 3: Winter

Fish Size

Weight data collected in December, January, February and March show fish in bag units continued to be consistently smaller than fish in control cages, after evidence of the onset of growth divergence in September (Table 4.6). Group 2 fish in both cages and bag containment units were larger than counterparts in Group 1.

Table 4.6 Fish weight in test and control groups, December 2001 to March 2002.

Containment Unit	Sample Date			
	December 14, 2002	January 20, 2002	February 22, 2002	March 22, 2002
Group 1				
Bag-Unit Mean	***2170***	***2520***	***2619***	***2997***
Steel Cage 2	**2350**	**2700**	**2839**	**3400**
Group 2				
Bag-Unit Mean	***2440***	***2723***	***2897***	***3219***
Steel Cage 1	**2800**	**2900**	**2975**	**3650**

Growth Rate

As described above for fall growth rate, winter growth rate was very similar for fish in the bag containment units and cage controls. Growth rate data over that period are summarized in Table 4.7. These data suggest that the difference in fish size observed above at the end of winter was mainly attributable to a difference in weight prior to winter and not to slower growth during winter.

Table 4.7 Growth rates in test and control groups, December, 2001 to March 2002.

	December 14 to March 22	
	Cages	Bags
Specific Growth Rate	0.32	0.30
Thermal Growth Coefficient	2.13	1.94

4.1.4 Periods 4: Spring

Fish Size

Half of the fish in Cage 2 were transferred to a new Cage 7 on May 2, thereby substantially reducing fish density in control Cage 2 and altering growing conditions. Fish were harvested from control cages and bag containment units in batches:

- The first harvest from control cages was May 14 (Cage 1); harvest continued to August 4; and
- The first harvest from bag containment units was June 3 (Bag 3); harvest continued to September 3.

Harvest timing for each containment unit is summarized in Table 4.8. Harvest numbers and average weights on each harvest date are presented in Appendix A1.

Table 4.8 Summary of fish harvest timing.

Unit	Harvest Period	Number of Harvest Events
	Group 1	
Cage 2	July 1-13	6
Cage 7	July 13-August 4	6
Bag 1	August 24-September 3	3
Bag 2	August 17-24	3
Bag 4	August 13-17	3
	Group 2	
Cage 1	May 14-June 18	10
Bag 3	June 3-18	3
Bag 5	June 17	1
	August 6 and 13	2 (3 harvests in total)
Bag 6	June 17	1
	August 4 and 6	2 (3 harvests in total)

Harvest data for bag and control cages in Group 1 cannot be readily compared because rearing conditions were altered in control cages several months prior to start of harvest and control fish were mainly harvested one month prior to harvest of fish in the bags. Rearing conditions in Cage 2 changed on May 2 when stock in that cage was split into two, with 50% of the fish going into a new cage (Cage 7), thereby reducing fish density.

Available data suggest that the difference in fish size between bag units and control cages that was evident in earlier data persisted into the spring (Table 4.9). Comparison becomes tenuous after April because harvest weights are not available for the same dates and data must be extrapolated.

Table 4.9 Fish weight in test and control groups, March 2002 to mid-June, 2002.

Containment Unit	Sample Date					
	March 22, 2002	April 20/22, 2002	May 14-21, 2002	June3-4, 2002	June 8-10, 2002	June 15-18,2002
			Group 1			
Bag-Unit Mean	***2997***	***3309***	**-**	**-**	**-**	**-**
Steel Cage 2	**3400**	**3881**	**-**	**-**	**-**	**-**
			Group 2			
Bag-Unit Mean	***3219***	***3828*** [1.]	**-**	***3764*** [2.]	**-**	***3965***
Steel Cage 1	**3650**	**4021**	**4170**	**-**	**4419**	**4262** [3.]

1. Bags 5 and 6 only; Bag 3 sample-value believed by site staff to be erroneous.
2. Bag 3 only.
3. 11-17 days of starvation prior to and during to harvest.

The overlap of Group 2 harvest events in June for control cages and bags is summarized in Table 4.10.

Table 4.10 Fish harvest from Group 2 bag units and control cage (Cage 1), June 2002.

