INVESTIGATION OF THE AUTOMATION OF ABALONE PRODUCTION CONTROL

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ABSTRACT

In the East abalone is seen as more than a delicacy, in fact it is associated with good luck, fertility and high social status. For these reasons, high prices will be paid for good quality product. This lucrative market has led to the establishment of abalone farms to produce the product legally.

Intensive land based abalone farming requires strict control and management practices to optimise yield. Sorting of abalone is a key activity to ensure adequate access to feed and high growth rates. The objective of this study is to introduce a more effective sorting and record keeping process to optimise yield and increase profitability.

The study investigates the effectiveness of conventional sorting practices based on visual size estimation, quality inspection and manual data capturing. A new method employing an electronic scale and automated data capturing is evaluated as an alternative to current practices. A pilot study was conducted to determine feasibility of the concept. Sample data collected proved the system to be suitable for full scale implementation.

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1 INTRODUCTION:
Abalone is esteemed seafood, particularly in Asia, where it has folkloric and symbolic value [1]. The great demand for abalone has resulted in high prices, as well as over-fishing and illegal poaching of abalone in their natural environment [2]. A substantial decline in the abalone populations has resulted from the lack of government regulations to protect these slow growing animals against the pressures of illegal poaching and high demand. Hence commercial farming of abalone has become a necessity to provide abalone to the hungry market [3].

The water temperatures of the Western Cape are conducive to abalone farming. The collective Western Cape production is 500 to 800 tonnes per annum from on-land cultivation systems [1]. The on-land cultivation systems consist of baskets into which the abalone are placed, located in tanks having open circulation systems to ensure a constant supply of fresh air and water to the abalone. Sorting of the abalone is required at regular intervals due to the increased pressures on water, air and space available as the abalone grow within the confines of the baskets. The sorting process allows for cleaning of the baskets, counting the number of abalone, and removal of abalone that are sick or damaged. The abalone are sorted according to size and placed into baskets containing abalone of a similar size.

The challenges encountered in the sorting process are firstly to minimise time out of water, secondly to improve accuracy of sorting and thirdly to minimise the labour requirement for the process.

The aim of this project is to increase the efficiency and effectiveness of the existing operations of a large commercial abalone farm in the Hermanus area. This is accomplished by reducing the reliance on the human eye. Control of the sorting process is achieved by using more scientific methods which will improve the economics of the operation.

2 BACKGROUND
The prominence of the South African abalone industry is due mainly to the high quality of its products and the wealth of natural product available. In recent years the natural population of abalone has decreased significantly as a result of the common occurrence of illegal poaching, the unpredictability of recreational catches and the unexpected appearance of the rock lobster [4]. Rock lobster prey on sea urchins that provide baby abalone with shelter in-between their sharp spines during the abalone’s early life. Therefore a decline in the abalone populations has resulted without the protection from the declining sea urchin populations [5]. This decline in conjunction with the high prices received for abalone and the decline in international fisheries has encouraged the increase in commercial production of abalone. These factors have contributed to making South Africa the largest producer of abalone outside of Asia [4]. Consequently streamlining of abalone farming procedures is an important subject not only for individual farms, but also for the socio-economic concerns of abalone farming of South Africa as a whole.

As the supply of oxygen and space are important growth factors, sorting are essential production practices. Abalone is sorted into baskets according to size to avoid dominance. To enable accurate feed supply, the total mass of abalone in the basket is adjusted to standard feed quantities during sorting. Furthermore the information obtained from the sorting process is essential for production management purposes.

Abalone require increasing amounts of oxygen and space as they grow, it is therefore necessary to conduct sorting and grading activities to ensure the continual growth of all the abalone. Abalone should be placed in baskets containing other abalone of a similar size to avoid dominance of the food and space resources available to the basket. Sorting also provides valuable information to the farm about the number of animals, the size of the animals and the growth rate of the animals.
3 PROCESS REDESIGN DESCRIPTION

3.1 Production operations overview
The production unit that was studied exports dried and canned abalone to the East. A constant supply of abalone weighing approximately 164 grams each is required to satisfy the market demands. The company produces approximately 300 tonnes of live abalone per annum collectively from three production units.

