FINANCIAL FEASIBILITY OF GEODUCK AQUACULTURE IN BRITISH COLUMBIA

Final Report

Submitted to:

Aquaculture Policy Branch
Fisheries & Aquaculture Management Directorate
Fisheries & Oceans Canada
Ottawa

Prepared by:

CANADIAN AQUACULTURE SYSTEMS INC.
BIOENGINEERING TECHNOLOGIES & BUSINESS MANAGEMENT SOLUTIONS

1076 Tillison Avenue
Cobourg, ON K9A 5N4
Tel (905) 377-8501 Fax (905) 377-8502

This review has been prepared under contract to the Department of Fisheries and Oceans Canada to provide context in support of policy analysis regarding geoduck production in Canada. The results do not necessarily reflect the perspective or intent of the Department with regard to geoduck aquaculture.

February 2012

TABLE OF CONTENTS

1.0 INTRODUCTION

The Department of Fisheries & Oceans (DFO) is investigating the feasibility of geoduck aquaculture development in British Columbia. The purpose of this study is to provide an analysis of current knowledge regarding the financial aspects of geoduck aquaculture and to present scenarios for review and consideration. The results of this study will be aggregated with other work and will be used to assess the long-term prospects for the Canadian cultured and wild-harvest geoduck sectors and to help develop a strategic approach for the sustainable development of geoduck production.

2.0 INTERACTIVE FINANCIAL MODEL

Research and development pertaining to geoduck aquaculture has been on-going for more than two decades in the Pacific Northwest (i.e. Washington, British Columbia and Alaska). A variety of journal articles, technical reports and bulletins have been reviewed to compile background information to support the development of an interactive model that can be used to help assess the financial viability of commercial geoduck aquaculture. In addition, several individuals with direct experience in the BC and Washington State geoduck sectors have been contacted to provide additional insight and information. A list of references used in this study is provided at the end of this report.

From this information, the fundamental assumptions pertaining to geoduck aquaculture were compiled for use as input data into a financial model that was constructed using a Microsoft Excel platform. The model is dynamic in that changes to the input variables are automatically reflected in the outputs, enabling a wide variety of scenarios to be explored by the user. In the model, the input cells into which the user can insert user-defined variables are shaded beige with a black border.

2.1 Model Assumptions & Inputs - Sub-Tidal Production

2.1.1 Production Site & Characteristics

The optimal biophysical parameters for sub-tidal geoduck aquaculture are summarized in Table 1.

Table 1: Optimal biophysical parameters for sub-tidal geoduck aquaculture.[8]

Substrate	mud/sand/pea gravel (penetration to 1m)
Depth	3-20 m
Temperature	8-18 degrees Celsius
Salinity	26-31 ppt
Clarity (Secchi depth)	2 > 10 m
Current	<1.5 kt (<0.75 cm/s)
Productivity	15-200 (mgC/m^2/day)

2.1.2 Production System

A 10-hectare sub-tidal Licence of Occupation has been modelled. The grow-out period for sub-tidal geoduck production varies from 6 years to >10 years (see chart below), depending of a wide variety of factors. Although geoduck may attain market weight within only 7 or 8 years, the shells may be thin resulting in breakage and a lower market price.

Time to Harvest (yrs)	Prod'n Method	Location	Source
6 - 9	Sub-tidal	BC	Heath (2005)
8	Sub-tidal	BC	DFO (2010)
8 - 10	Sub-tidal	BC	Producers
5 - 8	Sub-tidal	WA	Producers

A conservative 10-year production cycle has been assumed, allowing one 1-hectare plot to be seeded with juvenile geoduck each year. The planted geoduck would be harvested in the 11th year following seeding. After harvesting, the plot would be re-seeded in the same year. This rotational production system will enable one plot to be harvested and re-seeded every year after the first crop reaches market size. In the model, the number of years required to produce market-size geoduck (i.e. Time to Harvest) is linked to the total area under production. The model divides the total area by the time to harvest to determine the total area to be seeded and/or harvested in each year.

Seeding

It is assumed that seed would be purchased from an existing hatchery / nursery operation in British Columbia. There are currently four hatcheries and nursery operations[1] in BC that produce geoduck seed. A shortage of seed in 2011 has driven prices up; however, producers believe that industry expansion and hatchery experience will reduce seed prices. Producers generally plant seed with a total shell length greater than 6 mm into commercial plots. Larger seed are more robust and reportedly have higher survival rates. The model assumes that 6-10 mm seed are purchased from a hatchery and planted into the production plots. Seeding is done by contract service providers that supply the work boat, crew, divers, dive equipment, etc. Such services are available in BC for approximately $1,500 to $3,000 per day. Seeding rates used in the commercial aquaculture sector have been applied. After seeding, the plots are covered with netting to protect the seed from predation by crabs, moonsnails, seastars, bottom fish and other organisms. Predator nets are deployed for the first two years of production. A new net is used for each seeded crop.

[1] The objective of this review is to determine the feasibility and potential to establish a viable geoduck aquaculture sub-sector in British Columbia. Commercial development of the sector is dependent upon a consistent supply of seed (juveniles) from hatchery and nursery operations. Presently, there are at least four seed suppliers in BC, however, technologies and practices are not yet sufficiently advanced to enable a consistent and reliable supply of seed. Many factors (e.g. nutrition, broodstock conditioning, larval culture practices, etc.) need to be further enhanced. Consequently, seed supply is an inherent risk in the development of geoduck aquaculture in BC. Nevertheless, there is a growing commercial geoduck aquaculture sector in Washington State that depends on hatchery-produced seed.

Post-Seeding Operations

Throughout the production cycle, the site is monitored and maintained to manage and protect the crop. During the first two years post-seeding, the netting is cleaned to remove excessive biofouling and repaired as necessary. Maintenance is done by the same (or similar) contract service providers as for seeding operations. The frequency of maintenance operations on seeded plots ranges from once per week to once per month. A commercial dive service can effectively maintain 200 net panels in 1 to 2 days.

Harvesting

Commencing in the tenth year of operations, one 1-hectare plot will be harvested each year before re-seeding. Contract service providers are hired to harvest the product. Harvest costs, on a per kilogram basis, are calculated by dividing the daily charge-out rate for the service provider by the efficiency of harvest operations (i.e. kilograms per dive day). The model also contains an interactive option that either allows or precludes the aquaculturist from harvesting wild geoduck within the boundaries of the site. Selecting this option instructs the model to factor-in the costs incurred and revenues received by allowing the wild geoduck within the boundaries of the Licence of Occupation to be harvested by the aquaculturist. This is in contravention of DFO's *Interim Protocol for Pre-Seed Harvest of Subtidal Geoduck Aquaculture Sites* which mandates that G Licence holders be provided with a 3-month window to harvest wild geoduck from the site in advance of any aquaculture activity.

An allowance has also been made in the model for harvest monitoring and reporting. The latter is based on the current rates paid for this service by the G Licence holders[2]. Since this fee is based on wild harvest conditions, the model automatically adjusts the fee to account for the difference in density amongst cultured and wild harvest geoduck beds.

2.1.3 Model Assumptions

The **<Input>** page of the model allows the user to provide a variety of inputs pertaining to Site, Production, Harvest, Revenue and Finance matters. The assumed parameters applied in the model are presented in the shaded cells in the tables below. These data were derived from the literature and individuals referenced at the end of this document. Considerable input pertaining to the range and assumed values of the following parameters has been received from the Underwater Harvesters Association, government personnel and others involved in the geoduck sector. It is pertinent to note that there is a substantial variation in perspectives amongst the players and agreement has been difficult to obtain for many of the factors. Moreover, much of the information is difficult to validate. Users of the model can change input parameters to better reflect their own situation. It is also important to note that geoduck culture techniques continue to evolve and, therefore, techniques applied today are likely to change substantially within the period of time reflected in this study.

The assumptions and model outputs are for illustrative purposes. They project anticipated costs and returns for sub-tidal geoduck aquaculture. Results will vary as the assumptions are changed. The model has not been validated using actual production data.

[2] Average annual fee x number of G Licences ÷ annual geoduck quota; $13,600 x 55 ÷ 1,559,250 kg = $0.48/kg

Site:

	Low	Assumed	High	Description:
Total Area (ha):	na	10	na	▪ Total area under tenure
Production Area (ha):	na	10	na	▪ Total area under cultivation
Site Application Fee ($):	na	$ 1,200	na	▪ Per Provincial guidelines
Licence of Occupation ($/ha/yr):	na	$ 233	na	▪ Per Provincial guidelines
Aquaculture Licence ($/site/year):	na	$ 418	na	▪ Per DFO proposed fee schedule

Production:

	Low	Assumed	High	Description:
Seed Rate (seed/m²/yr):	10	25	40	▪ Recommended seeding rate
Seed Harvested (% Survival):	10%	25%	60%	▪ Survival, planted seed harvested
Seed Cost - 6-10 mm ($/seed):	$ 0.20	$ 0.35	$ 1.00	▪ Cost of hatchery / nursery seed
Seed Planting Rate (ha / dive day):	0.25	0.5	1.0	▪ Ha of seed planted per dive day
Seed Planting Cost ($/seed):	Dive Service Cost ÷ Seeding Rate			▪ Cost to hire contract seeders
Predator Nets ($/ha):	$4,000	$ 8,000	$ 10,000	▪ Cost of new nets (10,000m²)
Net Deployment Time (yrs):	2	2	2+	▪ Amount of time with nets in place
Net Maintenance (dive days/yr):	12	24	36	▪ Dive days required to maintain nets
Labour & Management (hrs/ha/yr):	- -	120	- -	▪ Routine maintenance time
Labour & Management ($/hr):	- -	$ 30.00	- -	▪ Routine maintenance wage
Miscellaneous ($/kg):	- -	$ 0.20	- -	▪ Miscellaneous expenses
Dive Service Cost ($/dive day)	$1,800	$2,200	$3,000	▪ Boat, crew, divers, equipment

Harvest:

Wild Harvest Geoduck	Low	Assumed	High	Description:
Avg. Wt. Wild Geoduck (kg):	0.70	1.07	- -	▪ Projected harvest weight (wild)
Density of Wild Geoduck (#/m²):	0.08	0.68	1.41	▪ Final harvest density (wild) [3]
Wild Harvest Recovery (%)	- -	85%	- -	▪ % of wild geoduck harvested
Wild Harvest Rate (kg / dive day):	800	1,000	2,000	▪ Harvest per dive day
Wild Harvest Fees ($/kg):	Dive Service Cost ÷ Harvest Rate			▪ Contract harvest fees
Wild Harvest Monitoring Fee ($/kg):	- -	0.48	- -	▪ Harvest observer fees

Cultured Geoduck	Low	Assumed	High	
Time to Harvest (yrs):	7	9	12	▪ Years to reach 800 gram avg. wt.
Area Seeded per Year (ha):	Production Area ÷ Time to Harvest			▪ No hectares seeded with geoduck
Avg Harvest Weight - Farmed (kg):	0.70	0.80	1.00	▪ Projected harvest weight (farmed)
Density of Farmed Geoduck (#/m²):	Seed Rate x Seed Survival			▪ Final harvest density - farmed
Culture Harvest Rate (kg / dive day):	1,000	1,500	2,000	▪ Harvest per dive day
Culture Harvest Fees ($/kg):	Dive Service Cost ÷ Harvest Rate			▪ Contract harvest fees
Harvest Monitoring Fee ($/kg):	Wild Fee x (Wild Density ÷ Culture Density)			▪ Harvest observer fees

[3] The low, high and assumed density of wild geoduck reflect the range and average of limited survey data for Areas 12, 13, 14, 16, 17, 18 and 19, all of which are in the Strait of Georgia (Bureau et al 2002, 2003); the mean density is to 0.68 geoduck/ m². Harvesters have commented that these limited data are not representative of the entire area. Furthermore, it is likely that geoduck aquaculture would be developed on sites that are conducive to geoduck production (where densities are higher) as opposed to those that are not.

