

**Draft Report
Halibut PEI Phase 1**

May 1, 2009



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DRAFT

EXECUTIVE SUMMARY

Halibut PEI Inc set out to determine if a halibut feedlot industry was viable using low salinity well water available in the province. The natural advantages of well water including stable geothermal temperatures (10°C) and under ground filtration through sandstone to avoid diseases, and the significant reduction of initial capital expenditures by modifying existing lobster holding tanks were anticipated to give economic advantages over other means of halibut culture. Beginning in September of 2008, with funding from both federal and provincial governments, equipment and expertise from both private and academic institutions and the cooperation of the plant owner, halibut were raised in PEI for the first time.

Through a series of evaluations and growth measurements of three different ages of young halibut, the project demonstrated excellent survivability and satisfactory growth of the fish and a variety of adaptive techniques to facilitate their successful culture in lobster tanks while promoting a high degree of environmental protection. Throughout the trial period, no treatment of any kind was necessary.

Fish from the system were sampled by local chefs and received rave reviews.

The saltwater wells on PEI can biologically support an efficient industry to grow halibut juveniles to market weight. The business model for success still requires extensive development. Fingerling costs must be reduced, growth discrepancy between males and females must be addressed, new markets must be found for different sizes of fish, and feeds have to be evaluated for efficiency in this type of water. Lobster facilities around the Island need to be made aware of the basic parameters for saltwater wells, tank modification and growth estimates in order to assess their potential for growing halibut as second product when not holding lobster. Halibut PEI Inc believes that capture of effluents needs to be refined to ensure the best environmental protection possible.

INTRODUCTION AND GOALS OF THE PROGRAM

Halibut PEI was formed in 2004 with the objective of developing a land based halibut aquaculture industry on PEI. Based on the scientific literature and first hand knowledge of the salt water wells on PEI, the principals sought a suitable location to initiate the project and managed to obtain use of the MorningStar Fisheries plant in Victoria PEI (Figure 1). After obtaining funding from the AIMAP initiative of Fisheries and Oceans, Canada and from the PEI Department of Fisheries, Aquaculture and Rural Development as well as in kind support from the same provincial department, Scotian Halibut Limited, Atlantic Veterinary College (AVC) and Ocean Choice International, the project began in September of 2008.

Figure 1: MorningStar Fisheries building in Victoria, PEI



The objective of the project was to determine the capability of PEI salt water wells to support an Atlantic halibut feed lot industry using existing equipment and facilities from lobster pounds. Several factors were inherent in this objective.

The geothermal regulation of water temperature from salt water wells was expected to be ideal for halibut culture. Water from deep wells was considered virtually abiotic containing no parasites, bacteria or known viruses but with a relatively low salinity (20 to 26 parts per thousand or ppt). The initial factor to be determined was the viability of the fish in this salt water well environment.

Halibut PEI intended to use existing facilities to minimize initial capital investment in the early stages of the province's halibut grow out industry. Lobster pounds could provide the infrastructure but would not allow year round production making it necessary to determine the size of fish to be placed into the tanks in order to provide a marketable product in the time frame available. This strategy recognized the availability of a ready supply of juveniles and young halibut from Scotian Halibut Limited but required an understanding of halibut growth rates under these water and tank conditions. This was a second factor to be determined.

Inherent to the philosophy of the company is an unwillingness to compromise the PEI environment which is so attractive to tourists. The project therefore also included plans to reduce any ecological foot print as much as possible. This was achieved at the MorningStar facility with the installation of a waste extraction system that gathered and removed solids and allowed analysis of effluent. The facility also allowed Halibut PEI to pursue its original intent of developing a holding system strategy which did not rely on the use of antibiotics, parasiticides, or hormones because of its abiotic salt water well supply.

Assessment of these factors was the focus of evaluation when the project started in September 2008. Two set ups were used. The first consisted of shallow fiberglass tank trials allowing close, detailed observation in order to determine the viability and growth of the fish in salt water well water. The second consisted of pre-commercial rearing of halibut in a modified concrete lobster holding tank. This part assessed the feasibility of using existing infrastructure and would ascertain that growth rates obtained in the fiberglass tanks could be achieved at commercial densities.

FIBERGLASS TANK TRIALS

The survivability and growth of Atlantic halibut, in water provided by salt water wells characteristic of PEI, was determined by rearing three groups of halibut, each representing different size classes, in research scale fiberglass tanks. These allowed close observation of the fish in order to determine their behavior, feeding activity and any demonstration of disease or stress. It also allowed more precise determinations of growth measured as increase in total biomass.

METHODS

Three sizes of tanks were used, because of their availability: 3.65m X 1.83m (2.34m³), 3.65m X 1.52m (1.94m³), and 3.65m X 1.22m (1.56m³). These tanks were equipped with 20 cm diameter, 56 cm long gas scrubbers previously used for lobster holding. These were modified with the addition of two water distribution plates supporting 2.5cm Bio Barrels (Aquatic Eco-Systems, Inc., FL) to optimize gas exchange. A line from a regenerative blower was connected to each scrubber to increase the air flow through the incoming water. In case of water flow shut down, oxygen was available at each tank delivered via fine pore diffusers for oxygen (Aquatic Eco-Systems, Inc., FL). The tanks all had rigid hardware cloth ("Vexar") wall extensions to allow for 40 cm of extra height

to prevent jumping (Figure 2). Eventually it became necessary to completely close in the top of the tanks with similar mesh to prevent jumping over the top of the walls.

Logistics

Group 1 (150g)

On October 2, 2008, 743 fish, at approximately 150g mean weight, were transferred from Scotian Halibut Limited to Halibut PEI's facility (MorningStar lobster plant) in Victoria, PEI. The fish were trucked to the facility by Scotian Halibut Limited in oxygenated sea water held in modified 1 m³ plastic fish tote boxes. Upon receipt, the fish were netted out of the tanks into self draining tubs which were carried to and emptied into eight fiberglass holding tanks (Figure 3).

Figure 2: Fiberglass tank set up



Group 2 (650g) in Fiberglass Tanks

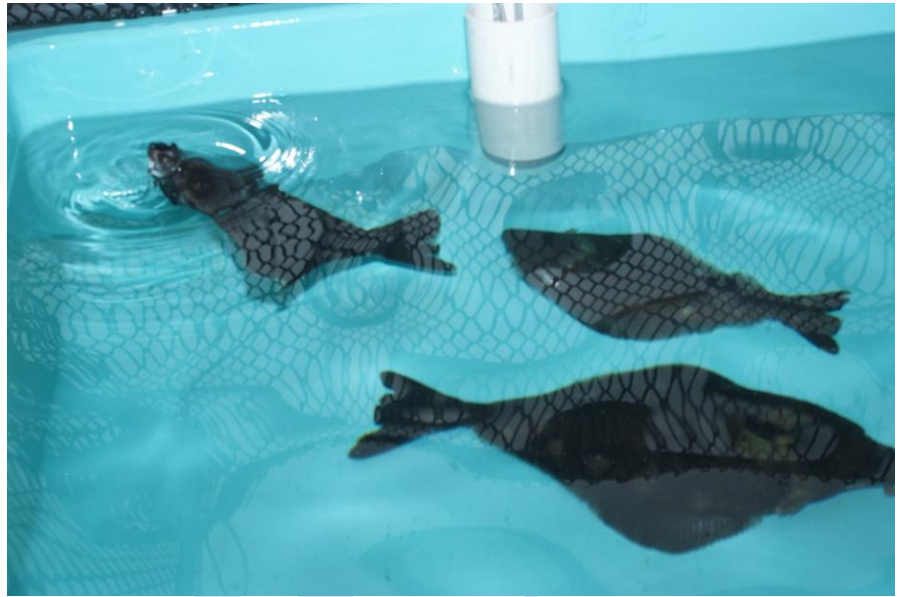
On December 20, 2008, 1459 halibut, with a mean weight of 642g, were successfully transferred from Scotian Halibut Limited to Halibut PEI's facility in Victoria, PE by CJ MacIntosh Trucking using fiberglass smolt transfer tanks on a trailer. A subset of 82 of these fish was allocated to two fiberglass tanks (2.34m³ each) previously used for Group 1 fish, after disinfection. These fish provided a comparison in growth with Group 1 in adjacent fiberglass tanks and with the majority of Group 2 fish housed in the concrete tank 1B as described below.

Figure 3: Release of Group 1 fish into fiberglass tank



Figure 4: Group 2 fish in the fiberglass tank

At the end of the growth trial, the Group 2 fish held in the fiberglass tanks were moved into the concrete tank (1B). Prior to the transfer, the fish from the fiberglass tanks were individually tagged with Visual Implant Elastomer (VIE) tags (Northwest Marine Technology, WA). At this time, the fish were anesthetized with MS-222 (180mg/L) (Syndel Laboratories Ltd., BC), individually weighed and the presence or absence of cherry belly (described below) was determined. The fish were tagged to differentiate those with and without this condition.



Group 3 (13g)

Figure 5 A, B: Group 3 fish



On February 12, 2009, 178 juvenile halibut with a mean weight of approximately 13.5g were transferred in buffered, oxygenated water in sealed plastic bags in styrofoam coolers from Scotian Halibut Limited to Halibut PEI's facility in Victoria, PE. They were all released into one fiberglass tank (1.56m³) after a one hour temperature acclimation was performed by floating the sealed bags in the recipient tank.

