Increase sustainable use of crab fisheries resources by recovering revenue from crabs currently rejected at market

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SYDNEY FISH MARKET

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Non-Technical Summary

2012/758 Increase sustainable use of crab fisheries resources by recovering revenue from crabs currently rejected at market

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PROJECT OBJECTIVES:

1. To increase the revenue gained from slow mud crabs by $70,000 pa by January 2014
2. To reduce the mud crab seizure rate from NSW coop's from 9% to the non-coop average of 4.5 % by January 2014
3. To reduce the spanner crab mortality rate from 7% to 3.5% by January 2014
4. Assess the stress bio-markers of C grade crab in simulated supply chain trials to determine the survivability of C grades under different supply chain conditions.

OUTCOMES ACHIEVED

1. Increased revenue gained along the mud and spanner crab supply chains
2. Greater responsibility of resource use
3. Increased sustainability of the crab fisheries
4. Stress bio-markers of C grade crab in the supply chain determined

LIST OF OUTPUTS PRODUCED

1. Mud crab recovery system instructional manual

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1. Introduction and Background

Financial losses on the live mud and spanner crab supply chain into Sydney Fish Market (SFM) have been significant. An analysis of data from the 2010/11 financial year demonstrated that:

- Mud crabs that received a downgraded value due to being slow represented 2.8% (around 11 tonne) of product supplied worth $71,238 pa.
- Mud crab rejections comprising of mortalities and CUC (commercially unacceptable crabs) represented 5% (around 19 tonne) of product supplied worth $430,406 pa.
- Spanner crabs that were dead or slow represented 7% (6 tonne of product) of product supplied which represents a loss of value of approximately $28,000 pa.

SFM was obviously keen to stem these losses and ensure the whole supply chain can redeem as much of this loss as possible. To that end SFM approached the QLD DAFF seafood team to develop a research program to address this issue.

Benioni Iakoba is the Quality Assurance Officer at SFM responsible for live crabs and is involved in hands-on grading of crab at the market and feedback to suppliers. He was involved in the Australian Industry Live Mud Crab Grading Scheme (AILMCGS) project (FRDC 2011-225) and has recently completed the National Seafood Industry Leadership Program. This project therefore also served as a personal development process for Benioni. The project was overseen by SFM's Risk and Compliance Manager - Mark Boulter.

Consultation

Many of the supply chain sectors supplying these products to SFM were approached and letters of support were been obtained from the following:

- Queensland Seafood Industry Association
- East Coast Crabfishers Network Inc
- C-AID Consultants (Chris Calogeras)
- Northern Territory Mud Crab Licensee Committee
- Macleay River District Fisherman’s Co-operative Ltd
- Coffs Harbour Fishermen’s Co-operative Ltd

Project Approach

The project approach was to use knowledge attained within previous research undertaken by the co-investigators (FRDC 1992-71[1], FRDC 2003-240[2], FRDC 2010-302[3] and FRDC 2011-225[4]) and apply to specific Sydney Fish Market supply chain situations with adaptations as necessary.

Previous research findings

Mud crabs are subjected to extreme stress factors along the supply chain and these stress factors are accumulative. Many stress biomarkers are available to identify the amount of stress incurred. Ammonia in crab haemolymph is present as either NH_3 or NH_{4+} and shifts between the two forms depending on the pH of the blood. Both forms are toxic to the animal as levels increase. When crabs are immersed in water, a build-up of ammonia in the haemolymph is prevented by rapid gaseous exchange across the gills. During emersion (being held out of water), crabs are able to absorb some oxygen but unable to excrete the ammonia. This build-up of ammonia, together with the accumulative effects of other stress biomarkers eventually results in crab becoming very slow or dead, both of which are not marketable. Previous investigations[2] have already demonstrated the benefits gained from including a recovery step in the supply chain whereby crabs are fully immersed into water so that the built-up ammonia is able to be released into that recovery water. Importantly, the recovery water used does not need to be salt water. *Scylla serrata* has been reported to tolerate salinities between 1% and 42% and survive for extended periods in fresh water[5] due to its strong osmoregulatory physiology.

Previous research[2] demonstrated that a spray system for holding crabs for a short to medium term was most beneficial to reduce stresses. This holding system was developed using salt water to maintain optimum crab vigour.

The SFM is located within close proximity to salt water. However, due to the unknown quality of this water, it would be unwise to incorporate its use in a recovery system for a food product. Live mud crabs are sourced from around Australia, arriving by a variety of transport means throughout the night prior to the live SFM auction each working day. Crabs are delivered in various individual containers including fish crates, product specific cardboard boxes, and Styrofoam eskies. Prior to adaptions to the live mud crab auction system, each container was lined up on the auction floor to allow individual inspection preceding the traditional voice driven auction. The new auction system is now on the electronic clock and crab boxes are now able to be stacked which restricts individual buyer inspection of each boxes contents. Details of each box (supplier, weight, sex, grade, number of crabs) are displayed and collated into a daily catalogue for buyer's reference. Each box is offered for auction on the electronic clock, followed by a QA process where buyers can check consignments for total weights, and individual crabs for correct grades, liveliness, damage or mortalities. Crabs assessed as slow were downgraded with a purchase price reduction (80%). Crabs assessed as very slow were rejected entirely.

It was proposed to establish a recovery system appropriate to SFM operations that would allow these slow or very slow reject crabs to be quarantined at the QA process step and sent to a recovery unit to potentially promote increased liveliness. Crabs that have attained saleable liveliness would then be offered for resale at the next day's auction. Recovery unit procedures and equipment have previously been reported (FRDC 2003-240 and 2010-302), as have salt water spray holding systems. Adaptations were investigated as to whether a spray system itself was sufficient to 'purge' crabs of accumulated ammonia, as well as the use of freshwater rather than salt water, within the spray system. Recovery of crabs was measured using a liveliness rating (five-point Vigour Index developed in previous work[2]) assessing all crabs, pre- and post- recovery. Ammonia secretions in fresh water spray systems were compared to the immersion recovery systems. The combination of the two systems was also investigated.

Project Variation – Stress within grades

A Project Variation was initiated to investigate crab stress levels within the three grades as per the AILMGS[4]. The aim was to provide a gauge for the potential weakness &/or mortality of crabs specific to those grades and within certain supply chains. SFM was supportive of this additional initiative and in reply to the draft of the Variation of Contract stated *"It would be useful to have an analysis of 'weakness potential / stress levels' across all 3 grades. This would give useful supply chain knowledge that could help supply chain management and lead to more good quality product arriving at the marketplace. It will also be useful to look at the issue of regional anomalies where mud crabs from certain regions just don't seem to get fully hard. That is the other piece of work SFM is looking forward to happening.*"

1.1. Need

As outlined in the background section, there is an economic and sustainability imperative to maximise the utilisation of the crab resources being sold through SFM. To achieve this it was felt that the following steps should be taken:

- to investigate the potential for the development and introduction of a mud crab recovery step at SFM for recovering downgraded or seized slow and very slow mud crabs back to a lively state where they would be commercially marketable.

- to develop strategies to reduce the rejection / mortality of mud crabs in the SFM supply chain, especially from suppliers with greater than average rejection / mortality rates. (The rejection rate at SFM in a recent assessment ranged from 0.6% - 15.9%). This will include assessing temperature management issues and determine the most appropriate product packaging methods.

- to investigate whether the losses in the spanner crab supply chain can be reduced.

Mud crabs arrive to the SFM from QLD and NSW (sporadically from NT) via refrigerated vehicles or air freight. The conditions the crabs have been exposed to and the time of their exposure to these conditions prior to and during transportation is predominantly unclear.

It is believed by those in the mud crab supply chain that the following conditions have direct impact on the crabs health and wellbeing thus their strength and liveliness on their sale date at the market:

- the type of bait the fisher has used.
- the distance of travel on water from point of catch to land and finally to market. In extreme cases, fishers travel up to 8 hours one way by boat to harvest grounds. They would then camp in that location for approximately two weeks, harvest and store crabs for the duration, then return via boat for 8 hours, load the crabs onto awaiting 4WDs then drive 10 hours back to their town of origin. Crabs would then be loaded into refrigerated trucks for transport to airports.
- environmental – temperature, breeze, air pressure, sea conditions, noise
- whether the crabs have been stored dry or in sea water tanks
- the total length of time crabs have been out of their natural environment and exposed to any or all of the above conditions

Recognition of the ability to redress wastage of mud crab resource was gained by QLD DAFF through research within the Northern Territory fishery (FRDC project 2003-240) which identified the best practice handling for minimising stress in mud crabs including incorporating a recovery step in the supply chain. An outcome of follow on work Communicating Best Practice Handling to the Mud Crab Industry (FRDC 2010-302) was identification of the potential opportunity to adopt this practice at the SFM where rejected crabs incur large economic losses as outlined above.

Project Variation – Stress with grades

The original research into stress bio-markers was conducted for the NT industry (FRDC Project 2003/240). Commercially Unsuitable Crab (CUC) 'C' grade crabs are prohibited to be harvested by law in Northern Territory but not in other states. Also, up until recently the SFM rejected excessively soft crab. The introduction of the AILMGS has given the entire Australian mud crab industry a standard grading scheme. The original stress bio-marker research was performed prior to the introduction of the AILMGS. As such, the specific crab grades 'A', 'B' and 'C' were not specifically assessed for effects of environmental and supply chain stress factors within previous research. Anecdotally, and from a general understanding of stress induced bio-makers, it can be assumed that 'C' grade crabs are more prone to mortality or slow condition through a supply chain. Industry representatives have asked for substantiating, scientific proof that these 'C' grade crabs are indeed more prone to stress resulting in early mortality or slowness.

It was proposed to conduct trials to determine stress levels within each grade within the AILMGS. Findings will be delivered to industry via Fact Sheets and media. This added knowledge may convince some fishers and distributors that the harvest of 'C' grade crabs can be anti-productive. If the research shows 'C' grade crabs have a significantly higher chance of becoming weak or succumbing to mortality then this could also be used in any industry driven case for non-take of 'C' grade crabs by fishers in other states, as it is in the Northern Territory.

Long term and full time crab fishers argue that supply and demand factors should not dictate any variance in the quality of crab grades supplied to market. It is viewed by others in the catching sector that the supply of inferior ‘C’ grade crab is more likely to come from part-time fishers who enter the market at periods of peak market prices. This is particularly prevalent in Queensland with the large latent effort in the crab fishery. Knowledge of the potential weakness of these ‘C’ grade crabs may alter their harvest strategy.

