

**Project Report
Halibut PEI Phase 2**

April 20, 2010

INTRODUCTION AND GOALS OF THE PROGRAM

Halibut PEI Inc, in 2008-09, with the assistance of AIMAP and other funding agencies set out to determine if a halibut feedlot industry was viable using moderate salinity well water available in the province. Through a series of evaluations and growth measurements of young halibut, the project demonstrated excellent survivability and good growth of the fish in salt water well systems. In addition, relatively minor modifications to existing concrete lobster holding tanks were able to create viable and efficient halibut production systems while controlling effluents to promote a high degree of environmental protection. The project concluded that saltwater wells and lobster holding facilities on PEI can biologically support an industry to grow halibut juveniles to market weight as a halibut feed lot. The final report of the Phase 1 project is available at http://people.upei.ca/gjohnson/090430_Draft_report_with_pics-5.pdf.

This Phase 2 focuses on proving the commercialization of halibut feedlots on PEI.

PEI salt water wells are typically of relatively stable temperatures (ca 8-10°C) due to natural geothermal moderation of the highly variable deep sea temperatures occurring in the Northumberland Strait. They produce high quality salt water, with characteristics including high clarity and pathogen free status, due to natural under ground filtration through sandstone. Well water salinity can range from 10 to 27 ppt (parts per thousand) on PEI, but the wells at this facility run between 23 and 27 ppt. Access to such well water has proven to be advantageous for the culture of halibut. Use of well water combined with use of existing lobster holding tanks and infrastructure supplemented with reuse and recirculation technology are anticipated to give economic advantages over other means of halibut culture while still maintaining a low environmental footprint. These theories remain to be proven in practice.

The objectives of this “Phase 2” were to (1) evaluate the status of commercial readiness of the halibut feed lot concept, (2) reduce production costs and improve the environmental performance of the culture of Atlantic halibut in modified lobster tanks, and (3) introduce an environmental impact reduction and monitoring program that can be used for land based Atlantic halibut aquaculture farms. Completion of these objectives will establish the viability of and encourage investment in commercial halibut culture in similar lobster facilities.

This document reports the results obtained to date. Although the AIMAP funding process was prompt, its completion was necessary before beginning negotiations with the other funding partners. This negotiation and co-ordination took more time than anticipated with funding from all partners not finalized until December 19, 2010. This resulted in delays to construction and fish delivery such that data collection is not complete at this time. An addendum with the remaining information will be provided September 30, 2010. Halibut PEI respectfully acknowledges and appreciates the support of all agencies involved.

1) STATUS OF COMMERCIAL READINESS EVALUATION

Abstract

Atlantic halibut were stocked in modified concrete lobster holding tanks at commercial densities. They were fed to satiation and water quality was closely monitored to ensure maximum growth of the populations. We were able to produce a harvestable, saleable high quality halibut product within this system in a timely manner. Activities related to this objective carry on as we continue to grow out halibut and collect data on the fish populations of various ages.

Introduction

After completion of Phase 1, 1400 halibut were held to harvest size in one of the concrete tanks at MorningStar Fisheries. From that group, statistics were assembled on fish weight, dressout percentage, gender determination and other observations. The main clients, the Claddagh Oyster House, and the PEI Culinary Institute provided constant feed back on the quality and acceptance of the product. This trailer from Phase 1 became the initial stage of the Phase 2 project since the fish were stocked at commercial density (100% floor space initially and then grown to harvest size). The initial work on marketing has helped to define the growth objectives required for Phase 2. The objective of Phase 2, dealing with larger populations of fish in several tanks, was to determine if a whole cohort of fish will grow as rapidly as the test population did.

Methods and Results

Facility Retrofit

The MorningStar facility consists, in part, of four large concrete basins previously used for holding lobster contained in floating crates. These tanks varied in size (Table 1). Three tanks (Tanks 1, 2, 3) were modified to hold halibut. The fourth tank (Tank 4) was chosen to be used for holding water treatment equipment and environmental remediation equipment (Objective 3). Modifications applied to the other three tanks to equip them for holding halibut included the following:

- 1) Installation of single point delivery of well water
- 2) Installation of plastic mesh screening and jump nets
- 3) Installation of bottom drainage plumbing
- 4) Installation of water treatment equipment
- 5) Installation of re-use delivery lines
- 6) Installation of tank specific water treatment equipment

Table 1: Concrete lobster holding tank specifications

Tank	Length (m)	Width (m)	Depth (m)	Surface Area (m ²)	Volume (m ³)
1	9.5	5.8	0.96	54.7	52.5
2	20.4	7.0	0.83	142.8	118.5
3	14.1	13.1	0.96	184.7	177.3

1) Water delivery to tanks

The preliminary study on the use of the concrete tanks for holding halibut (activities conducted as a result of “Halibut PEI - Phase 1”) demonstrated that water delivery at the surface in a single tank corner through a passive degasser was not ideal.