Revenues:

				Description:
Wild Harvest Geoduck				
#1 Grade Product (%):	- -	100	- -	▪ Harvest percent of #1 Grade
#2 Grade Product (%):	- -	0	- -	▪ Harvest percent of #2 Grade
Landed Price #1 Grade ($/kg):	- -	$26.00	- -	▪ Price of #1 Grade
Landed Price #2 Grade ($/kg):	- -	$18.00	- -	▪ Price of #2 Grade
Cultured Geoduck				
#1 Grade Product (%):	- -	100	- -	▪ Harvest percent of #1 Grade
#2 Grade Product (%):	- -	0	- -	▪ Harvest percent of #2 Grade
Farm-Gate Price #1 Grade ($/kg):	- -	$26.00	- -	▪ Price of #1 grade
Farm-Gate Price #2 Grade ($/kg):	- -	$18.00	- -	▪ Price of #2 grade

Financial:

		Description:
Simple Annual Interest Rate (%):	6.0%	▪ Interest on bank loan; prime + 3%
Term of Debenture	10	▪ Duration of bank loan
Corporate Tax Rate	13.5%	▪ BC small business taxation rate

Wild Harvest (On-Site):

		Description:
Access (0 = Not Allowed; 1 = Allowed)	0	▪ If "0", wild harvest is not allowed

The **<Cash Flow>** page of the model allows the user to input the amount of owner equity and debt (bank loan) invested to finance the venture. Debt financing charges are amortized over the term of the loan and the interest and capital portions of the blended payments are calculated and linked to the Income Statement and Cash Flow Statement. The total amount of investment capital required to fund the operation can be determined by entering a combination of equity and/or debt that reduces the 'Maximum Cash Deficiency' to $0. When the cash deficiency is equal to $0, there is sufficient funding to finance the venture until revenues are able to carry the operation.

Funding

		Description:
Equity	$ -	▪ Amount of owner equity invested
Bank Loan	$ -	▪ Amount of money to be borrowed

The **<Capital>** page allows the user to input the amount of money required to finance capital expenditures for the project. The default inputs are presented below.

	Unit Price	Number	Budget
Infrastructure			
Environmental Assessment	$ 5,000	1	$ 5,000
Site Marking Equipment	$ 1,600	1	$ 1,600
Site Marking Dive Service	$ 2,200	4	$ 8,800
Storage Building (40' x 80')	$ 25	3,200	$ 80,000
Contingency (10%)			$ 9,540
Subtotal			$ 104,940
Production Equipment			
Harvest Cages (Totes)	$ 12	500	$ 6,000
Truck (used)	$ 30,000	1	$ 30,000
Contingency (10%)			$ 3,600
Subtotal			$ 39,600
Other Equipment			
Office Equipment	$ 5,000	1	$ 5,000
Miscellaneous	$ 10,000	1	$ 10,000
Contingency (10%)			$ 1,500
Subtotal			$ 16,500
TOTAL PRODUCTION CAPITAL			$ 161,040

The model is in an accompanying file entitled:

Geoduck Aquaculture Model - Sub-Tidal (Final).xlsx

2.1.4 Model Output

Due to the length of time required to produce market-size geoduck, the financial projections are forecast over a 15-year horizon. The 15-year time period appears to be sufficient to provide an indication of the expected costs and returns associated with geoduck aquaculture. Nevertheless, it is difficult enough to project financial performance one to two years in advance; thus, the data and results should be viewed within this context. Moreover, within 15 years, it is likely that the technologies and practices utilized in geoduck aquaculture will have evolved considerably. Therefore, those reading this report and/or using the accompanying financial model should be cognizant of these factors.

Conventional breakeven analysis[4] is difficult to apply in geoduck aquaculture due to the extended start-up period during which costs are incurred in the absence of revenues followed by the commencement of harvesting in year ten and the immediate realization of profits. Given these extraordinary circumstances, breakeven has been defined as the level of output (harvest) where total costs equal total revenues at the end of the start-up phase. This is consistent in principle with breakeven analysis in that costs equal revenues, there is no profit and there are no losses.

Economies of scale are factors that cause the average cost of producing something to fall as the volume of its output increases. They tend to be more pronounced in industries with high capital costs, which result in a higher proportion of fixed costs. Hence, when production increases, the fixed costs are divided amongst a larger number of units, thereby reducing the average cost of production. Economies of scale in aquaculture generally result from the adoption of larger pieces of equipment or more advanced technologies[(6)]. For example, in the geoduck sector, a very large-scale operation may be able to purchase its own vessel and hire a full-time captain and dive crew to service the geoduck beds at a lower average cost than is attained by contracting out these services.

There are two types of economies of scale; internal and external. *Internal economies of scale* are cost savings that accrue to a firm regardless of the industry, market or environment in which it operates; the cost per unit depends on size of the individual firm. By increasing the scale of production, companies may be able to generate and benefit from internal

[4] A company has broken even when its total sales or revenues equal its total expenses. At the breakeven point, no profit has been made, nor have any losses been incurred. The following costs are pertinent to a breakeven analysis. *Variable costs* are those that vary in direct proportion to the level of output. These are the costs incurred for direct contributions to production such as materials, supplies, labour, etc. As production volume increases or decreases, variable costs increase or decrease in direct proportion. In geoduck culture, these are the costs for seed, seed planting, predator netting, harvesting, etc. *Fixed costs* are costs that remain the same regardless of how many units are produced. They remain constant regardless of the total output volume. Such costs typically include management salaries, insurance, rent, etc. In geoduck aquaculture, fixed costs would include tenure and licence fees and depreciation. The breakeven point is defined as the fixed costs, divided by the difference between the per-unit selling price and the variable cost of production; i.e.

Breakeven Point = Fixed Costs ÷ (Unit Selling Price - Variable Costs)

The answer represents the number of units of a product that must be sold to break even. At the breakeven point, all costs associated with producing the product (both variable and fixed) have been recovered. Every unit sold above the breakeven point generates a return in the amount of the unit contribution margin; i.e. the amount of money that each unit contributes to covering fixed costs and increasing profits. Unit contribution margin is calculated as follows:

Unit Contribution Margin = Sales Price - Variable Costs economies of scale. Cost reductions via external economies of scale are generally due to the effect of technology in an industry. E*xternal economies of scale* benefit a firm because of the way in which its industry is organized; the cost per unit depends on the size of the industry, not the firm. The effect of economies of scale is to reduce the average (unit) costs of production(11).

2.1.5 Results - Sub-Tidal Culture

Using the default parameters identified above, the financial model allows for two scenarios with regard to the wild geoduck that exist within the area under Licence of Occupation (i.e. on-site):

(1) The proponent is not allowed to harvest and sell wild geoduck from within the site boundaries; and

(2) The proponent is allowed to harvest and sell wild geoduck from within the site boundaries.

Economies of scale in sub-tidal geoduck aquaculture have been evaluated by adjusting the total size (hectares) of the proposed venture. Operations of 5-hectares, 10-hectares and 20-hectares are compared for ventures with and without access to wild geoduck on-site.

No Access to Wild Geoduck

Financial projections indicate that an investment of $2,368,952 is required to establish a 10-hectare sub-tidal geoduck aquaculture operation. Of this, $161,040 is required to finance capital equipment (i.e. truck, shore-base facilities, equipment, etc.), including 10% contingency. An additional $2,207,912 is required for working capital to finance the purchase of seed and to pay for labour, management and maintenance expenses.

The *pro forma* financial statements reflect a 100% equity investment ($2,368,952). Due to the 10-year time period before the first product is ready for harvest, it is infeasible to leverage the financing for a 10-hectare geoduck operation with debt (entering a nominal value for a Bank Loan on the spreadsheet demonstrates that the cumulative deficit increases due to the interest payments over the extended period prior to first harvest). The owner is required to support the venture for ten years in the absence of revenues.

In the eleventh year of operations, the venture realizes a net profit of $967,555 on total sales of $1,300,000 from the harvest of the first one-hectare plot of geoduck. Thereafter, the venture is projected to realize a net profit of approximately $970,000 per year (Table 2). By the thirteenth year, the venture is projected to attain a positive cumulative cash position (Table 3); that is, the initial investment made by the owner has been recouped; however, at this point, there is a return of investment but not yet a return on investment. In fact, after 15 years, the internal rate of return for the venture remains negative at -0.6% (Table 4). Average profitability ratios have been calculated over three time periods; years 1 through 5, years 1 through 10 and years 1 through 15. Since no sales are generated until the seeded geoduck are ready to harvest, the venture is not profitable within the first ten years but shows modest profits within a 15 year period (Table 4).

Sensitivity analyses were conducted to evaluate the impacts of various production, harvest and market factors on the level of investment required to finance a 10-hectare sub-tidal geoduck venture in British Columbia when the proponent is not granted on-site access to wild geoduck. Variables were arbitrarily increased and decreased by 20% to observe their overall financial impact (Table 5). With no on-site access to wild geoduck, dive service fees and the cost of seed have the largest financial impact on the amount of investment required. The number of years required to produce a harvestable product has a nominal impact on investment. Since the vast majority of the working capital for a geoduck farm is invested prior to the first harvest, changes to the market price of the product do not influence the amount of investment required to start the venture (Table 5). They will, however, have a downstream impact on the overall profitability of the operation.

In the absence of access to wild geoduck on-site, it is not possible to calculate a breakeven point during the 10-year start-up phase since there is no revenue.

