FISHERIES RESEARCH REPORT NO. 172, 2008

Identifying Obstacles to Profitably Growing Out Western Rock Lobsters

A Report Prepared for the Aquaculture Development Council

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Correct citation:

Melville-Smith,R., Johnston, D., Johnston, B. and Thomson, N. 2008. Identifying Obstacles to Profitably Growing Out Western Rock Lobsters from Pueruli. Fisheries Research Report No. 172, Department of Fisheries, Western Australia, 44p

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Front cover: A handful of western rock lobsters *(Panulirus cygnus)* raised at the West Australian Fisheries and Marine Laboratories from post-pueruli

Disclaimer

The model inputs used in this report, such as labour force, labour costs, carapace size at harvest, cost of pueruli, are best-estimate assumptions and are subject to significant uncertainties and contingencies, many of which are outside our control. Accordingly, the actual results of a commercial rock lobster growout operation may differ substantially from those projected here.

The authors have taken all reasonable care in the preparation of this report. However, they, and the research organisations with which they were when the work was undertaken affiliated (Department of Fisheries, Western Australia, Queensland Department Primary Industries), assume no responsibility for any errors, omissions or mis-statements, however caused.

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The Aquaculture Development Council acknowledges the care taken in the preparation of this report and also the disclaimer of the authors.

The assumptions made and variables used are, in many cases, theoretical and have been optimised. It is the considered opinion of the ADC that assumptions used in the model may not be achievable in many of the possible production locations. Any persons wishing to undertake the growout of western rock lobster pueruli are encouraged to critically review the assumptions made and apply realistic economic figures to the model, as this report indicates the economic indicators are highly sensitive to most of the changes investigated.

ISSN: 1035-4549 ISBN: 1 921 258 08 X

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Abstract

The cost of growing out western rock lobsters from pueruli to marketable-sized lobsters has been modeled from available information. The model uses different scenarios of survival rates, marketing weights, market prices, feed costs, puerulus prices, labour costs, puerulus compensation costs, discount rates and capital costs. The sensitivity of estimated profitability to various input costs and rock lobster prices was assessed by estimating the impact of changes on the estimates of net present value (NPV) internal rate of return (IRR) and benefit:cost ratio. Importantly, the aim of the study was to identify key cost and benefit-driving parameters, so that future research directions and policy decisions can be directed towards overcoming these potential barriers to profitability, but not to provide conclusive evidence of overall expected profitability at this stage.

Economic analysis suggests that, because of growth and mortality relationships over time, the optimal period to market the lobsters may be at about two years post-settlement, or ~250 g. However this conclusion is highly sensitive to the assumed price at which the product can be sold. Western rock lobsters of 250 gm are below the legal size limit (~400 g) upon which the pricing data are based, so estimating a market price for “undersized” lobsters was particularly difficult. Survival rates were also shown to be crucial in determining the potential financial success of an ongrowing venture; the rates achieved experimentally to date would need to be substantially improved.

Labour is expected to be the biggest single expense in a western rock lobster growout operation, with estimated costs for this component contributing around 38% of the cost of each kg of farmed lobster produced. It follows that labour cost assumptions (along with assumptions about the survival rate of pueruli) had the biggest impact on profitability. Other costs – such as the price of feed, the price of pueruli for ongrowing, compensation costs for harvesting pueruli and capital expenses – were, within their chosen sensitivity constraints, all shown to be moderately influential in determining the success or otherwise of a growout venture.

The study has not attempted to assess the profitability of growing out western rock lobster pueruli. However, the data suggest that positive returns would be more likely if the grown out lobsters are marketed below the legal size limit of wild-caught lobsters.

While some input parameters had a greater impact on the resultant profitability estimate than others, the impact of each parameter on the profit result provided useful insight into the way research effort could be directed to improve profitability.

Acknowledgements

This project was funded by the Aquaculture Development Corporation (ADC). We thank members of the ADC and Dr Nick Caputi (Department of Fisheries, Western Australia) for many useful comments on earlier drafts of this report. We also thank Phil Unsworth and Shirree Burton for sourcing information for the model.

Much of the recent biological knowledge about the potential for western rock lobster growout, which has been used in an indirect way in this study, has been gained from research funded by the Fisheries Research and Development Corporation through its Rock Lobster Enhancement and Aquaculture Subprogram.

1.0 Introduction

Western rock lobster (*Panulirus cygnus*) is only found on the west coast of Australia. It has been fished commercially since soon after European colonisation, but catches were not large until after the Second World War, when good export markets developed (Phillips et al. 2002). Landings in the fishery fluctuate from year to year with the species' variable recruitment, but annual catches have been within the range of about 8000 to 14000 t since the 1980s (Phillips and Melville-Smith 2006). The fishery is recognised as being well managed and in 2000 was the first fishery in the world to receive Marine Stewardship Council certification.

Although the commercial wild-capture fishery is currently ecologically sustainable and profitable, a report by the Department of Fisheries, Western Australia, (Department of Fisheries 2006a) predicted there are likely to be unprecedented economic challenges in the future due to rising costs (e.g. fuel, bait and labour) and lower lobster prices in real terms for the catch. The report stated there is limited scope for landings to increase without compromising the sustainability of the fishery, but noted that bio-economic modelling has provided possibilities for fishers to become more efficient and thereby reduce costs. A flow-on from this process would be a reduction in direct and indirect employment opportunities in the industry.

A possible means of achieving both an increase in the overall production of the fishery while providing employment opportunities to rural coastal towns could be by harvesting and growing pueruli on to marketable size. The idea is not new. Chittleborough (1974a) first recognised and proposed the potential for capturing and growing out western rock lobster pueruli in the 1970s. His ideas were followed up in the 1980s by Phillips (1985) and in greater depth in the 1990s by Meagher (1994). Meagher (1994) concluded, that a hypothetical commercial-sized farm producing 1000 t per year, based on reasonably conservative operating parameters, would be likely to produce a return on investment of 24.5%. However, despite this positive forecast, the idea was not taken up by investors.

Since Meagher (1994), research funded through the Fisheries Research and Development Corporation's Rock Lobster Enhancement and Aquaculture Subprogram, has examined the potential for catching western rock lobster pueruli for on-growing (Phillips et al. 2001, 2003a), harvesting pueruli in a biologically neutral way (Phillips et al. 2003a, 2003b), on-growing juveniles (Johnston et al. 2006, in press a, in press b) and the development of growout diets (Glencross et al. 2001; Johnston et al. in press a, in press b).

The mortality rates of juvenile rock lobsters are considered to be high. Mortality rates for juvenile *Panulirus argus* in the Florida fishery were reported to be between 96 and 99% in the first year after settlement (Herrnkind and Butler 1994). Similarly, model estimates of mortality in the first year after settlement in one area of the western rock lobster fishery were as high as 97–98% down to 80–84%, with only between 0.9 and 6.4% of settled pueruli surviving from settlement to entry into the commercial fishery 3.5 years later (Phillips et al. 2003).

The capture and on-growing of pueruli has much appeal, because, given these very high mortality rates of juvenile animals, harvesting pueruli for aquaculture would have minimal impact on wild-capture fisheries (Phillips et al. 2003). The harvesting of pueruli could therefore take place in combination with wild capture fishing and in so doing would use the resource more efficiently, by turning excess settlement into additional production.

Note that it is not an objective of this report to examine this hypothesis further, nor do we believe there is sufficient information currently available to infer the profitability of

growing out western rock lobster pueruli. With our present state of knowledge, there are many uncertainties in the establishment of a growout farm, the costs of acquiring the seed stock and the growing out and marketing of the farmed product. The objective of this report to identify which parameters, in a hypothetical western rock lobster puerulus growout farm, are likely to have the greatest impact on the profitability of such an operation. It is hoped that it will assist both researchers and potential investors by pointing to the most important profitability drivers for consideration in future research. This report does not attempt to forecast the economic potential of growing out western rock lobster pueruli.

2.0 Methods

2.1 Modelling financial viability

The model upon which this work is based is a modified version of profit models written for other aquaculture industries by Bill Johnston (e.g. for the barramundi and prawn farming industries). The model is in Microsoft EXCEL. Data upon which decisions relating to the profitability of an operation are based are entered into a series of worksheets that cover a description of the farm, the juvenile on-growing operation, the actual growout operation, labour requirements, capital requirements and other components of the farming operation (Appendix A). Not all of the capabilities of the model have been utilised in this report.

2.2 Hypothetical puerulus growout farm specifications

Currently there are no rock lobster aquaculture growout operations in Australia to use as a template for an operating farm. We have therefore had to envisage how and where such a farm might work, based on the substantial amount of information available on the biology and potential for growout of western rock lobsters supplemented with information on other aquaculture enterprises (such as abalone farming). That information, together with the knowledge of the way that growout facilities for other species operate, has provided a model farm which has then been used to explore the sensitivities of changes to its production parameters.

2.2.1 Managing water temperatures

The hypothetical farm is based on a flow-through system located close to the sea, in an area where temperatures are optimal for the growth and survival of western rock lobster. Chittleborough (1975) has shown that the growth rates of western rock lobster increase with temperature to a maximum of 26°C. The water temperature and consequent size/weight-at-age relationships in this modeled situation (Table 1) have been based on those obtained at 23°C in an experimental long-term growout trial (Melville-Smith et al. 2007).

The growout farm in this model has been assumed to be in an area where water temperature is at a constant 23°C year-round. The reason for this is that the best information on growth rates of cultured western rock lobsters fed on artificial diets is from a study in which the animals were held at 23°C (Melville-Smith et al. 2007).

It is possible to keep water at a constant temperature year-round. However, the systems for heating or chilling the water would be prohibitively expensive, so we have assumed that variations in temperature could be overcome at no cost either in the form of heating or chilling or in the form of production losses. Chittleborough (1975) showed that growth is almost linearly related to temperature up to a peak close to 26°C, above which it becomes depressed. The assumptions for growth may therefore be realistic for a farm experiencing a temperature range that includes some of the higher-growth temperatures close to 26°C, as well as some of the lower-growth ones below 23°C. On this basis, the assumption of no-cost water-temperature variations is reasonable, provided the growout facility is at an appropriate site along the west coast of Western Australia and that cost-neutral measures can be adopted to manage extremes in climate, if they occur.

2.2.2 Pueruli

Peak settlement for western rock lobster is from September to November (Caputi et al. 1995); most of the pueruli harvested could be expected to be collected over those months. Post-pueruli can be stocked at much higher densities than juveniles one or two years after settlement (Johnston et al. 2006), so we assumed the pueruli would be ongrown for 12 months in "juvenile raceways", at a stocking density of 50 per m^2 (Table 1).

2.2.3 Juveniles

The model assumes that 180 juvenile raceways (each 1.8 x 15 x 0.3 m holding 8.10 m^3 of water) (Table 1). The number of pueruli that would be required to achieve the proposed stocking density is 243,000. Western rock lobsters of all sizes are tolerant of high levels of ammonia (Crear and Forteath 2002; Melville-Smith et al. in press) and the 5% per hour exchange rates in the hypothetical farm are well within flow rates that are safe at a far higher stocking density than has been proposed here (Melville-Smith et al. in press). The proposed exchange rates would require 420 megalitres of water to be pumped through the juvenile raceways per year (Table 1).

2.2.4 Juveniles (age 12 months) in growout raceways

2.2.4.1 Raceways

At 12 months or ~100 g (Melville-Smith et al. in press), the juveniles in this hypothetical farm would be transferred into growout raceways, where they would remain until harvesting. Stocking densities during this phase have been set at 24 per m^2, which provides acceptable levels of survival and growth for juvenile western rock lobsters held under growout conditions (Johnston et al. 2006). In the baseline situation (Table 1), it has been assumed that survival in the juvenile phase (first 12 months) would be 80% and that therefore 300 growout tanks similar in size to those for juvenile raceways, would be required for growout. Exchange rates of 1% per hour have been proposed in the growout tanks, which would require the pumping of 213 megalitres of water per year (Table 1).

The length of time that the lobsters might be held in the growout raceways is dependent on the size/age at which they are to be marketed. Although other size/ages at marketing have been considered in the scenarios examined, the size chosen in the baseline situation has been 250 g, which according to Melville-Smith et al. (in press), corresponds to a 2-year post-settlement lobster at 23°C. This therefore means that the juvenile animals would have been held in the growout raceways for 12 months (Table 1) i.e. a total of about 24 months since collection as pueruli.

2.2.4.2 Shelters

The provision of shelters is vital to achieving good survival of rock lobster held in growout conditions (Crear et al. 2000; James et al. 2001). For the hypothetical farm, it is proposed to use rigid plastic shelters of the size and style described in Johnston et al. (2006). Shelters, which could be much larger for the lobsters in the growout raceways, have been allocated at a ratio of one for every five juveniles and 10 growout-sized lobsters (Table 1). In the baseline situation, the juvenile and growout raceways would require 48,600 shelters and 19,440 shelters respectively. The cost of these shelters is based on past experience in their construction (Johnston et al. 2006) and is considered to be reliable.

2.2.4.3 Time and survival rates to marketable size

In western rock lobster growout trials to date, survival rates have been variable. To a large degree this reflects the infancy of this work, for survival rates have improved substantially in each new research growout trial. In the most recent, the cumulative survival of both sexes to a legal size of 360 g was ~35% (Melville-Smith et al. in press). There is no question that experience from these growout trials, combined with size grading to reduce cannibalism (which was not done in Melville-Smith et al. (in press)), would substantially improve survival rates. Accordingly, for the baseline case in the hypothetical farm, we have assumed 80% survival of juveniles in the first 12 months, followed by 80% survival in the next 12 months to when market size is achieved (Table 1). The cumulative rate has therefore been assumed to be 64%. The sensitivity of survival rates to estimates of the profitability of the farm has been considered in scenarios in which higher and lower survival rates have been used.