	June 3	June 4	June 8	June 9	June 10	June 11	June 15	June 17/18
Cage 1			4445	4406	4406	4306	4282	4199
Bag 3	3756	3772						3848
Bag 5								3874
Bag 6								4173

These data suggest that fish in Bags 3 and 5 were smaller than those in Cage 1 by early to mid-June; the difference would likely be greater than that shown in the table because Cage 1 were subjected to protracted pre-harvest starvation and would have attained a larger size if feeding had continued. Fish in Bag 6 may also have been smaller, though the decline in the average size of fish in Cage 1 harvests from June 8 to June 18 masks a clear distinction.

Growth Rate

Farm staff calculated growth rates for the spring period by using extrapolated values to extend comparison into mid-June. Growth rate data over that period are summarized in Table 4.11.

Table 4.11 Growth rates in test and control groups, December, 2001 to June 2002.

	March 22 to June 17	
	Cages	**Bags**
Specific Growth Rate	0.23	0.23
Thermal Growth Coefficient	1.3	1.25

As indicated for fall and winter growth, these data suggest that the growth rate over spring again was very similar for fish in the bag containment units and cages. Accordingly, this suggests that the difference in fish size observed over spring was mainly attributable to a difference in weight prior to spring and not to slower growth during spring.

4.1.5 Period 5: Summer

Fish Size

Few data can be compared directly over summer because fish weight values were obtained at different times during harvest from the rearing units (Table 4.8).

Harvest of fish from Cage 7 (which received 50% of the fish contained in Cage 2, the control cage for Group 1, on May 2) overlapped with Bags 5 and 6 during late July and early August; these values are summarized in Table 4.12.

Table 4.12 Fish harvest from Cage 7 and Bags 5 and 6, late July and early August, 2002.

	July 13	July 15	July 16	July 21	July 28	Aug 4	Aug 6	Aug 10	Aug 13
Cage 7	4535	4540	4620	4648	4389	4355			
Bag 5							4513	4526	4526
Bag 6						4797	4688		

The data-trends suggest that by mid-July fish in Bag 5 may have attained a smaller size than fish in Cage 7, and fish in Bag 6 may have attained a comparable size to fish in Cage 7. This suggests that the performance of fish in Bag 6 was good, considering that fish in Cage 7 had been grown at a substantially reduced density for several months before harvest (Table 4.1). Overall, the data (Appendix A1) suggest that fish in bag containment units reached sizes that were smaller than, or possibly in some bag units (Bag 6) equal to, sizes of fish in steel cage units at comparable harvest times.

Growth Rate

Again, in the absence of directly comparable data, farm staff extrapolated values to aid calculation of growth rates in order to extend comparison from mid-June to early September. Growth rate data over that period are summarized in Table 4.13.

Table 4.13 Growth rates in test and control groups, December, 2001 to June 2002.

	June 17 to August 28	
	Cages	**Bags**
Specific Growth Rate	0.20	0.25
Thermal Growth Coefficient	0.8	1.0

These data suggest that the growth rate of fish in the bag units were comparable to and possibly slightly better than the growth rate of fish in the control cages.

4.1.6 Summary

Fish size was comparable in bag containment units and control cages over the first several months of the trial until the end of August. At some point over the end of summer or early fall fish average fish size in bag units fell behind that in the control cages, possibly as a result of oxygen-supply difficulties for the bags. The differential in weight was evident for the remainder of the trial until harvest, even though growth rates in the bag units were similar to or better than those in the control cages. Final lower weights in the bag units do not appear to be a result of sustained poor growth performance, but rather a depression in growth that resulting from some factor in September or October, 2001.

Initial size difference in the two starting fish groups (Group 1 - Control Cage 1 and Bags 3, 5, and 6; and, Group 2 – Control Cage 2 and Bags 1, 2 and 4) remained evident throughout the trial. Growing conditions for the two test groups were altered in early May:

- Group 1 - fish were removed from the control pen for Group 1 (Cage 2) on May 2 (50% of the fish from Cage 2 were transferred to Cage 7); and
- Group 2 – the first harvest from any test/control unit took place on May 14, when the first batch of fish were harvested from Cage 1.