Protocols

Group 1 (150g)

Water quality was checked and fish were fed to satiation a minimum of twice daily. Fish were offered Corey AquaSea diet for marine fish in a 5mm pellet: 50% protein, 14% fat, 18.9MJ/kg digestible energy (Figure 6). Feed offered each day was recorded along with oxygen, temperature, salinity and differential gas pressure. Oxygen levels were maintained at optimum (greater than 8.5mg/L or 88% saturation) to enhance appetite and reduce any stress on the fish.

Figure 6: Feeding Group 1 fish



Any debris (feces, uneaten food) in the tanks was swept into the drain daily or as required. Mortalities were removed immediately. Mortalities were sent to AVC for detailed disease testing or frozen to provide retrospective reference.

Group 1 fish status was very closely monitored. The system was set up for early disease detection as individual fish could be seen and examined visually with a pencil light. The bright aquamarine color of the tanks was remediated with low ambient lighting: approximately 1 lux or less as measured by a light meter. All tanks were within 0.5 lux of each other. The lower light level did not seem to inhibit their predation for pellets and all fish appeared quiet and unperturbed in the tanks.

The fish were not weighed when the tanks were initially stocked to reduce stress at the time of transfer. This was particularly important because the transport truck was delayed for 6 hours on the New Brunswick side of the Confederation Bridge due to a freak storm causing high winds in excess of 100km/hr. An initial assessment of fish biomass in each tank was conducted October 16, 2008. Subsequent tank biomass determinations were conducted at 2 week intervals from this point to December 11, 2008, and monthly thereafter. Biomasses were determined by netting fish out of the fiberglass tanks into self draining tubs that were then placed in water filled receptacles on a tared scale.

On December 16, 2008, the fish were graded by size into six tanks to free two tanks for use for another cohort of fish (Group 2). February 3, 2009, the Group 1 fish were again

redistributed but into five tanks to make room for the smallest size cohort of fish in the study (Group 3).

Group 2 (650g) in Fiberglass Tanks

The fish put into the fiberglass tanks were weighed at two week intervals January 6 to March 3, 2009. Adjustments to the biomass determination procedure were required to accommodate the larger fish. Water quality was checked and fish were fed to satiation a minimum of twice daily. Fish were offered Corey AquaSea diet for marine fish in a 10mm pellet: 47% protein, 19% fat, 19.1MJ/kg digestible energy. Feed offered each day was recorded along with oxygen, temperature, salinity and differential gas pressure. Any debris (feces, uneaten food) in the tanks was swept into the drain daily or as required. The planned procedure was to remove mortalities immediately and send to AVC for detailed disease testing but none occurred. Vinyl mats (1.9m²) were added to one of the tanks February 24, 2009 to determine their effect, if any on incidence of “cherry belly”.

Group 3 (13g)

These fish were fed every half hour throughout the working day. Fish were fed in excess in an attempt to reduce cannibalism which is common in very young halibut. Fish were offered Gemma Wean Diamond diet for marine fish in a 1.8mm pellet: 55% protein, 15% fat. Feed offered each day was recorded along with oxygen, temperature, salinity and differential gas pressure. The tank bottoms were swept with a soft broom daily to move uneaten feed and feces to the drain. The single mortality was removed immediately but was not sent to AVC for disease testing because it was only partially intact, the remainder having been cannibalized. A biomass determination was done twice in 6 weeks on these fish.

RESULTS

Water Quality, All Groups

All tanks were subjected to the same water quality conditions since they were supplied with the same water. Initially, the water was derived from Well #1. The temperature in the fiberglass tanks remained close to 10°C until mid December when it began to drop appreciably (Figure 7). Soon after reaching 8°C, the tank water supply was switched to Well #3 – temperature 8.8°C. The salinity of the tanks changed gradually but with regular fluctuations when on Well #1, eventually peaking between 26 ppt and 27 ppt. Regular fluctuations were still apparent after switching to Well #3 but were less marked (Figure 8). Oxygen levels were maintained above 85% saturation by adjusting water flow. Total gas pressure hovered around 100% (Figure 9). pH was not a concern in the tanks because of the high turnover and low stocking densities. It was measured on one occasion and all tanks were within the range of 7.70 to 7.71. Water clarity remained excellent. Some tanks were noted to have low spots where some debris settled but nothing of significance.

Figure 7: Temperature profile of water in fiberglass tanks. The yellow point represents the day after the well water source was switched.

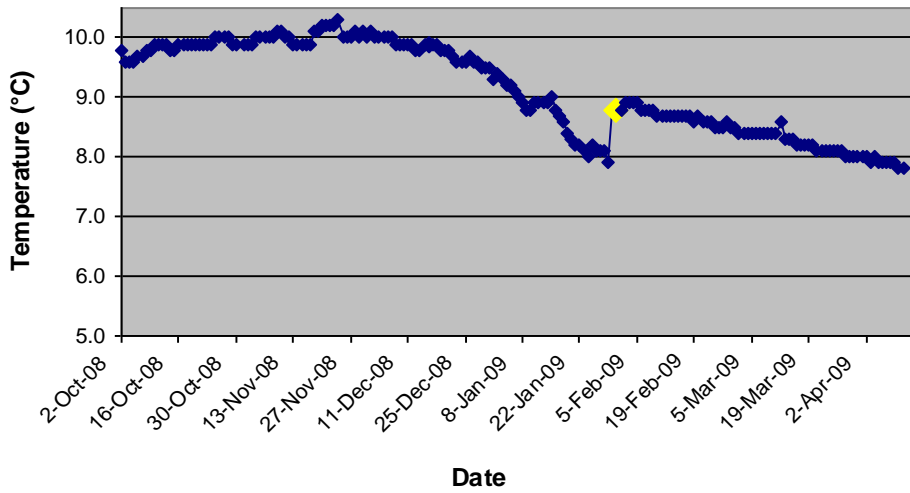


Figure 8: Salinity profile of water in fiberglass tanks. The yellow point represents the day after the well water source was switched.

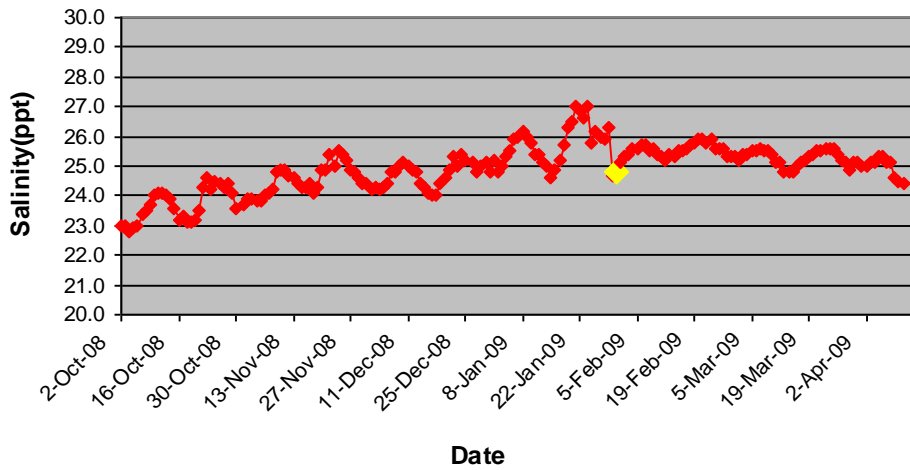
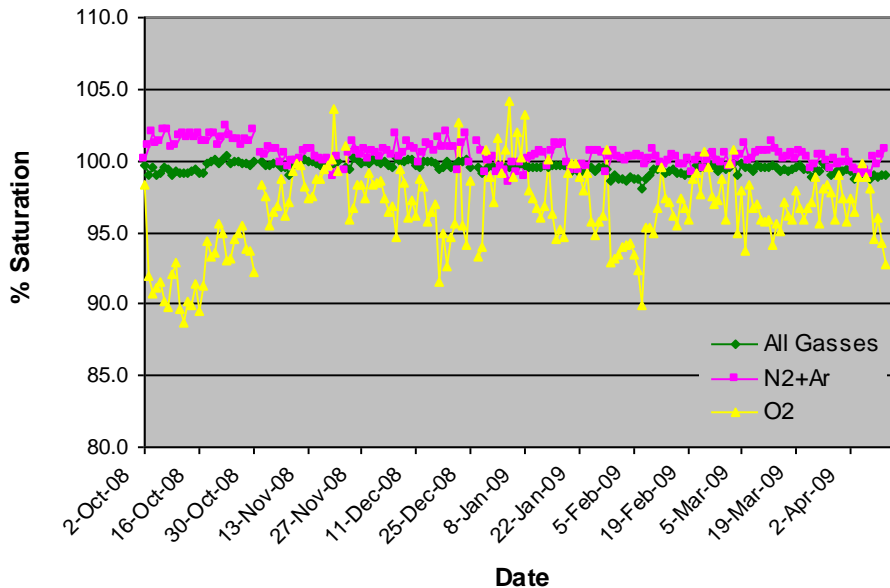


Figure 9: Gas profiles of water in fiberglass tanks



Survival and Health

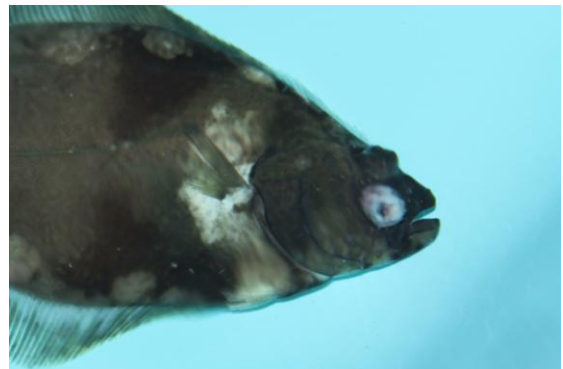
Group 1 (150g)

Once transferred to the small fiberglass tanks in MorningStar, the fish settled quickly and could be observed individually. The 6 hour transportation delay of the 743 fish from Scotian Halibut Limited in NS to Victoria, PEI, on October 2, 2008 contributed to 16 fish dying on Friday, October 3 as a result of stress and injury from the transport. These showed massive effusion of gill mucus, pale color of the gills and gaping mouth and opercula to indicate hypoxia (asphyxiation) and subsequent respiratory distress leading to death. Other changes noted included some transportation related damage to fins and eyes.