2.2.4.4 Feed

Research to date has shown that, although the pellet feeds developed for *Panulirus ornatus* produce optimal growth rates in that species (Smith et al. 2005), they do not optimise growth rates in *Panulirus cygnus* (Johnston et al. in press b). Currently, a combination of pellet feed and mussel gives the best rates for western rock lobster (Johnston et al. in press b). Providing mussels in the diet is expensive and labour-intensive, so is not considered a long-term solution. Accordingly, in this financial analysis we have assumed that a future pellet diet will produce growth rates comparable to those achieved to date by the pellet-mussel combination. We have used feed conversion ratios (FCRs) of 1.5 for early post-pueruli and 1.3 for juveniles (Table 1). These FCR values are close to those reported for pellet diets developed for *P. ornatus* (Smith et al. 2005) and to the pellet component of the mussel-pellet diet reported in Johnston et al. (in press b).

2.2.4.5 Staffing

We calculated that the farm could operate efficiently with a full-time manager, a skilled worker and two labourers, as well as three casual labourers employed for three months each per year during peak work periods. This assumption, which may not be realistic, is based on other crustacean aquaculture farms.

2.3 Capital budgeting analysis

Discounted cash-flow analysis has been used to determine the annual cost of production and the likely profitability of the hypothetical growout operation. This process uses an interest or "discount rate", which has been assumed to be 15%, 25% and 35% in three separate scenarios, to discount future cash flows to their present value and thereby produce a single figure known as the net present value (NPV) of the project. These discount rates were adopted on the advice of Aquaculture Development Council members who have experience in investing in aquaculture projects (e.g. Russell Burnett, Australian Venture Consultants Pty Ltd, West Perth; Murray Konarik, Cell Aquaculture Ltd., South Fremantle). The rates reflect a high perception of inherent risk in the project (comparible to the rates used for risky small business ventures and resources-sector investments). As an indication of the degree of risk, returns to the wild-capture fishing sector are generally expected to be lower than 15%. The project has been considered over a 10-year timeline, again on the advice of ADC members, and the project budget has incorporated the initial capital and establishment costs.

The NPV is the difference between the present value of cash inflows and the present value of revenue outflows over the life of the project. The usefulness of NPV is that it provides an estimate of the scale of profits generated over the life of the project.

In this report NPV has also been annualised (known as the "equivalent annual return") to better gauge the expected annual returns.

The internal rate of return (IRR) is another useful measure of financial performance; it calculates the break-even discount rate. In other words, this is an estimate of the discount rate that would result in a NPV of zero, and is therefore the expected return generated by the investment. Where the estimate is positive, it can provide a different perspective to that of NPV on the project's financial viability. However, the IRR becomes meaningless if the estimated financial benefits are outweighed by the costs.

The final indicator of project profitability used in this report is a benefit : cost ratio. A benefit : cost ratio is the ratio of the present value of benefits to the present value of costs. If a project is potentially worthwhile, the ratio is greater than 1 (i.e. benefits exceed costs). This is a useful indicator of the scale of returns relative to the total investment made.

2.4 Cash outflows

The financial data for the farm have been considered in terms of cash outflow (capital and operating costs) and cash inflow (yield and market price). The way these have been dealt with is outlined below.

2.4.1 Capital costs

Capital costs have been considered in the model under land, and (separately) infrastructure and equipment, vehicles and machinery.

2.4.1.1 Land

It is calculated that raceways would occupy 12,960 m^2 in the modeled farm. Space for walkways and sheds would occupy a similar amount of space, so that the total farm would need to occupy in the order of 2 ha. It is envisaged that, because of water-temperature considerations, the farm would have to be in the central to northwestern part of Western Australia. This region is underpopulated and has poor potential for land-based farming. In keeping with these specifications, the land necessary for this farm was considered to be worth $200,000 (a figure considered realistic by Coralie Waterford, Realtor and Specialist Property Manager, Ray White Real Estate, Shark Bay, WA). One hundred percent of the value of the land would be recoverable at the end of the project.

2.4.1.2 Infrastructure and equipment, vehicles and machinery

Equipment and infrastructure required for the model farm are listed in Table 2, with estimates of their replacement lifespan. Costs of replacement have been assumed in the model to be the price of the new item, less the salvage or trade-in value of the item being replaced. Initial startup costs have been estimated as $1,474,980.

Estimates for electricity connection ($275,000) obtained from Mr Alan Porter, Horizon Energy, Karratha, WA, were based on connection costs in the Burrup Peninsula in northwestern Western Australia. The estimate included pump transformers, an electricity current transformer board and connection to an end user 3 km from the main electricity supply line.

Estimates for water-monitoring equipment ($50,000) were obtained from Mr John Wilson, Embedded Technologies, Bentley, WA, and pumps from Mr Ivan Lightbody, Department of Fisheries, Research Division, Hillarys, WA.

No processing equipment, such as scales, ice-making machines and cookers are included in the budget because, for the purposes of this model, it has been considered that the product would be on-sold to a processing company (which also obviated the need to estimate transport costs to the markets).

2.4.2 Operating costs

Operating costs, which incorporate the variable and fixed costs of the enterprise, including owner/operator and labour, are considered under separate headings and are tabulated in Table 3.

2.4.2.1 Purchase of pueruli

The number of pueruli required each year to stock the farm is calculated to be 243,000. In the baseline situation, pueruli have been costed at $0.50 each (total cost $121,500, Table 3). It is assumed that the task of collecting pueruli from the wild would be undertaken by appropriately authorised commercial fishers using cheap commercial-scale collectors and existing capital equipment such as a boat, with collection effort probably taking a few weeks each year. Collection would be only part of the fisher's overall operations.

2.4.2.2 Compensation for puerulus removal

Policy on the allocation of pueruli for ongrowing is currently being developed (WA Department of Fisheries 2006b). One option being considered, is to make the removal of pueruli a neutral process in terms of its impact on future egg production by removing an agreed number of pots from the wild-capture fishery. Calculations aimed at achieving biological neutrality have been made for one part of the fishery (Phillips et al. 2003). That research found that the number of pueruli that could be removed per unfished pot while still achieving biological neutrality is variable, depending on the strength of that year's settlement and the area on the coast from which the harvest is taken.

The pueruli-to-pot compensation that has been used throughout this study is that one pot needs to be removed from the fishery to compensate for the removal of 40,000 pueruli. Based on this conversion ratio, seven pots would be required to be removed to allow for the harvest of 243,000 pueruli. Current lease costs per pot (2006) are around $1,500 p.a., or $10,500 p.a. for seven pots (Table 3).

2.4.2.3 Feed

The total estimated amount of food consumed by lobsters grown out in the baseline scenario is 29,014 kg in the juvenile phase and 50,544 kg in the growout phase. Feed costs have been budgeted at $2.00 per kg (the cost per kg of pelletised feed is based on past experience in its manufacture (Johnston et al. 2006) and is considered to be reliable), putting the cost of feeding the animals for the two-year growout period at $159,116. (These feed values assume that a viable low-cost diet suitable for western rock lobsters will have been developed. At present experimental feed costs are higher because the tropical rock lobster diet used in growout trials has had to be supplemented with fresh mussels).

2.4.2.4 Labour

The labour force has been costed as the farm manager ($100,000 p.a.), a skilled worker ($120,000 p.a.), 2 labourers (total $62,400 p.a.) and 3 casual employees for 3 months each ($1,300 p.w.). In addition to salaries, allowances have been made for workers' compensation (5% of wages), superannuation contribution (9%), leave loading (17.5%) and training (2%). The total annual wage bill is $506,712. The cost of hiring appropriately skilled staff for a hypothetical aquaculture farm in rural central Western Australia was estimated after discussions with Mr Peter Purchas, ORD Group Pty Ltd. West Perth, WA. The assumed salaries reflect the inflated salaries that are currently being paid in this part of the country as a result of the boom in the mining sector.

2.4.2.5 Electricity

The farm has been allocated an annual budget for electricity of $100,000, excluding the costs of pumping water through the raceways. To achieve adequate flow rates through the raceways would require an estimated flow rate of 632.8 megalitres p.a. (Table 1). The electricity costs for pumping that volume of water are estimated at $10 per megalitre, which adds $8,427 to the electricity budget, bringing the total budgeted cost to $108,427 p.a. These costings have been estimated from the electricity rates paid by an abalone farm in Australia (confidentiality prevents disclosure of its name and location). Pumping costs for a rock lobster growout operation are far lower than for an abalone farm, which needs a higher volume of water pumped through.

2.4.2.6 Fuel, oil, repairs and maintenance

An annual budget of $20,000 has been set aside for fuel and oil and a further $70,000 for repairs and maintenance.

2.4.2.7 Incidental operating expenses

Several items have been incorporated under this heading. These include budgeted annual expenses for accounting and legal fees ($10,000), unspecified administration ($10,000), telephone ($3,000), travel ($6,000), vehicle registration ($1,000), vehicle insurance ($1,500), other insurance ($5,000), aquaculture licences and permits ($500), chemicals ($1,300), consultancy fees ($15,000), subscriptions and IT expenses ($3,000) and security ($5,000). The total budget cost for these items is $67,300.

2.4.2.8 Contingency expenses

It is recognised that costs are more likely to be under-than over-budgeted, given that it is hard to foresee some of the adverse eventualities that are inevitable in a project of this size. Accordingly, an amount of $80,000, which is approximately 8% of operational costs, has been set aside for unforeseen contingencies.

2.5 Cash inflows

The two components used to calculate cash inflows in the modeled farm are yield and the selling price of the product.

2.5.1 Yield

There is considerable uncertainty around the estimate of the likely annual yield from the farm. For example, it is not possible to estimate losses that might occur due to water-quality problems or unusually adverse environmental conditions. It is also not clear how a low puerulus settlement year might affect the financial viability of catching the pueruli required. Mortality rates and growth rates are also vitally important assumptions that affect the final yield. In this assessment, it is assumed that the growout from the juvenile stage to a marketable size can occur within 24 months. Similarly, it is assumed that growout from puerulus to juvenile stage can occur within 12 months, with total production being achieved within two years. Any extension beyond these times would have a negative impact on production.

2.5.2 Price and size/weight at marketing

The value of an aquacultured western rock lobster corresponding to 76 mm carapace length or ~360 g, which is the minimum legal size in the wild-capture fishery, could be assumed to be similar to the price paid for wild product. The beach price for wild captured lobsters varies within and between years, depending on the availability of product, but over the last decade the price paid each season has generally been in the order of $20 to $30 per kg (Department of Fisheries, Western Australia, unpub. data). It could be assumed that growout product would be marketed at a time of year when there is little or no wild product available and that aquacultured product might therefore be able to achieve similar, or higher, prices.

The relative stability in the beach price of wild-captured lobsters provides some comfort for price assumptions based on a 10-year average beach price, which is $27 per kg (after adjustments for inflation) (Neil Thomson unpub. data). However, there is far less certainty in the price assumption if the lobsters were to be marketed below the legal minimum size for the wild-capture fishery. This possibility has not been considered before because the industry is currently based on wild-caught product. However, lobster marketers who were consulted, were divided as to what price might be attained. The consensus was that the price for lobsters smaller than 360 g would be marginally lower to around 200–250 g, with a considerably lower price for smaller lobsters. It was pointed out, however, that there might be niche boutique markets for small lobsters – particularly for the Japanese wedding market – which might lead to them achieving a premium price.

In the baseline scenarios that have been modeled, a standard market price of $25 per kg was selected, with a sensitivity upper and lower range of $30 and $20. However, a farm might be able to achieve higher prices by marketing its own product rather than selling to a processor at beach price. Although the model can factor in process, packaging, market and freight costs, this capability was not utilised.

2.6 Modelling different growout scenarios

Having established the specifications for a hypothetical puerulus growout farm and estimated its a budget, it has been possible to explore the importance of different production parameters in driving the costs of the farm.

The first step was to establish the economic indicators for a baseline farming operation (Table 4). Then, by keeping the number of pueruli that are grown out constant, and varying different production parameters one at a time (see scenario columns 1 and 2 in Table 4) and re-running the model, it was possible to explore the sensitivities of those parameters to variations, in terms of the financial viability of the hypothetical growout operation.

In all cases, the sensitivity of a particular parameter was analysed by varying the baseline parameter by what are considered to be realistic values above and below the value given to the parameter in the model.

Note that in the model, gross revenue is calculated by averaging annual production over the 10-year life of the project, multiplied by the price per kg of lobsters sold. The three growout scenarios modeled have no production in the first year, and in one scenario (growing out lobsters for 2.5 years to 350 g), there are other years without production. By including these years of no production in calculating the average production over 10 years, gross annual revenue is lower than it would have been had the less-realistic approach of omitting these years been taken.

Table 1. Summary of specifications and assumptions of a hypothetical western rock lobster growout production facility for the baseline growout situation used in this report.

Specifications	Juvenile nursery	Growout
Facility		
Size of tanks	1.8 x 15 m by 0.3 m deep	1.8 x 15 m by 0.3 m deep
Volume of tanks (m^3)	8.10	8.10
Flow rate (l per day)	1,749, 600	583,200
Lobsters		
Weight at start (g)	0.5	100
Period grown (months)	12	12
Weight at harvest (g)	100	250
Stocking density (n/m^2)	50	25.5
Survival rates (%)	80	80
Animals per shelter	5	10
Feed cost ($/kg)	2	2
Feed conversion rate	1.5	1.3
Pueruli to pot ratio	40,000:1	
Price per puerulus ($)	0.5	
Price per kg of lobsters sold		$25

Table 2. Capital costs of a hypothetical western rock lobster growout production facility.

Item	New value ($)	Life (years)	Salvage value (%)
Land	200,000	10	100
Storage sheds	200,000	10	40
Staff accommodation	100,000	10	60
Electricity connection	275,000	10	100
Raceways	240,000	10	0
Piping and infrastructure	48,000	10	0
Generator	50,000	10	0
Pumps	150,000	10	0
Feeding equipment	500	5	0
Water-monitoring equipment	50,000	5	0
Harvesting equipment	1,000	1	0
Air blower	3,000	10	0
Workshop tools	10,000	10	50
Growout shelters ($2 ea.)	38,880	5	0
Juvenile shelters ($1 ea.)	48,600	5	0
Utility vehicle	30,000	10	50
Four-wheeler vehicle	10,000	5	20
Other capital items	20,000	10	0
Total	1,474,980		

Table 3. Operational costs (baseline) of a hypothetical western rock lobster growout production facility.