Comparison of data after early May is subject changes in rearing conditions resulting from these activities and relies on weight data derived from batch-harvests that varied considerably over time.

4.2 SURVIVAL

Mortalities were low over the trial period in both bag and control cage units. Fish mortality in each containment unit is summarized in Table 4.14.

Table 4.14 Cumulative mortality (%) during the trial period.

Date	Cage 1	Cage 2	Bag 1	Bag 2	Bag 3	Bag 4	Bag 5	Bag 6
July 1	0.3	0.3	0.6	0.3	0.4	0.2	0.3	0.2
January 1	2.0	2.2	2.1	2.1	2.0	1.9	1.5	1.5
Final Harvest Date	*3.0 June 18*	*3.2 July 13*	*3.4 Sept. 3*	*3.5 Aug. 24*	*4.0 June 18*	*3.0 Aug 17*	*3.0 Aug 13*	*2.3 Aug 16*

The percentage fish mortalities in bag containment units ranged from 2.3% (Bag 6) to 4.0% (Bag 3); steel cages ranged from 3.0 to 3.2%.

4.3 FEED CONVERSION

Feed conversion in bag containment units and control cages over the trial period is summarized in Figure 4.3. Only economic feed conversion data are shown – these values were very similar to calculations of biological feed conversion because fish mortalities were low. These data suggest that feed conversion was typically high for both types of rearing unit in the first summer and fall and low over the following winter, spring and summer.

Feed conversion ratios in individual bags are summarized in Figure 4.4. Where site staff had indicated weight values of questionable accuracy in weight-sample data, feed conversion ratios were excluded. The values in Figure 4.4 indicate high variability among bag units in the same experimental groups.

4.3.1 Period 1: First Summer

Feed conversion data for the first summer (trial start, June 21, 2001, to August 30, 2001) of the trial-period indicate slightly better feed conversion for fish in the bag containment units was compared to control units (1.16 versus 1.35). Variability among the closed containment rearing units in each group was low over the first summer and fall compared to the later time periods. Growth rates were also better for fish in the bag units over this period (Section 4.1).

4.3.2 Period 2: Fall

Feed conversion data for the fall (August 30, 2001, to December 14, 2001) indicate comparable feed conversion for fish in the bag containment units and control units (0.96 versus 0.95), though variability among bag units is greater than during the preceding summer (Figure 4.4). In contrast to the previous summer, growth rates during the fall were slightly better for fish in the cage control units over this period (Section 4.1).

4.3.3 Period 3: Winter

As with the fall period, feed conversion data for the winter (December 14, 2001 to March 22, 2002) also indicate comparable feed conversion for fish in the bag containment units and control units (1.39 versus 1.37). Again feed conversion variability among bag units was relatively high compared to feed conversion data for the first summer (Figure 4.4). Growth rates during the winter were again comparable in both the bag units and cage control units over this period (Section 4.1).

4.3.4 Period 4: Spring

Feed conversion data for the spring (March 22, 2002, to June 17, 2002) again indicate better feed conversion for fish in the bag units compared to the control cages (1.82 versus 1.99), though June end-point values for this comparison are based on extrapolation of weight data (Section 4.1). However, a marked difference is evident in the relation between bags in Group 1 and Group 2 (Figure 4.4). Growth rates using the same weight data were comparable for bag units and control cages.

4.4.5 Period 5: Summer

Gross valuations of feed conversion have been included in Figure 4.3. As described in Section 4.1 and shown in Appendix 1, the bag units and control cages were harvested at different times, and under different conditions (including numbers and timing of batch harvests and starvation periods before and during harvest times). Data suggest that feed conversion may have been better in control cages than in bag units (Figure 4.3), but the relation between bags and cages differs substantially between the two experimental groups (Figure 4.4).

4.4.6 Summary

Feed conversion in the bag containment units was comparable to or slightly better than feed conversion in the steel cages up until mid-June, 2002. Feed conversion data over the harvest period may not be directly comparable because harvest timing and pre-harvest starvation varied considerably among rearing units. Data suggest that feed conversion may have been slightly better in control cages than in bag units, though data vary considerably among rearing units in the two experimental groups.