One fish found several days later (report number 28020), describes evidence of bacteria in the vessels and elsewhere. This fish was in the tank undetected for at least a day and the bacteria described were interpreted as being a post mortem (after death) contaminant typical of autolysis (rotting). The fish in the tank were monitored intensively and no others were lost or became ill. All other reports indicate no evidence of infectious or any other disease. The cause of death was not determined but was likely transfer related.

Figure 10: Halibut with traumatic eye damage

No other in tank mortalities occurred for the entire course of the study, more than a six month period. Two fish surviving transport difficulties had ulcerative traumatic damage to one eye as a result of the shipment. One fish was removed, culled and sent for necropsy (November 6, 2009) while the other had the eye surgically removed and went on to heal uneventfully. Two additional fish were culled late in the study (March 13, 2009) due to



their apparent weak state (pale and small) to used for disease monitoring and a further fish was culled April 3, 2009 due to an abrasive growth on its jaw. No indications of infectious or environmental diseases were found in any examined fish.

In week two after their arrival, fish in several tanks began flashing and demonstrating intermittent irritability. The tanks were flushed with increased water flows and no further manipulation. The problem never returned so no diagnosis was made. Likely the incident involved protozoan infection which is common after transport; and the reduced salinity and higher water flow controlled any parasites on the skin. Skin scrapings of the halibut that died immediately post transport did not reveal any parasites and fish necropsies did not reveal any parasites either. Throughout the entire demonstration project no treatments of any kind were used.

Despite the securing of tanks with elaborate jump nets and covers, 15 fish losses occurred over the six month period due to fish jumping out of tanks.

Mild lesions were noted on the abdominal surface of the fish at weighing and grading, a condition known in the aquaculture and fishing industries as “cherry belly”. This condition seemed to lessen as tank densities were increased after grading into another tank and remained very mild in this group of fish. Halibut PEI embarked on an investigation of this dermatitis and the initial results will be appended.

Group 2 (650g) in Fiberglass Tanks

No in tank mortalities occurred for this group. One fish died as a result of jumping out of the tank. The only other fish losses were a result of culling for disease testing. Five fish were culled specifically to examine a multifocal dermatitis labeled as “cherry belly”. Handlers noticed these small, red, circular, elevated lesions about one month after receipt. And they continued to increase in number and severity. The lesions caused no noticeable irritation to the fish and feeding appeared normal. A new substrate was put in Tank 1 in the form of a vinyl anti-fatigue mat on February 24, 2009. When the fish were examined six weeks later (April 9, 2009) incidence of cherry belly in tank 1 fish had reduced dramatically compared with tank 2 which had only a fiberglass substrate. At this time, the tank with the vinyl mats had a 5% incidence of the condition whereas the tank without the mats had an 86% incidence. Fish with the lesions were lethally sampled March 27, 2009 and April 3, 2009 for detailed histopathologic study of the lesions. Though commonly referred to by others, this condition has never been examined in detail. Initial histopathology indicated severe edema (fluid collection) around the scales, papilloform proliferation of the skin (forming wart like growths) and proliferation of blood vessels adjacent to the lesions and under the skin accounting for the red color. The lesions are now being examined by electron microscopy and a report will follow.

Group 3 (13g)

One very small fish (less than 1g) was found dead 2 days after the shipment arrived. It was not sent for disease testing because it was only partially intact. Three obvious “runts” (smaller than average fish) were noted upon receipt of shipment. These remained much smaller than the rest of the population. One of the small fish was noted to have a

freshly injured eye on April 11, 2009. The eye subsequently healed but the fish was still often observed swimming at the surface while other fish rested on the tank bottom the vast majority of the time. Three of the small fish were removed April 29/09 and examined by necropsy. All pathology reports are appended.

Growth and Feeding

Group 1 (150g)

Feeding began within a day of transport and remained strong throughout, though the decrease in water temperature later on did inhibit feed consumption. (Figure 11). Handling for biomass determination also inhibited feed consumption the following day. Feeding rates ranged from 0.43% to 0.79% body weight per day. Feed conversion ratios averaged 1.2 over the sampling period. Specific growth rates ranged from 0.31% to 0.86% and were also affected by temperature (Figure 12). There was no significant tank effect on fish performance (growth and food conversion).

Figure 11: Effect of temperature on feed consumption

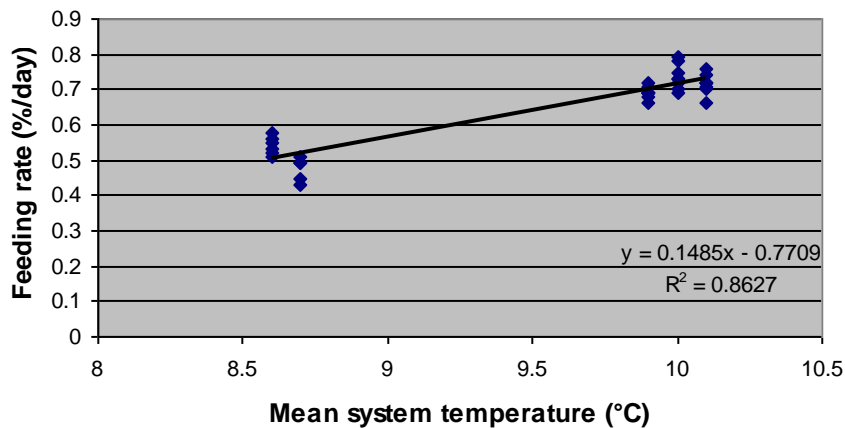
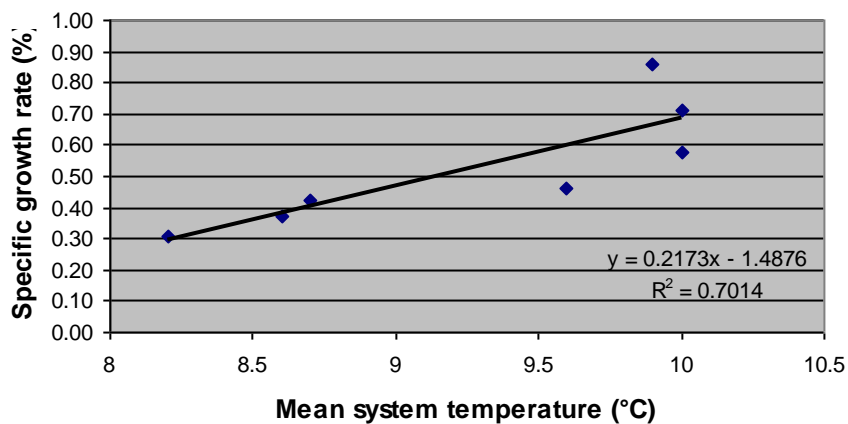
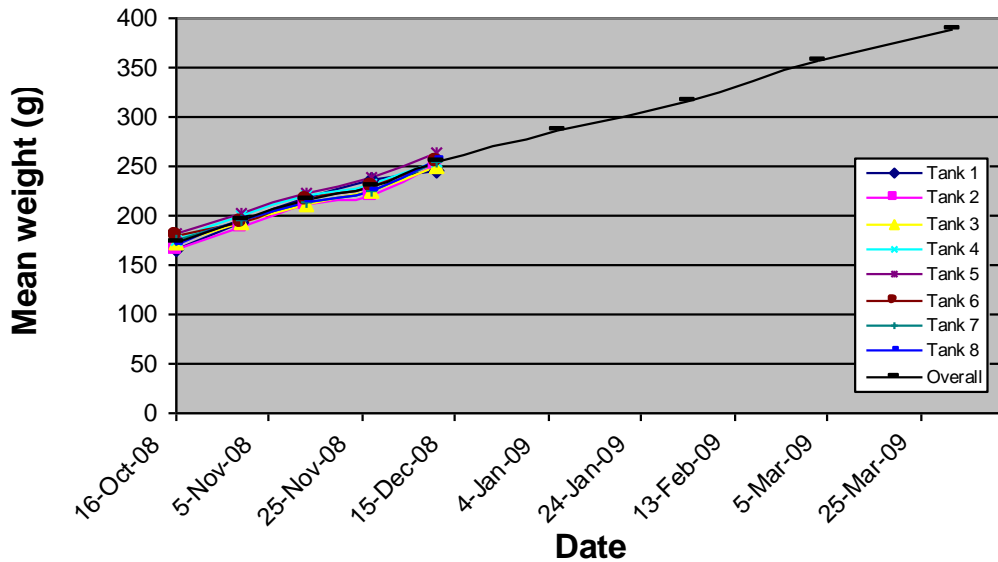


Figure 12: Effect of temperature on growth



The Group 1 fish achieved a mean weight of 389g by the end of the study (Figure 13). A broad size distribution was noted in the fish with the smallest fish estimated at being less than 100g and the largest fish greater than 500g.