Item	Annual cost ($)
Puerulus costs (@$0.50 each)	121,500
Pueruli to pot compensation (40 000:1)	10,500
Feed cost (@$2/kg)	124,124
Electricity	108,427
Fuel, oil, repairs and maintenance	90,000
Incidental expenses	67,300
Contingency factor	80,000
Casual workers (3 for 3 months)	54,288
Skilled worker (1)	160,152
Labourers (2)	166,608
Farm manager (1)	133,495
Total	1,105,894

Table 4. Model parameters and ranges outside of the baseline scenario that were used to model the sensitivity of western rock lobster puerulus growout to parameter changes (scenario 1 = growout period 1.5 years; baseline = growout period 2 years; scenario 3 = growout period 2.5 years).

Sensitivity range Parameters	Scenario 1	Baseline	Scenario 2
Growout period to harvest	1.5 years	2 years	2.5 years
Size to harvest	150 g	250 g	350 g/2.5
Feed cost ($ per kg)	$1 per kg	$2 per kg	$3 per kg
Market price ($ per kg)	$20 per kg	$25 per kg	$30 per kg
Puerulus price ($ each)	$0.20	$0.50	$1.00
Survival rates (% cumulative over two years)	49	64	81
Puerulus compensation cost	1 pot=10,000 pueruli	1 pot= 40,000 pueruli	No compensation
Labour cost (per annum)	$431,239 (1 labourer less)	$514,543	$597,847 (1 labourer more)
Discount rate	15%	25%	35%

2.7 Assessing profitability

As noted at the outset, there is insufficient information to establish the profitability of western rock lobster growout with any certainty. To investigate the range of uncertainty in estimating profitability, we used the production parameters in Table 4 that predicted the most optimistic and pessimistic profitability results, in two separate model runs. The actual parameters used in the two modelling scenarios are shown in Table 5. The results of the two runs were then each bootstrapped over 1,000 iterations to produce a risk analysis of the percentage that a hypothetical farm, using the parameters chosen, would be likely to succeed or fail.

Table 5. Model parameters and ranges outside of the baseline scenario that were used to model the sensitivity of western rock lobster puerulus growout to parameter changes.

Parameters	Optimistic scenario	Pessimistic scenario
Size and growout period to harvest	250 g/2 years	350 g/2.5 years
Feed cost ($ per kg)	$1 per kg	$3 per kg
Market price ($ per kg)	$30 per kg	$20 per kg
Puerulus price ($ each)	$0.20	$1.00
Survival rates (%)	81	49
Puerulus compensation cost	No compensation	1 pot=10,000 pueruli
Labour cost (per annum)	$431,239 (1 labourer less)	$597,847 (1 labourer more)
Discount rate	15%	35%
Capital expenditure	$764,220 (50% of baseline)	$2,229,480 (150% of baseline)

3.0 Results

The data entry interface for the model and its reporting worksheets are shown in Appendix A. The actual examples displayed are those for the baseline situation. Note that the cells are colour-coded; the yellow cells are data-entry cells that enable the user to change the input data at will, while the red cells are data-secured (locked) cells, because they contain calculated answers.

Having established assumedbase line costs of setting up and stocking a hypothetical rock lobster growout operation, the model was used to explore the sensitivities of changing different parameters within a range of likely values. The parameter changed and its resulting outcome on the estimated indicator of the farm's profitability is summarised below. A table providing more detail on the model production parameters and summary statistics is given in Appendix B.

The parameter of internal rate of return could not be calculated for all but one of the scenarios examined below (the exception was survival rate). This indicated an internal rate of return below zero – that is, even with a discount rate of zero, the project would not provide a net benefit under the assumptions used. It has therefore been omitted in all the tables except Table 10.

3.1 Size at harvest

Key statistics relating to the production of western rock lobsters at different weights and growout time periods are shown in Table 6. When the lobsters are marketed at 150 and 250 g, it is possible to have an annual harvest without increasing the number of raceways on the farm (Fig. 1), because the juvenile and growout phases can be run simultaneously. At 350 g there are years when no production is possible. These constraints, together with the fact that the longer the growout period the lower the final number of animals surviving, result in a smaller annual production for longer growout periods (Table 6). This would particularly apply for growout periods longer than two years, because trials have shown that some western rock lobsters held under aquaculture conditions at 23°C have slower growth rates, maturing only in their third year (Melville-Smith in press).

In these scenarios the sale price of the product has been kept constant at $25 per kg so as not to confound the end result by changing too many parameters. However, in reality the smaller (150 g) and bigger (360 g) lobsters would be likely to reach lower and higher prices respectively (views expressed by processor company marketing specialists who wished to remain anonymous).

Economic indicators (Table 6) show the optimal growout period to be two years, during which time the lobsters are growing faster and increasing weight more rapidly than they do later. It is also it is possible to harvest animals each year without increasing the number of juvenile and growout tanks.

Table 6. Some key production parameters and economic indicators for a western rock lobster ongrowing operation, with lobsters marketed at three different weight and growout time periods

Production parameters	150 g; 1.5 years	250 g; 2 years	350 g; 2.5 years
Annual production (kg)	41,990	34,992	32,659
Production cost ($ per kg)	$42.42	$45.33	$45.80
Net present value	–$3,128,662	–$2,970,228	–$3,115,429
Annual return	–$876,252	–$831,879	–$872,546
Benefit : cost ratio	0.51	0.48	0.42

3.2 Feed cost

The total estimated amount of food consumed by juvenile lobsters in the baseline scenario is 29,014 kg and by lobsters in the growout phase is 50,544 kg (calculated from feed conversion ratios, survival rates and production figures).

The modeled economic indicators are moderately sensitive to what are quite large changes in the price of feed (Table 7). Overall production costs increased by around 5% for each $1.00 per kg rise in the price of feed over the current cost of laboratory-manufactured feed pellets.

Table 7. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at three different feed costs

Production parameters	Feed $1 per kg	Feed $2 per kg	Feed $3 per kg
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$43.19	$45.33	$47.46
Net present value	–$2,703,389	–$2,970,228	–$3,237,067
Annual return	–$757,145	–$831,879	–$906,614
Benefit : cost ratio	0.50	0.48	0.45

3.3 Market price

The modeled economic indicators are highly sensitive to the price at which the product is sold (Table 8). Selling the production at $30 per kg, produced one of the more optimistic (albeit-loss making) net present values and annual return of all the parameters tested (Table 8).

Table 8. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at three different sale prices.

Production parameters	Sold at $20 per kg	Sold at $25 per kg	Sold at $30 per kg
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$45.33	$45.33	$45.33
Net present value	–$3,508,814	–$2,970,228	–$2,431,643
Annual return	–$983,723	–$831,879	–$681,036
Benefit : cost ratio	0.38	0.48	0.57

3.4 Puerulus price

An increase in the price of a puerulus from $0.20 to $0.50 resulted in an increase in the production cost of a marketable-sized lobster of 6%, and the difference between a puerulus costing $0.50 and $1.00 added a further 9% to the production cost (Table 9). These, and other indicators such as the net present value and benefit : cost ratios (Table 9), show that the success or otherwise of a growout production facility will be moderately sensitive to the price of a puerulus. However that there is a large degree of uncertainty in the value of a puerulus caught for ongrowing; this is reflected in the 400% difference in puerulus price that has been used in the model scenarios.

Table 9. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at three different prices for pueruli sold for ongrowing.

Production parameters	Sold at $0.20 per puerulus	Sold at $0.50 per puerulus	Sold at $1.00 puerulus
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$42.78	$45.33	$49.58
Net present value	–$2,651,619	–$2,970,228	–$3,501,245
Annual return	–$742,646	–$831,879	–$980,603
Benefit : cost ratio	0.50	0.48	0.43

3.5 Survival rates

The survival rates used in the scenarios presented in Table 10 are the combined survival rates of the twelve-month juvenile and twelve-month growout phases (i.e. a 70, 80 and 90% survival rate in both the juvenile and growout phase results in an overall survival of 49, 64 and 81% respectively). The overall survival rate had a very profound influence on the economic indicators of a growout operation, with the percentage change in production cost being higher for each percentage point difference in survival rate (i.e. 24% for the 17% difference between 64 and 81% survival, and 28% for the 15% difference between 49 and 64% survival) (Table 10).

Although not presented, we have modeled the effects of keeping survival in the growout phase constant at 80% and varying the juvenile phase to 70 or 80%, or alternatively keeping the juvenile phase constant at 80% and varying the growout phase to 70 or 80%. Both these scenarios had a substantial influence on the economic indicators, though they were less influential than a reduction in the overall survival rate. In each case the difference between changing either the juvenile or growout phases to 70 or 90% resulted in the economic indicators changing by about half their change if both growout phases were adjusted.

Table 10. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at three different lobster survival rates.

Production parameters	49% survival	64% survival	81% survival
Annual production (kg)	26,791	34,992	44,287
Production cost ($ per kg)	$58.12	$45.33	$36.53
Net present value	–$3,497,589	–$2,970,228	–$2,367,465
Annual return	–$979,579	–$831,879	–$663,062
Internal rate of return	na.	na.	–12.70
Benefit : cost ratio	0.37	0.48	0.59

3.6 Puerulus compensation cost

Three different model scenarios were examined to test the impact on the bottom line of a growout operation if it has to lease pots from the wild-capture fishery to biologically compensate for the removal of pueruli. The scenarios examined used puerulus to pot conversion factors of 10,000 pueruli per pot, 40,000 pueruli per pot and no requirement for compensation. The cost of leasing a pot ($1,500 p.a.) has been applied.

The three scenarios show that the costs of leasing pots to compensate for puerulus removal have a relatively small influence on the profitability of the growout venture. Even the extreme difference between 1 pot requiring the removal of 10,000 pueruli compared to no compensation being required resulted in the production cost increasing by only 2% (Table 11).

Table 11. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at three different puerulus harvest compensation costs.

Production parameters	10,000 pueruli = 1 pot	40,000 pueruli = 1 pot	No compensation
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$46.10	$45.33	$45.07
Net present value	–$3,066,632	–$2,970,228	–$2,938,094
Annual return	–$858,879	–$831,879	–$822,879
Benefit : cost ratio	0.47	0.48	0.48

3.7 Labour cost

Increasing the labour costs (by adding a second full-time labourer) has a moderate effect on the financial outlook of the growout operation. Staffing differences examined in Table 12 resulted in production cost increasing by 5 to 6% for each additional labourer taken on staff.

Higher labour costs would be one of the potential threats to any operation being established in the State's Midwest. The current cost of labour in Western Australia in the north of the state is acknowledged as being very high because of the boom in the resources mining sector.

Table 12. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at different staffing levels.

Production parameters	1 labourer more	Baseline staffing	1 labourer less
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$47.71	$45.33	$42.95
Net present value	–$3,267,666	–$2,970,228	–$2,672,791
Annual return	–$915,183	–$831,879	–$748,575
Benefit : cost ratio	0.45	0.48	0.50

3.8 Capital expenditure

The effects of additional capital expenditure are shown in Table 13. Changing the cost of capital from the baseline situation ($1,474,980) by reducing it by 50% (scenario 1) and increasing it by 50% (scenario 2) resulted in production costs changing by 12.9% downwards and upwards respectively.

Table 13. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at different capital expenditures.

Production parameters	Capital x 0.5	Capital 1	Capital x 1.5
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$39.49	$45.33	$51.17
Net present value	–$2,240,585	–$2,970,228	–$3,699,872
Annual return	–$627,526	–$831,879	–$1,036233
Benefit ; cost ratio	0.55	0.48	0.42

3.9 Discount rate

The effects of a range of discount rates are shown in Table 14. As would be expected, economic indicators were very sensitive to discount rates, particularly as the range explored was so large.

The apparent inconsistencies of net present value estimates (i.e. whereby the net present value estimate at a 15% discount rate is less, for example, than at a 35% discount rate) was a result of inter-temporal variation in the sequence of costs and benefits. The reason for this outcome was that high discount rates combined with lumpy capital costs that resulted in only a small return when salvaged at the end of the project resulted in costs into the future being so devalued that they actually improved the net present value.

Table 14. Some key production parameters and economic indicators for a western rock lobster ongrowing operation at different discount rates.

Production parameters	Discount rate 15%	Discount rate 25%	Discount rate 35%
Annual production (kg)	34,992	34,992	34,992
Production cost ($ per kg)	$41.49	$45.33	$49.33
Net present value	–$3,253,616	–$2,970,228	–$2,767,339
Annual return	–$648,290	–$831,879	–$1,019,262
Benefit : cost ratio	0.55	0.48	0.41

3.10 General Assessment

The overall conclusion that can be drawn from changing different parameters in the financial model for a western rock lobster ongrowing operation, is that the economic indicators are very sensitive to most of the changes investigated. The effects on the net present value (NPV), of changing the baseline assumptions are presented in Figure 2. The steepness of the lines in Figure 2 indicates the sensitivity to change in the particular parameter being plotted. The length of the lines indicates the uncertainty around the limits of sensitivity of the parameter tested. In Figure 2 this is presented as a percentage of variation on the baseline assumption. Lines sloping upwards to the right indicate positive benefits to NPV for a higher percentage parameter value, while lines sloping upwards to the left indicate negative benefits to NPV for higher percentage parameter values.

It is clear from Figure 2 that NPV is most sensitive to changes in survival rates and market price, and is also very sensitive to changes in capital costs and assumed labour costs. The parameter with the widest limits (proportionally) as set in the sensitivity analysis was the assumption around the price of pueruli needed for on-growing. However, the financial potential of ongrowing lobsters was not particularly sensitive to the assumed prices of pueruli that were trialed.

3.11 Profitability Assessment

The results for model runs using the optimistic and pessimistic scenarios shown in Table 5 are presented in Table 15. Risk analysis showed that under the optimistic scenario, the farm would show a profit 100% of the time; conversely, under the pessimistic scenario, it would show a loss 100% of the time.