1.2. Objectives

1. To increase the revenue gained from slow mud crabs by $70,000 pa by January 2014.
2. To reduce the mud crab seizure rate from NSW co-operatives from 9% to the non-co-operative average of 4.5 % by January 2014.
3. To reduce the spanner crab mortality rate from 7% to 3.5% by January 2014.
4. Assess the stress bio-markers of ‘C’ grade crab in simulated supply chain trials to determine the survivability of ‘C’ grades under different supply chain conditions.

2. Methods

The following methods, as developed in FRDC 2003-240, are the standard analytical techniques used in all trials undertaken in this project.

2.1. Sampling and preparation of mud crab haemolymph

A 22G x ¾" Terumo needle attached to a 3ml Terumo syringe was inserted at the synapse where the 3rd walking leg (from the front) joins the carapace. The leg joint must be extended to stretch out the membrane and reveal a white triangular marking. The needle is inserted 5-10mm into an interstitial cavity beneath the tip of the triangular marking on the membrane of the leg joint (Plate 2.1) and angled to follow an imaginary line to the apex of the belly flap. Haemolymph (1.5ml) is withdrawn slowly to avoid collapsing the cavity.

Plate 2.1 Insertion point and syringe positioning and angle of the needle required to extract mud crab haemolymph.

2.1.1. Total protein (Refractive Index, RI)

The Refractive Index (RI) of freshly sampled haemolymph is measured immediately by placing 1-2 drops (enough haemolymph to cover the prism without air bubbles) directly from the sample syringe onto the glass prism of the hand-held refractometer (Atago model SUR-NE calibrated with distilled water). The refractometer lid is then closed before the haemolymph clots and held towards a fluorescent strip light to assist reading the internal scale accurately. Results are manually recorded from the refractive index scale in nD units.

2.1.2. Total protein (conversion of Refractive Index)

Haemolymph is sampled as per 2.1 and RI determined as per 2.1.1. This RI value can then converted using the equation below, calculated from the standard curve of RI plotted against total protein derived using a spectrophotometer (Figure 2.1). The RI method above can be performed more quickly than the spectrophotometer method with a result obtained within one minute (Paterson *et al.* 2001)[6].

RI to total protein conversion equation: (RI x 4568.3018) - 6104.407 = Total protein (mg/ml)

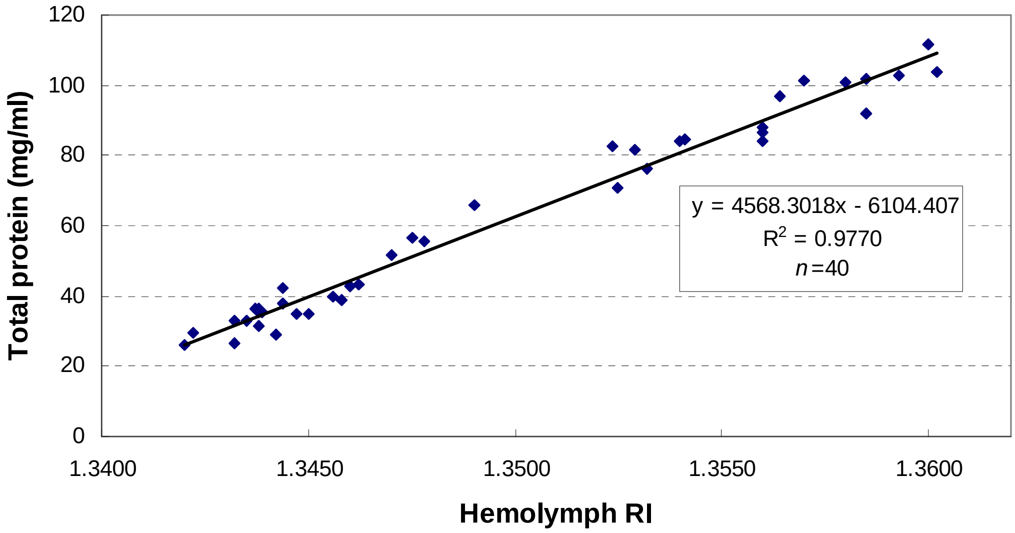

Figure 2.1 Standard curve of refractive index against total protein.

2.1.3. pH

The pH of freshly sampled haemolymph is measured immediately by part filling a 1.5ml graduated microcentrifuge tube (QSP cat No.509-GRD-Q) with 0.5ml of haemolymph directly from the sampling syringe. This is measured within 15 seconds using a TPS hand-held pH meter (WP80) fitted with an Ionode intermediate junction pH electrode (TPS part No. 121236) calibrated at pH 4 and pH 7. This shape electrode is used because it fits the profile of the microcentrifuge tube, excluding air and only requiring 0.5ml sample size. The probe is gently inserted into the microcentrifuge tube containing the haemolymph. This forces any trapped air out until the haemolymph rises to the top of the tube ensuring the potassium junction of the glass bulb is completely covered. Results are manually read from the display once the reading has stabilized. The pH probe is cleaned with distilled water and wiped dry after each sample.

2.1.4. Glucose

After pH analysis, the sample is then held for a minimum of 15 minutes to allow the haemolymph to clot. At this point the clot is broken up using a 3mm stainless steel rod before being spun at 10,000 RPM for 10 minutes (Beckman Coulter Microfuge 18) at 4°C. It is then broken up again and spun a second time at 10,000RPM for 10 minutes. The separated liquid portion of the sample is then pipetted directly into an assay tube. A haemolymph sample (10µl) is analysed using Randox assay kit GL2623 as per instructions, (semi-micro method, 25 minutes incubation at 22-25°C, 30 second timed intervals between samples). Fixed absorbance is read at 500nm using a Unicam Helios Alpha spectrophotometer with a 1ml quartz cuvette. Samples are read alongside a sample blank and standard (as provided with the kit) and calculations made as per Randox kit instructions. Results are expressed as mmol/L.

2.1.5. Ammonia of recovery water

Crabs are placed in a 200L tub containing 10L of water (sea water or fresh water depending on treatments) for every 1kg of crab to be purged. An air stone provides gentle aeration while crabs are in the tub. Water samples to be tested are taken by submersing a 100ml vial completely filling with purge water and replacing the lid whilst under water (this excludes any air bubbles). Samples are placed on ice and tested immediately after the purge trials are complete.

A sample (0.1ml) of purge water is analysed for ammonia using Randox assay kit AM 1054 (semi-micro procedure, five minutes incubation at 22-25°C, 30 second timed intervals between samples). Fixed absorbance is read at 340nm using a Unicam Helios Alpha spectrophotometer with a 1ml quartz cuvette. Glutamate dehydrogenase (0.01ml) is then added to all samples, standard (supplied with the kit) and blank before a further five minutes incubation at 22-25°C. Samples are read again at 340nm (30 second timed intervals) and differential calculations made as per Randox kit instructions. Results are expressed as g/L.

2.1.6. Temperature logging

Temperature logging is recorded using ibutton thermocron temperature loggers. Temperature range of the loggers is -40 to 85°C with a resolution +/- 0.5°C. Accuracy was tested against a "NATA" certified standard thermometer. These waterproof loggers are placed in direct contact with the crabs during transit and storage to assess temperature conditions. Temperature data is retrieved using USB reading fobs with eTemperature V5.10 software (onsolution.com.au).

2.1.7. Vigour or liveliness index

A crab's liveliness is a critical factor used in Quality Assurance grading assessments. The following table (Table 2.1) describes the observations of strength or weakness of specific crab components to provide a liveliness index.

Table 2.1 Liveliness Index.

Score	Term	Description
0	dead	dead
1	very slow	near dead, legs have no resistance to force, pincers non-responsive, negligible eye stalk response, mouth parts may be drooping, may be foaming from mouth
2	slow	legs move slowly and have slight resistance to force, pincers slow, slow eye stalk response
3	lively	legs move quickly with reasonable resistance to force, pincers strong, fast eye stalk response
4	very lively	legs strong with tips digging in with precision and force, pincers active and aggressive, rapid eye stalk response

2.2. Fresh water spray v fresh water immersion

A series of trials were conducted to determine the optimum configuration and parameters for a large scale recovery system suitable for SFM requirements.

2.2.1. Fresh water spray v fresh water immersion – trial 1

Seized 'C' grade NSW crabs were sourced from SFM, transported to the Brisbane research facilities, and conditioned in sea water tanks with daily feeding for two weeks prior to commencement of the trial. At this stage, crabs were assessed as 'B' grade by shell hardness testing following the AILMCGS. Traditionally, 'C' grade crabs would not be part of a recovery process as they are rejected for sale at SFM if they were considered to have very soft shells. However, as these crabs were readily available from auction rejects, they were acquired for further research use. Sixteen crabs were selected equally by sex and size for storage in two damp hessian lined crates for seven days within a temperature controlled room. Sufficient quantities of fresh town water for the trials were stored in tubs and aerated to remove chlorine overnight prior to treatments (1:10 ratio of crab : water). The spray system was designed with a false draining floor in a 200L tub to house a pump that recirculates water through spray nozzles located along an overhanging manifold of 10mm poly-pipe. The immersion vessels used were 200L tubs (Plate 2.2).

Plate 2.2 Crabs post-immersion (L) and spray treatment (R).

Both systems were supplied with aeration and covered to minimise crab disturbance during trials.

Liveliness observations were taken of each crab as they were transferred to the treatment systems for the recovery process. After the recovery procedure, crabs were stored in Styrofoam eskies for two days to simulate a market or retail situation.

Four water samples were taken during the three hour immersion treatment and eight water samples during the 22 hour spray treatment for ammonia analysis. These were analysed by a commercial pool ammonia test kit and compared against the Randox AM 1054 kit using the semi-micro procedure.

Individual crab liveliness and treatment bulk weights were recorded at four stages of the trial:

- pre-recovery
- immediate post-recovery
- one day post-recovery
- two days post-recovery

2.2.2. Fresh water spray v fresh water immersion – trial 2

The ammonia levels in trial 1 were lower than expected. Therefore, an increased number of crabs from different sources were stored emersed for a greater period to obtain higher ammonia levels in the recovery waters.

A new consignment of both NSW and QLD seized 'C' grade crabs were sourced from SFM and conditioned in sea water tanks with daily feeding for two weeks prior to commencement of the trial. 26 crabs were sorted equally by sex, size and grade for storage in two damp hessian lined crates for 10 days. Treatment systems were setup exactly as previously outlined above and analysed by a commercial pool ammonia test kit and the Randox AM 1054 kit.