Figure 13: Growth of Group 1 halibut. (Groups are combined after the first grade)

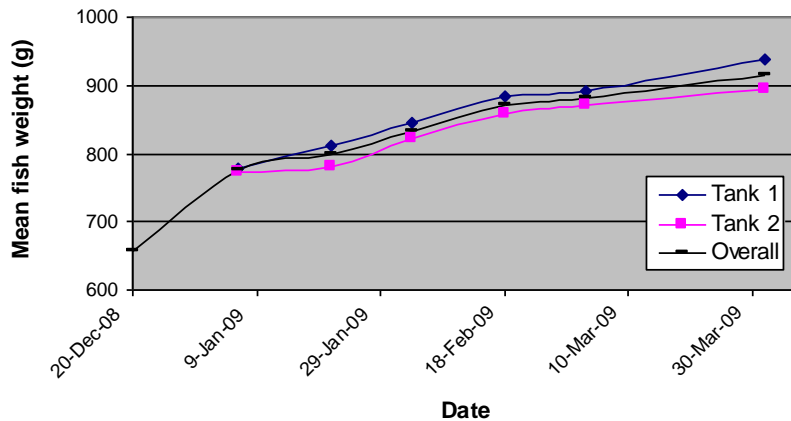


Group 2 (650g) in Fiberglass Tanks

Feeding began within a day of transport. A high feeding response was never noted in this group of fish. Handling for biomass determination inhibited feed consumption the following day. Feeding rates ranged from 0.35% to 0.56% body weight per day with feeding rate dropping over time. Initial feed conversion ratios averaged 1.5 until mid February. After this point, they increased considerably in conjunction with a reduction in growth of the fish. Overall specific growth rate was 0.46%. There were not enough replicates to determine tank effect on fish performance.

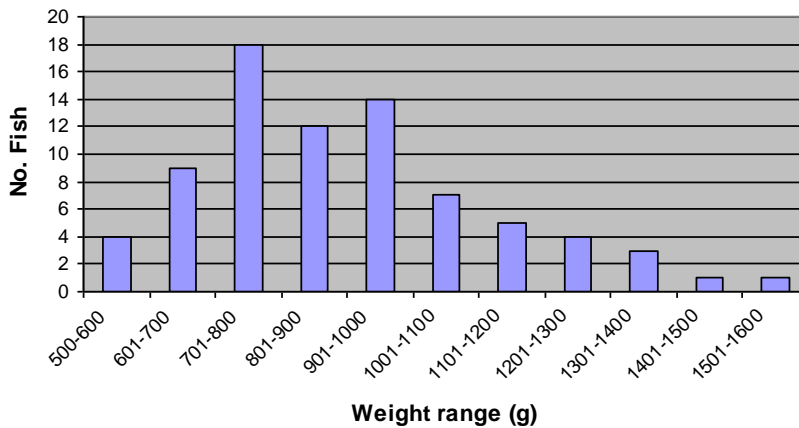
In the fiberglass tanks, the Group 2 fish achieved a mean weight of 914g by the end of the study (Figure 14). Initial growth was excellent. It tailored off in the latter part of the study (post mid February). A broad size distribution was noted in the fish at the end (Figure 15). We quantified this by weighing individuals on April 9, 2009. At this time size ranged from 523g to 1584g. One of the smallest fish (543g) was found to be a precocious male with running milt.

Figure 14: Growth of Group 2 halibut. (Initial weight sample did not designate



tank.)

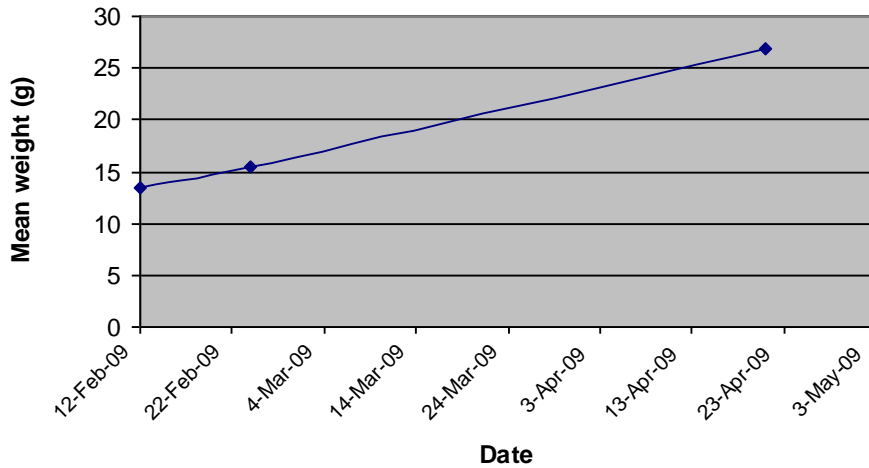
Figure 15: Size distribution of Group 2 fish in fiberglass tanks at the end of the study (N=78)



Group 3 (13g)

Feed was constantly left on the tank bottom to reduce competition. Little feeding response was noted in these fish. Pellets were eaten off the tank bottom with no feeding in the water column observed. Feed was offered at 3-5% body weight per day. Specific growth rate averaged 1.0% over the sampling period. The Group 3 fish achieved a mean weight of 24.9g by the end of the study (Figure 16).

Figure 16: Growth of Group 3 halibut



DISCUSSION

Water Quality

Before each well was used for holding halibut, a complete chemical analysis was done. Reports are appended. The chemical qualities of the water were similar for the wells and all minor differences follow the same trends of detection. Fluctuations in temperature and salinity had the most significant effects on the project. Salinity varied from 22.9 to 27.0 ppt. All indications from the literature plus fish behaviour and feeding in the MorningStar system indicate that this much salinity change, especially when introduced slowly over time, has little or no effect on growth. However, temperature variations as little as one degree Celsius slowed feed consumption and feeding activity. Over a long term this would set back growth. The halibut did adjust to the changing temperature and continued to feed well but did not consume as much as was anticipated. After November, as the draw on the MorningStar well continued, the temperature continued to drop. Pumping all summer will determine how much temperature decline will occur and over what time frame the lower temperature continues. This information will be crucial to the long term strategies of optimizing growth.

Based on this project's results, despite the differences in depth, both wells used originate from the same source and that source is only a moderate distance away. The well water temperature is likely a function of the temperature in Northumberland Strait with moderate geothermal warming in winter and cooling in summer to modify the more drastic temperature seasonal variation naturally occurring in open water. By monitoring the rise in water temperature in the Strait and calculating the delay time in which that becomes apparent in the wells this summer, we hope to provide accurate indicators of annual growth. By switching wells we were able to raise water temperature to near optimum for the duration of the project. With the facility full of fish, it may be necessary to combine geothermal strategies of well water use and recirculation technology to maintain the optimal temperatures as long as possible.

Survival and Health

The water provided by the wells proved to be no deterrent to survival of halibut in the fiberglass tank system. The only mortalities encountered in the three size groups were attributable to transport or fish jumping out of tanks. The only substantiated fish health issues were trauma due to transport and cherry belly. Cherry belly is a well recognized phenomenon for halibut in fiberglass tanks at low stocking densities. Use of a substrate reduced its severity drastically.

Being the initial introduction of halibut into the well water available on PEI, the eight fiberglass tanks provided an artificial system which allowed close monitoring of any activities which were anticipated to affect the fish. Few complications occurred and the fish survived well beyond expectations.

Growth and Feeding

The second goal was to estimate biomass increases while feeding a commercial pelleted feed to ensure that growth would occur at a rate sufficient to reasonably expect that a commercial activity could proceed. This arrangement had some limitations that have to be included in any interpretation of the data.

The fish were normally weighed every two weeks. They were not fed previous to weighing and the process caused them to go off feed for approximately a day. This likely reduced specific growth rates.

Group 2 fish did not adapt well to the shallow water and higher visibility, refusing to move when fed. Also, it is likely they experienced what is colloquially known as the “Goldfish effect” in which the small size of the tank relative to the fish inhibits growth.

Slower growing fish were not culled on a regular basis. Close observation confirmed that the data has to be interpreted in this light since a significant size discrepancy became apparent in the latter months with some fish growing much faster than others. When the Group 1 fish were graded to put fish of similar size in each tank, the slower growing fish seemed to respond by increasing their growth although there was insufficient replication to prove statistical significance. Even after grading there were a few individuals that did not adapt well to this system and did not grow. Regular grading and discard of non-growing fish is common in other aquaculture systems to improve feed conversion efficiencies and overall fish performance. The strategy for this study did not promote fish culling, even though it would have increased the final statistics on growth. The high price of juveniles means that every fish is a major expense such that determining how and if poor performing fish fit into a viable economic model is important. In particular, male halibut can become precocious, as evidenced by the ca. 500g fish found with running milt, and spend all energy consumed producing sperm rather than growing. The broad size ranges of the fish at the end of the study confirms that work assessing the impact of males on growth curves is necessary as is the impact of pedigree to determine if factors other than gender are at play. This was not within the scope of the current project.