The abalone is spawned from brood stock and is kept in the hatchery for approximately three months. The hatchery aims to produce 529,200 settled animals per annum. Through the abalone’s development they will be graded and sorted and be moved to a closer proximity to the facility accommodating the main production unit and the canning factory. The canned abalone are transported, as a unit load of 24 cans per box, to the Cape Town harbour by a security company that uses vehicles similar to those used for cash-in-transit operations. The abalone is shipped from Cape Town harbour to various distributors in China.

As seen in figure 1 below an overview of the abalone production process is shown.

![Diagram of abalone production process]

Figure 1: Different stages of the abalone production process
Abalone may either be canned or sold live. Canned abalone must be approximately 200 grams in mass, whilst live abalone is required to be 164 grams in mass. Both canned and live abalone is exported to the East.

3.2 Process redesign description
The chosen design proposal consists of multiple sub-systems including the scale and scale platform, the printer, the drying rack for the abalone, the empty basket removal rack, the sorting chutes, and the LED lights. These lights indicate when a basket is full and which chute to place the abalone on. Additionally, sedation tanks, the tanks for the sorted abalone and the computer are comprised in the system.

4 METHODOLOGY
The customer requirements set for the new system were divided into sub functions which include; assigning abalone to the correct size categories, removal of defective abalone, cause minimum harm to the abalone, maintain a throughput of three hundred baskets per week, determine the growth rate of the average abalone, inflict minimum strain on the workers, be a reliable and safe system.

These sub functions can be identified to have the following quantifiable characteristics; time out of water, computer assignment of the abalone to the correct size category and the computation of the mass basket of each size category. The Quality function deployment technique was used to determine the relationships between the customer sub-functions and
the quantifiable characteristics to assist in the designs of a new system to meet the needs of the production company.

In addition to the quality function deployment the process flow chart of the current system and a multiple activity chart of the current system were used in developing new system designs for the sorting process.

4.1 Experimental method

An algorithm according to which the proposed system should function was compiled in collaboration with electronic engineers. Due to the time constraints of this project the evaluation of the system concept had to be conducted before the actual construction and implementation of the system. Time out of water and sorting accuracy were identified as the major performance indicators. Time out of water was ascertained by comparing the mean time and variance of the process flow charts and multiple activity charts of the current and the proposed system. The sorting accuracy was determined by reweighing the sorted abalone.

Multiple experiments were conducted to test the accuracy of the proposed sorting system using abalone from various stages of growth from the different sections of the farm. The following sorting errors were identified: not sorting the correct basket; the mass variation within the basket being too large; over counting error; and basket weighing error. The relative performance of the system was judged on the number of errors and the percentage of each error type.

5 RESULTS AND DISCUSSION

5.1 Time out of water

<table>
<thead>
<tr>
<th>Table 1: Present systems’ time out of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove abalone from basket and place into bucket</td>
</tr>
<tr>
<td>Remove basket</td>
</tr>
<tr>
<td>Take grey buckets from basket to scale</td>
</tr>
<tr>
<td>Weigh grey buckets and record mass</td>
</tr>
<tr>
<td>Takes recorded mass to team leader</td>
</tr>
<tr>
<td>Moves grey buckets to sorting station</td>
</tr>
<tr>
<td>Sorting</td>
</tr>
<tr>
<td>Remove full bags</td>
</tr>
<tr>
<td>Drip dry abalone bag</td>
</tr>
<tr>
<td>Record new mass and dispatch to farm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2: Present systems’ time out of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove abalone from basket and place into bucket</td>
</tr>
<tr>
<td>Move basket closer to scale</td>
</tr>
<tr>
<td>Enter basket number into key pad</td>
</tr>
<tr>
<td>Sorting</td>
</tr>
</tbody>
</table>
For the purposes of this investigation it is assumed that once a basket is full it will be returned to the farm. Simulating the process time, constant times were used, and the variable elements were calculated using computer generated random numbers and measured averages.