Fluctuations in nitrogen saturation were noted when readings were taken daily over an extended time period, such that improvements to gas equilibration were desired. In addition, the surface delivery caused eddies of water around the water delivery outlet and these resulted in the accumulation of uneaten food and feces on the tank floor in these areas.

In order to moderate these two problems, a new gas equilibration and water delivery unit was designed. Primary gas equilibration occurred via passing the influent water through stacked modified lobster trays as done previously. The water then collected in a header tank infused with pure oxygen. The oxygen effectively displaced additional nitrogen as a secondary defence against nitrogen supersaturation (Table 2). The header tank also allowed delivery of influent water across the bottom of the tank via a pipe manifold.

Table 2: Nitrogen saturation levels in concrete tank before and after additional water treatment

Treatment	% Saturation Nitrogen + Argon
Raw well water	105.7
Scrubber only	102.7
Oxygen stone in head tank	99.9
Tank operating level	97.9

2) Plastic mesh screening and jump nets

Previous experience with Atlantic halibut made us aware of the tremendous jumping ability of these fish. Because of the high individual fish value, great care was taken to ensure that no possible means of exit from the tank or “suicide” was possible. Vexar ® diamond mesh plastic sheet netting was the material of choice for covering any hazard areas since it is easy to clean and disinfect but more importantly would not inadvertently hook, entangle or entrap the fish as can occur with fabric mesh.

3) Bottom drainage

The tank drainage used in previous adaptations of a concrete lobster tank worked satisfactorily so a similar tank drain was constructed for these tanks. This drainage system consisted of a pipe manifold that lay across the bottom of the concrete tank on the opposite end as the inlet. This manifold had a series of slits cut across the bottom for water to exit the tank. In addition, surface skimming occurred via uprights attached to the main drain manifold. Both surface and bottom water left the tank via a single pipe that was inserted through the concrete wall of the tank. This pipe carried the water to the water treatment sump to be discussed below.

4) Water treatment equipment

Effluent water for each tank gravity flowed to a central sump (“Collection Sump”), gravity fed through one of two drum filters with 50µm screens (Aquacare Environment Model 4672) and was collected again to a second sump (“Clear Water Sump”) before leaving the facility for release to ocean. Limitations in elevation allowances within the facility required very specific engineering of piping and equipment placement so gravity drainage could be applied to the high tide mark. This eliminated costly pumping of effluent water.

The clear water sump was fitted with through-hole fittings equipped with pumps to allow pumping of water back to the concrete tanks for water reuse.

Backwash water from the drum filters was clarified by settling the solids in a collection basin. These solids were collected in an outside septic settling tank which was emptied as required.

5) Re-use delivery

The systems were sized to re-use 50% of the post drum filter water. Each concrete halibut rearing tank had a separate re-use water line which delivered water from the clear water sump in the central water treatment area (“Tank 4”) to the top of the passive gas balancer. The amount of water re-used was limited by the capacity of the drum filters and system elevations and is not a reflection of the maximum amount of re-use possible.

6) Tank specific water treatment equipment

A detailed discussion of tank specific water treatment equipment occurs below under Objective 2: Production Cost Reduction via Effective System Design and Management.

Fish Transport

Transport of fish was a concern for Halibut PEI. The business plan requires shipment of large fish for 2010 and 2011. This initial trial would dictate the size of fish for future shipments.

Transport of the large fish went well. CJ Macintosh Trucking was the transport company of choice due to its history of success with transferring halibut. Several lots of fish were moved to the facility as shown in Table 3.

The large fish were dipped out of their originating tanks into 1m³ boxes full of oxygenated salt water then netted into the oxygenated transport tanks. Oxygen level of the water was maintained on the transport truck using injection of pure oxygen through ceramic diffusers. Upon arrival at the Morningstar facility, the fish were again netted out of the transport tanks into 1m³ boxes full of oxygenated water (Figure 7a). The fish were released to the recipient tank via rotating the boxes (Figure 7b) with a fork lift. Relatively low stocking densities were used for the transports (69 kg/m²) because of the high fish value. Post transport mortality was 0.3%.