Without access to wild geoduck on-site, the projected capitalization is more than $252,000 per hectare for a 5-hectare operation. The required investment decreases to about $229,000 per hectare for a 20-hectare operation. Economies of scale are not shown to affect the gross margin since no assumptions are made regarding discounted input values with higher levels of production; such economies could exist, for example, for seed cost or contract dive services. Other profitability ratios demonstrated marginal gains with increasing scale. In the absence of access to wild geoduck on-site, projections suggest that a 90-hectare operation having a total capitalization cost of $20,100,000 and yielding a harvest of 450,000 kilograms of cultured geoduck per year is required to generate an internal rate of return equal to 0% after 15 years of operation.

Economies of scale in sub-tidal geoduck aquaculture where the producer does not have access to wild geoduck on-site

Size of Operation (ha)	5	10	20
Cultured Geoduck (kg/yr)	25,000	50,000	100,000
Capitalization (Total Investment)	$1,260,712	$2,368,952	$4,580,592
Capitalization ($/hectare)	$252,142	$236,895	$229,030
Gross Margin	41.0%	41.0%	41.0%
Return on Sales	32.5%	36.5%	38.6%
Cash Earnings on Sales	29.9%	32.3%	33.5%
ROI (Cash in - Cash out)	5.1%	5.9%	6.3%
Internal Rate of Return	-1.2%	-0.6%	-0.2%

Access to Wild Geoduck

With access to the wild geoduck within the site boundaries, the proponent is able to harvest geoduck and use the revenues to offset the working capital requirements necessary to finance aquaculture operations. In this scenario, wild geoduck would be harvested from a one-hectare plot each year prior to seeding. The harvest is projected to be 0.58 geoduck per square meter (0.68/m^2 x 85% recovery) at an average weight of 1,070 grams[3,4,20].

Pro forma projections indicate that although the aquaculturist is allowed to harvest wild geoduck, the venture still realizes an average operating loss of approximately $88,000 per year over the first ten years of operation (Table 6). The first profits are not realized until the eleventh year of operations when the harvest of cultured geoduck commences. Despite the revenues from the sale of on-site wild geoduck, the cash flow statement (Table 7) illustrates that a producer would need to invest $939,072 to support the 10-hectare geoduck farm until cultured geoduck can be harvested. Debt financing remains infeasible. Profitability ratios improve when the producer has access to wild geoduck, however, positive returns are still not realized until cultured geoduck are harvested (Table 8). The sale of wild-harvest geoduck to partially finance the venture improves the internal rate of return for the venture. After 15 years, the IRR is projected to be 7.84% (Table 8).

Sensitivity analyses were conducted to evaluate the impacts of various production, harvest and market factors on the level of investment required to finance a 10-hectare sub-tidal geoduck venture in British Columbia when the proponent is granted on-site access to wild geoduck. Variables were arbitrarily increased and decreased by 20% to observe their overall financial impact (Table 9). When producers have on-site access to wild geoduck, market price and the density of wild geoduck available for harvest have the largest financial impact on the amount of investment required. At 0.54 harvestable animals per square meter versus 0.68 per square meter, the investment requirement increases by 30%. In contrast, when the density increases to 0.82 harvestable animals per square meter the required investment decreases by 30%. This underscores the significance of the working capital investment necessary to launch a geoduck aquaculture venture that will not realize cash flow from farm-raised product for ten years or more as well as the benefit associated with selecting a site with a high production capacity. Changes in market price have a similar influence (Table 9).

In the scenario where the producer is granted access to the wild geoduck within the boundaries of the tenure, a reasonable measure of the breakeven point could be defined as the level of output (harvest) that yields a Cumulative Net Profit of $0 at the end of the ten-year start-up phase. In this case, a key variable as noted in the sensitivity analysis is the density of wild geoduck on-site. The breakeven point occurs when the average density of wild geoduck on-site is 1.1 per square meter; 63% higher than the 0.68/m^2 projected in the base-case scenario. At this higher density, the required capital investment is only $92,876 and the 15-year IRR equals 31%.

The trends due to economies of scale when the producer is granted access to wild geoduck on-site are similar to the trends experienced in the absence of access to wild geoduck; however the magnitude of the effects is considerably different. That is, marginal improvements in profitability were observed with increased volume and total capitalization per hectare decreased with scale. As the scale of the operation was increased to 50 hectares, the capitalization and performance ratios were observed to plateau. Beyond 20 hectares in size, the benefits of further increases in scale appear to become increasingly marginal; that is, there appear to be diminishing returns to increases in scale beyond approximately 20 hectares.

Economies of scale in sub-tidal geoduck aquaculture where the producer is granted access to wild geoduck on-site

Size of Operation (ha)	5	10	20
Cultured Geoduck (kg/yr)	25,000	50,000	100,000
Capitalization (Total Investment)	$500,892	$939,072	$1,815,433
Capitalization ($/ha)	$100,178	$93,907	$90,772
Gross Margin	50.5%	50.5%	50.5%
Return on Sales	45.5%	46.9%	47.6%
Cash Earnings on Sales	39.5%	40.3%	40.7%
ROI (Cash in - Cash out)	21.3%	23.2%	24.2%
Internal Rate of Return	7.1%	7.8%	8.2%

Scale effects on total investment required to finance sub-tidal geoduck aquaculture when the producer is granted access to wild geoduck on-site

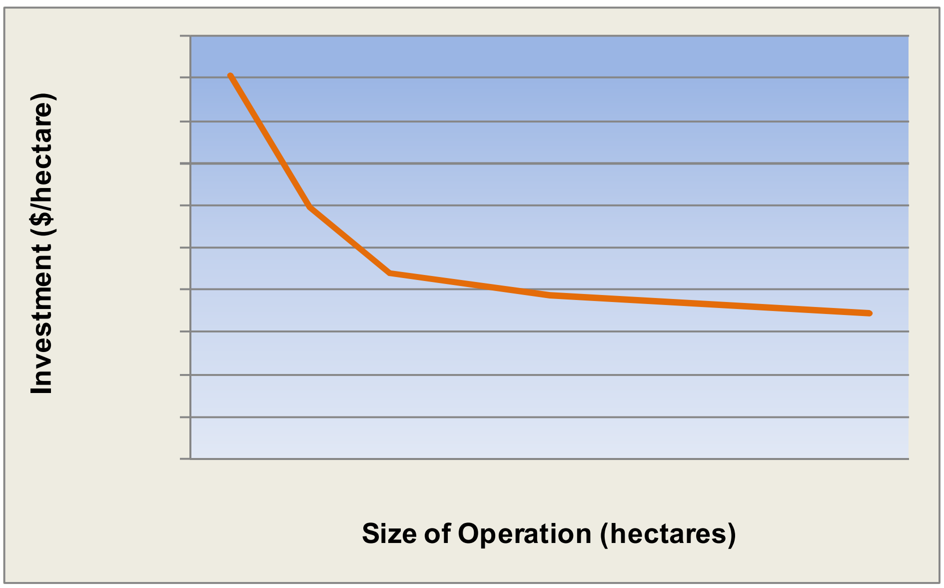

Table 2: Pro forma Income Statement for a 10-hectare geoduck aquaculture venture with no on-site access to wild geoduck

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue															
Aquaculture Sales															
#1 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
#2 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Aquaculture Sales	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Wild Harvest Sales															
#1 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
#2 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Wild Harvest Sales	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Revenue	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1,300,000**	**$1,300,000**	**$1,300,000**	**$1,300,000**	**$1,300,000**
Cost of Production															
Direct Costs															
Seed	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500
Seed Planting	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400
Predator Netting	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000
Labour & Management	$ 3,600	$ 7,200	$ 10,800	$ 14,400	$ 18,000	$ 21,600	$ 25,200	$ 28,800	$ 32,400	$ 36,000	$ 36,000	$ 36,000	$ 36,000	$ 36,000	$ 36,000
Net Maintenance	$ 52,800	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600
Miscellaneous	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
Harvest Cost (Wild)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Harvest Cost (Cultured)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 73,333	$ 73,333	$ 73,333	$ 73,333	$ 73,333
Wild Harvest Monitoring	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cultured Harvest Monitoring	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,611	$ 2,611	$ 2,611	$ 2,611	$ 2,611
Total Direct Costs	$ 156,300	$ 212,700	$ 216,300	$ 219,900	$ 223,500	$ 227,100	$ 230,700	$ 234,300	$ 237,900	$ 241,500	$ 327,445	$ 327,445	$ 327,445	$ 327,445	$ 327,445
Gross Margin	**($156,300)**	**($212,700)**	**($216,300)**	**($219,900)**	**($223,500)**	**($227,100)**	**($230,700)**	**($234,300)**	**($237,900)**	**($241,500)**	**$972,555**	**$972,555**	**$972,555**	**$972,555**	**$972,555**
Indirect Costs															
Aquaculture Licence	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418
Aquaculture Tenure	$ 1,433	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233
Depreciation	$ 25,674	$ 20,401	$ 16,433	$ 13,415	$ 11,089	$ 9,275	$ 7,840	$ 6,690	$ 5,756	$ 4,988	$ 4,349	$ 3,812	$ 3,355	$ 2,964	$ 2,626
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Indirect Costs	$ 27,525	$ 21,052	$ 17,085	$ 14,066	$ 11,740	$ 9,926	$ 8,491	$ 7,341	$ 6,407	$ 5,639	$ 5,000	$ 4,463	$ 4,006	$ 3,615	$ 3,278
Net Income Before Tax	**($183,825)**	**($233,752)**	**($233,385)**	**($233,966)**	**($235,240)**	**($237,026)**	**($239,191)**	**($241,641)**	**($244,307)**	**($247,139)**	**$967,555**	**$968,093**	**$968,549**	**$968,940**	**$969,278**
Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$130,754	$130,807	$130,853
Profit (Loss) After Tax	**($183,825)**	**($233,752)**	**($233,385)**	**($233,966)**	**($235,240)**	**($237,026)**	**($239,191)**	**($241,641)**	**($244,307)**	**($247,139)**	**$967,555**	**$968,093**	**$837,795**	**$838,133**	**$838,425**

Table 3: Pro forma Cash Flow Statement for a 10-hectare geoduck aquaculture venture with no on-site access to wild geoduck