5.0 WASTE PRODUCTION

5.1 DIRECT OBSERVATION

Environmental observations of the benthic environment beneath the closed-containment and the traditional growout cages used at the Saltspring farm site were made on three occasions at all, or a subset, of four survey transects identified in Figure 5.1, below. The transects were established from the centre walkway (between the two systems) with the ROV pathways extending in four directions, two under each of two traditional (steel) cages and two under the bag system.

Table 5.1 indicates when and where the ROV transects were completed for this epibenthic evaluation.

Table 5.1 ROV transects used for epibenthic evaluation.

	Station ROV-1	Station ROV-2	Station ROV-3	Station ROV-4
October/2001	x		x	
May/2002	x		x	
September/2002	x	x	x	x

NOTE: Comparison of epibenthic observations of impact between the two cage system designs has limited value given the fact that fish were entered to the steel cages in December/2000, retained for six months and grown from 145 to 475 grams, and then graded and entered into the closed- containment system for ongrowing and operational evaluation. The following comments should consider this limitation.

5.1.1 October 2001

Conducted approximately four months after the start of the production cycle of this Pilot Project (fish entry to the bag system), this initial survey examined the conditions under a single bag and a single steel netcage (stations ROV-1 and ROV-03 shown in Figure 1).

The transects were conducted across comparable bathymetric contours (28-31 metres) with substrate comprised of fine sand, shell and some silt/clay. Station ROV-03, under the steel cage system, revealed scattered evidence of fish fecal material and incidental feed pellets. However, under the bag system the fecal and feed material was concentrated near the centre of the system and was quite dense; excess feed was clearly evident and a potential issue with feeding was relayed to farm staff. Changes in camera operational procedures, orientation within the bag, etc. was apparently adopted following this bottom survey.

Biological attributes of the benthic environment under both cages appeared to be minimally affected by the farm operation. Under both systems there were numerous flatfish, rockfish, sculpins, and sedentary macroinvertebrates such as *Metridium senile*. Other observations included the presence of Dungeness crab (*Cancer magister*) and incidental seastars such as *Pycnopodia helianthoides*.

There was no evidence of *Beggiatoa sp*. or any discoloration in bottom sediments that may be related to chemical changes in the sediments.

5.1.2 May 2002

The second survey was conducted 11 months following entry of fish into the closed containment system (18 months after entry to the cage system). Survey transects were the same as those completed in October 2001.

The primary observation of note from this survey was the lack of "piled" feed and fecal material beneath the closed-containment bag system. It is likely that changes to the feeding practices, as applied to the bag system following the October surveys, were successful in reducing wastage and in limiting the localized benthic affects of these inputs. The apparent visual effect of waste distribution across the seafloor was comparable between the two systems (along each of the surveyed transects).

Biological attributes were comparable with the previous survey, with notable numbers of flatfish, sculpins and rockfish. Although there was no obvious discoloration of sediments, despite disruption with the ROV thrusters, there was some *Beggiatoa sp*. noted along edges of rocks, branches, or other material, which provided some protection from tidal current flows across the sediment-water interface. Nevertheless, the perceived impacts from the visual record were minimal.

5.1.3 September 2002

This survey was conducted immediately following harvest of all cages at this site. It was assumed that this survey would represent a worst-case period in the production cycle, with impacts associated within the cumulative organic input across the farm over the entire production cycle (cages: 21 months; bags: 15 months). Two additional transects were completed as a part of this survey.

Again, the distribution of excess feed and/or fecal material appeared comparable between the areas beneath the cage and bag production systems. Macroinvertebrate and fish species present in the area remained unchanged from previous surveys, with numerous flatfish, rockfish, sculpins, seastars, *Metridium*, etc.

Disruption of the surface sediment using the ROV thrusters did not reveal any black subsurface sediments which might have suggested a shift from aerobic to anaerobic assimilation of organic material at the site. However, a dramatic increase in the presence of *Beggiatoa sp*. was noted in all areas observed directly beneath the cages and bags, a condition directly related to the distribution pattern and assimilative process of the organic wastes originating from the farm operation.

Given the strong bottom currents at this site, it is anticipated that the organic material will be quickly assimilated and that the biological condition of the epibenthic environment will not be jeopardized further from the farm activities. Ongoing monitoring is recommended.