Figure 7a: Netting the fish out of the transport tanks at Morningstar facility



Figure 7b: Release of fish into recipient tank at Morningstar facility

Fish Performance

Table 3: Fish holding at Halibut PEI Inc.

Mean fish size at arrival (g)	Data received/anticipated arrival	Fish number	Comments
1530 (Size Sept 09)	Held over	1400	More than half of these fish have since been harvested
12	December 22, 2009	10000	
65	December 22, 2009	10000	
70	December 22, 2009	8400	
1050	March 15-18, 2010	6000	
1050	May 3-4, 2010	4000	
500	June 5, 2010	7000	

Acclimation of New Arrivals

Within days of receipt, fish were offered feed and their feeding response was observed. Feeding practices were amended to mimic those of the donor facility as much as possible in order to accelerate fish acclimation. Observations continue regarding fish feeding, growth and performance as the project continues.

The largest fish transported to the facility had an average weight of 1.05kg. These fish took noticeably longer to acclimate to the facility and feed at projected levels. Smaller fish previously moved to the facility showed little problem adjusting to the new site and typically displayed exceptional growth within weeks of arrival. This adaptation issue, as

reflected in feeding response, may become a concern when shipping to other facilities and needs further study.

Growth

Fish were received at the facility at various sizes and dates (Table 3). This discussion will be limited to the large fish held at the facility the longest. Information for this section will be expanded as fish continue to be reared at the facility.

Fish grew at the rate anticipated in Phase 1 of this project with mean harvested halibut weight nearing the predicted 1816g after 9 months. Actual mean harvested fish weight after nine months was 1747g, a difference of less than 4% from the projected value. We expect to be able to increase this weight to 2000g in the same time frame through husbandry and feed improvements.

Feeding rate

Feeding rate of the fish was higher than expected initially (at 0.65% of biomass weight per day or BWd). It later followed more expected trends, varying with temperature and generally averaging 0.35% BWd. The high initial feeding was likely not an accurate portrayal of consumption but a reflection of overfeeding due to lack of accurate observation ability because of the use of aeration in the tank at the start of the project. Food conversion rate was poor at 1.5. This will improve at higher fish densities and with increased staff experience.

Size distribution

One of the greatest challenges going forward with commercialization will be the broad size distribution of halibut populations. The standard deviation of the mean weight of populations has been observed to range from 20% to 26% of the mean weight value. It is currently unclear whether the bimodal distribution seen in Population 1 is a reflection of disparity between the sexes.

Harvest results

As fish were harvested, data were collected. Whole weight (WW), head on gutted weight (HoG), gonad weight, sex and reproductive status were recorded, as well as any other notable comments, including the state of the eyes (especially eye migration and trauma). Some disparity between the sexes was noted in terms of mean weight of harvested fish. Females weighed on average 13% more than the males at harvest and the largest fish tended to be female. In addition, mean yield of females was higher than males at 93.1% HoG versus 91.6% HoG. Yield was most affected by the reproductive status of the fish with mature males having gonads averaging 4.4% of WW, while immature male gonads averaged 0.2% WW and female gonads averaged 0.7% WW. No mature female gonads have been encountered at this point.

Market results

The marketing of the fish was still relatively small scale at the writing of this report. The product was provided to a number of high end restaurants in Charlottetown and was met with rave reviews by all recipients, including restaurants, chefs and guests. The demand

for product from customers, including restaurant customers in the Toronto market, currently exceeds available supply by far, which is testimony for the exceptional market opportunity available. Marketing will be ramped up in early summer with much larger fish harvests from the facility. Price obtained for the product was \$8.50/lb HoG.

Small fish

Some fish did not grow well, even after months of rearing. These fish were marketed as “extra small” fish at a discount rate in order to remove them from the system and save spending money on non-performing fish. These fish represented as high as 6% of a population.

Discussion and Conclusions

To this point, the halibut performed as projected in terms of growth rate. The broad size distributions of the populations grown to date are of concern, however, and will cause issues as the venture is scaled up. It is anticipated that in order to maintain optimal feeding and growth, the halibut will require constant grading and movement between tanks. These logistical problems will likely pose the next greatest challenge since grading and fish movement techniques used for salmon or other schooling fishes do not work with flat fish.

The halibut harvested yielded an excellent quality product that was met with enthusiasm in all markets pursued to date. A quick market penetration can be assumed as the demand for the product is high.