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cash Receipts																
Aquaculture		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Wild Harvest		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Receipts		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Cash Disbursements																
Direct Expenses		$ 156,300	$ 212,700	$ 216,300	$ 219,900	$ 223,500	$ 227,100	$ 230,700	$ 234,300	$ 237,900	$ 241,500	$ 327,445	$ 327,445	$ 327,445	$ 327,445	$ 327,445
Indirect Expenses		$ 1,851	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651
Taxes		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 130,754	$ 130,807	$ 130,853
Total Cash Disbursements		$ 158,151	$ 213,351	$ 216,951	$ 220,551	$ 224,151	$ 227,751	$ 231,351	$ 234,951	$ 238,551	$ 242,151	$ 328,096	$ 328,096	$ 458,850	$ 458,903	$ 458,948
Operating Cash Flow		-$ 158,151	-$ 213,351	-$ 216,951	-$ 220,551	-$ 224,151	-$ 227,751	-$ 231,351	-$ 234,951	-$ 238,551	-$ 242,151	$ 971,904	$ 971,904	$ 841,150	$ 841,097	$ 841,052
Capital Expenditures		$ 161,040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Cash		-$ 319,191	-$ 213,351	-$ 216,951	-$ 220,551	-$ 224,151	-$ 227,751	-$ 231,351	-$ 234,951	-$ 238,551	-$ 242,151	$ 971,904	$ 971,904	$ 841,150	$ 841,097	$ 841,052
Funding																
Equity	$2,368,952	$2,368,952	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bank Loan	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Funding		$2,368,952	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Increase (Decrease) in Cash Position		$2,049,761	-$ 213,351	-$ 216,951	-$ 220,551	-$ 224,151	-$ 227,751	-$ 231,351	-$ 234,951	-$ 238,551	-$ 242,151	$ 971,904	$ 971,904	$ 841,150	$ 841,097	$ 841,052
Cash (Deficiency) - Beginning of Period		$ -	$2,049,761	$1,836,410	$1,619,458	$1,398,907	$1,174,756	$ 947,005	$ 715,654	$ 480,702	$ 242,151	$ 0	$ 971,904	$1,943,809	$2,784,959	$3,626,056
Cash (Deficiency) - End of Period		$2,049,761	$1,836,410	$1,619,458	$1,398,907	$1,174,756	$ 947,005	$ 715,654	$ 480,702	$ 242,151	$ 0	$ 971,904	$1,943,809	$2,784,959	$3,626,056	$4,467,108

Table 4: Profitability ratios for a 10-hectare sub-tidal geoduck aquaculture venture with no on-site access to wild geoduck

Base Case Assumptions	**Year 1-5**	**Year 1-10**	**Year 1-15**
Gross Margin	No Sales	No Sales	41.0%
Return on Sales	No Sales	No Sales	36.5%
Cash Earnings on Sales	No Sales	No Sales	32.3%
ROI (Cash in - Cash out)	-10.1%	-10.0%	5.9%
Internal Rate of Return	Negative	Negative	-0.6%

Gross Margin = Gross Profit ÷ Sales

Return on Sales = Earnings Before Interest, Tax & Depreciation ÷ Sales

Cash Earnings on Sales = Net Cash Flow ÷ Sales

ROI (Cash in - Cash out) = Net Cash Flow ÷ Equity Invested

Internal Rate of Return = The interest rate at which the net present value of all cash flows from the project equal zero. The higher a project's internal rate of return, the more desirable it is to undertake the project.

Table 5: Sensitivity analyses for a 10-hectare sub-tidal geoduck aquaculture venture with no on-site access to wild geoduck

Production Factors:			
Seed Cost @ 6-10 mm ($/seed)	$0.28	$0.35	$0.42
Total Investment	$2,193,952	$2,368,952	$2,543,952
Variance	-7%	-	7%
Time to Harvest (yrs)	8	10	12
Total Investment	$2,318,450	$2,368,952	$2,415,054
Variance	-2%	-	2%
Density of Cultured Geoduck (#/m2)	5.00	6.25	7.50
Total Investment	$2,368,952	$2,368,952	$2,368,952
Variance	0%	-	0%
Harvest Factors:			
Dive Service Fees ($/dive day)	$1,760	$2,200	$2,640
Total Investment	$2,159,512	$2,368,952	$2,578,392
Variance	-9%	-	9%
Market Factors:			
Average Market Price ($/kg)	$20.80	$26.00	$31.20
Total Investment	$2,368,952	$2,368,952	$2,368,952
Variance	0%	-	0%

Table 6: Pro forma Income Statement for a 10-hectare geoduck aquaculture venture with on-site access to wild geoduck

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue															
Aquaculture Sales															
#1 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
#2 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Aquaculture Sales	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Wild Harvest Sales															
#1 Grade Product	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ -	$ -	$ -	$ -	$ -
#2 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Wild Harvest Sales	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ -	$ -	$ -	$ -	$ -
Total Revenue	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$160,800**	**$1,300,000**	**$1,300,000**	**$1,300,000**	**$1,300,000**	**$1,300,000**
Cost of Production															
Direct Costs															
Seed	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500	$ 87,500
Seed Planting	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400	$ 4,400
Predator Netting	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000
Labour & Management	$ 3,600	$ 7,200	$ 10,800	$ 14,400	$ 18,000	$ 21,600	$ 25,200	$ 28,800	$ 32,400	$ 36,000	$ 36,000	$ 36,000	$ 36,000	$ 36,000	$ 36,000
Net Maintenance	$ 52,800	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600	$ 105,600
Miscellaneous	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 1,237	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
Harvest Cost (Wild)	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ 13,606	$ -	$ -	$ -	$ -	$ -
Harvest Cost (Cultured)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 73,333	$ 73,333	$ 73,333	$ 73,333	$ 73,333
Wild Harvest Monitoring	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ 2,969	$ -	$ -	$ -	$ -	$ -
Cultured Harvest Monitoring	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,611	$ 2,611	$ 2,611	$ 2,611	$ 2,611
Total Direct Costs	$ 174,112	$ 230,512	$ 234,112	$ 237,712	$ 241,312	$ 244,912	$ 248,512	$ 252,112	$ 255,712	$ 259,312	$ 327,445	$ 327,445	$ 327,445	$ 327,445	$ 327,445
Gross Margin	**($13,312)**	**($69,712)**	**($73,312)**	**($76,912)**	**($80,512)**	**($84,112)**	**($87,712)**	**($91,312)**	**($94,912)**	**($98,512)**	**$972,555**	**$972,555**	**$972,555**	**$972,555**	**$972,555**
Indirect Costs															
Aquaculture Licence	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418
Aquaculture Tenure	$ 1,433	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233
Depreciation	$ 25,674	$ 20,401	$ 16,433	$ 13,415	$ 11,089	$ 9,275	$ 7,840	$ 6,690	$ 5,756	$ 4,988	$ 4,349	$ 3,812	$ 3,355	$ 2,964	$ 2,626
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Indirect Costs	$ 27,525	$ 21,052	$ 17,085	$ 14,066	$ 11,740	$ 9,926	$ 8,491	$ 7,341	$ 6,407	$ 5,639	$ 5,000	$ 4,463	$ 4,006	$ 3,615	$ 3,278
Net Income Before Tax	**($40,837)**	**($90,764)**	**($90,397)**	**($90,978)**	**($92,252)**	**($94,038)**	**($96,203)**	**($98,653)**	**($101,319)**	**($104,151)**	**$967,555**	**$968,093**	**$968,549**	**$968,940**	**$969,278**
Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$130,620	$130,693	$130,754	$130,807	$130,853
Profit (Loss) After Tax	**($40,837)**	**($90,764)**	**($90,397)**	**($90,978)**	**($92,252)**	**($94,038)**	**($96,203)**	**($98,653)**	**($101,319)**	**($104,151)**	**$836,935**	**$837,400**	**$837,795**	**$838,133**	**$838,425**

Table 7: Pro forma Cash Flow Statement for a 10-hectare geoduck aquaculture venture with on-site access to wild geoduck

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cash Receipts																
Aquaculture		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Wild Harvest		$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ -	$ -	$ -	$ -	$ -
Total Receipts		$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$ 160,800	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Cash Disbursements																
Direct Expenses		$ 174,112	$ 230,512	$ 234,112	$ 237,712	$ 241,312	$ 244,912	$ 248,512	$ 252,112	$ 255,712	$ 259,312	$ 327,445	$ 327,445	$ 327,445	$ 327,445	$ 327,445
Indirect Expenses		$ 1,851	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651
Taxes		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 130,620	$ 130,693	$ 130,754	$ 130,807	$ 130,853
Total Cash Disbursements		$ 175,963	$ 231,163	$ 234,763	$ 238,363	$ 241,963	$ 245,563	$ 249,163	$ 252,763	$ 256,363	$ 259,963	$ 458,716	$ 458,788	$ 458,850	$ 458,903	$ 458,948
Operating Cash Flow		-$ 15,163	-$ 70,363	-$ 73,963	-$ 77,563	-$ 81,163	-$ 84,763	-$ 88,363	-$ 91,963	-$ 95,563	-$ 99,163	$ 841,284	$ 841,212	$ 841,150	$ 841,097	$ 841,052
Capital Expenditures		$ 161,040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Cash		-$ 176,203	-$ 70,363	-$ 73,963	-$ 77,563	-$ 81,163	-$ 84,763	-$ 88,363	-$ 91,963	-$ 95,563	-$ 99,163	$ 841,284	$ 841,212	$ 841,150	$ 841,097	$ 841,052
Funding																
Equity	$ 939,072	$ 939,072	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bank Loan		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Funding		$ 939,072	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Increase (Decrease) in Cash Position		$ 762,869	-$ 70,363	-$ 73,963	-$ 77,563	-$ 81,163	-$ 84,763	-$ 88,363	-$ 91,963	-$ 95,563	-$ 99,163	$ 841,284	$ 841,212	$ 841,150	$ 841,097	$ 841,052
Cash (Deficiency) - Beginning of Period		$ -	$ 762,869	$ 692,506	$ 618,543	$ 540,979	$ 459,816	$ 375,053	$ 286,690	$ 194,726	$ 99,163	$ -	$ 841,284	$1,682,496	$2,523,646	$3,364,743
Cash (Deficiency) - End of Period		$ 762,869	$ 692,506	$ 618,543	$ 540,979	$ 459,816	$ 375,053	$ 286,690	$ 194,726	$ 99,163	$ -	$ 841,284	$1,682,496	$2,523,646	$3,364,743	$4,205,795

Table 8: Profitability ratios for a 10-hectare sub-tidal geoduck aquaculture venture with on-site access to wild geoduck

Base Case Assumptions	**Year 1-5**	**Year 1-10**	**Year 1-15**
Gross Margin	-39.0%	-47.9%	50.5%
Return on Sales	-61.2%	-63.5%	46.9%
Cash Earnings on Sales	-59.6%	-58.4%	40.3%
ROI (Cash in - Cash out)	-10.2%	-10.0%	23.2%
Internal Rate of Return	Negative	Negative	7.8%

Gross Margin = Gross Profit ÷ Sales

Return on Sales = Earnings Before Interest, Tax & Depreciation ÷ Sales

Cash Earnings on Sales = Net Cash Flow ÷ Sales

ROI (Cash in - Cash out) = Net Cash Flow ÷ Equity Invested

Internal Rate of Return = The interest rate at which the net present value of all cash flows from the project equal zero. The higher a project's internal rate of return, the more desirable it is to undertake the project.