Other than these complications, the fish were held in ideal conditions regarding water flow, water quality, light quality and manipulations, and feeding practices. Their stay in the facility was kept as stress free as possible even considering the many visitors (195) accommodated during the project (almost every day as the project closed).

Even with the above considerations, growth rates of the fish were comparable to published studies (Table 1) when temperature is considered.

Table 1: Published growth rates for Atlantic halibut

Study Authors	Mean Starting Fish Size (g)	Temperature (°C)	Average SGR (%/day)
Imsland et al., 2007	26	12	1.25
Simensen et al., 2000	30	11	0.8 to 1.05
Imsland & Jonassen, 2005	30	11	0.95
Tuene & Nortvedt, 1995	197	8-9	0.4
Imsland & Jonassen, 2005	200	11	0.55
Tuene & Nortvedt, 1995	422	8-9	0.2 to 0.4
Imsland & Jonassen, 2005	600	11	0.3

Though not indicative of commercial growth potential, this tank set up proved its capability to provide consistent growth projections in 150+g halibut and confirmed that the system would be suitable for detailed growth studies. Halibut PEI Inc intends to use the system for feed trials in which each fish will be weighed and measured to contribute more accurate data on different feeds and feeding practices.

Group 3 juveniles, placed in the fiberglass tanks at 13.5g, was an addition to the original project description. With survival and growth of larger fish established, Halibut PEI Inc needed to know if these significantly younger fish would grow in PEI well water at a rate that would offset the cost of larger fingerlings. Though only a short experiment, these juveniles have been performing admirably, encouraging the importation of younger fish.

As an additional note, Halibut PEI Inc has arranged to keep Group 2 and Group 3 fish over the summer at the MorningStar facility to further assess performance.

CONCRETE TANK TRIAL

A pre-commercial assessment of the feasibility of using existing lobster holding infrastructure for rearing Atlantic halibut was conducted. The survivability and growth of halibut in a modified concrete lobster holding tank was determined at commercial densities using water provided by sea water well.

METHODS

Initially, a concrete lobster holding tank and its infrastructure were examined to determine the best set up for water and aeration. Different water inlet and outlet arrangements were investigated combined with various air flow configurations and

intensities. Pattern of water flow at surface and tank bottom were estimated by adding floating and sinking media to the tank.

The information gathered was used to design the water inflow and drainage for a concrete tank that would be stocked with Atlantic halibut. The concrete tank modifications were complete by mid-December. The water source was a salt water well. All effluent was filtered through a drum filter before leaving the facility.

Upon arrival in December, Atlantic halibut were put into the modified tank system. These Group 2 fish (Dec 20/08 arrival, 650 g average) were maintained under optimal lighting, optimal oxygen levels and fed to satiation twice a day. Fish were offered Corey AquaSea diet for marine fish in a 10mm pellet: 47% protein, 19% fat, 19.1MJ/kg digestible energy. Oxygen, temperature, salinity and gas pressure readings were taken daily. Unlike the fish in the fiberglass tanks, they were not handled in any way. An overhead walkway provided ready access for observation of the fish for feeding and the evaluation of behavior. The fish were trained to ignore tours that frequently used the walkway and to enhance feeding by the use of a red light as operative conditioning. They soon realized that when the light was turned on, feeding began. The only disruptions they experienced were monthly regular hip wader assisted “tours” of the tank by the biologist to check tank condition and ensure no mortalities had occurred.

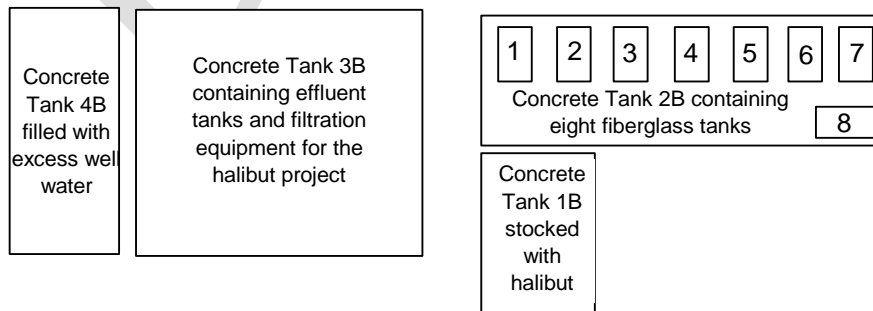
RESULTS

Lobster Tank Modification

Tank Selection

Concrete lobster holding tank “1B” was chosen for modification for halibut production. Its elevations would facilitate drainage, and it was centrally located next to Tank “2B” where the other fish were held in the fiberglass trial tanks (Figure 17). Concrete tank 1B had inside dimensions of 5.64m X 8.69m X 1m depth, representing an effective surface area of 49m² and water volume of 44m³.

Figure 17: Layout of concrete lobster holding tanks at MorningStar facility. Tank 1B was at floor level; the other three tanks were sunken 1 m.



Tank Effluent Piping

To allow drainage, a 25cm diameter hole was cut into the 25cm thick concrete wall of the tank to accommodate 2 of 15.2cm (6") female threaded bushings. These bushings would allow easy dismantling of the tank when return to lobster holding was required. The location of the hole was determined by the plumbing design of the tank drain. All discharge plumbing was sized for 600 lpm flow. Void areas of the wall around the plumbing were patched with hydraulic cement which was then sealed with PQ 4020 (Edco Technologies Inc., Permaquick), a two part (A + B) cement sealing compound). A 10cm diameter (4") pipe on the floor of the tank along the back wall (Figure 18) was drilled to form the drain with hole number and size allowing maximum suction pull from each hole. The first 0.9m outer ends of pipe had 2.5cm diameter holes at 10 cm centers while the central 1.8m sections of pipe had 2.0cm holes at 10 cm centers. This would allow an effective surface area of 96cm² on each side, ample for the expected 300 lpm flow per half of the drain pipe, while still causing good suction and promoting self cleaning of the pipe and tank. When the drain pipe was removed from the tank in mid April there was absolutely no fouling evident on the holes or the pipe itself indicating a self cleaning flow of water. A surface drain consisting of an open ended 15cm (6") pipe with Vexar mesh to prevent fish escape was also incorporated into this pipe to accommodate overflow and prevent airlocks. The surface drain did not always skim the surface properly and an ability to adjust its height would have improved surface cleaning action. The floor drain and surface drain were connected to an external standpipe that could be pulled for tank flushing. All effluent water drained into a drum filter.

Figure 18: Drain plumbing for Tank 1B



Drum Filter

The drum filter used was a Model 4672 from Aquacare Environment, rated at 5000lpm for a 40µm screen (Figure 19). 50µm screens were installed for this study. Discussions with the manufacturer revealed that more realistic expectations for this unit would be 3000-4000 lpm because of the design of the water inlet. This was still much greater than anticipated flows for this demonstration tank system.

A jet pump receiving water from the salt water well was hooked up to the spray bar unit to provide water to rinse down the screens. The jet pump operation was controlled with a pressure switch. This set up was very effective when on constantly. We experienced problems (drum motor burn out) when we attempted to operate the unit on a timer linked in conjunction with a solenoid valve. Having the solenoid valve operate under control of a float switch located within the drum would likely improve the efficiency of the design. This was not accomplished within this study because the design of the drum filter was not conducive to this set up and major alterations would have been necessary. Several maintenance experts and an engineer were consulted on how to do this. Plans were made to do so and will be implemented before the drum filter is put into operation again.

Figure 19: Drum filter for effluent water



The waste from the drum filter was collected in a double decant settling system.

Water Inflow Design and Treatment

The inflow was designed to allow gas passage into and out of the water via an improvise scrubber. The scrubber was composed of stacked lobster holding trays with holes drilled in each tray to allow free air passage throughout (Figure 20).



Figure 20: Lobster tray modification
Figure 21: Scrubber in use in Tank 1B



The stack height was 1.4 m (12 trays, Figure 21) as determined by the clearance required to make adjustments to the inflows, if necessary. Inflow arrangement was critical for this design due to the large surface area available for the water to pass through. Water was well distributed in the scrubber via a four outlet water distributor, taking advantage of the full surface area available (Figure 22).

Figure 22: Water inflow distribution manifold seen from below



A line from the air blower was also hooked into the scrubber to allow air to be blown through its center trays to increase the G/L (gas/liquid) ratio and maximize its degassing ability. This could be particularly important for its putative future use to remove CO₂. In particular, the air to be blown through the scrubber would be from an external source and not contain an increased CO₂ component as air from the tank environment could. No bio-barrel addition was required since the lobster trays were successful at balancing the nitrogen and oxygen saturation levels of the water (Table 2).

Table 2: Gas saturation of the water feeding Tank 1B (Well #3)

Source	Nitrogen saturation (%) ³	Total gas saturation (%) ³	Oxygen level (mg/L) / % ⁴	Temperature (°C) ⁴
Raw well water ¹	106.1	97.7	6.6 / 66	8.1
Post scrubber water ²	100.7	100.5	10.0 / 100	8.2

¹Raw well water measurement was taken in a 5 gallon bucket filled with water from flow alarm outflow

²Post scrubber water measurement was taken in Tank 1B at the base of the stripper next to the concrete wall

³Nitrogen and gas saturation as calculated using Alpha Designs spreadsheet and confirmed with In Situ Inc. Extended Gas Analysis, Version 2.0 (2006)

⁴Oxygen level and temperature as measured using Oxyguard Polaris meter

Air Infusion

Prior to fish entry, trials were conducted to determine the usefulness of the intact water aeration system. The system tested is typical of lobster holding tanks and consists of a regenerative air blower connected to a piping manifold sitting on the bottom of the tank. Holes are drilled in the pipes to allow air flow.