The optimistic scenario presented in Table 15 was the only occasion that the model produced a reportable internal rate of return. This was because the parameters used under this scenario were the only ones modeled that produced financial benefits that outweighed the costs of the growout operation.

Table 15. Some key production parameters and economic indicators for a western rock lobster ongrowing operation under optimistic and pessimistic scenarios.

Production parameters	Optimistic scenario	Pessimistic scenario
Annual production (kg)	40,682	19,084
Production cost ($ per kg)	$26.60	$100.11
Net present value	$693,308	–$5,458,713
Annual return	$138,143	–$1,528,836
Internal rate of return (%)	24.67	—
Benefit : cost ratio	1.13	0.20

4.0 Discussion

4.1 Assumptions in the model

Where possible, we have chosen the most robust estimates as assumptions in the financial assessment. However, due to the innovative nature of the proposal, there are many cases where such information has not been available, so it has been necessary to make assumptions without independent substantiation.

Some of these assumptions are clearly not representative, but we believe them to be adequate for the objectives of this report – that is, to identify the impact of changing parameters on the outcome. For example, Chittleborough (1975) showed that western rock lobsters grow fastest in warm water (he recorded similar growth rates at 23°C and 29°C, but peak growth at 26°C. In the model, we used growth rates recorded at 23°C and assumed the hypothetical farm had year-round water at this temperature. Clearly, no such situation could exists. Without adding the electricity costs of warming or chilling the water flowing through the system. Estimating these costs would have introduced another uncertainty, so it was not done.

In other cases, while the assumption might have been reasonable, other scenarios not tested could have a substantial influence on the result. For example, choice of the size of the farm could radically influence its viability, because capital costs (or fixed costs) and operational costs (or variable costs) tend to increase in different proportions with the size of the operation. As a result, the marginal cost of production varies over different scales of operation.

The main reason for standardising the size of the farm and number of pueruli to be grown out, was to avoid altering the input costs of many parameters. To have done that would have confounded the comparisons of different scenarios, especially as there is insufficient detailed knowledge of the true costs of many of the parameters that have been used. The development of whole-farm budgets for different-sized farms will be a more realisable goal in the future when more reliable data on production costs are available.

At the outset, the choice of an appropriate discount rate proved to be contentious. The range that has been tested (15 to 35%) was considered by some experts to be high. Aquaculture is acknowledged to be a high-risk investment and consequently investors would expect rates be well above 6% – 7%, which can currently be obtained in a risk-free environment. Despite the range of discount rates used reflecting the different risk considerations of different individuals, even the 15% rate proved to be too high a hurdle for the proposal to generate a positive return.

The results of this study should not deter industry from investigating the proposal further, given that there is still much to be understood about the parameters that drive the profitability of the proposal.

4.2 Future research and policy needs

This financial analysis, which has not taken into account any possible differences in price for different-sized animals, has nonetheless shown that the most financially viable option may be to market aquacultured product below the legal size limit for the wild-capture fishery. The reason for this is that harvesting at a smaller size would result in fewer "gap years" with no income than if the larger sizes were to be harvested annually (see Figure 1). Harvesting at small sizes also minimises the mortality that is inevitable when holding stock for a longer time. However, if the marketing of aquacultured western rock lobsters at small sizes is to be permitted in the future, changes to current legislation will be required. At present, all western rock lobster of less than 76 mm CL are totally protected fish under the *Fish Resources Management Act* 1994, thereby precluding the marketing of aquacultured western rock lobster at below the legal minimum size.

There will be a limit to how small a lobster aquaculture operations would want to market. Clearly, the selling price would have to change according to product size, but because western rock lobsters have not previously been marketed below the legal size limit there is currently no information on the market price for the smaller grades. There is information on the market value of small-sized wild-caught lobsters of other species, but they are generally marketed by third world countries where the quality of the product is not good. Since the market price of small grades is one of the most crucial factors in determining the profitability of a growout venture (Figure 2), the question of pricing small western rock lobsters will need to be answered in the future.

One of the concerns for any proponent of ongrowing rock lobsters should be how successful aquaculture production might affect the overall price of rock lobster. In other aquaculture experiences, success has almost invariably led to a decline in the real price of seafood, and future market prices may not be as optimistic as those modeled in this report, particularly if the recent success in producing pueruli (van Barneveld 2006) results in large-scale aquaculture operations in southeast Asian countries that have flourishing lobster growout industries, which are currently constrained by the supply of pueruli.

An equally important factor determining the potential economic success of a western rock lobster ongrowing venture is the survival rates of the animals (Figure 2). The only year-long growout study undertaken to date achieved survival rates at the lower end of those used in this financial evaluation (around 35–40%, Melville-Smith et al. in press). While we consider the higher survival rates in the model to be attainable with commercial systems, it is clear that optimising survival rates will need to be a future research priority.

Survival in the various modeled scenarios was 70%, 80% or 90% in the juvenile phase, with similar percentages in the growout phase. The same survival percentages were used when comparing growing the lobsters to 100 g, 250 g and 300 g, despite the growout phase being 6, 12 or 18 months in the three scenarios. Clearly, this assumption is incorrect and its shortcoming needs to be borne in mind when assessing the results, because it would have positively biased the profitability of growing out lobsters to larger sizes.

It has been assumed that lobsters grown to 100, 250 or 350 g would reach these sizes in 18, 24 or 30 months respectively. This would only be possible if all seed stock were harvested in the same month and reached the target weight at the same time. In reality, this would not occur; puerulus settle throughout the year (with a regular peak period in August to November) and growth rates in the tanks are variable, which would necessitate regular size-grading. While not strictly correct, the assumptions in this scenario would not be expected to radically alter the estimated outputs.

Whether the number of workers in this hypothetical farm is realistic is unknown. Too many workers for the size of the farm would inflate the cost of production in the same way as too few would result in an underestimate of the costs. However, the important fact is that labour costs have been kept constant in all baseline modeled scenarios and therefore the sensitivities of the various model runs are comparable with each other.

Labour was shown to be the biggest single expense in a western rock lobster growout operation, with costs in most of the scenarios examined ranging from $12 – $17 per kg of farmed lobster produced. There is a need for future research on ways to minimise these costs, such as by optimising the designs of the tanks or raceways to cut maintenance costs and automate the cleaning processes.

Although an optimal formulated feed has been developed for the tropical rock lobster *Panulirus ornatus* (Smith et al. 2005), that diet did not produce optimal growth in western rock lobsters in Johnston et al.'s (in press b) study. In western rock lobster growout trials that have been undertaken to date, it has been necessary to supplement the tropical rock lobster diet with fresh mussels to improve growth rates (Johnston et al. in press b). The addition of mussels to the feed costs would not be economically feasible for commercial operations (Johnston et al. in press b); it is therefore clear that developing a formulated feed suitable for growing out western rock lobsters must be a research priority. The fact that it has been possible to develop a nutritionally complete feed for tropical rock lobsters has justified our using the costs of that feed ($2.00 per kg) in this analysis and typical FCRs that have been obtained by tropical and western rock lobsters on the pellet diet. The financial analysis has shown that the potential profitability of a growout operation is less sensitive to the cost of feed than several other parameters (Figure 2). This is encouraging, because it provides some room for increase in future feed costs and FCR values in a future western rock lobster diet, without radically changing the economic impacts identified in this study.

Although inexpensive equipment has been developed to catch rock lobster pueruli (Phillips et al. 2003; Mills and Crear 2004), their harvesting has not as yet been undertaken on a commercial basis. In this financial evaluation, the cost of a puerulus for ongrowing has been given wide bounds. The profitability of a growout venture was found in our study to be moderately sensitive to the price of a puerulus; research into minimising the costs of collecting large numbers of pueruli should be a future research goal.

Compensating for the harvesting of pueruli by leasing pots could impact on profitability. Compensation arrangements are being considered in the policy to establish property rights to puerulus (Department of Fisheries 2006b).

In addition to what has been presented, we considered the possibilities of growing out pueruli in closed systems and cage culture. Closed systems would probably result in more costly infrastructure and more sophisticated management of their operation – neither of which seemed justified when compared to the open system used in the model. Cage culture could possibly be a more profitable method of operation, but it has many disadvantages: there is a scarcity of suitable sheltered surroundings in Western Australia; the potential for losses from predators such as turtles would require expensive exclusion arrangements; and management of the environment around the cages. For all of the above reasons, flow-through systems along the lines of those modeled appear to be the best economic prospects in the short-term.

4.3 Can a rock lobster growout venture be economically viable?

The growing out of tropical rock lobster pueruli (*Panulirus ornatus*) has been very successful in Vietnam, where an estimated 4,000 farmers and households were estimated to be producing 1,500 t p.a. in 2004, and where average profit margins at that time, were estimated at 50% (Tuan and Mao 2004). In 2005, Vietnam was reported to have produced 4,000 t of aquacultured lobster for export to China (van Barneveld 2006).

It is not clear whether growout of rock lobsters would be profitable in countries wehre labour costs are higher. The results of our study suggest there is considerable work to be done to improve the likely viability of the proposal by shifting the expected values of either benefit or cost parameters – where this is possible.

As noted previously, our study provides insight into the extent to which expectations around key parameters need to be altered to provide greater confidence in the likely profitability of growing out western rock lobster in Australia.

Aside from our study, the only other in-depth investigation into the profitability of a rock lobster on-growing venture in a first world environment was by Jeffs and Hooker (2000). That study, which considered a flow-through system similar to the one used in our study, found that the cost of producing *Jasus edwardsii* lobsters from pueruli was more than double the expected market return. *Jasus edwardsii*, a temperate species found in New Zealand and across southern Australia, is slower-growing than *P. cygnus*.

Uncertainty about inputs into a financial model preclude any firm assessment at this stage of the potential profitability of growing out western rock lobster from pueruli. However, the work has shown that profit margins in a western rock lobster growout venture will have to overcome the high labour and capital costs. Additionally, potential profitability would be greatly assisted if it becomes permissible to market lobsters grown out from pueruli to below the legal size limit. Finally, it is clear from the modelling work, that profitability of a western rock lobster growout venture will improve if research is successful in (i) developing methods of harvesting hundreds of thousands of pueruli more economically than is currently possible, (ii) developing a low-cost, high-growth, formulated feed for *Panulirus cygnus*, and (iii) optimising survival rates.

As greater certainty can be attached to cost and revenue assumptions, investors may be satisfied with lower discount rates when undertaking financial assessments. This poses a conundrum to advocates of investment because the application of higher discount rate hurdles reduces investor confidence, and may therefore reduce the appetite for further investigation. However, investigation is required to reduce uncertainty — which is why this study has focused on identifying parameters that have the greatest impact on the outcome.

5.0 References

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6.0 Figures

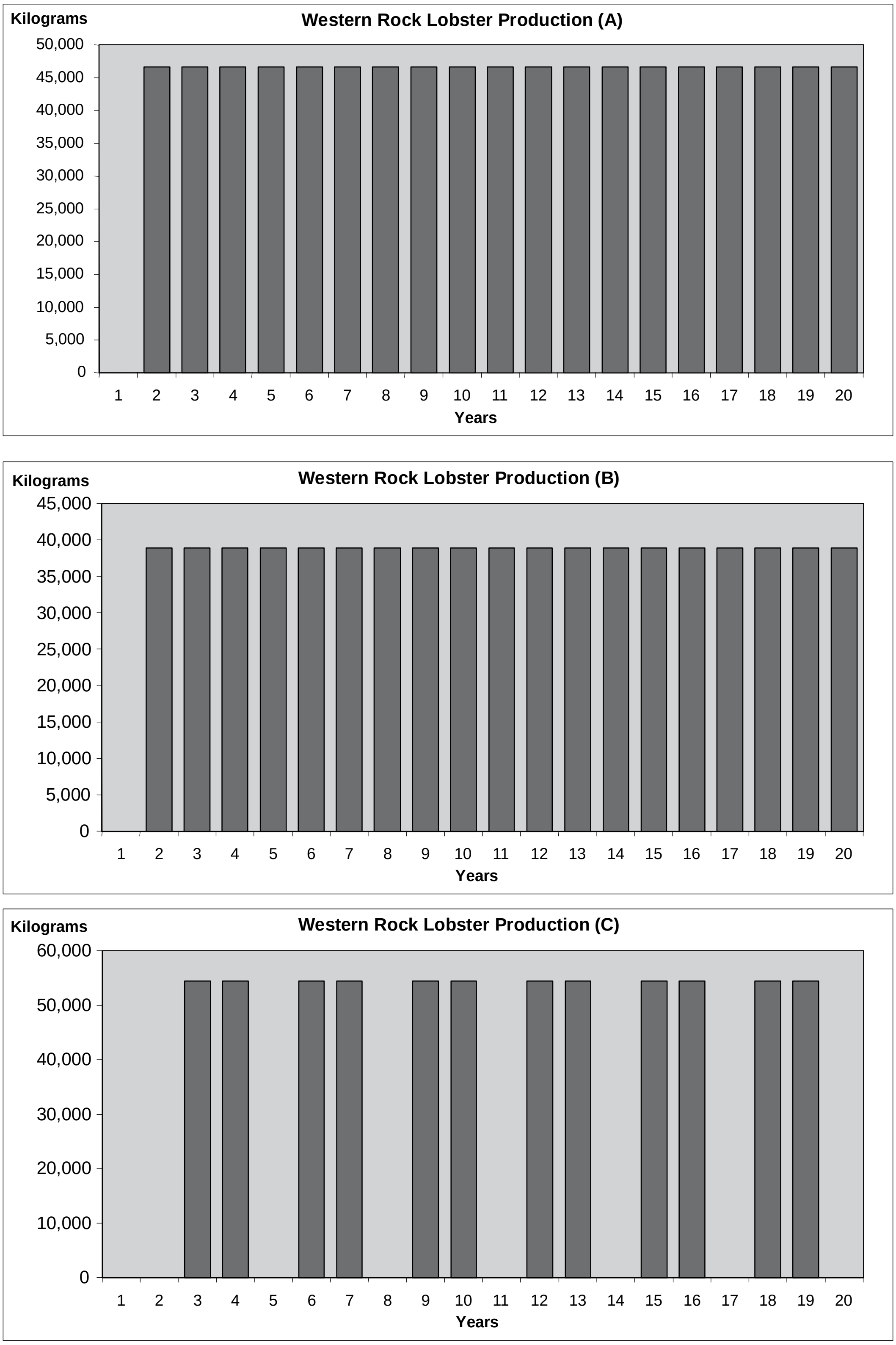

Figure 1. Graphical representation of expected production assuming that the pueruli are grown for (A) 18 months, (B) 24 months and (C) 30 months.