5.2 WASTE ESTIMATES BASED ON FEED CONSUMPTION

Feed conversion data suggest that feed conversion in the bag containment units is comparable to that in the steel cages, though feed conversion ratio variability was high at times among rearing units. Maximum waste loading occurs during the final months of production when fish biomass and food administration is greatest. If clear differences in food conversion become evident during future production cycles, waste production could be calculated by use of factors to estimate amounts of eaten feed and digestibility of eaten feed. This has not been for the first production cycle because there is no clear difference in feed conversion between the closed containment units and control units.

6.0 OTHER INTERACTIONS WITH THE SURROUNDING ENVIRONMENT

6.1 PREDATOR INTERACTIONS

One incident of predator interaction was noted in data recorded for the first four months of the trial period; this was observation of a sea lion being present within the cage system on October 19, 2001. No net damage or fish mortality was associated with this observation, though fish were taken off feed for a day in the control steel cages to avoid stress-related difficulties. This single observation is not sufficient to indicate a difference in predator interaction between the bag units and cage units, though clearly the ability of the sea lion to see fish in the cages may have been an inducement to enter the cage system.

6.2 FISH ESCAPES

Between the start of trials and November 1 2001, no fish had escaped from any containment unit. These initial results over the first production-cycle trial period suggest no difference in escape-prevention between the closed containment system and conventional cage system.

6.3 HEALTH PROBLEMS

Fish mortalities were low in all containment units. Numbers of mortalities over the trial period from the time of placement in the trial containment units until the end of harvest are summarized in Table 4.13. Causative factors recorded by site personnel included non-performing growth, gill damage, birds/predators, plankton and possible disease pathogens. No disease outbreaks occurred during the trial period. The most common disease-related mortality was associated with mouthrot. Mouthrot is usually caused by myxobacteria, which are a group of microorganisms that are widespread in the natural environment and tend to invade fish tissue that has been damaged or for which protection is reduced by a weakened immune system. Mortalities attributed to mouthrot were comparable between the bag containment units and control cages over the trial period (3-5% of all mortalities in bag units and 4-6% of all mortalities in cage units).

Health conditions were generally good in both the steel cage and bag containment units, with comparable survival in both types of unit. Disease problems that may have placed wild fish species at risk were not evident in either type of containment unit. The most common disease-related mortality that was reported, mouthrot, is associated with a commonly-occurring group of microorganisms.

7.0 SUMMARY AND CONCLUSIONS

1. Fish size was comparable in bag containment units and control cages over the first several months of the trial (until the end of August 2001). At some point over the end of summer or early fall fish average fish size in bag units fell behind that in the control cages, possibly as a result of oxygen-supply problems. The differential in weight was evident for the remainder of the trial until harvest, even though growth rates in the bag units were similar to or better than those in the control cages. Final lower weights in the bag units do not appear to be a result of sustained poor growth performance, but rather a depression in growth that resulting from some factor in September or October, 2001.

Initial size difference in the two starting fish groups (Group 1 - Control Cage 1 and Bags 3, 5, and 6; and, Group 2 – Control Cage 2 and Bags 1, 2 and 4) remained evident throughout the trial. Growing conditions for the two test groups were altered in early May:

- Group 1 - fish were removed from the control pen for Group 1 (Cage 2) on May 2 (50% of the fish from Cage 2 were transferred to Cage 7); and
- Group 2 – the first harvest from any test/control unit took place on May 14, when the first batch of fish were harvested from Cage 1.

Comparison of data after early May is subject changes in rearing conditions resulting from these activities and to weight data derived from batch-harvests that varied considerably over time.

2. Mortalities were low over the trial period in both bag and control cage units. The data do not indicate a difference in fish survival between the two types of rearing unit.

3. Feed conversion in the bag containment units was comparable to or slightly better than feed conversion in the steel cages up until mid-June 2002. Feed conversion data over the harvest period is difficult to compare because harvest timing and pre-harvest starvation varied considerably among rearing units. Data suggest that feed conversion may have been slightly better in control cages than in bag units.