2.2.3. Extended emersion

A workshop was held in December 2012 to demonstrate best handling, packaging and grading techniques at the NSW fishing co-operative that consistently produced the highest volumes of reject crabs. Crabs that had been supplied to SFM from this fishing co-operative and subsequently seized at QA were used to demonstrate specific grading issues. During the workshop, all crabs were subjected to thorough examination by the large group of fishers. Many crabs were damaged and subjected to extreme stresses by this process. Surviving crabs were then re-packed in Styrofoam eskies for road transport back to the research facilities for recovery treatments. The total period of emersion from capture to recovery treatments for these crabs was in excess of 12 days. On return to the research facility, surviving crabs were cleaned, graded and put only into the fresh water spray system for recovery overnight.

2.2.4. Immersion followed by overnight spray

As demonstrated in previous trials, a three hour immersion was most beneficial for recovery of slow crab. However, SFM QA staff may not be available to remove crabs from the recovery tank after three hours. Therefore, a system was tested where crabs were treated in the fresh water immersion recovery system and then held in the fresh water spray system. The aim was to determine the possible benefit in the recovery of the crabs from this two-stage process and any reduction of weight loss that mostly occurs in the first two hours out of water. By flushing the initial purge water from the three hour immersion and starting with clean, fresh, de-chlorinated water for the spray stage, system blockages from faeces and dirt should be minimised.

Eighteen healthy and strong crabs were selected from previous recovery trials and sorted equally by sex, size and grade into two damp hessian lined crates for 13 days. This further increase of storage time should be enough for a measurable amount of ammonia to be accumulated within the crabs and their liveliness to be severely compromised. Crabs were then transferred to two tubs for three hours immersion, after which one lot of crabs were transferred to the spray system (Plate 2.2) and the other batch of crabs were placed into a Styrofoam esky for four days. After 19 hours the spray treatment crabs were transferred to a Styrofoam esky. 19 hours would be the time between recovery and resale at SFM. Crabs in both eskies were soldier packed and covered with damp hessian to minimise crab movement. Observations were made on liveliness, weight, grade, haemolymph protein and physical damage at all stages of the trial.

2.2.5. Friday recovery option – trial 1

Friday auctions at SFM generally have the highest volume of crabs. As such, it was important to develop a viable solution for recovery of seized very slow crabs over the weekend when no SFM staff are available. In previous trials, crabs were removed from the recovery system and stored in Styrofoam eskies. This trial simulated crabs being recovered in the immersion recovery system and then left dry in the fish bin over the weekend. In a SFM situation, crabs would then be transferred to fish crates for auction on Monday morning. It is important to note that buyers would usually then transfer these crabs to Styrofoam eskies for distribution down the supply chain (Plate 2.3). Therefore, treated crab's liveliness was observed for several days post-recovery to ascertain any post auction or on-sale degradation of product.

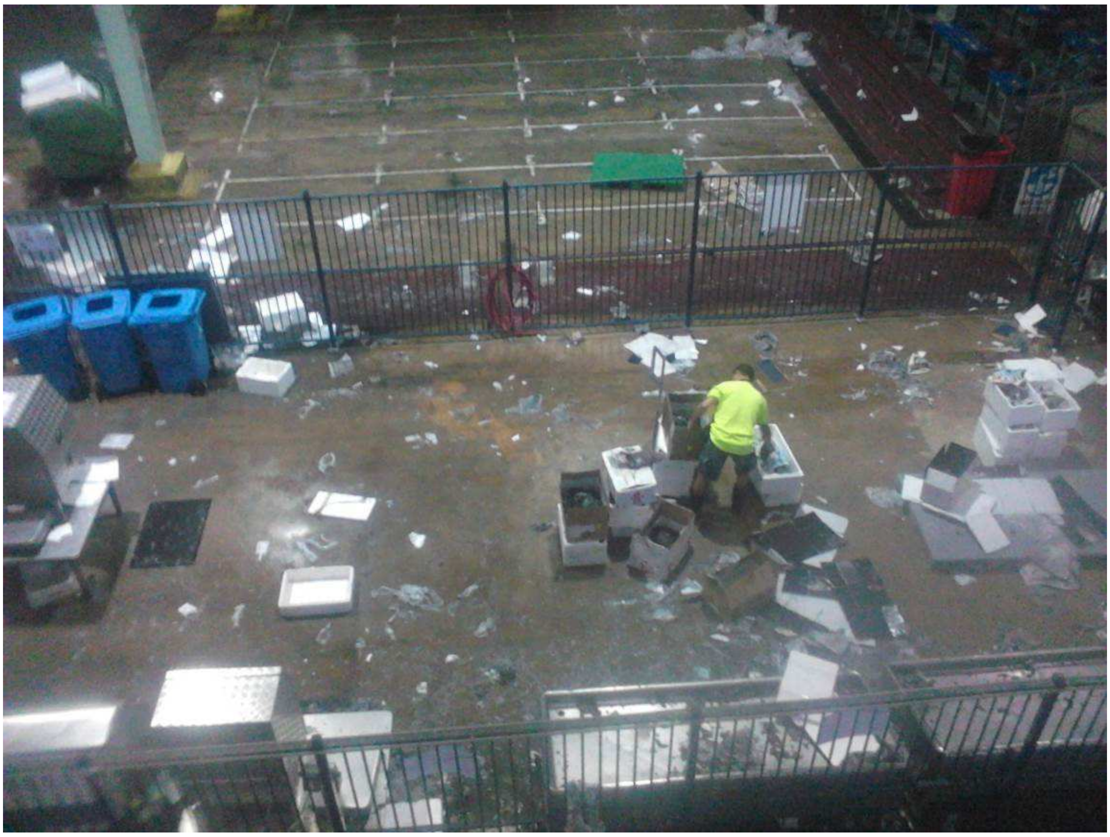

Plate 2.3 Buyer repacking crabs for further distribution.

Eleven crabs were selected across a range of sizes, grades for storage in a damp hessian lined crate for six days. During this period crabs were shipped for several hours by vehicle and stored in noisy environments to simulate typical transport conditions to market. An immersion recovery system was setup similar to previous trials. However, during this trial crabs were immersed for three hours within a fish crate placed in the 200L recovery tub for easy transfer post-recovery. The crate was then transferred into a Xactics 1000L fish bin with covering lid for dry storage. After the weekend, the crabs were transferred to Styrofoam eskies and observed over the following four days. They were then put back into the sea water holding tanks and observed over the next six days. Crabs were not fed during this time as would be the case in retail conditions.

2.2.6. Friday recovery option – trial 2

Previous trials used pilot scale equipment and include manual transfer of crabs between stages. After evaluating the effectiveness of the variety of conditions tested a simple automated recovery system (Plate 2.4) was then developed with minimal equipment, thus minimising possibilities of system failure.

The system included:

- 2 x 1000L Xactics insulated fish bins – a reservoir and a recovery tank
- 1 tap timer to fill the reservoir with town water
- 1 air pump (40L/min) with 2 x 50mm air-stones to de-chlorinate reservoir water over 23 hours prior to being used in the recovery tank
- 1 submersible pump (180L/min) to exchange water from reservoir to recovery tank
- 1 power supply timer for reservoir tank pump
- 1 air pump (60L/min) with 6 x 50mm air-stones to aerate all fish creates in the recovery tank
- 1 power supply timer for recovery tank air pump
- 1 submersible (180L/min) pump to remove water from recovery tank
- 1 power supply timer for recovery tank pump

- connecting hoses, elbows, t-pieces, taps and clamps
- 1.5m 90mm storm water pipe as a snorkel to stop syphoning
- 3 draining fish creates raised off the recovery tank floor
- 3 draining fish creates as a second layer
- 3 draining fish creates as lids to stop crabs escaping
- recovery tank lid to maintain air temperature, reduce light and exposure

The system was trialled and all timings adjusted as required.

Plate 2.4 Recovery tank with stacked fish creates.

A fish create containing previously emersed crabs was placed on 50mm high spacers creating a platform within the recovery tank which was then filled with the de-chlorinated fresh town water pumped from the reservoir tank. After three hours the recovery system water was pumped out. Crabs were observed for liveliness at this time and over the next two days.

2.3. SFM recovery system

A pre-installation site visit was conducted to source materials and space for a recovery unit. Materials sourced were two Xactics 1000L fish bins, and nine SFM draining fish creates. The identified facility, the disused QA laboratory, was inspected and agreed upon (Plate 2.5). A resale strategy was also developed.


Plate 2.5 Recovery unit facilities pre-installation.

2.3.1. Installation and recovery trial 1

The immersion recovery system was installed and tested. The bottom layer of three SFM fish creates was raised with permanent 150mm legs. Five seized crabs with slow or very slow liveliness index were transferred to the recovery unit.

2.3.2. Recovery trial 2

A repeat of the previous trial was conducted with increased numbers. From a Friday auction, 39 crabs with liveliness index of slow or very slow were sent to the recovery unit. Temperatures for the recovery unit's reservoir and recovery waters were recorded as well as dry storage bins of the recovery tank, and no variations were identified that would be problematic for crab recovery.

2.3.3. Recovery trial 3

At a mid-week auction, 14 rejected slow crabs plus an additional three seized crabs of haemolymph protein values greater than the arbitrary cut-off for 'B' grade as measured by refractometer (RI>1.3475) and an independently assessed shell hardness of 'B' grade were sent to the recovery unit.

2.3.4. SFM recovery activities

The recovery unit was originally established upstairs in a disused QA laboratory, an ideal location for security and optimum recovery conditions. The downside was the transfer of crabs to and from the unit via a lift was both tedious and time consuming. The laboratory was subsequently required for other purposes and a closer location on the same level as the SFM auction market floor was identified. The crab recovery unit (Plate 2.6) was transferred and water supply connected to allow recovery operations to restart. The downside of this location is that it's exposed to noise from a crate washer, fork lifts, human traffic and is a cooler environment. This was addressed with tank covers and a water heater added to the reservoir tank.

Plate 2.6 Relocated recovery unit.

Improvements / alterations to the recovery tank setup

After moving the tank system to its new location obstacles were observed that needed to be overcome:

- Fluctuations in SFM's mains water pressure meant that the water input timer had to be replaced with a cistern based float switch filling mechanism, to ensure the reservoir tanks was filled up each time.
- It was observed during the 2013 winter season that water temperature in the new location was an issue. Therefore a submersible heater was installed in the reservoir tank and set at 26°C.
- The air pumps had to be replaced. The two smaller pumps were replaced with one bigger pump running 24/7 in both the reservoir and recovery tanks.
- The fish crates were replaced with bread trays that would allow more water flow.
- It was theorised that the crabs would respond better if the stronger crabs were placed above not below weaker crabs. Therefore SFM staff graded the crabs for levels of weakness, putting weaker crabs lower down and the stronger ones in upper trays. The procedure formulated was to place crabs that have mucus flowing from their mouth in the bottom tier of the stacked bread crates, then on the next tier up to stack crabs that are frothing dark bubbles and finally, on the highest tier to stack crabs that do not have any form of fluid seeping from them. This was also associated with limiting the number of crabs to 6 per bread tray to facilitate greater water-flow around and through the crabs' bodies with the hope of triggering them to release their maximum amount of ammonia.