The final analysis of the commercial readiness of the halibut feedlot concept will not be complete until more fish populations have completed their growth cycle to harvest.

2) PRODUCTION COST REDUCTION VIA EFFECTIVE SYSTEM DESIGN AND MANAGEMENT

Abstract

The water system designed for holding halibut in concrete tanks designed in Phase 1 was modified in order to increase biomass holding and production efficiencies. Improved water oxygenation allowed a substantial increase in the fish holding capacity of the concrete tanks. Methods of oxygen injection and source of oxygen were two primary areas of production efficiency improvement. Other investigations into the use of side loops for water cleaning and improved tank self cleaning continue.

Introduction

The rectangular shallow concrete tanks typical of lobster pounds create a challenge to properly establish water flow that ensures self cleaning of a tank fully stocked to commercial densities of Atlantic halibut. Maintenance of optimal water quality is essential to efficient operation. In Phase 1, we tested some equipment on a small scale. This is being scaled up for commercial application. Side loops were the method of choice for water cleaning, especially for oxygenation, biofiltration and foam fractionation

to allow easy assembly and disassembly when switching back to lobster holding. These side loops, designed to provide increased water movement to assist self cleaning, provide increased water flow while not increasing water use from the well. The system is also designed to reuse post drum filter water similar to Phase 1. All installations took into account the requirement of adaptability to other facilities and versatility to return to lobster holding.

Methods and Results

Tank Modification

General tank modifications and system set up are described under Objective 1 of this project. These are inherent in improving production efficiencies as are the specific tank treatments that increase biomass loading capacity as described in this section.

Oxygen Supplementation

Operation of a facility without supplemental oxygenation would severely limit the biomass potential. In the previous year, we supplemented oxygen in the concrete tank via air infusion through diffusers. (The typical lobster holding aeration system of pipes with drilled holes had very low transfer efficiency and was deemed unsuitable.) The air diffuser system was able to increase the supportable biomass of fish, but minimally, and at relatively high cost. The cost of increasing oxygen levels in water using aeration is a well studied model. Reference materials state that aeration is cost effective for maintenance of oxygen levels at 70% saturation or below. Although halibut can survive at oxygen levels below 70% saturation, in order to promote maximum growth of halibut, it is desirable to maintain oxygen levels above 90%. A second negative attribute associated with the use of air diffusers within the concrete tank was the turbulence which made fish observation difficult and resulted in the suspension of feces and broken feed particles.

Ceramic oxygen diffusers had been used previously as a means of injecting pure oxygen into the water. They were shown to have a transfer efficiency of close to 30% in this system as predicted by the manufacturer. We continue to investigate other means of increasing oxygen transfer efficiency in order to arrive at the most cost effective method of oxygen injection to improve production efficiencies.

a) Oxygen saturator

An oxygen saturator column injects pure (or highly pure) oxygen into water under pressure in a specially designed column. The shape of the unit maximizes oxygen transfer efficiency. Transfer efficiencies of up to 100% are possible with these units according to the manufacturers. Because of the relatively high pressure requirements of these units, extra pumping power is typically required.

b) Low head oxygenation units

Low head oxygenation units are a means to effectively transfer oxygen into water under lower pressure than that required for oxygen saturators. We are currently in discussion with a manufacturer of a unique low head oxygenation system to design a unit for testing on a concrete halibut rearing tank system at Halibut PEI.

c) Oxygen generation

An additional consideration when using oxygen injection is the option of producing oxygen on site versus purchasing oxygen in liquid form. We are in the process of comparing these two alternatives in order to determine the pay off time for an oxygen generation system.

Foam Fractionation

Foam fractionation, or protein skimming, uses foam to remove hydrophobic molecules, such as those composing organic waste. In the previous project, we tested a 40 gallons per minute (gpm) foam fractionator on a small scale. We are in the process of setting up large , 150gpm, foam fractionation units (RK2 Systems RK 150PE) to test commercial scale application of this technology. Our intent is to use the units as tank side loops. They are intended to improve the quality of the water for rearing halibut and improve growth of the fish, reduce disease risk and reduce the amount of make up water required for a set biomass. These outcomes will be achieved through the cleaning of the water by the units themselves as well as via increased water movement in the tank and therefore improved tank self cleaning. All of these outcomes will improve productivity of the site.

Biofiltration

We are still under discussion with a biofilter manufacturer to determine the best approach for biofilter installation. We are not yet at fish densities where biofiltration is usable.