4. The distribution of excess feed and/or fecal material appeared comparable between the areas beneath the cage and bag production systems. Feed conversion data do not show a clear difference between fish in the closed containment units and control cages and are not sufficient to suggest feed digestion and feces production differs between the two systems.

5. Predator interactions at the farm were very low. Data do not indicate a difference in predator interaction between the bag units and cage units.

6. Fish escapes did not occur from either the closed containment or control units; data do not indicate that the potential for fish escapes differs between the bag units and cage units.

7. Health conditions were generally good in both the steel cage and bag containment units, with comparable survival in both types of unit. Disease problems that may have placed wild fish species at risk were not evident in either type of containment unit.

Appendix A1 Marine Harvest average fish weights collected from net pens and closed containment systems from groups 1 and 2. (Harvest weights are italicized).

Date		Group 1			Group 2			
	Pen 2	Bag 1	Bag 2	Bag 4	Pen 1	Bag 3	Bag 5	Bag 6
23-Mar-01					0.289			
25-Mar-01	0.221							
29-Apr-01	0.303				0.372			
11-Jun-01	0.440	0.440	0.440	0.440	0.480	0.480	0.480	0.480
21-Jun-01								
16-Jul-01	0.620	0.630	0.600	0.590	0.700	0.730	0.680	0.670
30-Aug-01	0.840	0.910	0.870	0.840	0.970	1.030	1.030	1.020
11-Oct-01	1.500				1.780			
12-Oct-01		1.450	1.490	1.320		1.600	1.610	1.640
15-Nov-01					2.490			
16-Nov-01	2.200	1.760	1.910	1.890		2.200	2.010	2.230
14-Dec-01	2.350	2.120	2.220	2.190	2.800	2.390	2.370	2.560
12-Jan-02	2.774	2.280	2.360	2.157	2.575	2.560	2.480	2.700
20-Jan-02	2.700	2.390	2.520	2.650	2.900	2.680	2.814	2.810
22-Feb-02	2.839	2.623	2.620	2.613	2.975	2.800	2.942	2.968
22-Mar-02	3.400	3.057	3.016	2.919	3.650	3.130	3.209	3.317
20-Apr-02		3.409	3.214	3.306	4.021	4.083	3.675	3.982
22-Apr-02	3.881							
14-May-02					***4.222***			
15-May-02					***4.143***			
19-May-02					***4.110***			
21-May-02					***4.207***			
03-Jun-02						***3.756***		
04-Jun-02						***3.772***		
08-Jun-02					***4.445***			
09-Jun-02					***4.406***			
10-Jun-02					***4.406***			
11-Jun-02					***4.306***			
15-Jun-02					***4.282***			
17-Jun-02							***3.874***	***4.173***
18-Jun-02					***4.199***	***3.848***		

Date			Group 1			Group 2		
	Pen 2	Bag 1	Bag 2	Bag 4	Pen 1	Bag 3	Bag 5	Bag 6
01-Jul-02	***3.919***							
02-Jul-02	***4.578***							
06-Jul-02	***4.487***							
08-Jul-02	***4.338***							
09-Jul-02	***4.234***							
13-Jul-02	***4.232***							
04-Aug-02								***4.797***
06-Aug-02							***4.513***	***4.688***
10-Aug-02							***4.526***	
13-Aug-02				***4.260***			***4.526***	
14-Aug-02				***4.241***				
17-Aug-02			***4.264***	***4.268***				
20-Aug-02			***4.241***					
24-Aug-02		***3.860***	***4.264***					
27-Aug-02		***4.284***						
03-Sep-02		***4.166***						

Weight recorded by the hatchery noted as 5% less than actual weights.

* Weights present in regular font indicate regular sample weights; bold and italicized values indicate harvest weights.

** Actual weights recorded and recommended modifications by the salmon farm are listed in the following table.

Date	Pen 2		Pen 1		Salmon Farm Comments
	Measured Value	Fish wt (kg) Reported from Farm	Measured Value	Fish wt (kg) Reported from Farm	
22-Feb-02	2.975	2.839	2.839	2.975	Pens 1 and 2 believed to have been mislabeled and should be switched
22-Mar-02	3.571	3.400	3.927	3.650	Actual sample weight seemed high in relation to growth curve