Table 9: Sensitivity analyses for a 10-hectare sub-tidal geoduck aquaculture venture with on-site access to wild geoduck

Production Factors:			
Seed Cost @ 6-10mm ($/seed)	$0.28	$0.35	$0.42
Total Investment	$764,072	$939,072	$1,114,072
Variance	-19%	-	19%
Time to Harvest (yrs)	8	10	12
Total Investment	$888,570	$939,072	$985,175
Variance	-5%	-	5%
Density of Wild Geoduck (#/m2)	0.54	0.68	0.82
Total Investment	$1,225,048	$939,072	$653,097
Variance	30%	-	-30%
Harvest Factors:			
Dive Service Fees ($/dive day)	$1,760	$2,200	$2,640
Total Investment	$702,420	$939,072	$1,175,725
Variance	-25%	-	25%
Market Factors:			
Average Market Price ($/kg)	$20.80	$26.00	$31.20
Total Investment	$1,260,672	$939,072	$617,473
Variance	34%	-	-34%

2.2 Model Assumptions & Inputs - Inter-Tidal Production

2.2.1 Production Site & Characteristics

Inter-tidal geoduck aquaculture is generally most successful on beaches where sand has accumulated in bars and flats to depths of one meter or more. Sand that is clean and free of large amounts of gravel, wood or shell debris is preferable. Geoduck reared in muddy or gravel substrates can become discoloured and of lower value(5). Besides substrate, other factors such as water quality, availability of natural foods, tidal height (relative to the mean lower low water level - MLLW[5]) and exposure to storm waves are also key considerations. From a socio-economic perspective, it is important to consider the needs and interests of upland property owners, the presence of sensitive habitat (e.g. eelgrass) and the interests of adjacent users of the aquatic resource base. The inter-tidal habitat in WA State is similar to that in the Strait of Georgia, however, it is generally believed that there is more habitat suitable for inter-tidal geoduck culture in Washington than in British Columbia.

2.2.2 Production System

The industry norm for inter-tidal geoduck culture is to plant seed into short sections of PVC or plastic mesh (e.g. Vexar) tubing set vertically into the beach sand. The tubes are generally 10 to 15 cm in diameter (4"-6") and 23 to 41 cm (9"-16") long. Ten-centimetre (4") tubes are most common. Shorter tubes are used on more protected beaches while the longer tubes are planted on beaches that are subject to greater wave action. Once planted, only 5 to 8 centimetres of the tube extends above the sand. Tubes are usually arranged in rows at a density of about 10 tubes per square meter (~1 per square foot).(2,5,26,27)

The tubes are planted into the beach at an elevation between -0.75 and +1 meter (-2½ and +3 feet) relative to the MLLW level. Most farms utilize the lower portion of this range where growth and survival are enhanced. Higher failure rates can be experienced in the upper portion of the range due to the longer periods of time that seed are exposed to high summer temperatures at low tide(5). After installation, 3mm to 8mm seed are hand-planted into the tubes at a rate of 2 to 4 seed per tube. Similar to sub-tidal geoduck culture, netting is placed over the entire tube field to protect the geoduck from predators and wave action, and to reduce visual impacts(5,14). In most areas, it is necessary to keep the netting in place for two years, although some producers keep the nets for the first three years of production. Once removed, the tubes are cleaned and re-used whereas new netting is used for each planting. While in place, it is necessary to clean the nets to remove excessive biofouling and to ensure its integrity.

Site specific differences in growth rate are expected. In Washington State, geoduck grow fastest in southern Puget Sound where 0.8 kg geoduck are routinely harvested in 5 years. Sites in north Hood Canal appear to require an extra year to reach this size, and sites planted on the north coast (Discovery Bay) may require more time as suspended food levels

[5] Mean Lower Low Water (MLLW): A tidal datum used by the United States' National Oceanic and Atmospheric Administration and referring to the average of the lowest water height recorded at a tide station each day during the recording period.

tend to be lower[5]. Typical growth rates in WA State are presented in the chart below. In comparison, it is likely that growth to market size in BC will require 1 or 2 additional years.

Time to Harvest (yrs)	Prod'n Method	Location	Source
5 - 6	Inter-tidal	WA	Davis (2004)
5 - 7	Inter-tidal	WA	WA-DNR (2011)
5 - 6	Inter-tidal	WA	Producers
5 - 7	Inter-tidal	WA	Northern Economics Inc. (2004)

A typical survival rate for inter-tidal geoduck culture is 1 to 1½ clams per tube (10-15/m^2) or about 33% to 50%, although as many as 19-23 clams per square meter have been reported. Harvesting of market-size geoduck is done using a "stinger" which injects pressurized water into the substrate adjacent to each geoduck to fluidize the sand bed, making it easy to remove the clams by hand. An average harvest rate of 4-6 geoduck per minute is the norm for experienced harvesters over a four-hour tide[5,26,27].

Geoduck farming requires a minimal amount of infrastructure due mainly to the relatively low maintenance requirements following planting. Infrastructure needs include a means for storing, cutting and transporting tubes, netting and harvest totes to the production site. A large raft or barge is commonly used. The raft also supports the diesel pump and harvest stingers (four per pump)[5,26].

2.2.3 Model Assumptions

The **<Input>** page of the model allows the user to provide a variety of inputs pertaining to Site, Production, Harvest, Revenue and Finance matters. The assumed parameters applied in the model are presented in the shaded cells in the tables below. These data were derived from the literature and individuals referenced at the end of this document. Users of the model are able to change the input parameters to better reflect their own situation.

It is important to note that geoduck culture techniques continue to evolve and, therefore, techniques applied today are likely to change substantially within the period of time reflected in this study. The input assumptions and model outputs are for illustrative purposes. They project anticipated costs and returns for inter-tidal geoduck aquaculture. Results will vary as the assumptions are changed. The model has not been validated using actual production data.

Site:	Low	Assumed	High	Description:
Total Area (ha):	na	2	na	▪ Total area under tenure
Production Area (ha):	na	2	na	▪ Total area under cultivation
Site Application Fee ($):	na	$ 1,200	na	▪ Per Provincial guidelines
Licence of Occupation ($/ha/yr):	na	$ 233	na	▪ Per Provincial guidelines
Aquaculture Licence ($/site/year):	na	$ 418	na	▪ Per DFO proposed fee schedule

Production:	Low	Assumed	High	Description:
Density of Tubes (# tubes/m^2):	8	10	12	▪ Number of tubes per sq meter
Tube Planting Costs ($/tube):	$ 0.28	$ 0.45	$0.54	▪ Cost to install tubes in beach
Seed Rate (# seed/tube):	10	25	40	▪ Recommended seeding rate
Seed Harvested (% Survival):	<25%	33%	>60%	▪ Survival, planted seed harvested
Seed Cost - 6-10 mm ($/seed):	$ 0.20	$ 0.35	$ 1.00	▪ Cost of hatchery / nursery seed
Tube Seeding ($/tube):		$ 0.23		▪ Cost to plant seed & install netting
Predator Nets ($/ha):	$4,000	$ 8,000	$ 10,000	▪ Cost of new nets (10,000m^2)
Tube & Net Deployment Time (yrs):	1	2	3	▪ Amount of time with tubes in place
Site Maintenance (hrs/ha/yr):	312	416	520	▪ Hours required to maintain site
Maintenance Wages ($/hr):	- -	15	- -	▪ Wages & benefits
Site Management hrs/ha/hr):	312	416	520	▪ Hours required to maintain site
Management Wages ($/hr):	- -	25	- -	▪ Wages & benefits
Miscellaneous ($/ha/yr):	- -	$ 2,500	- -	▪ Miscellaneous expenses

Harvest:

	Low	Assumed	High	
Time to Harvest (yrs):	6	8	10	▪ Years to reach 800 gram avg. wt.
Area Seeded per Year (ha):	Production Area ÷ Time to Harvest			▪ No hectares seeded with geoduck
Avg Harvest Weight - Farmed (kg):	0.70	0.80	1.00	▪ Projected harvest weight (farmed)
Density of Farmed Geoduck (#/m^2):	Seed Rate x Seed Survival			▪ Final harvest density - farmed
Geoduck Harvest Fees ($/kg):	- -	$1.75	- -	▪ Labour plus operating costs
Harvest Monitoring Fee ($/kg):	- -	$0.05	- -	▪ Harvest observer fees

Revenues:				
#1 Grade Product (%):	- -	100	- -	▪ Harvest percent of #1 Grade
#2 Grade Product (%):	- -	0	- -	▪ Harvest percent of #2 Grade
Farm-Gate Price #1 Grade ($/kg):	- -	$26.00	- -	▪ Price of #1 Grade
Farm-Gate Price #2 Grade ($/kg):	- -	$18.00	- -	▪ Price of #2 Grade

Financial:		Description:
Simple Annual Interest Rate (%):	6.0%	▪ Interest on bank loan; prime + 3%
Term of Debenture	10	▪ Duration of bank loan
Corporate Tax Rate	13.5%	▪ BC small business taxation rate

The **<Cash Flow>** page of the model allows the user to input the amount of owner equity and debt (bank loan) invested to finance the venture. Debt financing charges are amortized over the term of the loan and the interest and capital portions of the blended payments are calculated and linked to the Income Statement and Cash Flow Statement. The total amount of investment capital required to fund the operation can be determined by entering a combination of equity and/or debt that reduces the 'Maximum Cash Deficiency' to $0. When the cash deficiency is equal to $0, there is sufficient funding to finance the venture until revenues are able to carry the operation.

Funding		Description:
Equity	$ -	▪ Amount of owner equity invested
Bank Loan	$ -	▪ Amount of money to be borrowed

The **<Capital>** page allows the user to input the amount of money required to finance capital expenditures for the project. The default inputs are presented below.