![Distribution of simulated time out of water for the present and proposed systems](image1)

**Figure 2:** Distribution of simulated time out of water for the present and proposed systems

### 5.2 Sorting Accuracy

\[
\text{% mass error} = \frac{\text{Documented mass value} - \text{Actual mass value}}{\text{Actual mass value}} \times 100
\]

**Equation 1:** Percentage mass error

### 5.2.1 Experiment one

**Table 3:** Theoretical size categories according to sort g-h

<table>
<thead>
<tr>
<th>Farm section</th>
<th>Small (gram)</th>
<th>Medium (gram)</th>
<th>Large (gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>g-h</td>
<td>133 - 143</td>
<td>143 - 153</td>
<td>153 - 164</td>
</tr>
</tbody>
</table>

![Experiment 1: Visual sorting performance of small sorted abalone](image2)

**Figure 3:** Experiment 1: Visual sorting performance of small sorted abalone
5.2.2 Experiment Two

Table 4: Theoretical size categories according to sort e-f

<table>
<thead>
<tr>
<th>Farm section</th>
<th>Small (gram)</th>
<th>Medium (gram)</th>
<th>Large (gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-f</td>
<td>83 - 90</td>
<td>90 - 98</td>
<td>98 - 105</td>
</tr>
</tbody>
</table>

Figure 4: Experiment 1: Visual sorting performance of medium sorted abalone

Figure 5: Experiment 1: Visual sorting performance of large sorted abalone

Figure 6: Experiment 1: Percentage mass error
Figure 7: Experiment 2: Visual sorting performance of large sorted abalone

Figure 8: Experiment 2: Visual sorting performance of large sorted abalone

Figure 9: Experiment 2: Visual sorting performance of large sorted abalone

Figure 10: Experiment 2: Percentage mass error
5.3 Discussion

5.3.1 Time out of water
According to Graph 1 the average time out of water can be improved from an average of 19 minutes out of water to an average of 10 minutes out of water by implementing the proposed sorting system. This means that the abalone will be out of water for an average of 9 minutes less during the sorting process. The stress incurred by the abalone whilst out of water is inversely proportional to the growth rate of the abalone. Since this stress will be reduced by decreasing the time out of water, the growth rate of the abalone will be improved; yielding a larger animal in a shorter period of time. Abagold will experience direct financial benefits as a result of this improvement in abalone growth, mainly stemming from the reduced growth period and therefore an increased production capacity.

5.3.2 Sorting accuracy
The abacus-chute system presently utilized by Abagold is based on visual sorting techniques and is therefore dependent on the individual sorter. The outcomes of experiments one and two may be found in Tables 2-9. The errors which occurred whilst conducting sorting for experiments one and two could result from several of causes; for example sorter variation, sorter fatigue, and the growth stage of the abalone. Such causes could be the root of the discrepancies found during experimentation as seen in Table 5.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average % mass error</td>
<td>12.53</td>
<td>19.16</td>
</tr>
<tr>
<td>Average % count error</td>
<td>9.14</td>
<td>26.58</td>
</tr>
<tr>
<td>Average % correctly sorted</td>
<td>48.28</td>
<td>52.26</td>
</tr>
</tbody>
</table>

The general trends that may be observed from the available data are;
- Counting errors and over-weighing errors are prevalent in the current system.
- When considering the theoretical specifications of the company, approximately 50% of the abalone is sorted correctly.
- The earlier growth stages have marginally fewer sorting errors, but larger counting and weighing errors than the later growth stages.

It is hypothesised that by the use of more accurate weighing a decrease of mass variation and weighing errors will result. This combined with decreased counting errors will result in more accurate data about the abalone and thus more accurate sales forecasts for the marketing function.

Accurate information about the environment and contents of each basket will allow for superior control of factors influencing the growth of the abalone, such as food-intake, congestion and other subtle factors within the basket. Management of such factors should result in more uniform growth of the animals.

6 CONCLUSION
Abalone farming is a capital intensive operation requiring long-term investment for the slow growing seafood. Therefore effective and efficient operation is essential to succeed in the abalone production industry. This industry is fuelled by the vast market demands in the East and the poaching of abalone in its natural environment. The farming operations are focused on the sorting process which is therefore key factor for successful abalone farming.
Data obtained from the experimental method described above show improvements of the sorting accuracy from approximately 50% to a negligible percentage, and 40% reduction in the time which abalone are out of water during the sorting process. If the proposed system were implemented these improvements would greatly increase the effectiveness and efficiency of the sorting process which is vital to the production process. Additionally increased data accuracy and uniform animal growth, as a result of the proposed system implementation, would greatly benefit the company in the control of abalone growth factors and therefore forecasting for financial purposes.

7 REFERENCES