2.4. Packaging

Temperature was monitored within all trials when holding crabs in damp hessian lined crates within the research facility tank room or simulated transport conditions. Temperatures were recorded by thermocrons to provide readings at set intervals either for crab temperatures or internal temperatures of eskies or fish creates. Ambient external temperatures were also recorded as a reference. Temperature has a major effect on the liveliness of crabs particularly when in transit via refrigerated vehicles. Several consignments of crabs were temperature logged through transit to provide a clear record of conditions that crabs were exposed to.

Variations of air hole configurations in eskies (Plate 2.7) were trialled to observe temperature fluctuations under a range of conditions. The most common air holes configuration used by fishers includes two holes of finger width size on the ends or lid of the esky. This provides adequate air supply as long as the esky is not stacked against others which happens during transport. Multiple air holes are used by several fishers and sometimes large or many air holes are made in the esky allowing maximum air flow. This could be detrimental by allowing cool air in, particularly during refrigerated transport. Crabs from eskies with no air holes at all are often observed to be warm on unpacking at QA. Together with the risk of a dead crab releasing toxic gases that often cause more deaths, this configuration is not recommended, particularly for long supply chains. The recommended air hole configuration trialled was a finger sized air hole located midway on each corner of the esky. This is designed to allow adequate air circulation and will not be blocked when eskies are stacked together.

Eskies were filled with a combination of defrosted freezer bricks, cooked crab carapaces and packaging to simulate internal parameters of live transport. Thermocons were positioned with the eskies in three locations – top, centre and bottom. External temperatures were also monitored for floor and raised ambient conditions. Obviously in a real situation internal temperatures may vary due to crab metabolism. The comparative performance of the various air hole configurations was the objective of the trials.

Plate 2.7 Esky air hole variations*.

*Esky hole configurations from left: multiple, none, typical, recommended.

2.5. Project Variation – Stress within grades

Crabs of each grade were sourced from a Moreton Bay consortium of fishers who harvest from various regions around Moreton Bay. At sample time, all crabs were generally regarded as excellent quality, exceeding typical market grades. The exception was a batch of 'A' grade crabs harvested from within the Brisbane River. Some crabs in this batch had an uncharacteristic appearance, odour and colour and others appeared somewhat sluggish. However, one of the better crabs was selected from the sample pool to observe any difference to other 'A' grade batches harvested elsewhere.

The 'B' grade crabs had minimal shell flex and would pass as 'A' grade in most markets. Most of the 'C' grade crabs would also easily pass for a 'B' grade in most markets. Many of the crabs from all the grades had mature barnacles on their shells which is a sign that they had moulted some time ago. A considered sample selection of eight crabs of each grade was made from these fisher graded groups based on what would be typical for that grade in most markets. An additional four 'C' grade crabs were added to allow for any mortalities prior to commencement of stress trials.

However, as the 'C' grades available on the day were of such good quality as depicted by shell hardness and signs of age, a second lot of 'C' grades crabs that were relatively newly moulted as denoted by a clean shell appearance was subsequently supplied. This fisher would normally return these 'fresh' crabs to the water at point of capture or reject at pack out prior to shipment. These crabs were more typical of the 'C' grades observed at major markets.

A consignment of 'C' grade crabs from SFM was sent via air freight and transported to the research facility to substantiate the belief from various sectors of the industry that air travel has adverse effects on the survival of crabs. However, these crabs were also of excellent quality for their grade. They were chosen from a consignment of an individual fisher who consistently supplies the market with quality crab across all grades. As such, a second consignment was requested from SFM that were typical 'C' grade. This consignment was a mixed batch of crabs from various regions including Wallis Lake as denoted by colour coded cable ties this co-operative uses to identify individual fishers. These crabs were either rejected or considered to be of a downgrade quality by SFM QA staff due to their excessively soft shells.
Upon arrival at the research facility, all crabs were graded and a sample of haemolymph taken for analysis. Crabs were then stored in damp hessian covered fish creates and subjected to a series of typical supply chain scenarios to induce stress. These scenarios included exposure to extremes of temperature abuse (range 10-36°C), sun light, breeze, physical shock from typical rough handling of eskies within the transport chain and human interference as in a retail situations over several days. Further grading and haemolymph analysis was performed on subsequent days related to significant points within the supply chain.

The periods of emersion were between five and eleven days depending on the liveliness observations of each batch of crabs. At the point when the majority of a batch of crabs where graded as slows or very slow they were relocated into seawater tanks to possibly recover and be used for subsequent trials. Observations continued during this phase to observe liveliness and mortalities.

Parameters measured included:

- physical damage - missing limbs, cracked shell, foaming, bleeding
- shell hardness at all test points - male top left and right, bottom six segments; female top left and right
- liveliness – five point scale (Table 2.1)
- weight
- width
- pH
- glucose
- Refractive Index (total protein)

2.6. Industry extension

SFM adopted and introduced the National Mud Crab Grading Scheme into their product specifications and QA grading procedures in December 2012. Since then several fishermen from NSW co-operatives have sought clarification on the grading standards. As reported in Section 2.2.3., a workshop was held to demonstrate best handling, packaging and grading techniques at a NSW fishing co-operative based on their high volume of crabs that are rejected. Crabs supplied and subsequently seized as 'C' grade from this fishing co-operative were used to demonstrate the issues. Prior to the workshop, as crabs were being weighed-in, grading was independently verified and in some cases fishers voluntarily withheld substandard crabs. Fishers were very happy to have their grading verified prior to weigh-in. One fisher's entire batch of crabs were demonstrated to be all 'C' grades and voluntarily not offered for sale. These crabs were harvested from a lake system where crabs apparently go to moult. Numbers are abundant in this system but as they are recent post moult crab, their quality was poor. It was demonstrated to the fisher with supportive research data that these crabs, if returned to the water, would be at least 'B' grade crab within a few weeks.

The co-operative manager had closed their associated weigh-in facilities for the day so that all fishers in the region would be encouraged to attend the workshop and presentation. Thirteen fishers and three co-operative staff attended with lively discussion on several points:

- seized crab percentages compared to other co-operatives
- SFM grading standards
- precise procedure on grading technique, avoiding shell damage
- shell hardness relationship to meat yield
- best packaging methods
- SFM auction system
    - o now on the auction clock
    - o minimal pre-checking of boxes by suppliers as boxes can now be stacked
    - o auction price driven by supplier's previous crab quality
    - o myths of rejected crab being on-sold were debunked
- seized crab return to sender options and policies
- options for objective grading tools
- co-operatives pooled pricing policy and individual downgrade data feedback

Data as presented in Figure 2.2 highlighted the significant amount of seized crab from this co-operative as compared to others. Individual co-operative names were not displayed at the workshop for confidentiality reasons.

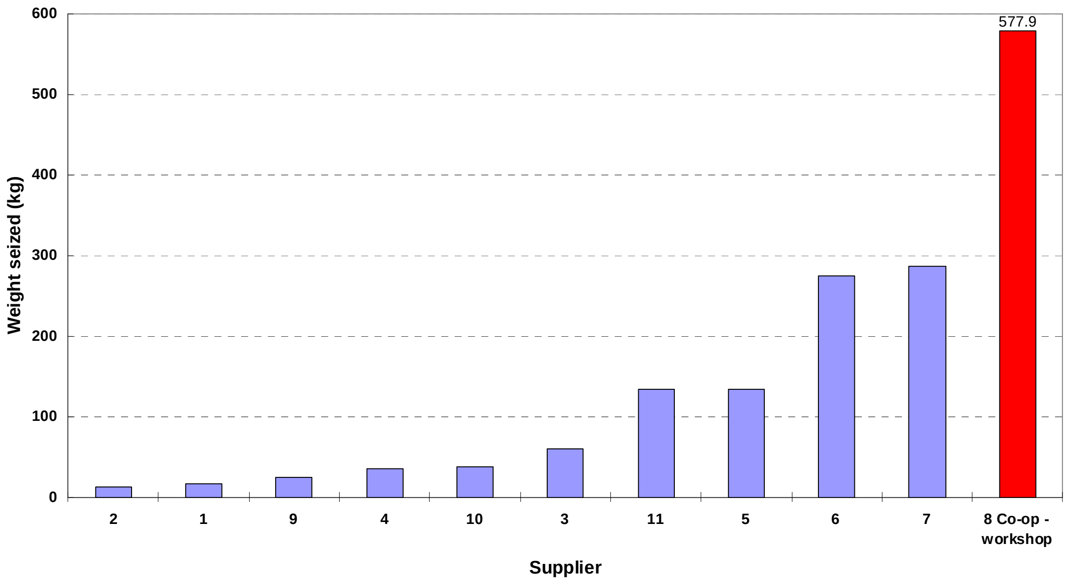

Figure 2.2 SFM seizures from individual NSW Fishermen's Co-operatives.

This volume was disproportionately large due to the amount of fishers that use this co-operative. However, their 10.3% seizure rate ranked high against the average for NSW Co-operatives of 6%, also indicating the extent of the problem for these fishers (Figure 2.3).

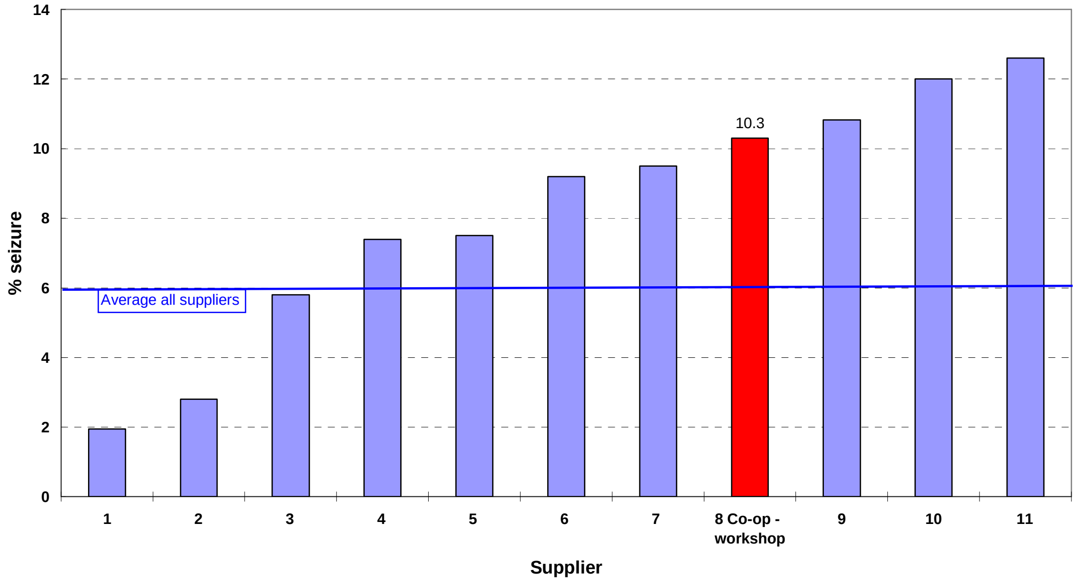

Figure 2.3 SFM percent seizures from individual NSW Fishermen's Co-operatives.