Water Reuse

Post drum filter water will be returned to the tanks at a maximum flow of 50% of the well water. This flow is largely limited by the drum filtration capacity and small elevation differential available for the system as discussed above. This increased flow will shorten the time to tank turnover and improve tank cleaning without increased well water consumption.

Discussion and Conclusions

Improved production efficiencies are expected with the application of improved oxygen supplementation and water cleaning side loops. However, we have not yet completed this portion of the project. Our anticipated deliverables continue to be:

- Reduction of production costs of Atlantic halibut culture through advancements in self cleaning design and recirculation innovations on lobster tanks while allowing increased biomass loadings and maintaining fish growth performance
- Improvements of environmental performance of Atlantic halibut land based culture through improved waste extraction from the tanks and reduced well water use
- Guidelines for retrofitting lobster tanks for Atlantic halibut culture that allow reduced production costs and enhanced environmental performance would be produced.

In addition fish population management strategies such as grading schedules and regimes and feed delivery method and regimes need to be investigated. Proper development of

management practices can have great impacts on system production efficiency.

3) ENVIRONMENTAL IMPACT REDUCTION AND MONITORING PROGRAM

Abstract

Effluent water treatment was a challenge due to the low head available for gravity flowing water throughout the facility to the water treatment equipment and to the ocean discharge, considering potential high tide levels. Detailed engineering and system adjustments were required in order to make such a system work. This would allow filtration of effluent water to 50µm. Use of mussels to further refine post drum filter effluent water should improve the environmental sustainability of land based halibut culture additionally. Investigations into effluent water treatment continue, including monitoring the effect of growing mussels in the effluent.

Introduction

Inherent to the philosophy of Halibut PEI Inc. is an unwillingness to compromise the PEI environment which is so attractive to tourists. The effluent system employed in Phase 1 if the project was successful at clarifying outgoing water as evidenced in our analysis of the effluent and our ability to recirculate it back to the culture tank with no loss of water quality. Scaling up of the system was necessary for commercial development of the feedlot concept.

Methods and Results

Physical effluent filtration

A system was designed in order to gravity flow all effluent water through 50µm drum filters before release to the ocean. Process flows and elevations for this system were discussed previously.

Biological effluent filtration

Capture of additional solids using blue mussels (*Mytilus edulis*) is under investigation.

a) System set up

For the biological filtration trials, cages of mussels are placed in the effluent stream of the facility within 450 liter (L) Saeplast ® plastic tanks. Each tank contains ten crates with 32 compartments, each compartment holding four mussels (mean length 60mm) for a total population of 2480 mussels per tank. The water flows from the bottom to the top of each tank with care taken to ensure proper distribution of water throughout the mussel population. For each trial a single effluent stream is split equally between a tank containing mussels and one without. Outcome variables to be measured include: 1) growth of shellfish, 2) total suspended solids a) entering containers b) exiting experimental unit c) exiting control unit and 3) sediment in the containers.

b) System parameters

The effectiveness of biological effluent filtration is expected to be primarily determined by the water flow rates through the mussels. Because of this, special care was taken in order to determine the starting point for water flow testing.

The temperature range of the well water at the Morningstar facility is well within the scale for mussel survival and growth. An examination of the clearance rate of mussels at 9°C suggested a starting flow rate of 2.2 liters per hour per individual (L/h/Ind). Investigations started at a total flow for each tank of 91 liters per minute (lpm) (2.2 L/h/Ind * 2480 Ind = 5456 L/h = 91 lpm).

Discussion and Conclusions

This study will continue with results to be gathered as identified above. Adjustments of flow rate will occur if needed. The outcomes of this study will show

- Evidence for the reduction of fine organic solids in the effluent water after passing through the shellfish
- That the effluent is harmless as indicated by high survival of the shellfish
- No contaminant release as indicated in chemical analyses of the shellfish
- Development of an in situ method for assessing and reducing the environmental impact of effluent water from a land based halibut farm.

SUMMARY

The halibut performed as projected in terms of growth rate with a 4 pound fish produced after nine months rearing in a modified concrete lobster tank. The product was very well received in the marketplace. The final analysis of the commercial readiness of the halibut feedlot concept will not be complete until all fish populations have completed their growth cycle to harvest. At this point, the primary concern is the broad size distributions of the populations. It is anticipated that this can be handled with proper management practices, some of which will require the development of novel technologies specific for halibut. Work continues on improving production efficiencies in husbandry and nutrition and environmental impact reduction for halibut feedlot applications.