	Unit Price	Number	Budget
Infrastructure			
Environmental Assessment	$ 5,000	1	$ 5,000
Storage Building (40' x 80')	$ 25	3,200	$ 80,000
Contingency (10%)			$ 8,500
Subtotal			$ 93,500
Production Equipment			
PVC Tubes (40 cm)	$ 5.35	50,000	$ 267,500
Raft / Barge	$ 20,000	1	$ 20,000
Diesel Pump & Stingers (4)	$ 20,000	1	$ 20,000
Harvest Cages (Totes)	$ 12	500	$ 6,000
Truck (used)	$ 30,000	1	$ 30,000
Contingency (10%)			$ 34,350
Subtotal			$ 377,850
Other Equipment			
Office Equipment	$ 5,000	1	$ 5,000
Miscellaneous	$ 10,000	1	$ 10,000
Contingency (10%)			$ 1,500
Subtotal			$ 16,500
TOTAL PRODUCTION CAPITAL			$ 487,850

The model is in an accompanying file entitled:

Geoduck Aquaculture Model - Inter-Tidal (Final).xlsx

2.2.4 Results - Inter-Tidal Culture

Pro forma projections indicate that the inter-tidal geoduck aquaculture venture modelled using the assumptions identified above realizes an average operating loss of approximately $124,000 per year over the first eight years of operation (Table 10). The first profits are not realized until the ninth year of operations when the harvest of cultured geoduck commences. Therefore, it s estimated that a producer would need to invest $1,055,520 to support the 2-hectare geoduck farm until cultured geoduck can be harvested (Table 11). As with sub-tidal geoduck culture, the *pro forma* financial statements reflect a 100% equity investment since, in the absence of cash flow for more than eight years, debt financing remains infeasible.

In the ninth year of operations, the venture is projected to realize a net profit of $384,206 on total sales of $520,000 from the harvest of the first quarter-hectare plot of geoduck. Thereafter, the venture is projected to realize a net profit of approximately $390,000 per year

(Table 10). By the eleventh year, the venture is projected to attain a positive cumulative cash position (Table 10); that is, the initial investment made by the owner has been recouped; however, at this point, there is a return of investment but not yet a return on investment. It is not until the end of the 14th year of operations that the internal rate of return for the venture becomes positive; albeit marginally at 0.24%. After 15 years, the IRR is only 1.7% (Table 12). Average profitability ratios have been calculated over three time periods; years 1 through 5, years 1 through 10 and years 1 through 15. Since no sales are generated until the seeded geoduck are ready to harvest, the venture is not profitable within the first eight years but shows modest profits within a 15 year period (Table 12).

In the absence of revenue during the eight-year start-up phase, it is not possible to calculate a breakeven point.

Sensitivity analyses were conducted to evaluate the impacts of various production, harvest and market factors on the level of investment required to finance a 2-hectare inter-tidal geoduck aquaculture venture in British Columbia. Production and market variables were increased and decreased to observe their overall financial impact (Table 13). The largest financial impact on the amount of investment required for the venture was due to the duration of tube deployment. When tubes were deployed for only one year rather than two, the total investment decreases by 14%, due largely to the reduced capital expenditure for PVC tubes; 25,000 tubes are required for each year that tubes are deployed. In contrast, when tube deployment was extended to three years, a more likely scenario, total investment increases by 14%. Seed survival to market size also influences the amount of investment required. When survival increases to 50%, thus requiring only 2 seed to be planted per tube, the total investment is projected to decrease by 7%. In contrast, when survival is only 25%, requiring four seed to be planted per tube, total investment increases by 7%. The cost of seed and the number of years required to produce a harvestable product (7, 8 or 9) have more modest impacts on investment. Since the vast majority of the working capital for a geoduck farm is invested prior to the first harvest, changes to the market price of the product do not influence the amount of investment required to start the venture (Table 13). They will, however, have a downstream impact on the overall profitability of the operation.

Economies of scale in the inter-tidal geoduck aquaculture venture have been evaluated by adjusting the total size (hectares) of the proposed venture. Operations of 1-hectare, 2-hectares, 5-hectares and 10-hectares are compared. Marginal improvements in profitability were observed with increased volume and total capitalization per hectare decreased with scale. As the scale of the operation increases beyond 2 to 5 hectares, the capitalization and performance ratios begin to plateau. Beyond 5 hectares in size, the benefits of further increases in scale appear to become increasingly marginal; that is, there appear to be diminishing returns to increases in scale beyond approximately 5 hectares.

Economies of scale in inter-tidal geoduck aquaculture

Size of Operation (ha)	1	2	5	10
Cultured Geoduck (kg/yr)	10,000	20,000	50,000	100,000
Capitalization (Total Investment)	$627,765	$1,055,520	$2,338,785	$4,477,560
Capitalization ($/hectare)	$627,765	$527,760	$467,757	$447,756
Gross Margin	60.7%	60.7%	60.7%	60.7%
Return on Sales	25.0%	34.8%	40.7%	42.7%
Cash Earnings on Sales	35.7%	39.8%	43.1%	44.2%
ROI (Cash in - Cash out)	6.9%	9.1%	11.2%	12.0%
Internal Rate of Return	0.2%	1.7%	2.9%	3.3%

Scale effects on total investment required to finance inter-tidal geduck aquaculture

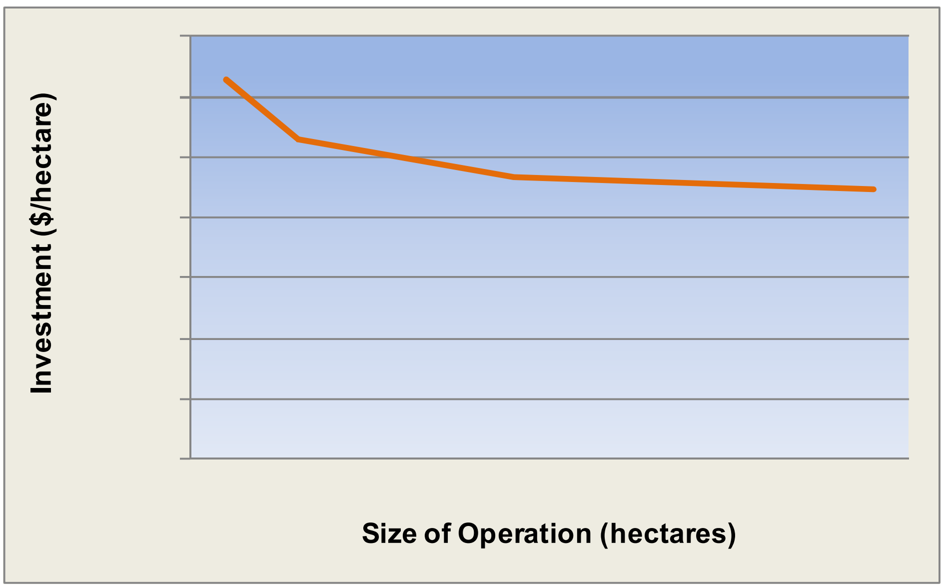

Table 10: Pro forma Income Statement for a 2-hectare inter-tidal geoduck aquaculture venture.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue															
Aquaculture Sales															
#1 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000
#2 Grade Product	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Aquaculture Sales	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000
Cost of Production															
Direct Costs															
Seed	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250	$ 26,250
Tube Planting	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250	$ 11,250
Seed Planting	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750
Predator Netting	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
Site Maintenance	$ 1,560	$ 3,120	$ 4,680	$ 6,240	$ 7,800	$ 9,360	$ 10,920	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480	$ 12,480
Site Management	$ 2,600	$ 5,200	$ 7,800	$ 10,400	$ 13,000	$ 15,600	$ 18,200	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800	$ 20,800
Tube Cleaning	$ -	$ -	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500
Miscellaneous	$ 625	$ 1,250	$ 1,875	$ 2,500	$ 3,125	$ 3,750	$ 4,375	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000
Harvest Cost	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000
Harvest Monitoring	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000
Total Direct Costs	$ 50,035	$ 54,820	$ 64,105	$ 68,890	$ 73,675	$ 78,460	$ 83,245	$ 88,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030
Gross Margin	**($50,035)**	**($54,820)**	**($64,105)**	**($68,890)**	**($73,675)**	**($78,460)**	**($83,245)**	**($88,030)**	**$395,970**	**$395,970**	**$395,970**	**$395,970**	**$395,970**	**$395,970**	**$395,970**
Indirect Costs															
Aquaculture Licence	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418	$ 418
Aquaculture Tenure	$ 1,433	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233	$ 233
Depreciation	$ 126,005	$ 90,404	$ 65,229	$ 47,387	$ 34,703	$ 25,654	$ 19,170	$ 14,499	$ 11,113	$ 8,640	$ 6,816	$ 5,459	$ 4,436	$ 3,656	$ 3,053
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Indirect Costs	$ 127,856	$ 91,055	$ 65,881	$ 48,038	$ 35,354	$ 26,305	$ 19,821	$ 15,151	$ 11,764	$ 9,291	$ 7,468	$ 6,110	$ 5,088	$ 4,308	$ 3,704
Net Income Before Tax	**($177,891)**	**($145,875)**	**($129,986)**	**($116,928)**	**($109,029)**	**($104,765)**	**($103,066)**	**($103,181)**	**$384,206**	**$386,679**	**$388,502**	**$389,860**	**$390,882**	**$391,662**	**$392,266**
Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$52,448	$52,631	$52,769	$52,874	$52,956
Profit (Loss) After Tax	**($177,891)**	**($145,875)**	**($129,986)**	**($116,928)**	**($109,029)**	**($104,765)**	**($103,066)**	**($103,181)**	**$384,206**	**$386,679**	**$336,055**	**$337,229**	**$338,113**	**$338,788**	**$339,310**

Table 11: Pro forma Cash Flow Statement for a 2-hectare inter-tidal geoduck aquaculture venture.