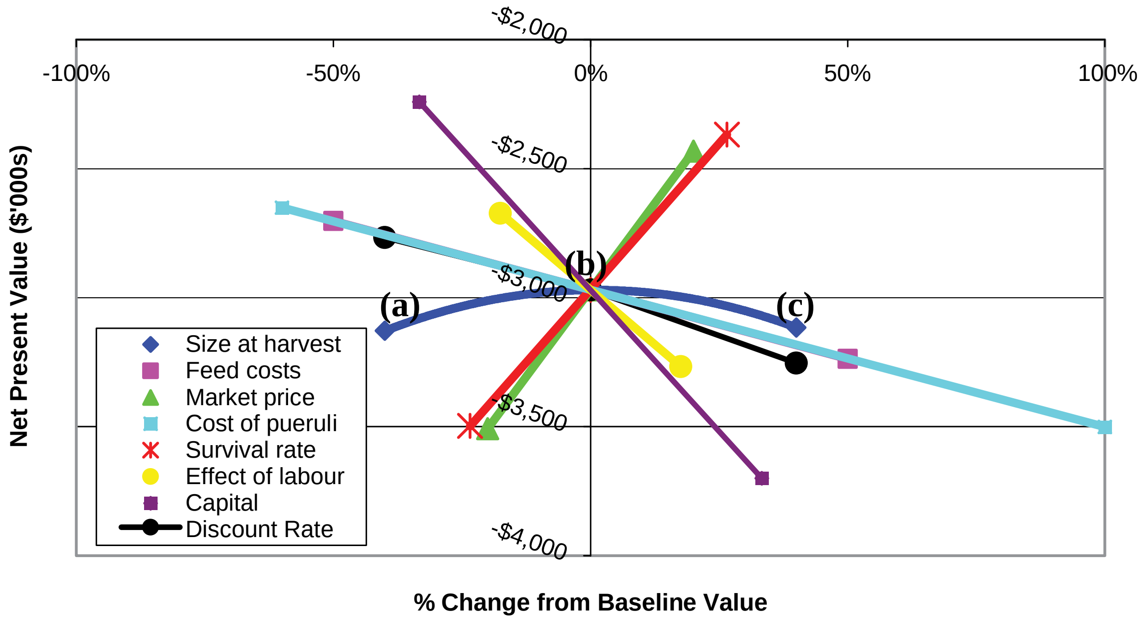

Figure 2. Modeled annual production from a hypothetical western rock lobster puerulus growout operation where the number of pueruli ongrown is similar each year in each scenario, the number of raceways is fixed and annual production is optimised. For harvest at (a) 1.5 years, (b) 2 years and (c) 2.5 years.

7.0 Appendicies

Appendix A Data entry interfaces and reporting worksheets of profit models for aquaculture industries (written by Bill Johnston)