The tank was filled with water and air lines were sequentially turned on in order to assess water current patterns. Sand and peat moss were used to help determine the fate of sinking (sand) and floating (peat moss) particles. A uniform water flow could not be established and areas of solids concentration occurred, particularly on the outer walls on the tank. Unequal distribution of air along the manifolds was the greatest problem. This was not pursued at great length since an assessment of gas transfer in this system revealed very low efficiency. Having all airlines on to their full capacity could not elevate tank oxygen above 85% saturation (influent water was 60%) at a 70 minute tank turnover. As a result, we abandoned use of the existing aeration infrastructure and added an air diffuser system.

Initially, after fish were added, no air was added to the tank through the diffusers or scrubber in order to determine oxygen requirements of the fish per kg of feed. Air was turned on at an effluent oxygen level of 8.5mg/L (Δ 1.5mg/L). At this time 6 kg of feed was being fed with a water flow of 900 lpm, to give an estimated 0.32g oxygen used/g fed. This is similar to rates used by salmon in a flow through system (0.3kg oxygen/kg fed). Basal oxygen consumption rates for Atlantic halibut are not available but would be useful in order to form energetics models for feed delivery.

Initially (January 6, 2009), a VB014 blower was hooked into the system. This did not have the pressure to run the diffusers. The diffusers would work only when elevated 1' off the tank bottom. The blower was changed to a larger model VB030 January 9, 2009. Air flowed well through the diffusers and air was obviously blowing through the scrubber as well as evidenced by water blowing around the outside of the scrubber. Addition of air through the diffusers increased oxygen levels in the tank substantially and slightly increased measured nitrogen and gas saturation levels despite the tank being shallower than 36" (Table 3). Addition of air to the scrubber did not change the characteristics of the post scrubber water. Post scrubber water was already near optimal such that a change would not be expected.

Table 3: Gas saturation of Tank 1B water before and after air diffuser use.

Source	Nitrogen saturation ³ (%)	Total gas saturation ³ (%)	Oxygen level ⁴ (mg/L) / %	Temperature ⁴ (°C)
Post scrubber water ⁵	n/a	n/a	9.9/100	n/a
Tank water before diffusers on ⁶	100.1	98.7	8.6/90	8.8
Tank water after diffusers on ⁶	101.9	101.6	9.8/100	8.8

⁵ Post scrubber water measurements were taken in a 5 gallon bucket filled with water from the scrubber

⁶ Tank water measurements before and after diffusers were turned on were taken in Tank 1B at the base of the stripper next to the concrete wall

Oxygen Use

From December 22 to December 31, small amounts of oxygen were infused into the tank water using fine pore diffusers for oxygen (Aquatic Eco-Systems, Inc., FL). There was no oxygen flow meter on the system and inflow was not regulated such that the oxygen tank was drained rapidly (9 days). Feeding was reduced slightly until water flow was increased to accommodate for the oxygen supply loss. Oxygen was not used in the tank after this date except when the pump was shut down.

On January 29, 2009, the water inflow to the tank was stopped to switch all fish in the MorningStar facility onto one well pump. At this time, the oxygen system was tested. According to the oxygen consumption calculation previously mentioned (under “Air Infusion”) and an assumed oxygen transfer efficiency of 20 to 25% by the diffusers, a flow of 5-6 lpm should maintain tank oxygen. This was confirmed to be true. An oxygen inflow of 5 lpm at a pressure of 25psi maintained tank oxygen at the level in the tank under normal operation.

Water Flows

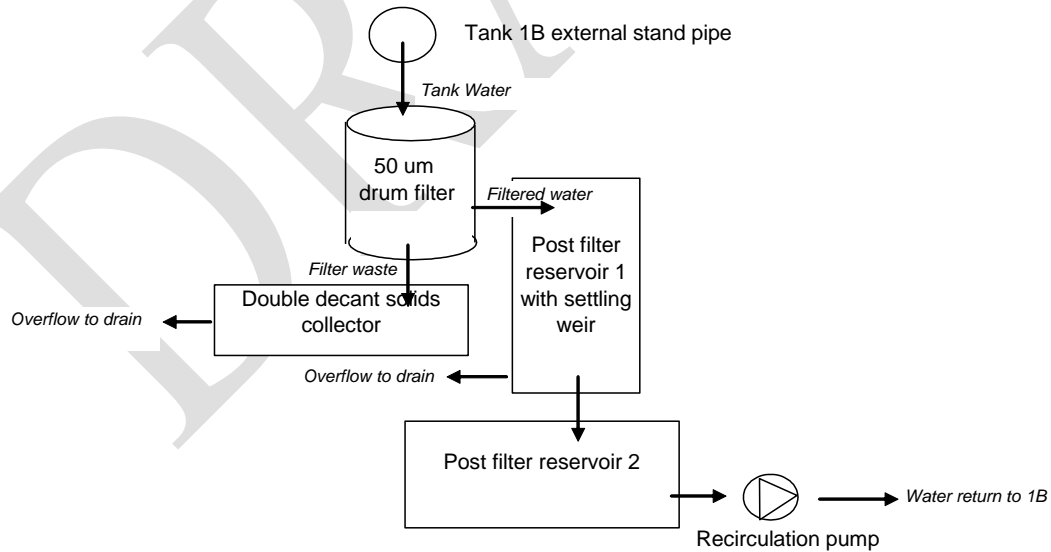
Water flow was turned on in Tank 1B December 15, 2008, several days before fish arrival. The flow was originally set by measuring the time taken to increase the tank water level 5 cm. Initial attempts to measure flow were confounded by leakage from the stand pipe so a dedicated solid stand pipe was made for the purpose of measuring tank flows. Flow was controlled with valves discharging water into Tank 4B, another lobster holding tank on the same water line. There was no valve in line to Tank 1B to allow direct water flow control. After the fish addition make up water flow was decreased until excessive debris was noted in the water of the tank. This occurred at a flow rate of 500 lpm. This represents a tank turnover every 88 minutes.

Table 4: Water flows in Tank 1B

Date	Well water flow (lpm)	Recirc water flow (lpm)	Comments
19-Dec-08	754	0	
12-Jan-08	897	0	
22-Jan-09	653	0	Cut down make up flow
23-Jan-09	566	0	Cut down make up flow, leakage out stand pipe, flow likely faster
25-Jan-09	613	0	New stand pipe made for measuring flows, less leakage
25-Jan-09	605	0	
28-Jan-09	624	0	
29-Jan-09	507	0	Cut down make up flow
2-Feb-09	500	208	Recirc pump on (208 lpm), well water flow not measured
10-Mar-09	384	341	Cut down make up flow, increased recirc flow

On February 2, 2009, the recirculation pump was turned on. This pump moved water from the post drum filter holding tank back to the scrubber (Figure 23). The scrubber inlet for the recirculated water was similar to that for the well water to ensure even distribution of the water over the scrubber and color coded for easy assessment. This allowed a decrease in tank turnover with no obvious ill effects on water quality. Maximum water flow reduction was not achieved before the end of the trial period. It is anticipated that make up water flow could be reduced a substantial amount further than that performed here.

Figure 23: Schematic representation of Tank 1B effluent and recirculating water flow



Foam Fractionator

A foam fractionator (RK25-PE Model from RK2 Systems), rated for 100-150 lpm water flow, was installed in early February and turned on February 10, 2009 to extract mid stream water from the tank for clarification of the fine suspended solids. A water fall pump was inserted in the base of a 20cm diameter pipe sleeve with holes drilled midway.

The pump and sleeve were placed 2/3 way back in tank, midway between the catwalk and the wall (Figure 24).

Figure 24 a, b: Pump sleeve piping and placement for foam fractionator feed



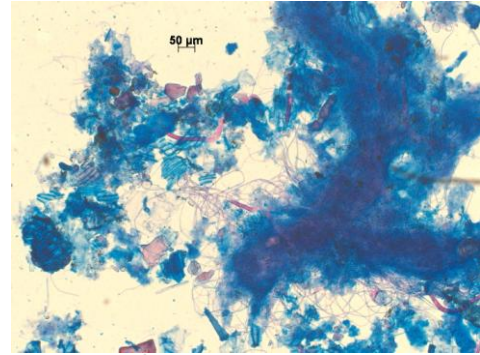
This pump provided the foam fractionator with 115 lpm of water. Many people were consulted on how to run the foam fractionator. Opinions varied greatly and all differed from the unit's instructions. We decided to try it at many different settings and discovered that balancing air flow and internal water flow gave the best results. This balance often had to be reset after re-starts. It was suggested that the tank water was not dirty enough for optimal foam fractionator performance. The suspended solids with halibut feces were evident only with diffracted light illumination. The water always appeared clear when viewed from the walkway except at the morning feeding. More evaluation will be required to demonstrate the advantage of maintaining foam fractionation for fish at this density.