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cash Receipts																
Wild Harvest		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000
Total Receipts		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000	$ 520,000
Cash Disbursements																
Direct Expenses		$ 50,035	$ 54,820	$ 64,105	$ 68,890	$ 73,675	$ 78,460	$ 83,245	$ 88,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030	$ 124,030
Indirect Expenses		$ 1,851	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651	$ 651
Taxes		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 52,448	$ 52,631	$ 52,769	$ 52,874	$ 52,956
Total Cash Disbursements		$ 51,886	$ 55,471	$ 64,756	$ 69,541	$ 74,326	$ 79,111	$ 83,896	$ 88,681	$ 124,681	$ 124,681	$ 177,129	$ 177,312	$ 177,450	$ 177,556	$ 177,637
Operating Cash Flow		-$ 51,886	-$ 55,471	-$ 64,756	-$ 69,541	-$ 74,326	-$ 79,111	-$ 83,896	-$ 88,681	$ 395,319	$ 395,319	$ 342,871	$ 342,688	$ 342,550	$ 342,444	$ 342,363
Capital Expenditures		$ 487,850	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Cash		-$ 539,736	-$ 55,471	-$ 64,756	-$ 69,541	-$ 74,326	-$ 79,111	-$ 83,896	-$ 88,681	$ 395,319	$ 395,319	$ 342,871	$ 342,688	$ 342,550	$ 342,444	$ 342,363
Funding																
Equity	$1,055,520	$1,055,520	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bank Loan		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Funding		$1,055,520	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Increase (Decrease) in Cash Position		$ 515,783	-$ 55,471	-$ 64,756	-$ 69,541	-$ 74,326	-$ 79,111	-$ 83,896	-$ 88,681	$ 395,319	$ 395,319	$ 342,871	$ 342,688	$ 342,550	$ 342,444	$ 342,363
Cash (Deficiency) - Beginning of Period		$ -	$ 515,783	$ 460,312	$ 395,556	$ 326,015	$ 251,689	$ 172,577	$ 88,681	$ -	$ 395,319	$ 790,638	$1,133,509	$1,476,196	$1,818,746	$2,161,190
Cash (Deficiency) - End of Period		$ 515,783	$ 460,312	$ 395,556	$ 326,015	$ 251,689	$ 172,577	$ 88,681	$ -	$ 395,319	$ 790,638	$1,133,509	$1,476,196	$1,818,746	$2,161,190	$2,503,553

Table 12: Profitability ratios for a 2-hectare inter-tidal geoduck aquaculture venture

Base Case Assumptions	**Year 1-5**	**Year 1-10**	**Year 1-15**
Gross Margin	No Sales	22.2%	60.7%
Return on Sales	No Sales	-63.7%	34.8%
Cash Earnings on Sales	No Sales	-25.5%	39.8%
ROI (Cash in - Cash out)	-10.1%	-2.5%	9.1%
Internal Rate of Return	Negative	Negative	1.7%

Gross Margin = Gross Profit ÷ Sales

Return on Sales = Earnings Before Interest, Tax & Depreciation ÷ Sales

Cash Earnings on Sales = Net Cash Flow ÷ Sales

ROI (Cash in - Cash out) = Net Cash Flow ÷ Equity Invested

Internal Rate of Return = The interest rate at which the net present value of all cash flows from the project equal zero. The higher a project's internal rate of return, the more desirable it is to undertake the project.

3.0 GEODUCK AQUACULTURE – SWOT-PLUS ANALYSIS

SWOT-Plus is a robust, strategic tool that requires reflection on a broad range of considerations pertaining to an issue, in this case, development of geoduck aquaculture. The SWOT acronym refers to the Strengths, Weaknesses, Opportunities, and Threats involved in a project. Strengths and weaknesses are internal considerations for which means to impose control and direction can be potentially developed. Opportunities and threats, however, are factors that are external to a project but which must, nevertheless, be considered in the planning and development process since they have a real capacity to influence success or failure.

When conducted thoroughly, a SWOT-Plus Analysis reveals key strengths to build upon and opportunities to exploit while simultaneously focusing attention on those areas where improvement is necessary and where external factors may impose additional constraints to be addressed. In short, the SWOT-Plus approach guides the compilation of necessary information in a way that enables the development of structured response plans to resolve underlying critical issues that must be addressed to generate the intended results.

The nature of the data and information gathered determines whether a specific issue is a Strength, Weakness, Opportunity or Threat. Where information is unknown or uncertain, it needs to be identified and interpretation of the analysis judged accordingly. Information gathering and information analysis are separate exercises and, therefore, it is important to avoid the tendency to interpret the information when populating the tables. The SWOT tables are used to compile pertinent data and information. At this stage, it is imperative to assemble factual information and to avoid a preliminary interpretation of the information (this is a common shortcoming in the application of the conventional SWOT analysis).

Production and economic factors have been compiled with regard to geoduck aquaculture. Interpretation of this information leads to a comprehensive understanding of the key functional issues associated with constraints to geoduck aquaculture development, producing an enhanced understanding of (a) the aspects of the issues that can be effectively managed and (b) what remains unknown and/or under-developed. The identification of those issues that are most pertinent is required.

The culmination of the analysis is the identification of "what needs to be addressed." The functional issues have been distilled down to the root cause and have been assessed and prioritized. This assessment provides for the development of recommendations on how to move forward.

3.1 SWOT-Plus Tables

The information gathered from published literature, technical reports and personal communication has been compiled into conventional SWOT tables for the first phase of the SWOT-Plus Analysis. This information is presented in the following tables. Information in the tables has largely been copied and pasted directly from other sources.

	Production Factors
Strengths/ Positives	▪ Growth in natural populations is relatively fast in the first 7-10 years(10). Geoduck at the best sites grow to about 0.7 - 0.8 kg in 5-6 years(5). Growth rate is also proportional to planting density(5). Growth to market size is 2-4 years faster in inter-tidal sites v. sub-tidal sites(12) ▪ The geoduck clam occurs throughout coastal British Columbia in beds featuring substrates consisting of a sand, silt, gravel, and shell mix. Geoduck are normally distributed at depths ranging from 3-20 m (8,10) ▪ At least four commercial hatcheries produce geoduck seed(2,20) ▪ Identified harvestable beds cover approximately 17,600 ha in BC.
Opportunities	▪ The larger the seed the better the planting success. Seed are normally planted at a size of 5-7mm shell length(18,21,24) ▪ Locations with high suspended food availability and/or high current flow will result in higher rates of growth for cultured geoduck ▪ BC has a range of sites suited to both inter-tidal and sub-tidal geoduck culture ▪ Recent geoduck nursery systems under development have begun to utilize tank or raceway systems where there is greater control over culture conditions.
Threats	▪ Geoduck are documented to uptake and retain PSP biotoxin at differential rates. Toxin retention may be prolonged in the visceral mass (gut ball) for weeks to months while siphon and mantle tissues are not affected(5) ▪ Because PSP levels vary between individual clams, closures for geoduck harvesting are strict and tend to be last weeks to months longer than closures for other shellfish species(5) ▪ Exposure to storm waves is detrimental to inter-tidal production; especially in winter months(5) ▪ Selection of the proper substrate for planting to produce #1 grade geoduck is critical. Muddy or other types of substrates produce #2 and lower grade(5) ▪ Losses of seed due to heat stress and predation of young clams are the major risk factors during the first year following planting(5)
Problems/ Challenges/ Weaknesses	▪ Hatchery-produced seed (juveniles) is a basic requirement of commercial geoduck culture and is in high demand, with limited supply currently. Seed is generally grown to 3-6 mm in the hatchery before transport to a nursery site or planted in a grow-out site(10) ▪ Technologies and practices are not yet sufficiently advanced to enable a consistent and reliable supply of seed. Many factors (e.g. nutrition, broodstock conditioning, larval culture practices, etc.) need to be further enhanced. Consequently, seed supply is an inherent risk in the development of geoduck aquaculture in BC. ▪ Nursery Strategies(2,8,10) • Land-based ponds and raceways with seed in sand substrate; supplemental feeding with cultured algae (from 6-12 mm SL); good survival; costs can be significant. • Floating upwelling system (FLUPSY): water-based nursery with sand-filled trays and forced circulation (paddlewheel), bringing natural phytoplankton and removing wastes; seed grown from 6-18 mm under considerable control, but with relatively high capital and operating costs. • Benthic tables at marine sites (sand-filled net bags on raised platforms), using natural phytoplankton for feed and netting for protection, initially over-winter (from 6-20 mm); managed by diving; effective, but cumbersome. • BOBs (Bags-on the-Bottom) at marine sites; zippered net bags installed on bottom sites and planted by divers; lower costs, but variable survival.

	▪ The grow-out period from seed to market-sized product is longer than first estimated (eight rather than five years) in sub-tidal culture ▪ Growth rates and size display strong spatial variation[10]; for example, average size decreases from south to north, and from shallow to deep ▪ Natural mortality from predation is very high during early benthic (bottom) life but decreases rapidly after one year[10] ▪ Site specific contamination from local pollution sources (fecal coliform bacteria from livestock, birds, seals, etc.) and should be considered prior to siting a geoduck farm[5] ▪ Geoduck that are reared in areas of muddy or gravel substrates will often be discoloured and lower in market quality[5] ▪ Survival rates for geoduck growing to a harvestable size of 700 grams (1½ lb) are variable and depend on a host of factors relating mainly to early seed survival and site characteristics. ▪ Overcrowding or sub-optimal growth rates will lengthen the time to harvest; proper planting density is critical. ▪ Fouling by green seaweeds and low salinity conditions can significantly affect the survivorship of seed in the first hours or days after planting. ▪ Environmental concerns regarding the use of PVC tubes in the inter-tidal zone[14] ▪ plastic debris invariably escapes commercial geoduck sites and washes up on public and private beaches ▪ Plastic debris (tubes, netting, etc.) tend to wash p on public and private beaches, creating local public opposition to inter-tidal geoduck aquaculture ▪ Inter-tidal tubes emerging from the beaches spoils the aesthetic characteristics of natural beaches

	Economic Factors
Strengths/ Positives	▪ The average density is BC is reportedly 1.7 animals per m^2. In inside waters, the average density is 0.68 per square meter [3,4] ▪ Plant seed at 20-32 animals per square meter[8,10] ▪ In the wild fishery, an experienced diver could expect to harvest 700-900 kg) in a 6-hour working day[8,18] ▪ Of a total of 39 licensed geoduck aquaculture sites (Nov 2010), three are on the west coast of Vancouver Island, assumed to be inactive, and were issued licences prior to 2004. Of the 39 sites, 2 are hatcheries, 26 are intertidal, suspended or mixed zone sites and 11 are sub-tidal sites ▪ These geoduck aquaculture tenures range in size from 9 to 89 hectares and cover over 300 hectares in total or about 2% of harvestable geoduck beds. In 2009 BC produced 175,000 lbs of geoduck through aquaculture in comparison to 3,527,000 lbs of wild geoduck
Opportunities	▪ Increased availability of geoduck may stimulate greater market demand, offsetting possible declines in price due to increased supplies[5]. The world supply of geoduck has increased to about 9 million lbs[12] ▪ The 2008 worldwide geoduck market (aquaculture and wild) was valued at approximately US$80 million ▪ World-wide supply of wild-harvest geoduck is not expected to increase dramatically from Washington, Alaska and British Columbia[12] ▪ Competition from Argentina, Chile, Mexico or New Zealand is not expected to be significant; production in these areas is compromised by inferior-quality product, limited market acceptance,