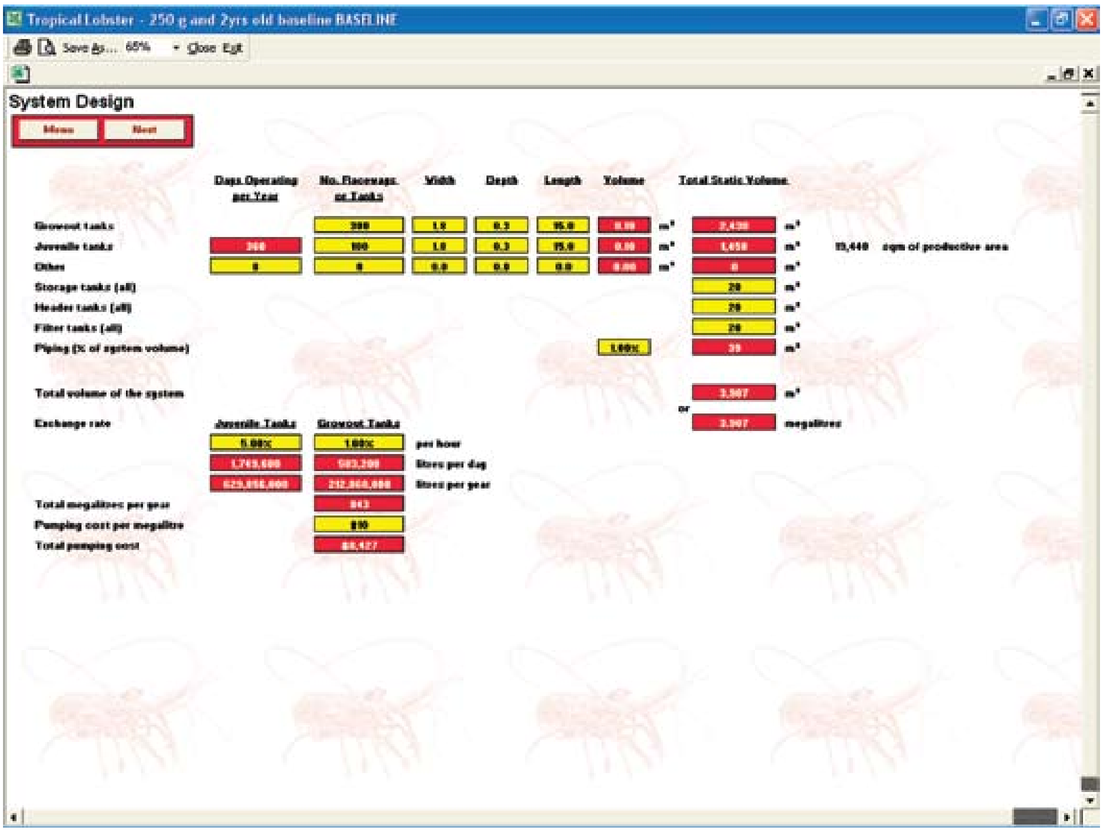

Figure 3. System design interface

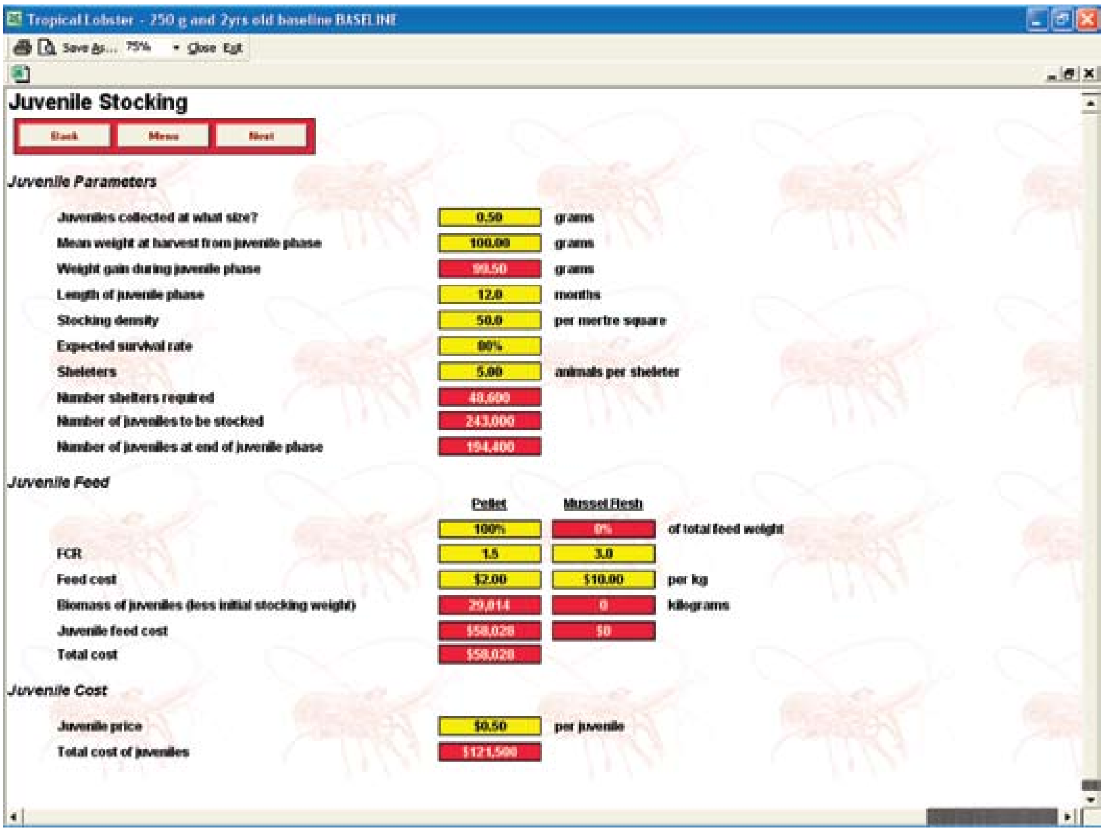

Figure 4. Juvenile phase interface

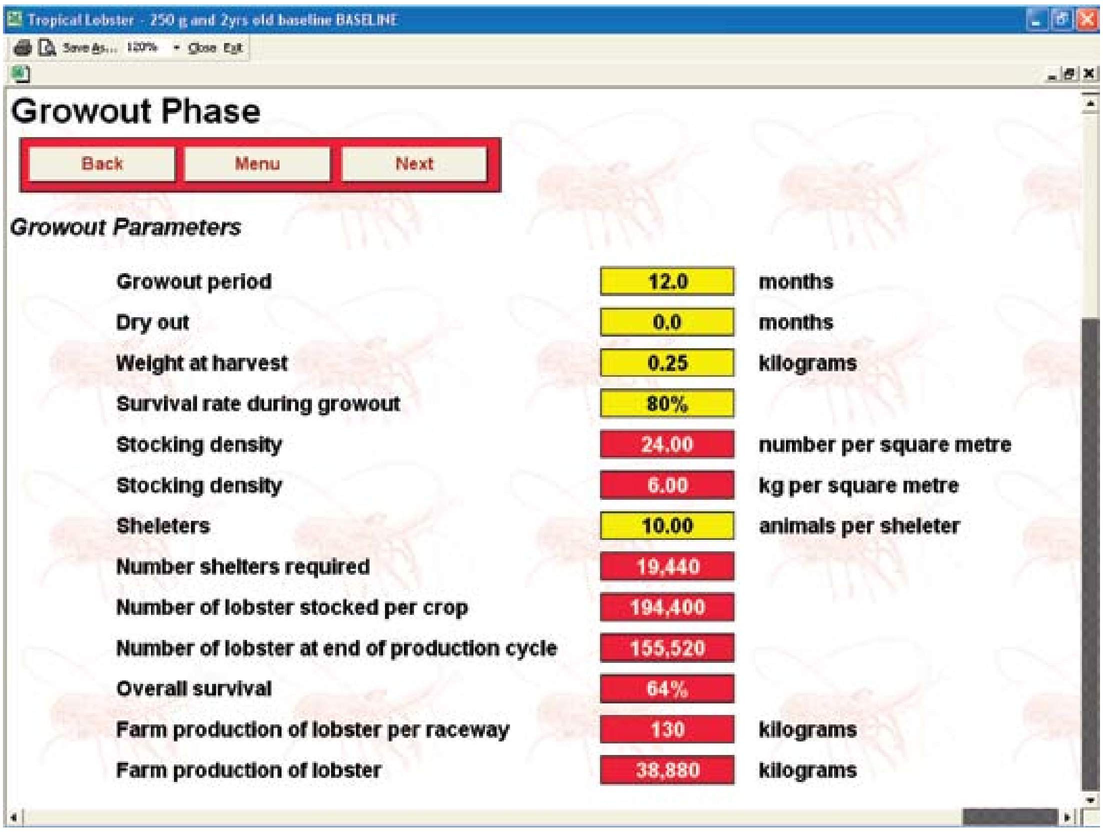

Figure 5. Growout phase interface

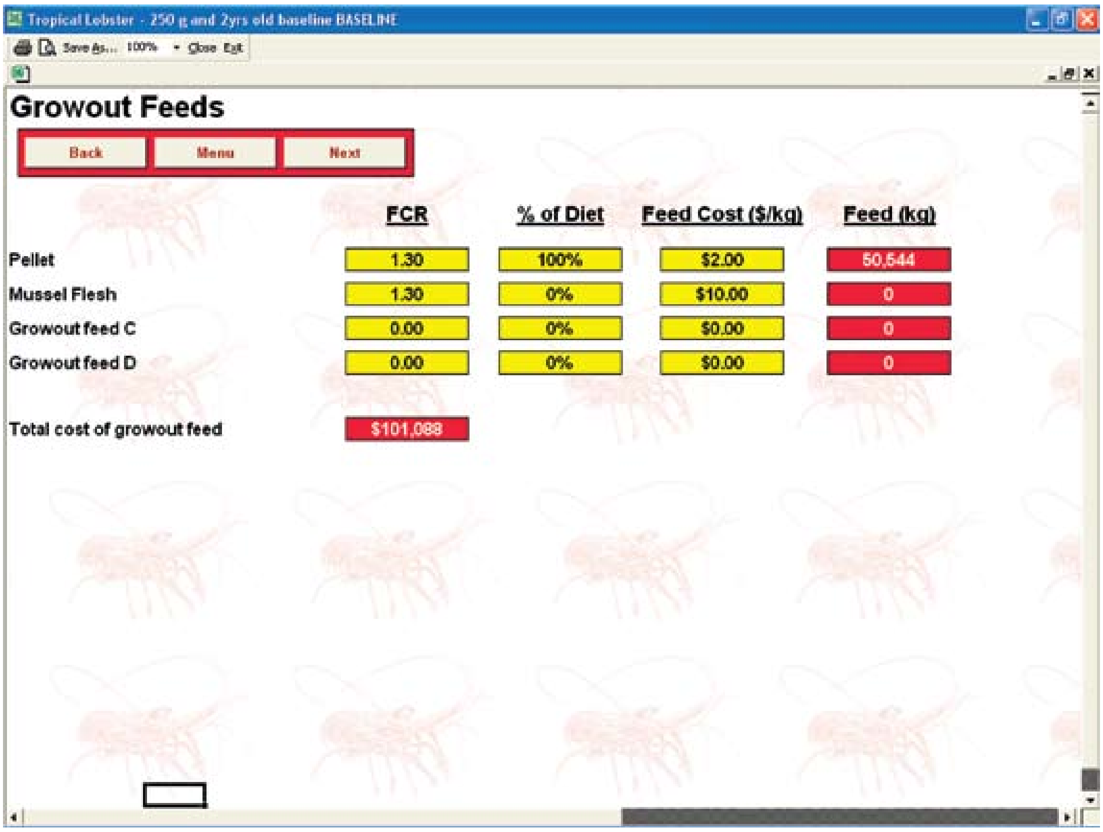

Figure 6. Growout feed interface

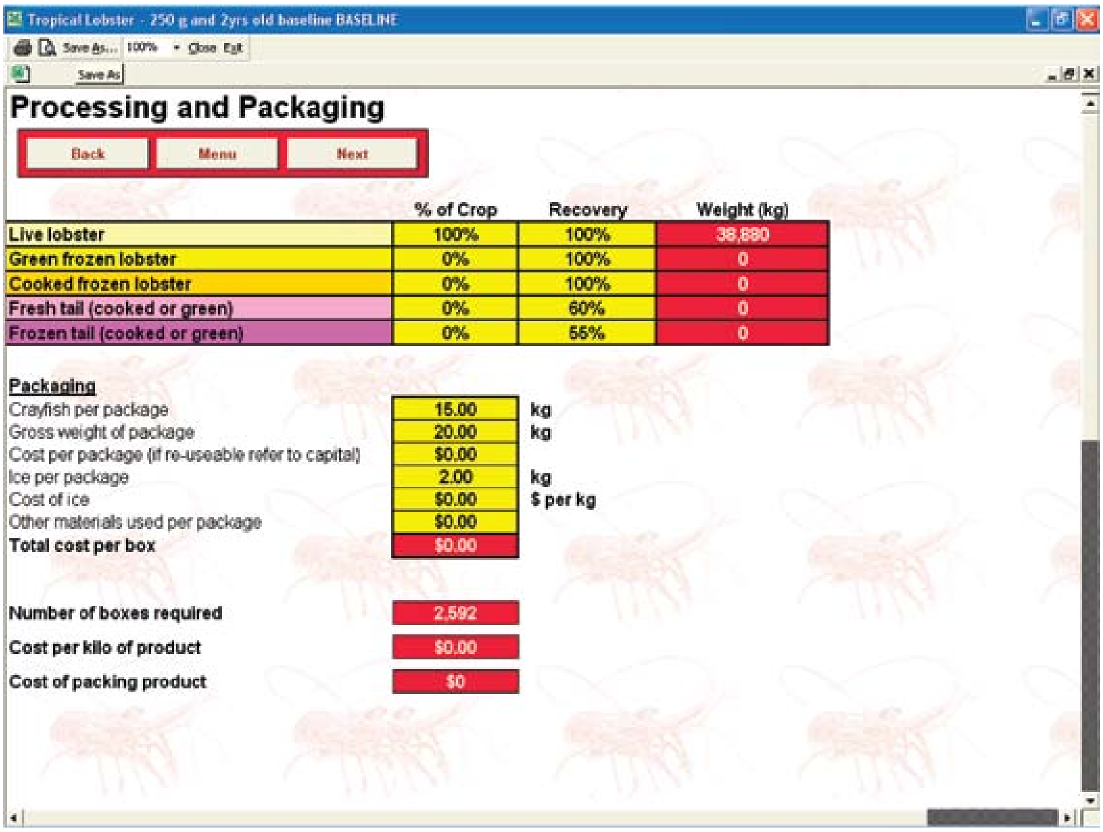

Figure 7. Processing and Packaging interface

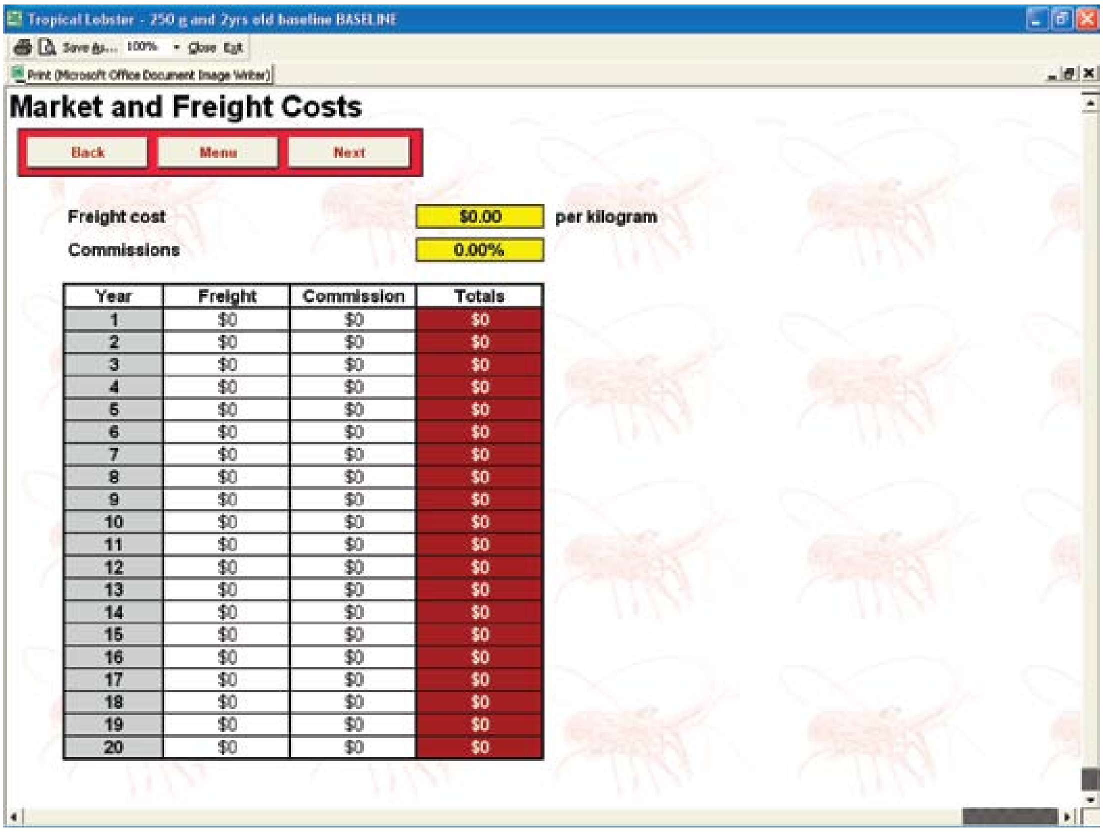

Figure 8. Market and Freight Costs interface

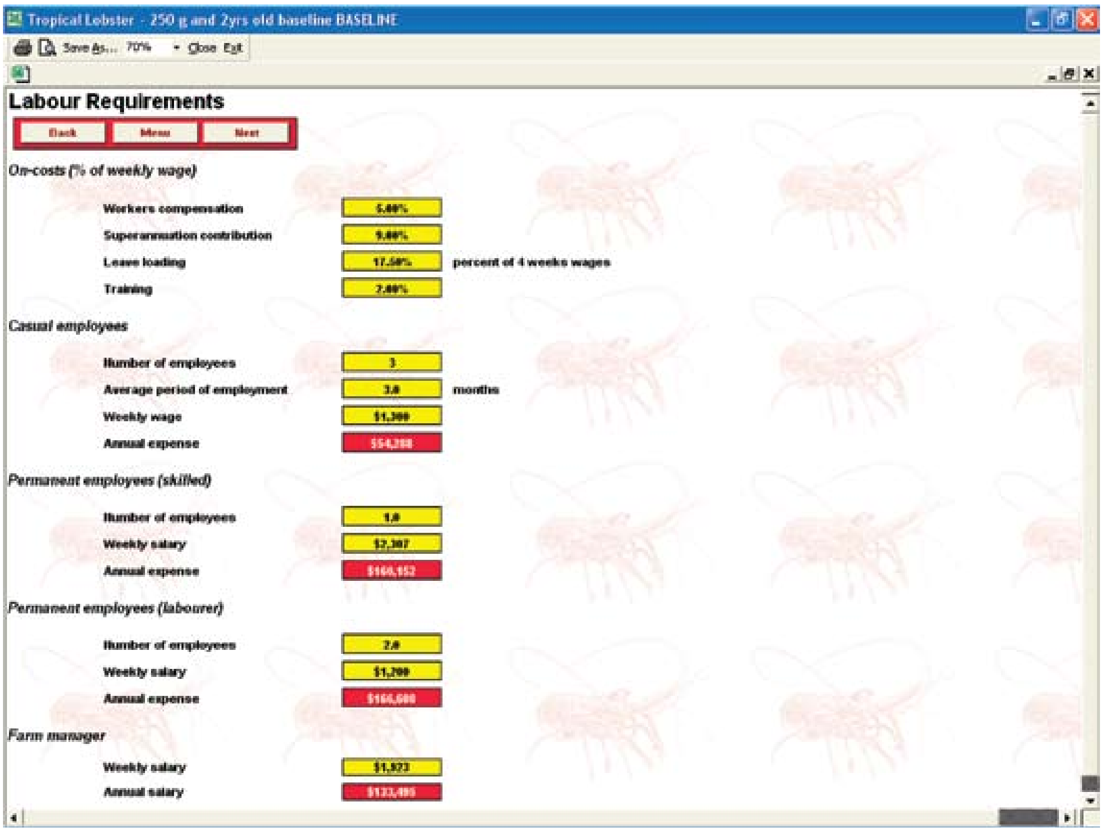

Figure 9. Labour Requirements interface

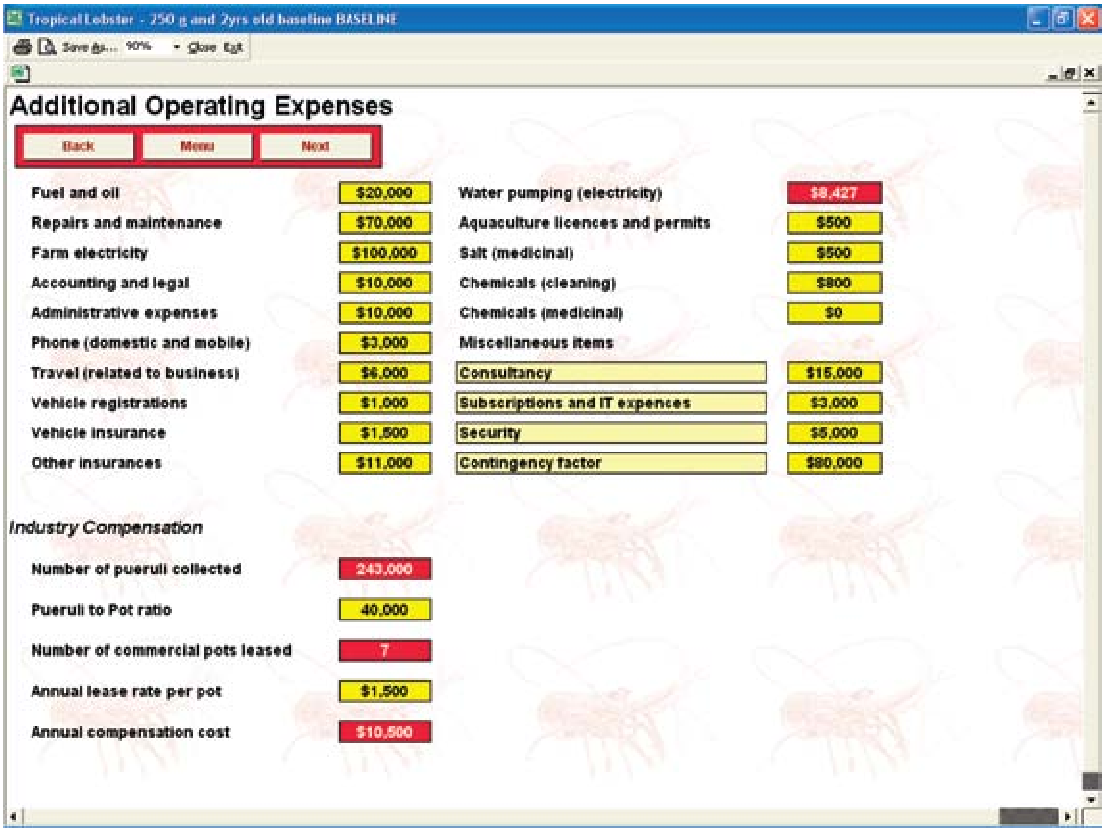

Figure 10. Additional Operating Expenses interface

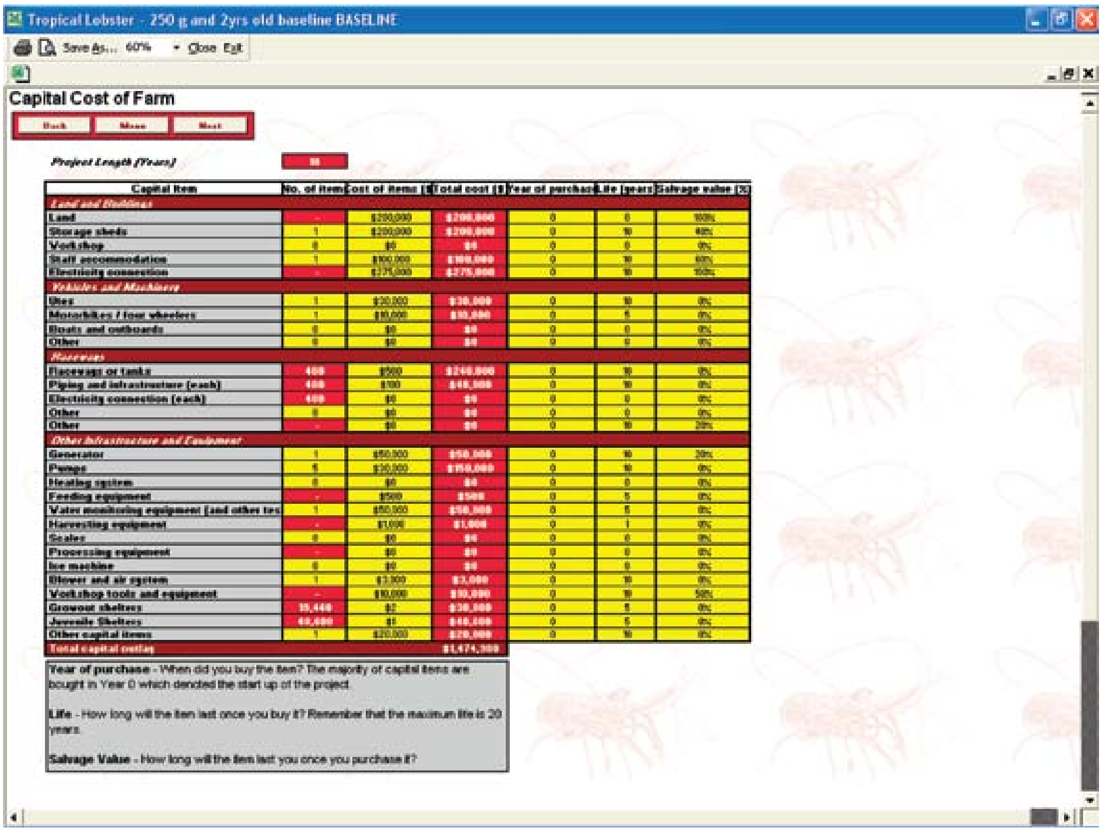

Figure 11. Capital Expenditure interface

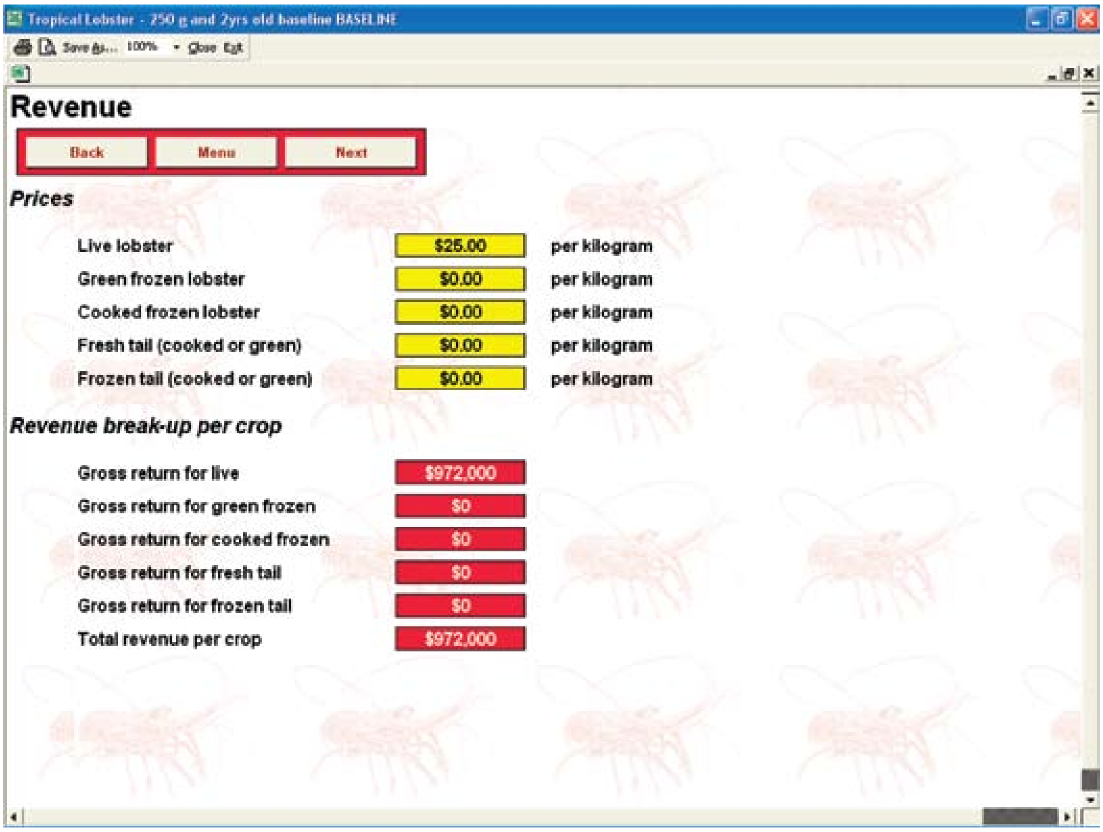

Figure 12. Revenue interface

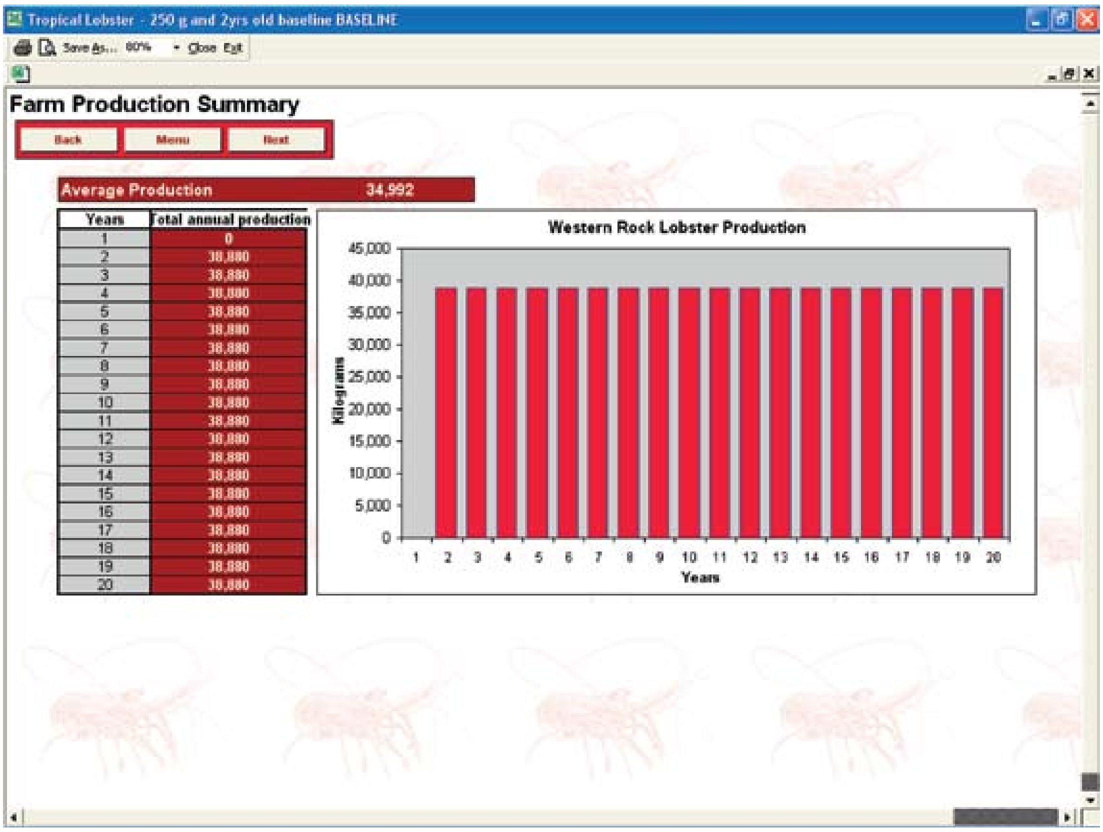

Figure 13. Farm Production Summary display

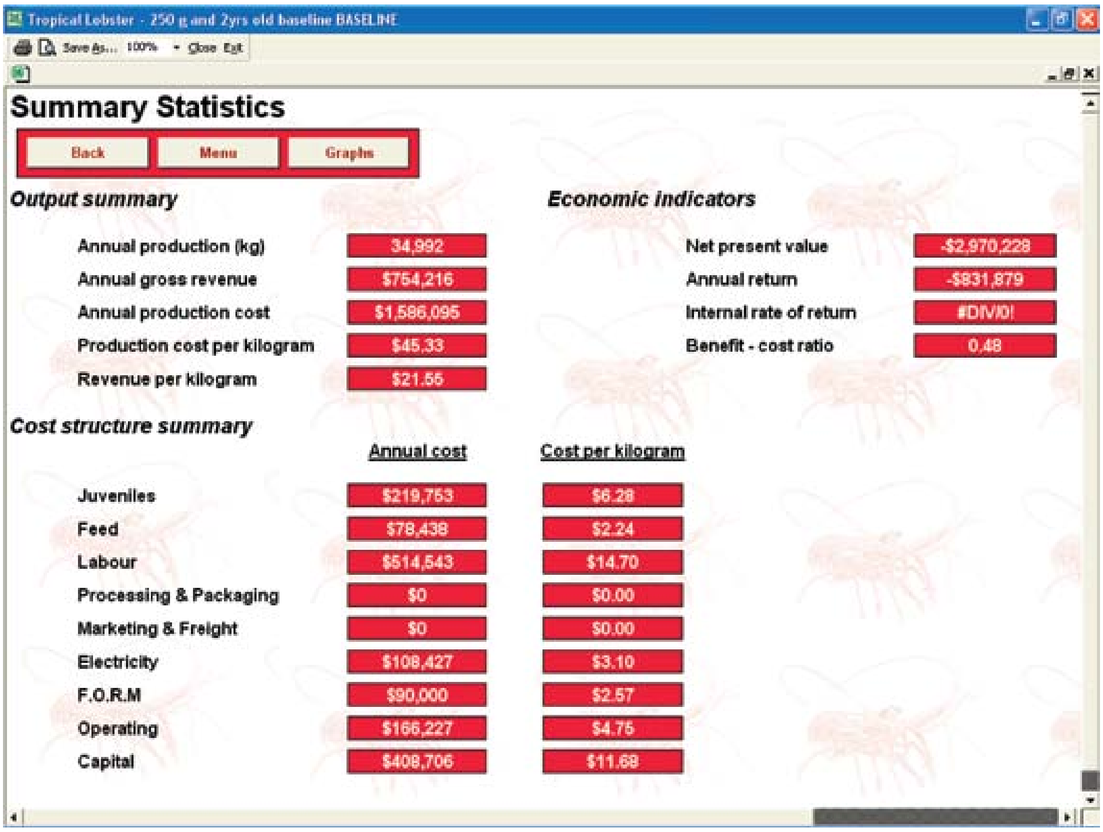

Figure 14. Summary Statistics display

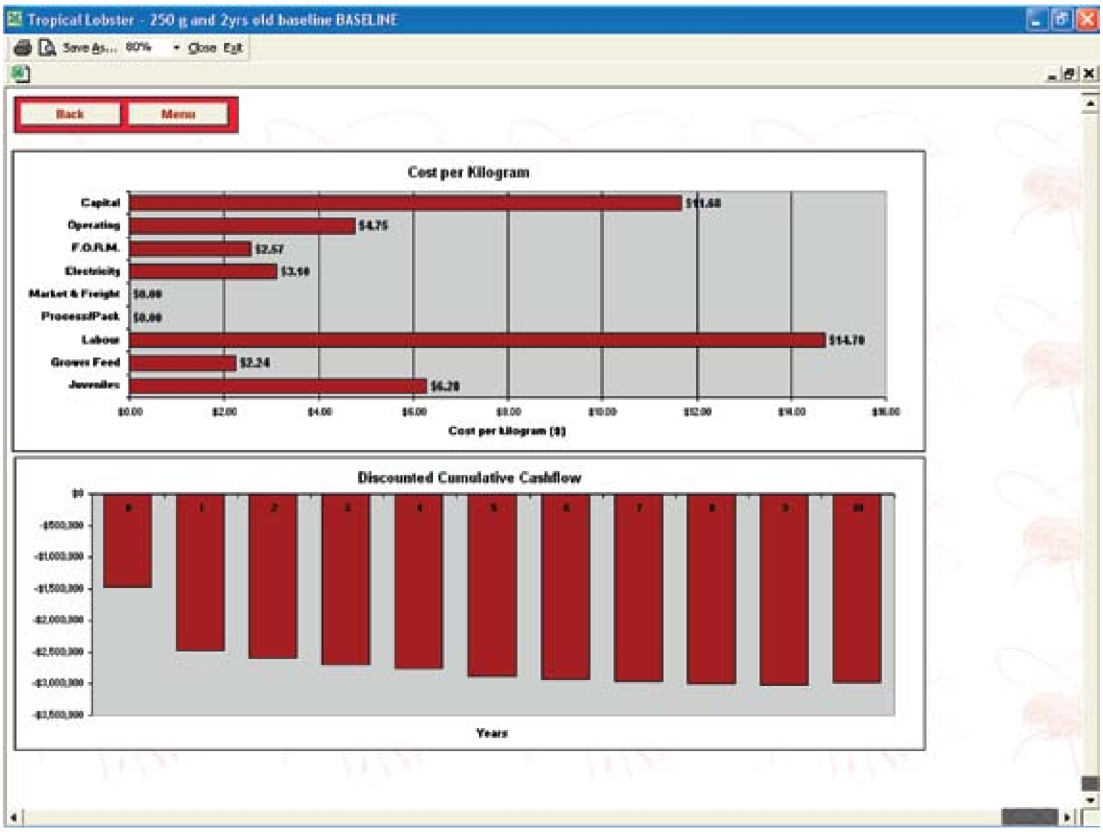

Figure 15. Graphs display

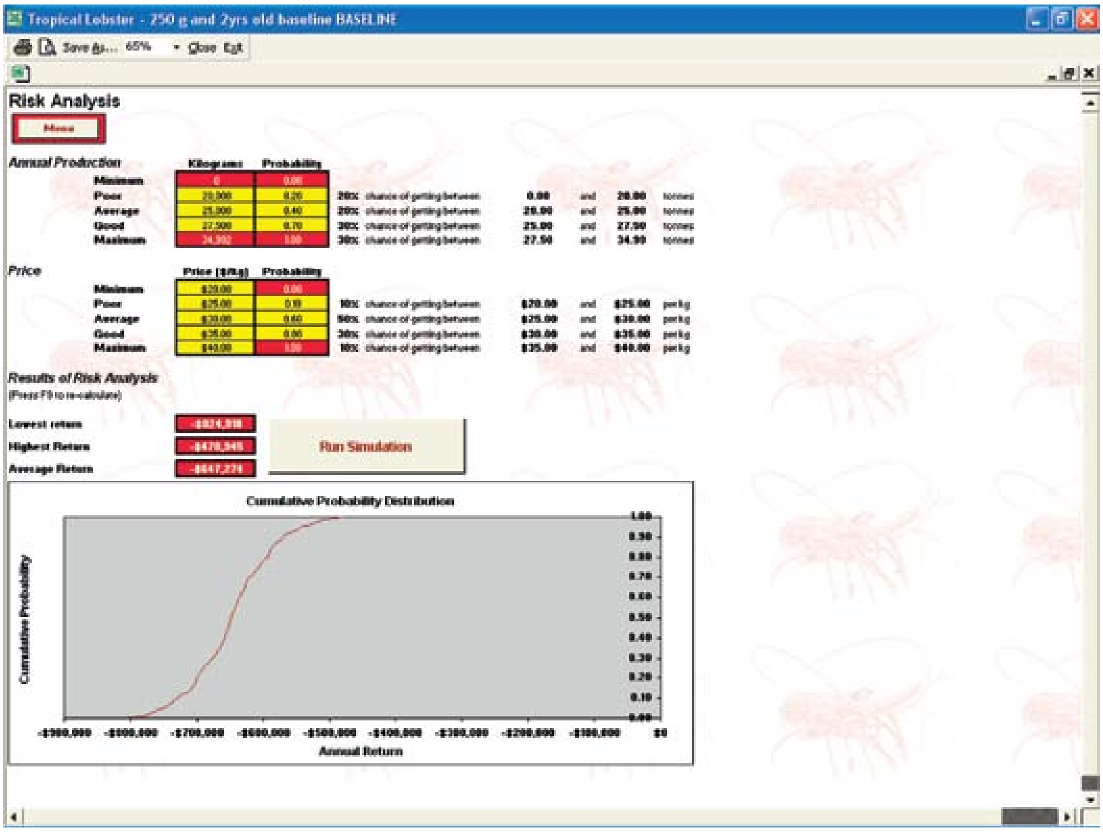

Figure 16. Risk Analysis display

Appendix B

Table providing detail on model production parameters and summary statistics for a range of scenarios in which individual parameters in the model have been varied from a baseline situation. Each set of three columns in the Table refers to the baseline situation (in yellow) and two variations caused by changes in parameter values. The columns are headed by the parameters changed and the parameter changed is indicated in pink. F.O.R.M. = fuel, oil, repairs and maintenance; FCR = feed conversion rate.

	Size at harvest			Feed costs			Market price		
		Baseline			Baseline			Baseline	
PRODUCTION PARAMETERS	**150 g + 1.5 yrs**	**250 g + 2yrs**	**350 + 2.5yrs**	**Feed $1/kg**	**Feed $2/kg**	**Feed $3/kg**	**Sale @ $20**	**Sale @ $25**	**Sale @ $30**
JUVENILE STOCKING									
Length of juvenile phase (months)	12	12	12	12	12	12	12	12	12
Stocking density (per m^2)	50	50	50	50	50	50	50	50	50
Expected survival rate (%)	80%	80%	80%	80%	80%	80%	80%	80%	80%
Animals per shelter	5	5	5	5	5	5	5	5	5
FCR	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Feed cost	$2.00	$2.00	$2.00	$1.00	$2.00	$3.00	$2.00	$2.00	$2.00
Juvenile price	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
GROWOUT PHASE									
Growout period (months)	6	12	18	12	12	12	12	12	12
Stocking density (per m^2)	24	24	24	24	24	24	24	24	24
Expected survival rate (%)	80%	80%	80%	80%	80%	80%	80%	80%	80%
Animals per shelter	10	10	10	10	10	10	10	10	10
Weight at harvest (kg)	0.15	0.25	0.35	0.25	0.25	0.25	0.25	0.25	0.25
GROWOUT FEEDS									
FCR	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Feed cost	$2.00	$2.00	$2.00	$1.00	$2.00	$3.00	$2.00	$2.00	$2.00
REVENUE									
Prices of lobsters sold per kg	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$20.00	$25.00	$30.00
FARM PRODUCTION SUMMARY									
No. years without production out of 10	1	1	4	1	1	1	1	1	1
SUMMARY STATISTICS									
Output summary									
Annual production (kg)	41990	34992	32659	34992	34992	34992	34992	34992	34992
Annual gross revenue	$905,059	$754,216	$623,155	$754,216	$754,216	$754,216	$603,372	$754,216	$905,059
Annual production cost	$1,781,311	$1,586,095	$1,495,701	$1,511,361	$1,586,095	$1,660,829	$1,586,095	$1,586,095	$1,586,095