Waste Characteristics

Water which passed through the drum filter had very little suspended solids. Watching the effluent with an offset light source only a few small bits of mucus could be seen leaving the collecting tank. Water that was reused was taken from a connected tank and some superficial oil scum occurred over a week long period and only small bits of debris accumulated in the tank. Because the post filter water was very clear with minimal fines present and it took so long to collect sufficient material to look at, our effluent study concentrated on the material that was filtered by the drum filter and sent to a separate collection tank. Solids from the drum filter effluent separated quickly into two parts- heavy material that settled quickly into a tote box and light material which decanted off the tote box then out of the tank. This material was white to brownish and stayed suspended in the water for a long time.



We made several unsuccessful attempts to quantify the solids collected by the drum filter over a 24 hour period (See appendix.) These attempts involved flowing the waste through a series of screens, including a 75 μm “rotifer rinsers” finishing with a 40 μm nitex mesh. In the end, we collected solids accumulated in one hour intervals. This was repeated for 5 sampling periods. Of interest was the short term clogging of the 40 μm nitex mesh with no visible debris on the mesh. When cleaned off the mesh there was a tiny amount of gel like material, sometimes too little to collect. Analysis of this material showed a large proportion of mucus, extensive growth of long chain algae and water mold as well as normal sewage worms (Figure 25). These were not the characteristics expected with normal waste removal systems in aquaculture facilities using other types of fish. Changes in collection strategy will require substantial modification to the originally proposed effluent clarification process.



Water Quality

Tank 1B was supplied with water from the highest producing well on the premises - Well #3. A detailed water quality analysis was performed on this water and has been appended. The make-up of this water was very similar to that of the other well tested - Well #1, suggesting a similar source from two different aquifers.

The water temperature of Well #3 increased then decreased slightly over the winter months remaining between 7.9°C and 9°C (Figure 26). The salinity slowly fluctuated up and down, keeping between 23 and 26 ppt (Figure 27). It is notable that on January 18, the temperature of Well #3 surpassed that of the Well #1 that was providing water for the fiberglass tanks.

Figure 26: Temperature profile for Tank 1B (Well #3)

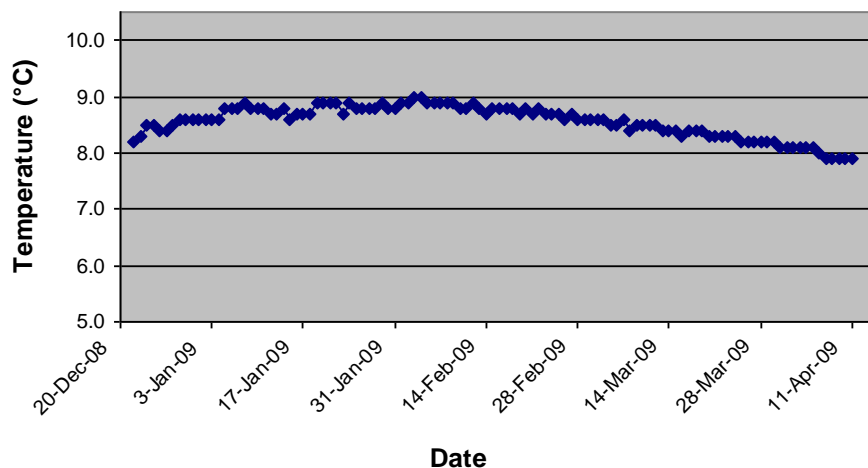
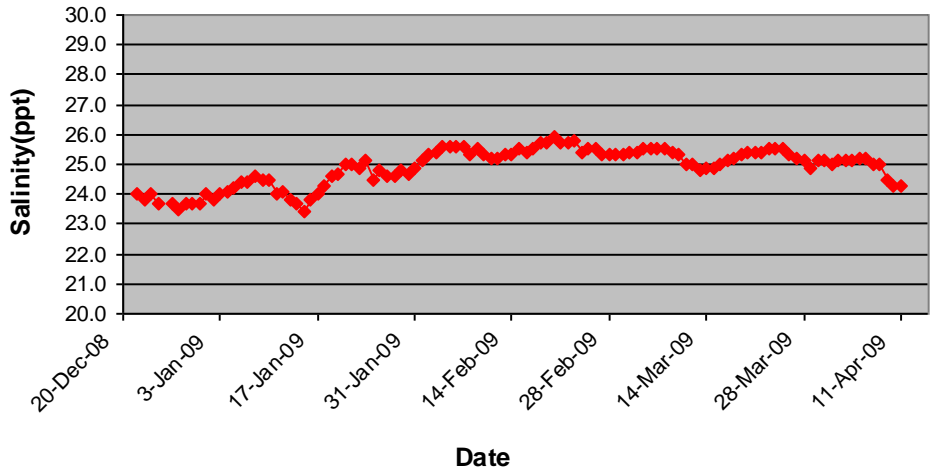
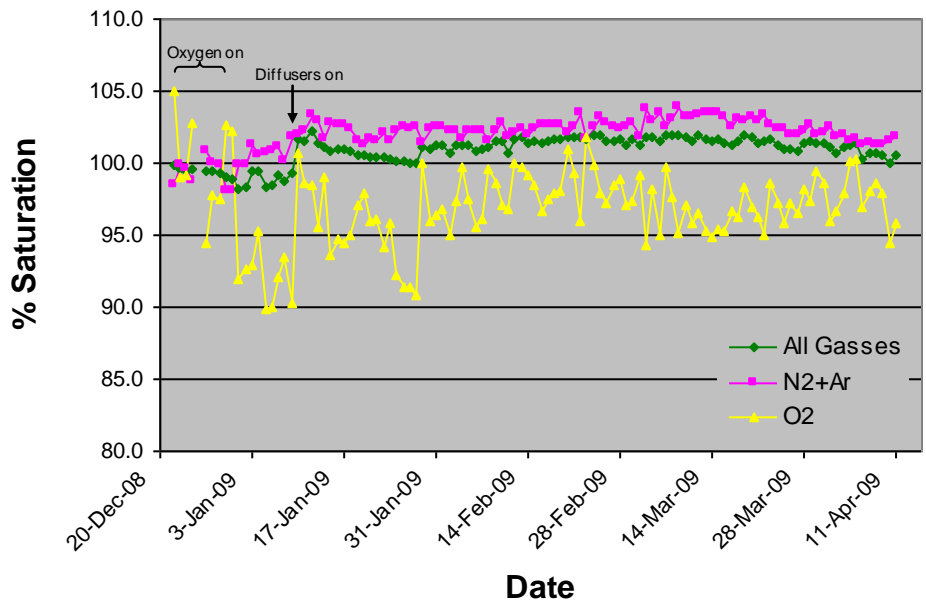


Figure 27: Salinity profile for Tank 1B (Well #3)



As mentioned previously, the scrubber was successful at balancing the oxygen and nitrogen components of the incoming water. However, it was necessary to turn on air diffusers in the tank to increase oxygen levels. This effectively increased oxygen levels but also caused a slight increase in total gas saturation and saturation levels of nitrogen (Figure 28).

Figure 28: Water gas saturation levels for Tank 1B. (Measurements taken in tank beside scrubber.)



Fish Arrival and Initial Assessment

On December 20, 2008, the fish arrived at approximately 6 am. They were delivered by C. MacIntosh Trucking in square smolt delivery tanks. The fish were unloaded by dip netting out of the transfer tanks into porous totes and carried by hand (Figure 29).

Figure 29 a, b: Unloading of 650 g fish.



Initial attempts were made to weigh and count fish prior to entry to tank but the time taken was excessive so that finally only weighing was done. The fish count done by Scotian Halibut Limited would be used. The biomass determined by Halibut PEI was 937 kg. This is very close to the biomass of 948 kg reported by Scotian Halibut Limited. At the time of unloading, 82 fish were put into 2 of the fiberglass (1A and 2A) tanks as mentioned above. More fish arrived than anticipated. Initial stocking density was estimated at 113% coverage or 18 kg/m².

Figure 30: Fish in Tank 1B

Survival and Health

One fish died as a result of jumping out of the tank. Only 2 fish were found dead in the tank. One was submitted for necropsy and disease testing with no evidence of infectious disease found. The necropsy report is attached. Both “in tank” mortalities were likely latent mortalities from the fish transfer. All fish not immediately necropsied were saved as retrospective controls and may be examined at the end of the project.



A number of fish were harvested in order to make a preliminary assessment of the response from the restaurant trade.