	insufficient infrastructure and restrictive regulations[12] ▪ Wild geoduck occur naturally in relatively sparse numbers in intertidal zones in BC, therefore there are no impacts to the existing sub-tidal commercial fishery areas by allocating intertidal areas for geoduck aquaculture ▪ Eleven new sites totalling 368 ha, or 5% of harvestable geoduck beds in the Strait of Georgia, were offered by BC in 2006 in areas agreed to be of low to medium impact to the existing fishery. This represents approximately 2% of the total coast wide geoduck bed area ▪ The ability to harvest and sell wild geoduck within the boundaries of an aquaculture lease provides an opportunity to offset the external investment requirement for geoduck aquaculture. ▪ Potential to work with the stable and profitable commercial fishery in BC[8]; in 2009, the sector harvest 1600 tonnes having a landed value of $31.8 million and a wholesale value of $42.7 million.
Threats	▪ As supply of farmed geoduck increases, prices for fresh geoduck may begin to decline[5] ▪ Development of geoduck aquaculture in China; however indications are that the quality is inferior to geoduck produced in the Pacific northwest[5] ▪ Washington companies are producing farmed geoduck on private inter-tidal lands and have the potential to become the dominant suppliers of farm-raised product in the sector; production is expected to continue to increase[12] ▪ There is no policy for geoduck aquaculture development in British Columbia.
Problems/ Challenges/ Weaknesses	▪ Hatchery-produced seed (juveniles) is a basic requirement of commercial geoduck culture and is in high demand, with limited supply[10] ▪ Nursery systems required to increase size of juveniles from 3-6 mm to 12-20 mm for planting, adding considerable cost[10] ▪ Assumed harvest efficiency of 85% is built into the overall 25% survival/recovery assumption ▪ Production is limited to areas that are classified as Approved or Conditionally Approved for growing and harvesting shellfish[5] ▪ The collective interests of the commercial fishery, existing producers and new entrants to aquaculture, First Nations and other stakeholders must be considered in decisions which relate to the future of geoduck production in BC ▪ While there have been successes with the FLUPSY nursery system, the cost of operating the FLUPSY is high relative to the amount of geoduck seed that can be produced in sand-filled totes. ▪ Sub-tidal culture has demonstrated slower growth rates than inter-tidal culture (7-8 years v. 5-6) as well as higher production and harvest costs, and greater technical barriers. ▪ The length of time to first harvest requires proponents to finance the operation entirely with equity; debt financing is infeasible. ▪ DFO's Pre-Seed Harvest Policy (purge fishery) prohibits geoduck aquaculture producers from accessing the wild geoduck within their lease, thereby eliminating a potential source of cash flow necessary to finance the venture during the 7 to 10-year start-up period when producers must provide working capital in the absence of a revenue stream.

3.2 Functional Issue Assessment

In this phase of the SWOT-Plus Analysis, the information compiled in the SWOT tables is assessed in terms of "what is the issue", "how it is manifested" and "why it is happening". This information is presented in the following table.

CRITICAL ISSUES	How is it manifested?	Why is it happening? Cause(s)?	Why is it Important? Implications?
Availability of hatchery-produced seed	▪ Seed supply is limited ▪ Only four producers of seed in BC ▪ Seed is relatively expensive	▪ Successful seed production remains inconsistent ▪ Insufficient demand for seed to advance technologies and practices and enhance production volumes	▪ Seed is essential for building a successful geoduck aquaculture sector
Knowledge and understanding of culture practices and technologies	▪ Variability in growth and survival ▪ Inconsistent performance in commercial production ▪ Few commercial geoduck aquaculture operations in spite of profit potential	▪ Insufficient practical information from production trials regarding critical success factors for commercial production ▪ Players are reluctant to share production data and information ▪ Absence of a cooperative aqua-culture development plan	▪ Difficult to establish consistent performance, productivity and profitability ▪ Constraint to sustainable development of geoduck aquaculture
Access to capital	▪ Difficult to finance geoduck aquaculture; ▪ Few commercial geoduck aquaculture operations in spite of profit potential	▪ Up to 10 years without cash flow before first harvest ▪ DFO Pre-Seed Harvest Policy precludes access to wild geoduck on leases ▪ No geoduck aquaculture development policy in BC	▪ Access to wild geoduck from within the site boundaries provides an opportunity for internal financing ▪ Without investment, the full potential of geoduck aquaculture will not be realized

3.3 Identification of Underlying Causes

Description of Underlying Cause (Common causes for multiple problems)	**Why is it Important? Implications?**	**Priority and Importance**		
		Low	**Med**	**High**
1. Access to capital to finance geoduck aquaculture	▪ Few investors can afford to self-finance geoduck aquaculture			✓
2. Insufficient knowledge regarding critical success factors	▪ Essential for establishment of long-term productivity			✓

4.0 SUMMARY

1. Geoduck aquaculture presents an opportunity to diversify the economy of coastal and aboriginal communities in British Columbia. The technology is fairly well advanced and the industry has gained sufficient experience to warrant and support expansion of the sector.

2. A principal constraint to geoduck aquaculture (aside from access to production sites which is not within the scope of this review) is the ability to finance a geoduck aquaculture venture. Due to the long grow-out time, developers are required to provide the capital necessary to support the venture until there is sufficient cash flow generated from harvested product. It appears to be impractical to finance geoduck aquaculture with debt instruments.

   Nevertheless, it is plausible that some producers may be able to secure debt financing based on their character, collateral and capacity to re-pay the loan. These factors will vary for each venture. One scenario where debt might be used to leverage shareholder equity could require the shareholders to provide equity financing for the venture for the first 5 years, for example, and then secure debt financing for the remainder of the pre-harvest cash flow requirements. In this example, the lender would undoubtedly require the un-harvested geoduck (inventory) to be pledged as collateral (perhaps in addition to other more conventional forms of collateral). A biomass assessment would be required to quantify the inventory.

   The inability to gain access to investment capital is not exclusive to geoduck aquaculture. A 2010 survey of the Canadian aquaculture sector[6] concluded that access to capital is in fact an impediment to sustainable development, particularly for small and medium sized enterprises and especially those organizations that are farming species other than four primary ones (salmon, trout, mussels and oysters).

3. Fisheries and Oceans Canada's Interim Protocol for Pre-Seed Harvest of Subtidal Geoduck Aquaculture Sites allows for harvest of a portion of the existing wild geoducks located on new subtidal aquaculture sites by the wild fishery, prior to the establishment of aquaculture operations. Aquaculturists are prohibited from harvesting wild geoduck until their seeded crop is ready to be harvested. Allowing geoduck aquaculturists to harvest and sell wild geoduck from within the boundaries of their aquaculture site could generate internal financing during the critical start-up years of an operation.

4. It appears that sub-tidal geoduck aquaculture in British Columbia is at the pre-commercial or early commercialization stage of industry development. At this stage, a dedicated strategic approach to address and overcome the remaining challenges and constraints to development of the sector is required to usher the industry ahead.

5. Geoduck aquaculture in British Columbia would benefit from the establishment and implementation of a productivity and performance monitoring program that would identify critical success factors for sustainable development of the sector.

[6] Robertson, W.D. and D. Stechey (2010). Access to capital requirements in the Canadian aquaculture sector. Seafood Value Chain Roundtable, Agriculture and Agri-Food Canada, Ottawa. 67 p.

REFERENCES

1. BC Ministry of Agriculture (2011). Policy and Industry Competitiveness Branch. British Columbia Seafood Industry – Year in Review 2009. 16 p.

2. British Columbia Shellfish Farmers' Association (2011). Geoduck. BCSFA Webpage. http://bcsga.ca/about/industry-encyclopedia/geoduck/

3. Bureau, D., W. Hajas, N.W. Surry, C.M. Hand, G. Dovey and A. Campbell (2002). Age, Size Structure and Growth Parameters of Geoducks (*Panopea abrupta*, Conrad 1849) from 34 Locations in British Columbia Sampled Between 1993 and 2000. Canadian Technical Report of Fisheries and Aquatic Sciences 2413, 84 p.

4. Bureau, D., W. Hajas, C.M. Hand and G. Dovey (2003). Age, Size Structure and Growth Parameters of Geoducks (*Panopea abrupta*, Conrad 1849) 'from Seven Locations in British Columbia Sampled in 2001 and 2002. Canadian Technical Report of Fisheries and Aquatic Sciences 2494. 29 p.

5. Davis, J.P. (2004). Geoduck Culture on Intertidal Beaches: Procedures, Expenses and Anticipated Income for an Intermediate-Size Farm. WDNR Geoduck Aquaculture Pilot Studies. 21 p.

6. Engle, C.R. (2010). Aquaculture Economics and Financing. Management and Analysis. Wiley-Blackwell Publishing, Ames, IA. 272 p.

8. Gardner - Pinfold, 2001. Economic potential of sea ranching and enhancement of selected shellfish species in Canada. MS report prepared by IEC International for the Office of the Commissioner for Aquaculture Development, Ottawa, Canada. 28pp. + 8 Appendices.

9. Hand, C. and K. Marcus (2004). Potential impacts of subtidal geoduck aquaculture on the conservation of wild geoduck populations and the harvestable TAC in British Columbia. Canadian Science Advisory Service Research Document 2004/131. 29 p. ISSN 1499-3848.

10. Heath, W.A. 2005. Estimated Costs and Returns for a Sub-tidal Geoduck Enterprise. Aquaculture Industry Development Report No. 05-01, BC Ministry of Agriculture and Lands, Victoria, British Columbia.

11. www.mindtools.com/pages/article/newSTR_63.htm (2011). Achieving Economies of Scale.

12. Northern Economics Inc. (2004). The world geoduck market and the potential for geoduck aquaculture on Washington State Lands. Prepared for Washington Department of Natural Resources. 76 p.

13. Pacific Shellfish Institute (2004). Geoduck Clam Research & Management. Report on Potential Siting and Environmental Conditions in Geoduck Farming and Summary of Subtidal Methodology Advances. 82 p.

14. Stang, J. (2011). Economic benefits and ecological questions stall geoduck industry's growth. Kitsap Sun July 23, 2011

15. Washington Sea Grant (2007). Geoduck Aquaculture. SeaStar – Summer 2007. 8 p.

In addition, commentary and input was provided into the core assumptions used in the modelling exercise by the following people:

16. Clapp, Bruce - Underwater Harvesters Association
17. Dovey, Grant - Underwater Harvesters Association
18. Gant, Eric - Manatee Holdings Ltd.
19. Heath, Bill - Government of British Columbia
20. James, Michelle - Underwater Harvesters Association
21. Kingzett, Brian - Vancouver Island University
22. Lochmatter, Fred - FAN Seafoods
23. Point, Flavian - Lummi Shellfish Hatchery
24. Saunders, Robert - Island Scallops Ltd.
25. Smyrichinsky, Sean - U.B. Diving
26. Gibbons, Jim - Seattle Shellfish
27. Hayes, Tom - Taylor Shellfish