Production cost per kg	$42.42	$45.33	$45.80	$43.19	$45.33	$47.46	$45.33	$45.33	$45.33
Revenue per kg	$21.55	$21.55	$19.08	$21.55	$21.55	$21.55	$17.24	$21.55	$25.86
Cost structure summary									
Juveniles	$9.51	$6.28	$4.38	$5.27	$6.28	$7.30	$6.28	$6.28	$6.28
Feed cost	$2.24	$2.24	$1.98	$1.12	$2.24	$3.36	$2.24	$2.24	$2.24
Labour requirements	$12.25	$14.70	$15.75	$14.70	$14.70	$14.70	$14.70	$14.70	$14.70
Electricity	$2.58	$3.10	$3.32	$3.10	$3.10	$3.10	$3.10	$3.10	$3.10
F.O.R.M.	$2.14	$2.57	$2.76	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57
Operating expenses	$3.96	$4.75	$5.09	$4.75	$4.75	$4.75	$4.75	$4.75	$4.75
Capital	$9.73	$11.68	$12.51	$11.68	$11.68	$11.68	$11.68	$11.68	$11.68
Economic indicators									
Net present value	-$3,128,662	-$2,970,228	-$3,115,429	-$2,703,389	-$2,970,228	-$3,237,067	-$3,508,814	-$2,970,228	-$2,431,643
Annual return	-$876,252	-$831,879	-$872,546	-$757,145	-$831,879	-$906,614	-$983,723	-$831,879	-$681,036
Internal rate of return									
Benefit : cost ratio	0.51	0.48	0.42	0.5	0.48	0.45	0.38	0.48	0.57

	Cost of pueruli			Survival rate			Puerulus compensation		
		Baseline			Baseline			Baseline	
PRODUCTION PARAMETERS	Pueruli @ $0.2	Pueruli @ $0.5	Pueruli @ $1	49% survival	64% survival	81% survival	Comp. 10K	Comp. 40K	Comp. nil
JUVENILE STOCKING									
Length of juvenile phase (months)	12	12	12	12	12	12	12	12	12
Stocking density (per m^2)	50	50	50	50	50	50	50	50	50
Expected survival rate (%)	80%	80%	80%	70%	80%	90%	80%	80%	80%
Animals per shelter	5	5	5	5	5	5	5	5	5
FCR	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Feed cost	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Juvenile price	$0.20	$0.50	$1.00	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
GROWOUT PHASE									
Growout period (months)	12	12	12	12	12	12	12	12	12
Stocking density (per m^2)	24	24	24	21	24	27	24	24	24
Expected survival rate (%)	80	80	80	70%	80%	90%	80	80	80
Animals per shelter	10	10	10	10	10	10	10	10	10
Weight at harvest (kg)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
GROWOUT FEEDS									
FCR	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Feed cost	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
REVENUE									
Prices of lobster sold per kg	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00
FARM PRODUCTION SUMMARY									
No. years without production out of 10	1	1	1	1	1	1	1	1	1
SUMMARY STATISTICS									
Output summary									
Annual production (kg)	34992	34992	34992	26791	34992	44287	34992	34992	34992
Annual gross revenue	$754,216	$754,216	$754,216	$577,446	$754,216	$954,554	$754,216	$754,216	$754,216
Annual production cost	$1,496,861	$1,586,095	$1,734,818	$1,557,025	$1,586,095	$1,617,616	$1,613,095	$1,586,095	$1,577,095
Production cost per kg	$42.78	$45.33	$49.58	$58.12	$45.33	$36.53	$46.10	$45.33	$45.07
Revenue per kg	$21.55	$21.55	$21.55	$21.55	$21.55	$21.55	$21.55	$21.55	$21.55
Cost structure summary									
Juveniles	$3.73	$6.28	$10.53	$7.87	$6.28	$5.16	$6.28	$6.28	$6.28
Feed cost	$2.24	$2.24	$2.24	$2.24	$2.24	$2.24	$2.24	$2.24	$2.24
Labour requirements	$14.70	$14.70	$14.70	$19.21	$14.70	$11.62	$14.70	$14.70	$14.70
Electricity	$3.10	$3.10	$3.10	$4.05	$3.10	$2.45	$3.10	$3.10	$3.10
F.O.R.M.	$2.57	$2.57	$2.57	$3.36	$2.57	$2.03	$2.57	$2.57	$2.57