Table 5: Inventory losses for Tank 1B December 20, 2008 to March 31, 2009

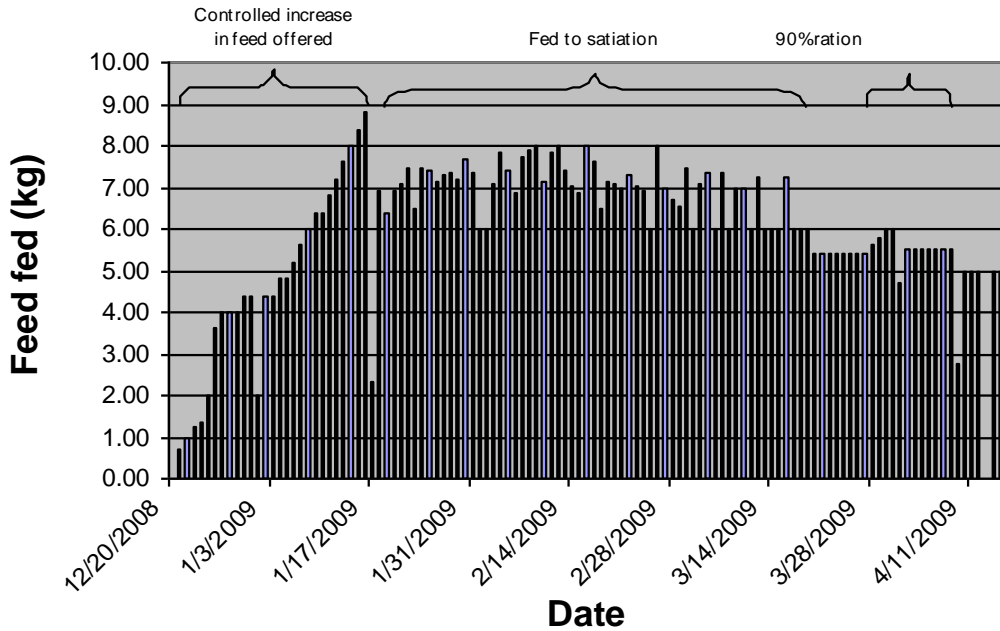
Date	Weight (g)	Cause of death	Necropsy?	Comments
8-Jan-09	428	Jumper	No	Good condition, frozen
9-Jan-09	560	Mort in tank	No	Good condition, frozen
20-Jan-09	693	Mort in tank	Yes	No infectious etiology
20-Feb-09	1455	Harvested	No	77% yield (head off, gutted)
23-Mar-09	1400	Harvested	No	77% yield (head off, gutted)
23-Mar-09	1300	Harvested	No	84% yield (head off, gutted)
23-Mar-09	1120	Harvested	No	78% yield (head off, gutted)
23-Mar-09	1020	Harvested	No	77% yield (head off, gutted)
23-Mar-09	1500	Harvested	No	79% yield (head off, gutted)
1-Apr-09	1520	Harvested	No	94% yield (head on, gutted)
1-Apr-09	1610	Harvested	No	94% yield (head on, gutted)
1-Apr-09	1370	Harvested	No	92% yield (head on, gutted)

Growth and Feeding

Fish were initially on reduced rations and feeding was increased slowly over the next few weeks (Figure 31) to assess system performance. Fish fed ravenously within days. They were generally fed twice daily; an occasional third feeding was attempted if feeding was slower than normal or if activity around the tank disrupted a feeding. In late January, a red light was used as operative conditioning to cue the fish that the feeding session would begin. This allowed them to differentiate from the many visitors using the overhead walkway.

Feeding amounts were not increased more rapidly since the expected feeding level for this size of fish at this temperature was 0.3%/day (approximately 3kg), according to feed manufacturer's feed charts. This amount was surpassed at day 6. Peak feed offering was 8.8kg. This occurred January 16, 2009. This does not represent potential feeding for these fish since the fish were obviously overfed on this day as evidenced by the large number of feed pellets still in the tank the next day. The fish were fed a reduced ration the following day and the feed was left to flush from the tank. From this point on, additional attention was paid to ensure the fish were fed to satiation but not overfed. More than 10 pieces of food on the floor of the tank was the signal to stop feeding for a session. For the month of February, daily feed offerings averaged approximately 7.1 kg, representing a roughly estimated 0.65 % BW. In February, we discussed increasing feeding to 3 times daily on a routine basis. This was a result of the observation that the first feeding of the day resulted in dirty water as the fish stirred up accumulated debris and feces. Three daily feedings were attempted for a few days but was abandoned as no benefit was obvious.

Figure 31: Amount of feed offered to Tank 1B daily.



Feeding was slightly reduced for a week in March in order to collect feces. For this period, a 90% ration was offered in an attempt to ensure that all feed was eaten so that collected matter would only be feces and no uneaten feed.

When we returned to feeding to satiation again in April, feed offerings were lower than other months, despite an expected increased biomass due to growth. This was likely the result of staff being better trained to assess the end point of feeding and reduced appetite of fish due to a decrease in temperature.

Fish grew very well in the concrete tank (Figure 32). A preliminary size assessment suggested a mean weight of 1007g by the end of the study. This represents better growth than the fish in the fiberglass tanks when temperature is considered. An overall FCR of 1.5 was estimated.

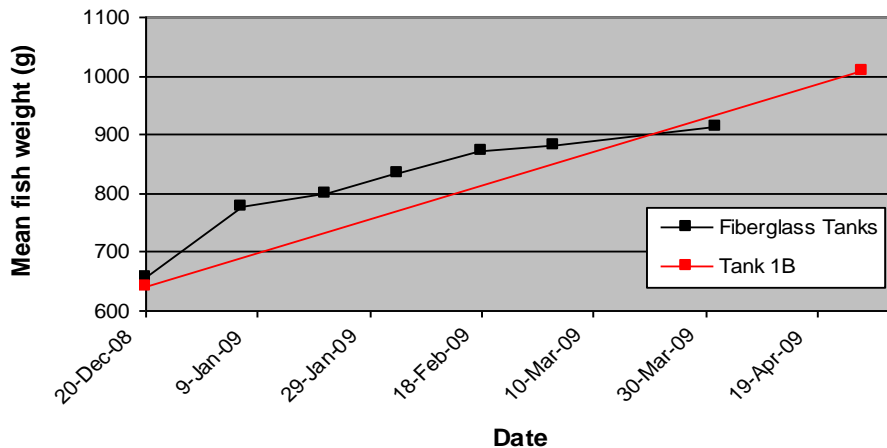


Figure 32: Growth of Group 2 fish in fiberglass tanks and the concrete 1B Tank.

DISCUSSION

The optimum culture set up would be inexpensive, promote self cleaning of the tank and require minimal maintenance while sustaining optimal water quality for commercial densities of halibut. The concrete tank used in this study, with the implemented modifications, met all of the above criteria.

Only minor modifications of the tank were required in order to sustain all parameters of water quality examined. It is notable that more work on tank design is required in order to increase recirculation of water and reduce required make up water flow. The benefits would include: application of a similar system in other facilities where copious amounts of water are not available, use of the recirculation system as a back up measure to hold fish in the event of emergency water shut down or use of the recirculation system to increase holding capacity for fish when awaiting market.

Fish survival was excellent. Only three fish died over a four month period, with one death being caused by the fish jumping out of the tank before it was fully secured with jump netting. The other two mortalities were most likely the result of the transport to the facility. No mortality could be associated with the quality of the water or tank design.

The fish grew very well in this setting, based on the two measurement points available, better than the analogous group in the fiberglass tanks. The feed conversion ratio was not as good as anticipated but staff experience will improve this drastically. Improvements in growth and feed conversion are possible and should be investigated to maximize profitability of similar ventures. These include advances through by stock selection and feed optimization.

The fish grew well enough for us to harvest a small number in order to gauge the response. The product produced was met with rave reviews by all recipients, including restaurants, chefs and individuals. Additional work in this area requires doing a formal review of the quality of the product and promoting its place in the local market.

Effectiveness of the drum filter for removing wastes produced in the system was evidenced by the clarity of the post filter water and our ability to recirculate it back to the culture tank with no loss of water quality. The potential environmental impact of this culture method still needs to be assessed however with more precise assays. In order to best protect the environment in future operations, Halibut PEI will filter all water leaving the facility through a 50 micron drum filter, separate the solids in a normal septic tank from which the sewage can be removed periodically and design a self cleaning mesh filter to remove most of the remaining debris. Halibut PEI also intends to evaluate bioscrubbing. Shell fish feed normally on seston (organic debris in sea water) and Halibut PEI intends to pass the effluent water through shellfish to determine if they will consume the fine suspended solids.

CONCLUSIONS

Based on the results of this project, salt water wells on PEI can reasonably support an Atlantic halibut grow out industry in lobster pounds. Fish survival was excellent with growth rates being on par or better than published studies. Only minimal modifications of a concrete lobster tank were required in order to sustain commercial densities of halibut.

Sufficient information was collected to estimate required stocking size of lobster pounds to achieve harvestable fish during the time of year they are not in use. These estimations are based on the application of a thermal growth coefficient.

Table 6: Estimated stocking size of halibut for lobster pounds

Harvest size (lb)	Required stocking size (g) for harvest after 9 months	Required stocking size (lb, oz) for harvest after 9 months
2	291	10 oz
3	514	1 lb, 2 oz
4	760	1 lb, 11 oz
5	1019	2 lb, 4 oz

Additional investigations are necessary to answer questions raised during the course of this study. They include:

- Optimizing growth of halibut in low salinity water by comparing growth of all female versus mixed sex halibut populations and using fish pedigrees to predict growth characteristics
- Evaluating feeds and alternative feed sources by procuring and testing globally produced halibut and flatfish feeds, and developing a “mussel meal” as a protein source.
- Determining the ecological footprint of commercial production including collection and analysis of fecal solids, and monitoring effluent environmental effects with a shellfish bioassay.
- Assessing recirculation technology to alleviate well water limits including predicting disaster time in the event of well failure, determining carrying capacity at 80% recirculation of water, and determining how long over- density conditions can be maintained to adjust for market fluctuations.
- Assessing the taste of halibut produced to determine optimum taste from feeding strategies implemented, and promoting PEI farmed halibut to the food service industry.

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