The long term benefits that have been shown by many proactive fishers in releasing newly moulted crabs for future catch needs to be emphasised to some sectors of the industry. Further communications were held to equip stakeholders with skills of best handling and packaging.

2.7. Spanner crabs

Seasonal data from 2012 indicates peak supply to SFM from August to November (Figure 2.4).

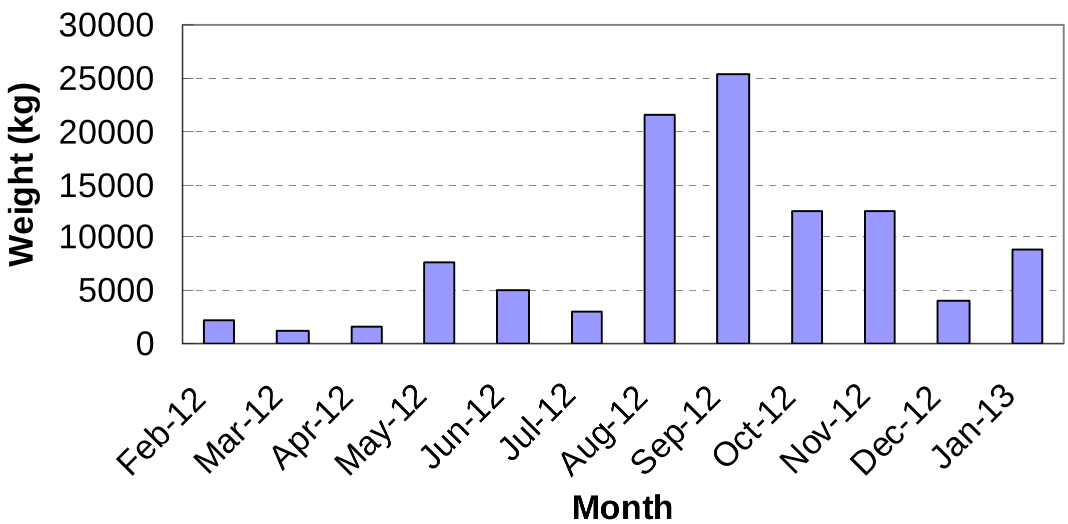

Figure 2.4 Seasonal supply of spanner crabs.

Best handling procedures were clarified with fishers that historically have minimal downgrades followed by workshops held prior to peak season focusing on suppliers with higher rates of downgrades (Table 2.2).

Table 2.2 Supplier adjusted weights 01/07/12 - 31/01/13.

Trading name (omitted)	Adjusted weight (kg)
A	23.92
B - Nth NSW	**5160.38**
C	55.29
D	0.80
E	10.03
F	740.46
G	259.41
H	10.91
Total	**6261.2**

Observations were made of a particular Queensland supplier's early season spanner crabs that had uncustomary issues resulting in higher than normal downgrades (Plate 2.8). Follow up discussions with the supplier revealed possible causes for the issue of that consignment and potential future remedies.

Plate 2.8 Downgraded spanner crabs at QA station.

Another major Queensland spanner crab quota holder approached the DAFF seafood research team to investigate if improvements in their cooked and frozen spanner crab meat product could be improved. Following preliminary investigations the major finding was variation in quality of live animals was impacting on the quality of the cooked meat. The cooked quality was shown to be directly related to the quality of the live product. Rather than further investigating processing aids to improve their product, this company is now focusing on improved handing procedures for crabs immediately postharvest that are destined to be processed into the cooked meat product.

3. Results

3.1. Fresh water spray v fresh water immersion – trial 1

All crabs from both treatments were observed as very lively immediately post-recovery treatments. Ammonia recordings were also inconclusive with little differences between the two treatments. Over the 22 hours, the spray system ammonia levels continued to increase but remained at low levels. The commercial pool ammonia test kit values were below the minimum recordable. At day one post-recovery the spray treatment crabs showed signs of less vigour (Table 3.1). All crabs from the immersion treatment were still very lively.

Table 3.1 Liveliness index at 1 day post-recovery.

Spray		Immersion	
Crab#	Liveliness*	Crab#	Liveliness*
9	4	1	4
10	4	2	4
11	3	3	4
12	3	4	4
13	4	5	4
14	2	6	4
15	3	7	4
16	4	8	4

* 0=dead; 1=very slow; 2=slow; 3=lively; 4=very lively

At day two post-recovery the spray treated crabs continued to deteriorate (Table 3.2) and the immersion treatment crabs still showed good liveliness.

Table 3.2 Liveliness index at 2 days post-recovery.

Spray		Immersion	
Crab#	Liveliness*	Crab#	Liveliness*
9	2 or 3	1	4
10	4	2	3
11	3	3	4
12	2 or 3	4	4
13	4	5	4
14	1 foaming	6	4
15	3	7	3
16	4	8	4

* 0=dead; 1=very slow; 2=slow; 3=lively; 4=very lively

Weight change during storage showed an initial decrease of 2% during the seven day emersion pre-treatment, the reversal of that loss during both treatments, followed by a decrease of 2% each day during storage in Styrofoam eskies post-treatment.

When crabs were re-immersed into the holding tanks it was observed that the spray treatment crabs were slower to start water exchange across their gills and the immersion treatment crabs were quick to start moving water across their gills.

3.2. Fresh water spray v fresh water immersion – trial 2

All crabs from both treatments were observed as very lively immediately post-recovery treatments. During three days post-recovery storage in Styrofoam eskies, crabs from both treatments showed equal signs of vigour. On day three, there were two deaths from the spray treatment and four deaths from the immersion treatment. However, these animals were all beside each other in one esky. It is common for one dead animal to cause others nearby to die due to released ammonia. The excretion rates of ammonia from the fresh water spray system were less than that for the immersion system (Table 3.3). Again the commercial pool ammonia test kit values were below the minimum recordable.

Table 3.3 Ammonia efflux (Randox kit).

	NH3 (g/L)	
Time (hrs)	Immersion	Spray
0	0.0000	0.0000
1	-0.0008	0.0017
2	0.0017	0.0025
3	0.0017	0.0033
19		0.0042
20		0.0017
21		0.0025
22		0.0042

Changes in crab weight between pre-recovery and post-recovery showed an increase of 2.5% and 6.1% for the spray and immersion treatments respectively. Over the following three days a subsequent decrease in crab weight of 5% was observed for both treatments.

3.3. Extended emersion

Crabs numbered 7, 14 and 16 were too damaged to be included in this fresh water spray recovery trial due to being handled multiple times prior to and during the workshop at the fishing co-operative. Crab number 1 died after two hours in the fresh water spray system. Of the nine crabs put through the recovery system seven (78%) survived with their liveliness index improving from very slow or slow to lively (Table 3.4). At day four post-recovery, six of these crabs had regained maximum liveliness.

Table 3.4 Liveliness index* during extended emersion and fresh water spray recovery.

	Day 10	**Day 15**	**Day 0**	**Day 1**	**Day 4**
Crab#	**Pre-workshop**	**Post-trip**	**Pre-recovery**	**Post- recovery**	**Tanked**
1	1	1	0		
2	1	2	1	3	4
3	3	3	1	3	4
4	2	3	1	3	4
5	2	0			
6	3	1	1	3	4
7	4	3	-		
8	4	4	1	0	
9	4	0			
10	4	4	2	3	4
11	3	0			
12	4	0			
13	4	0			
14	3	1	-		
15	3	0			
16	3	2	-		
17	3	4	3	3	4
18	3	2	1	3	3

* 0=dead; 1=very slow; 2=slow; 3=lively; 4=very lively

3.4. Immersion followed by overnight spray

There was no major difference between spray or immersion treatments (Table 3.5) until day four post-recovery when some crabs from the fresh water spray treatment started to lose vigour or die. The death of crab number 10 from the immersion treatment may have been because it was housed next to a very aggressive one-claw crab (number 29) that was observed to be constantly moving and disturbing crabs around it (top left Plate 3.1).

Table 3.5 Liveliness index* post-extended emersion for two recovery treatments.

		Initial emersion	**Post-recovery**				
Treatment	**Crab#**	**day -13**	**day 0**	**day 1**	**day 2**	**day 3**	**day 4**
Spray	1	4	4	4	4	4	4
	3	4	4	4	4	4	2
	6	4	4	4	4	4	4
	9	4	4	4	4	4	3
	19	4	0				
	23	4	3	4	4	4	3
	24	4	4	4	4	4	0
	26	4	4	4	4	4	2
	40	4	3	4	3	3	2
Immersion	3	4	4	4	4	4	4
	4	4	4	4	4	4	4
	5	4	4	4	4	4	4
	10	4	4	4	0		
	14	4	3	4	4	4	4
	16	4	3	4	4	4	3
	29	4	4	4	4	4	4
	31	4	4	4	4	4	4
	37	4	4	4	4	4	4

* 0=dead; 1=very slow; 2=slow; 3=lively; 4=very lively

Plate 3.1 Immersion (L) and spray (R) treatment crabs post-recovery.

Recorded temperatures within the two recovery treatments showed no relevant differences. Weight losses were 4.5% over 13 days emersion, return of that weight loss post-recovery treatments, followed by a 3% loss over the next three days when held in Styrofoam eskies.

3.5. Friday recovery option – trial 1

Of the 11 crabs put through the immersion recovery system all remained very lively until day three post-recovery when one crab died. At day four post-recovery another crab died, six were still lively or very lively and three had become slow. Between day five and ten post-recovery during which the crabs were returned to the holding tank, it was found most had regained good liveliness (Table 3.6).

Table 3.6 Liveliness index* from Friday recovery treatment.