Operating expenses	$4.75	$4.75	$4.75	$6.20	$4.75	$3.75	$5.52	$4.75	$4.49
Capital	$11.68	$11.68	$11.68	$15.19	$11.68	$9.27	$11.68	$11.68	$11.68
Economic indicators									
Net present value	-$2,651,619	-$2,970,228	-$3,501,245	-$3,497,589	-$2,970,228	-$2,367,465	-$3,066,632	-$2,970,228	-$2,938,094
Annual return	-$742,646	-$831,879	-$980,603	-$979,579	-$831,879	-$663,062	-$858,879	-$831,879	-$822,879
Internal rate of return						-12.70			
Benefit : cost ratio	0.5	0.48	0.43	0.37	0.48	0.59	0.47	0.48	0.48

	Effect of labour			Capital			Discount Rate		
		Baseline			Baseline			Baseline	
PRODUCTION PARAMETERS	**Labour plus 1**	**Baseline labour**	**Labour less 1**	**Capital - 50%**	**Baseline capital**	**Capital + 50%**	**Discount Rate 15%**	**Baseline Discount Rate 25%**	**Discount Rate 35%**
JUVENILE STOCKING									
Length of juvenile phase (months)	12	12	12	12	12	12	12	12	12
Stocking density (per m^2)	50	50	50	50	50	50	50	50	50
Expected survival rate (%)	80%	80%	80%	80%	80%	80%	80%	80%	80%
Animals per shelter	5	5	5	5	5	5	5	5	5
FCR	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Feed cost	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Juvenile price	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
GROWOUT PHASE									
Growout period (months)	12	12	12	12	12	12	12	12	12
Stocking density (per m^2)	24	24	24	24	24	24	24	24	24
Expected survival rate (%)	80%	80%	80%	80%	80%	80%	80%	80%	80%
Animals per shelter	10	10	10	10	10	10	10	10	10
Weight at harvest (kg)	25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
GROWOUT FEEDS									
FCR	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Feed cost	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
REVENUE									
Prices of lobster sold per kg	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00
FARM PRODUCTION SUMMARY									
No. years without production out of 10	1	1	1	1	1	1	1	1	1
SUMMARY STATISTICS									
Output summary									
Annual production (kg)	34992	34992	34992	34992	34992	34992	34992	34992	34992
Annual gross revenue	$754,216	$754,216	$754,216	$754,216	$754,216	$754,216	$803,589	$754,216	$706,811
Annual production cost	$1,669,399	$1,586,095	$1,502,791	$1,381,742	$1,586,095	$1,790,448	$1,451,878	$1,586,095	$1,726,073
Production cost per kg	$47.71	$45.33	$42.95	$39.49	$45.33	$51.17	$41.49	$45.33	$49.33
Revenue per kg	$21.55	$21.55	$21.55	$21.55	$21.55	$21.55	$22.96	$21.55	$20.20
Cost structure summary									
Juveniles	$6.28	$6.28	$6.28	$6.28	$6.28	$6.28	$6.02	$6.28	$6.53
Feed cost	$2.24	$2.24	$2.24	$2.24	$2.24	$2.24	$2.39	$2.24	$2.10
Labour requirements	$17.09	$14.70	$12.32	$14.70	$14.70	$14.70	$14.70	$14.70	$14.70
Electricity	$3.10	$3.10	$3.10	$3.10	$3.10	$3.10	$3.10	$3.10	$3.10
F.O.R.M.	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57
Operating expenses	$4.75	$4.75	$4.75	$4.75	$4.75	$4.75	$4.75	$4.75	$4.75
Capital	$11.68	$11.68	$11.68	$5.84	$11.68	$17.52	$7.96	$11.68	$15.57
Economic indicators									
Net present value	-$3,267,666	-$2,970,228	-$2,672,791	-$2,240,585	-$2,970,228	-$3,699,872	-$3,253,616	-$2,970,228	-$2,767,339
Annual return	-$915,183	-$831,879	-$748,575	-$627,526	-$831,879	-$1,036,233	-$648,290	-$831,879	-$1,019,262
Internal rate of return									
Benefit : cost ratio	0.45	0.48	0.5	0.55	0.48	0.42	0.55	0.48	0.41