	Post-recovery					
	Fri	**Sat**	**Sun**	**Mon**	**Tues**	**Mon**
Crab #	**day 0**	**day 1**	**day 2**	**day 3**	**day 4**	**day 10**
3c	4	4	4	3	3	3
6	4	4	4	4	4	4
9	4	4	4	4	4	4
26	4	4	4	4	4	4
40	4	4	4	0		
5	4	4	4	4	4	4
14	4	4	4	3	2	3
16	4	4	4	3	2	3
31	4	4	4	2	0	
37	4	4	4	4	4	4
41	4	4	4	1	2	2

* 0=dead; 1=very slow; 2=slow; 3=lively; 4=very lively

Weight gains and losses were similar to previously reported with a 6% loss during the initial emersion period, recovery of that loss during the recovery step and a 2% loss after a further four days emersed storage period.

3.6. Friday recovery option – trial 2

Crabs were all very lively after the three hour immersion recovery treatment. The next day, two crabs had died and the remaining were less lively. At day two post-recovery, all crabs were dead.

3.7. SFM recovery system

Dates of significant events impacting on mud crab sales at SFM are presented in Table 3.7.

Table 3.7 Events impacting mud crab sales

1/11/2012	Project start
5/11/2012	AILMCGS introduced to the entire Australian mud crab industry
3/12/2012	SFM introduced AILMCGS
27/03/2013	Recovery unit commissioned in SFM QA lab
1/5/2013	Recovery unit relocated
1/11/2013	SFM 'C' grade trial official start
1/5/2014	Recovery unit relocated
26/05/2014	Recovery unit recommenced
1/06/2014	Project Finish (original)
1/08/2014	Project Finish (extension)

Observations from the various trials conducted at SFM are given in the following sections.

3.7.1. SFM Installation and recovery trial 1

As reported in Section 2.3.1 five seized crabs with slow or very slow liveliness index were transferred to the recovery unit. The next day, three crabs had survived but had not regained enough liveliness to be sold. Sixteen seized ‘C’ grade crab were then put through the recovery system (Plate 3.2) with only a single mortality. These 16 crabs were specifically selected from the daily seizures as their haemolymph protein values were greater than the arbitrary cut-off for ‘B’ grade as measured by refractometer (RI>1.3475). Another 16 ‘control’ crabs that were seized as being reject ‘C’ grade were also stored in the recovery room with no recovery process applied. Five of these ‘control’ crabs died.

Plate 3.2 Recovery system installed.

3.7.2. Recovery trial 2 and 3

As previously reported in Section 2.3.2, 39 crabs with liveliness index of slow or very slow were sent to the recovery unit. At midday on Sunday, 50% had recovered and were extracted from the recovery unit for further observations. They were not offered for Monday's auction as these 'weekend' recovered crabs' liveliness and/or mortality needed to be evaluated post-recovery. It was seen as unwise to risk setting an early poor perception to the buyers of recovered crabs when mortalities could be high. These recovered crabs (Plate 3.3) were reported as having a good liveliness into the early part of the week.

Plate 3.3 Recovered crabs.

In trial 3, details of the seventeen crabs sent to the recovery unit and subsequently sold at auction were:

- original seized weight 15.41kg (17 crabs)
- weight re-sold post-recovery 13.3kg (14 crabs, 86% weight recovery, 82% animal recovery)
- auction price $16.59/kg
- total resale value $220.65
- days average 'No-grade' price $18/kg (SFM's 'No-grade' category signifies 'A' and 'B' grades mixed in the same box)

There was no observed reluctance to bid on these recovered crabs. On the contrary they were purchased without hesitation and a good price offered. The three largest crabs were rejected at post-sale QA inspection as being too slow. Independent grading assessment showed one crab to be very slow, one slow, and one slow digger (single claw crab). Larger crabs are generally considered more prone to mortality in the supply chain, hence the reluctance for some buyers to risk purchase.

3.7.3. Continued recovery operations

Initial prices attained during of the first phase of the recovery unit's operations were higher than anticipated (Table 3.8). The concept of recovering slow crab and presenting for resale was firstly viewed with some scepticism by a few buyers. The initial batches of crabs recovered and offered for sale were in good condition and attained good prices.

Table 3.8 Resale of recovered crab.

Date	**Box #**	**Weight (kg)**	**Weight post-recovery (kg)**	**Resale price ($/kg)**	**Total resale value ($)**	**Average daily 'B' price ($/kg)**
27/03/2013	1	15.4	13.3	$ 16.59	$ 220.65	$ 18.00
3/04/2013	1	4.9	0.4			
3/04/2013	2	5.5	3.1	$ 20.00	$ 62.00	$ 16.70
10/05/2013	1	3.0	0			
14/05/2013	1	8.0	3.0	$ 20.92	$ 62.76	$ 17.95
16/05/2013	1	7.3	4.1	$ 17.50	$ 71.75	$ 16.79
Total		**44.1**	**23.5**		**$ 417.16**	

SFM historical QA data shows that crabs that were downgraded due to being very slow represent 2.8% (around 11 tonne / pa). This 53% recovery rate achieved in this first phase would equate to $105,500 per annum from very slow crabs that are normally seized.

Unfortunately, the quantity of crab sent to the recovery unit in the first phase of recovery trials was less than had been hoped for various reasons:

- fewer slow crabs were rejected at QA than had been expected
- recovery unit needed relocation due to renovations
- delay in connection of water supply in the new location
- air pump failure once in the new location
- SFM staff annual leave and other work commitments

Once these issues had been overcome the following issue affected the recovery tank usage.

- Supply volume during 2012/13 was historically lower than recent preceding seasons (Table 3.9).

Table 3.9 SFM annual supply.

Year	Supply (tonne)
2010/11	392
2011/12	419
2012/13	331
2013/14	393

Therefore the live mud crab recovery unit was temporarily suspended in winter 2013.

Unusual weather patterns throughout SFM's main supplier regions disrupted harvests and supply rates. There were drought conditions in some regions of northern QLD simultaneous to flooding in southern QLD and northern NSW. These conditions impacted on the product supply to SFM and meant that there was greater demand for the fewer crabs that were available. This decreased supply had a number of flow-on effects:

- Buyers were less picky on whether crabs that they purchased met the defined grading specifications or not.
- The buyers were willing to buy very slow crab for 80% of a good crab's value. This meant that with a 50-57% survival rate in the recovery system it was more cost effective to just sell the slow crabs for 80% of the full price rather than operating the system and hoping to get a full price for the 50-57% of the crabs that survived the recovery process.

Prior to this period of low supply, recovered and re-sold crabs had achieved better than expected prices and despite initial skepticisms were viewed favourably. A qualitative analysis of buyer acceptance and assessment of benefits of recovered crabs as outlined in the initial proposal was not possible with the suspension of the recovery system.

Other factors that came into play around this time were that:

- the AILMCGS had bedded into the supply chain and been implemented within the SFM QA system. Until the introduction of 'C' grade sales by SFM in late 2013 there was some resentment of grading standards as evoked by SFM because under the new AILMCGS system crabs that would have previously been classified as 'B' grade, on the old SFM system, were now classified as 'top end' 'C' grade ('C+').
- the SFM auction of live mud crabs had changed from the traditional voice auction to a modified Dutch auction system on the electronic clock. Implications of this include:
    - crab boxes from the same supplier are stacked on top of each other. This minimized the buyer's pre-auction inspections which would reduce crab's stress from multiple handlings and exposure
    - reduced crab stress from not having buyers in the traditional auctions system haggle loudly over each box of opened crabs as they were auctioned
    - reduced the effect of cold floor temperatures from over-chilling crabs, particularly in winter months

- reputation of an individual supplier's crabs became a leading price determining factor at auction. Suppliers soon realized the importance of consistent quality crabs and accurate grades being displayed on each box.

- in late 2013 a trial of selling 'C' grade was introduced at SFM. Commercially unsuitable 'C' Grade crabs (CUCs) were previously rejected at SFM, whilst 'C' grades crabs were sold in other locations. The original SFM product specification as outlined in the SFM Seafood Handling Guidelines for a CUC described it as a very soft newly moulted crab. This would be at the lower end of the now Australian AILMCGS standard for 'C' grade crab. In February 2014 SFM announced the continuation of sale of 'C' grade mud crabs.
- changes in some buyers attitudes towards accepting slow crabs as opposed to having them seized and the flow on effect of this practice to other buyers that typically demand only the highest quality crab.
- new buyers and old buyers re-entering the market that were only interested in purchasing 'C' grade (and other low specification) crab.

Prior to this project and all these other industry changes, up to three wheelie bins of rejects were dumped per day in peak season. This is now between half and one bin per day. Reasons for this reduction in wasted product are also likely to include the steady implementation of best handling practices from crab pot to market which have been extended to the entire supply chain by the researchers[3].

Given the return of supply back to 393 tonne/year in 2013/14 and a subsequent change in buyer behaviour regarding the willingness to 'take 2nd grade crabs at 1st grade prices' the recovery unit has been deemed to be viable again and has recommenced operations from 26th May 2014

Table 3.10 May-July 2014 recovery results.

Date	Weight (kg)	Weight post - recovery (kg)	Resale Price ($/Kg)	Total Resale Value ($)
26/05	9.1	3.1	15.00	46.50
27/05	2	2	10.00	20.00
28/05	3.6	0.8	8.00	6.40
29/05	1.8	1.1	11.00	12.10
02/06	11	6.8	14.00	95.20
11/06	8.2	6.4	7.00	44.80
30/06	9.9	7.4	19.00	140.60
01/07	17.8	14.55	15.25	221.85
02/07	6.1	4.6	10.00	46.00
03/07	12.9	12.9	10.00	129.00
04/07	1.6	1.6	21.00	33.60
07/07	12.35	8.4	27.00	226.80
08/07	11	0	0.00	0.00
10/07	8	7	29.00	203.00
14/07	31.7	24.45	35.43	866.30
15/07	3.9	1.5	25.00	37.50
16/07	7.3	3.6	12.00	43.20
17/07	7.8	0	0.00	0.00
22/07	7	4.5	15.00	67.50
Total	**173.05**	**110.7**		**$2240.35**

Table 3.10 shows the recent recovery results. On average, a 64% recovery rate was achieved and product was sold for grade appropriate market prices.

Historical SFM reject and downgrade data has been analysed for the 2013/14 financial year (See below Table 3.11) and the results show that the overall seizure rate is now 3.95%. The downgrades are 7.76% with only 1.14% or 4.5 tonne being due to slow or very slow crab.

Table 3.11 SFM seizure and downgrade rates.

	Percentage of total mud crab sales at SFM during 13/14
Seized Crab	3.95
Downgraded Crab	7.76
Downgraded for reason of being slow / very slow	1.14

Analysis of sales (Figure 3.1) volumes at SFM shows that the introduction of the sale of 'C' Grade crabs in late October 13 was an industry game changer and led to an increase in volume of all grades of mud crab to the market.

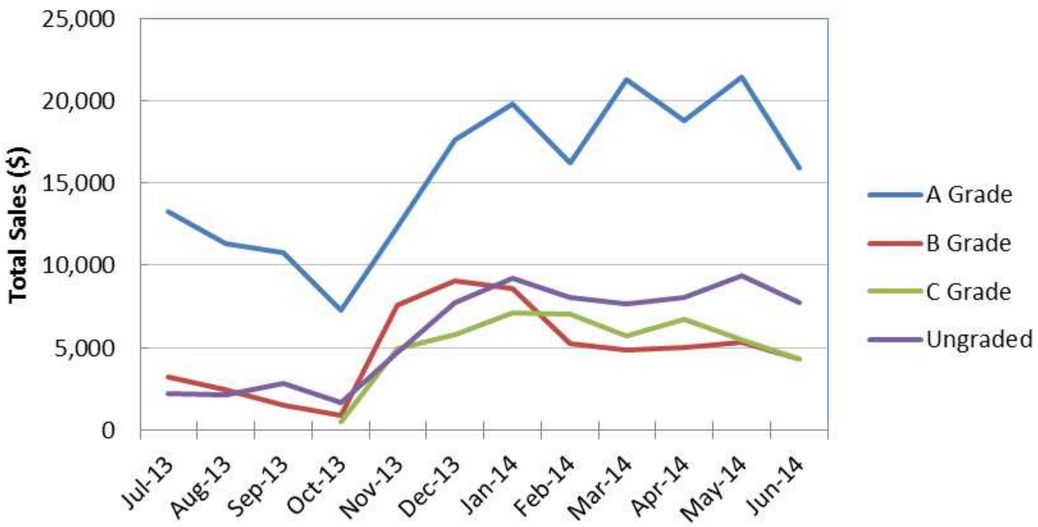

Figure 3.1 SFM sale volumes by grade category.

3.8. Packaging

Holding crabs in damp hessian lined crates within the research facility tank room prior to transit maintained optimum temperature only a few degree above ambient. This slight increase would be due to crab metabolism. Once packed in Styrofoam eskies and transported, the internal temperature rose considerably. An increase in crab metabolism resulting from disturbance is a possible explanation of this temperature increase (circled in Figure 3.2). This data was used to emphasise the importance of providing air holes in cartons and Styrofoam eskies and soldier pack crabs to minimise movement.

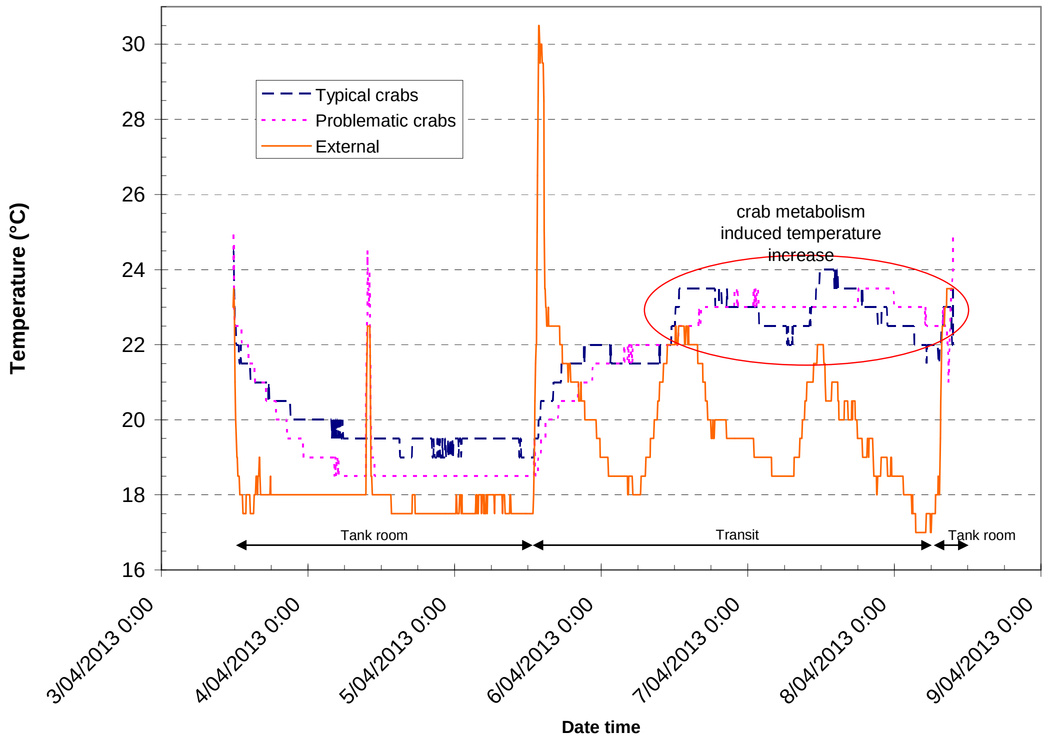

Figure 3.2 Storage temperature increase in transit.

As observed on the SFM auction floor, some consignments still arrive with no air holes at all (Plate 3.4). Crabs from these boxes are often warm to touch and foaming from the mouth, which invokes a higher rejection rate from buyers. Various packaging techniques have been discussed including demonstrations provided by SFM QA officers. Short videos of these consignments are sent (average of two per week) by the QA officers via mobile phone to the suppliers to show the condition of crabs and packaging conditions post-transport as presented for auction. Feedback from these suppliers was positive and remedial action usually took place.

Plate 3.4 Styrofoam esky with no air holes.

Analyses of data from temperature logging of eskies with a variety of air hole configurations demonstrated that the recommend configuration provides the best temperature stabilisation for either hot (Figure 3.3**Error! Reference source not found.**) or cold (Figure 3.4) environments. Benefits derived were a reduction of 10°C when exposed to a warm environment and an increase of 2°C when exposed to a cool environment as compared to the typical air hole configuration. Eskies with multiple or no air holes performed worse in both situations depending on the location of thermocrons within eskies.

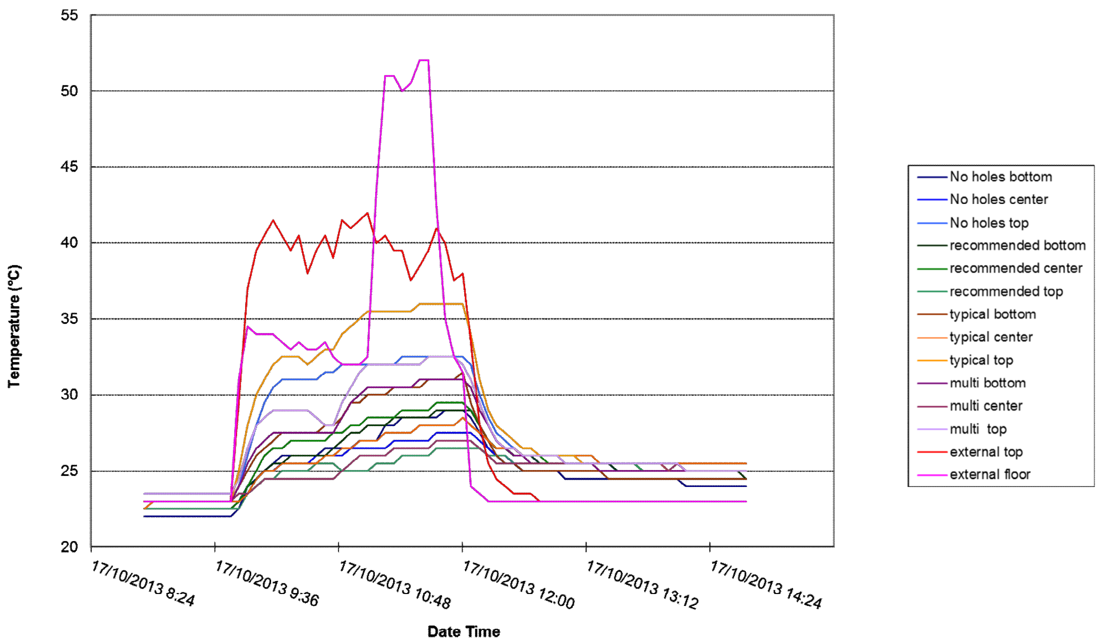

Figure 3.3 Temperature of eskies exposed to heat.

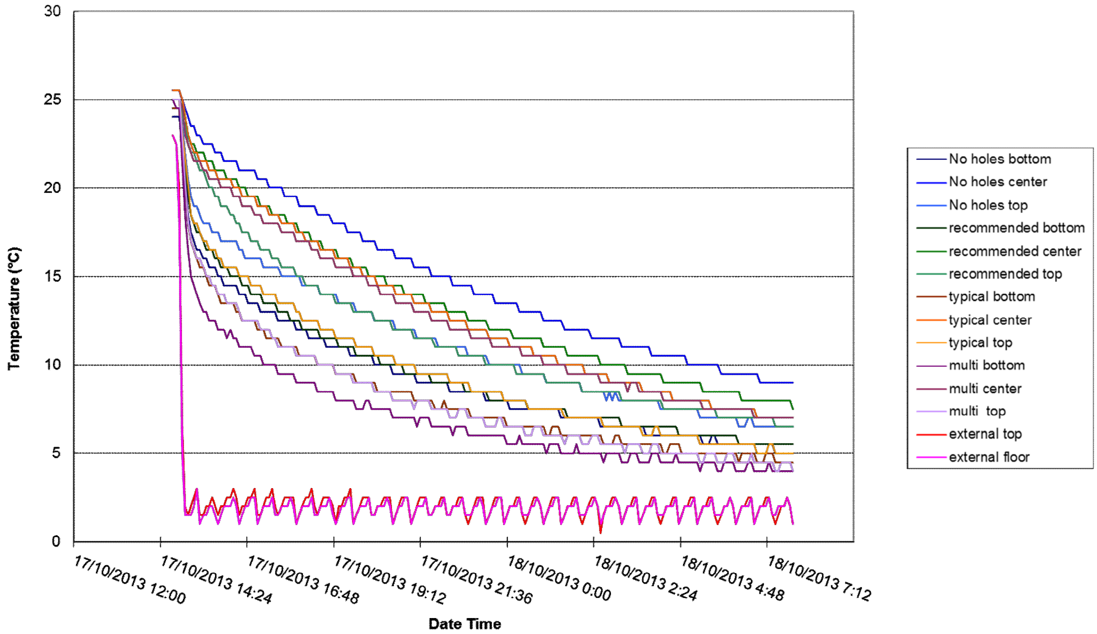

Figure 3.4 Temperature of eskies exposed to cold.

3.9. Project Variation – Stress within grades

As demonstrated in Figure 3.5 Figure 3.5mortality rates within the supply chain are strongly influenced by crab grades. The typical ‘C’ grade crabs from SFM (SFM C-) had the highest rate of mortality. Over 50% had died within four days and all but one had died within three weeks. It was observed that these crabs were prone to excessive bleeding from the slightest damage and in many cases actually bled to death. Also noted was the slow or complete lack of haemolymph clotting, both within storage conditions and during the laboratory procedure of preparing haemolymph samples for glucose analysis. This procedure requires the haemolymph sample to be centrifuged and the clot broken before a second period in the centrifuge. Many of the ‘C’ grade haemolymph samples would not clot at all. The sole survivor from this batch of nine SFM C- crabs was atypical of ‘C’ grade crabs in that it had a high haemolymph protein level yet a very soft shell. The protein level was in the range typical for ‘A’ grade crabs. This is considered to be an excellent example of the regional anomaly issue to be investigated within FRDC project 2014-218.

The ‘B’ and ‘C’ grade crabs had mortalities ranging between 22 and 38 percent respectively. The high number of mortalities within the ‘C’ grade crabs sent via air freight supports the belief that air travel has an adverse effect on the survival rate of these crabs. This was reinforced by the relatively low mortality rate of the market typical ‘C’ grade Moreton Bay crab (Mtn Bay C-). The ‘A’ grade crabs showed the best survival rate with only one crab dying. This individual crab was a Brisbane River harvested crab and, as mentioned previously, was considered uncharacteristic for the grade.

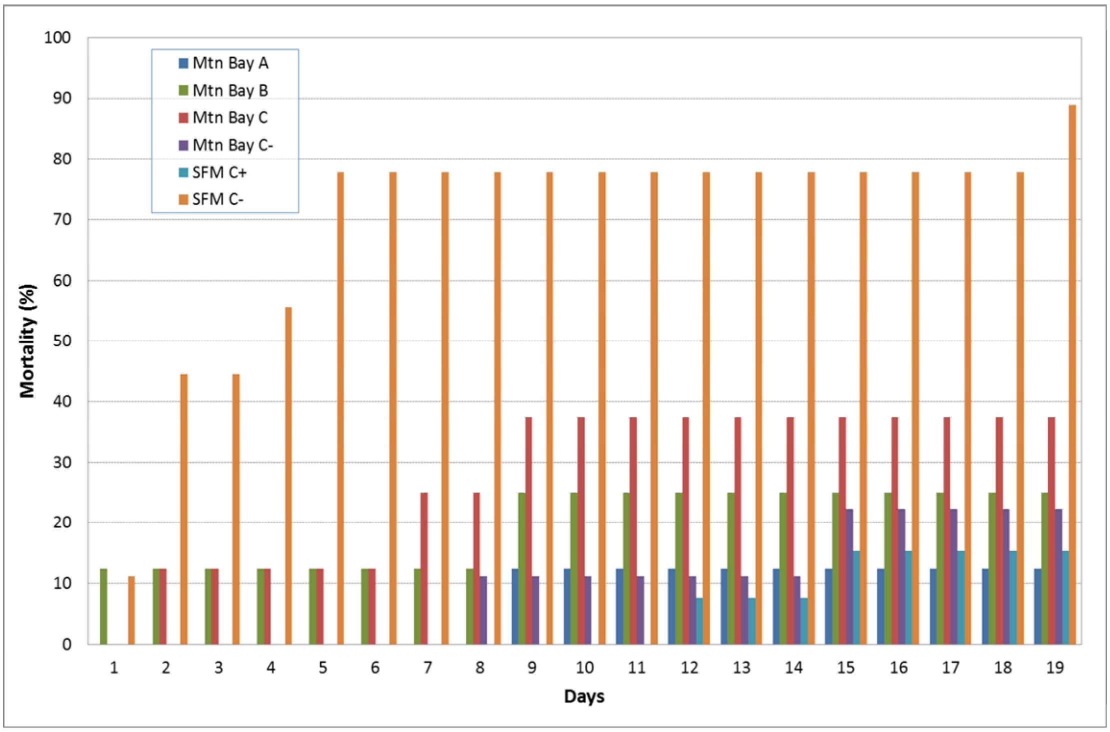

Figure 3.5 Mortalities with supplier grades.

The good quality 'C' grade crabs supplied to SFM by a supplier as C grade (SFM C+) also had a low a mortality rate. However, many of these crabs were not typical of 'C' grade crab, being found to be a mix of all grades. As such the following figure (Figure 3.6) better represents mortality rates within grades. In this representation all crabs were assigned to a grade using a combination of shell flex at all measure points, physical parameters such as wear and missing limbs and haemolymph protein levels.

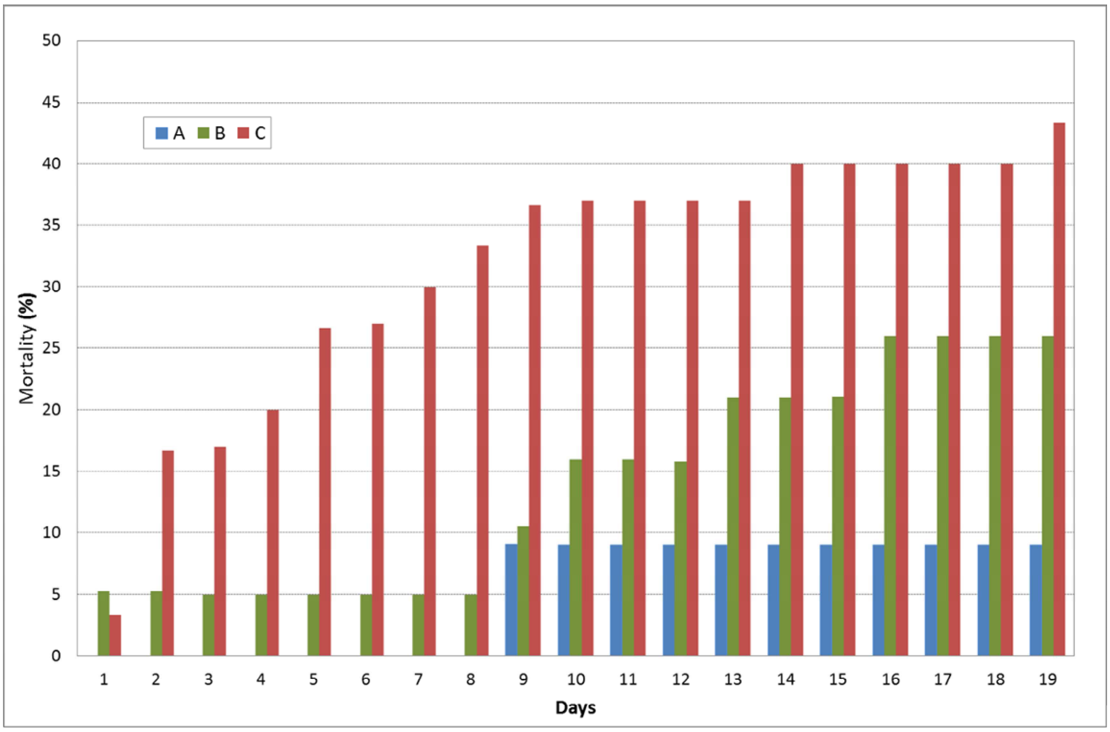

Figure 3.6 Mortalities with verified grades.

The mortality rate of 'C' grade crab increased steadily to 30% over seven days at which point most were returned to seawater tanks for recovery as they were considered very slow or near death. ‘C’ grade crabs mortalities are continuing over several weeks whilst in the sea water tanks. ‘B’ grade crab had minimal mortalities during the stress inducing transport chain scenarios. Mortalities during the recovery stage of ‘B’ grade crabs were mostly related to physical damage caused by aggression. ‘A’ grade crabs would have had no mortalities at all during the simulated transport chain and post-recover periods except for the individual suspect quality Brisbane River crab mentioned previously. This crab had the shell hardness of an ‘A’ grade crab but an extremely low haemolymph protein level consistent with the lowest range of ‘C’ grade crabs. Combined with a slightly low weight to width ratio it could have been classified as “an old crusty” and downgraded if it had the typical worn shell appearance. Inspection of cooked product revealed a very low and poor quality meat content confirming that it was not a good quality crab and should have been downgraded at pack out.

Stress biomarkers

As reported in previous research, many stress biomarkers are available to identify the amount of stress incurred. Some factors may not necessarily be lethal on their own but contribute in combination to a high overall stress level. Haemolymph pH and glucose have been demonstrated as being good stress biomarkers, but results need to be viewed in conjunction with each other and other typical indicators such as liveliness.

pH

The physiological basal pH of mud crab haemolymph is around pH 7.5. The pH is highly reactive to metabolic shifts within the crab and because of this the values obtained for rested crabs are extremely variable (pH 6.96 – 7.94). Crabs that had been subjected to severe stress of extreme temperature or extended emersion exhibited very high (>7.9) or very low (<7.2) haemolymph pH values. These crabs have a high likelihood of imminent death. However, for some crabs subjected to similar conditions, pH remained within the ‘rested’ value limits. Hence, pH alone is not an effective indicator of stress levels in crab but is useful when combined with other indicator parameters. The extreme values, both high and low for haemolymph pH were observed from ‘C’ grade crabs and in particular from the SFM C- crabs.

Glucose

Glucose is used as the major energy source in crabs and increases in haemolymph circulating glucose is indicative of activity or stress. Rested (unstressed) crabs have glucose levels in their blood of <1.0mmol/L although there is individual variation between crabs. Glucose levels rise quickly in immediate response to any form of stress imposition on the crab, but then tend to return to basal levels within a few hours as compensatory mechanisms come into play. From previous research, glucose levels can be correlated directly to stress level the crabs are subjected to as depicted inTable 3.13**Error! Reference source not found.** Table 3.12

Table 3.12 Haemolymph glucose stress levels.

Haemolymph Glucose (mmol/L)	**State of crab**
<1.0	‘rested’ crab
1.0 – 2.0	some stress has occurred
2.0 – 3.0	high stress but will recover under resting conditions
>3.0	extreme stress experienced

Glucose values from the different batches of crabs in this trial varied widely from 0.07 – 5.93 mmol/L. Of importance here is that the ‘C’ grade crabs demonstrated the greatest daily rise in glucose values (Table 3.13), indicating that their stress levels were likely to be an eventual cause of death. Again the SFM C- crabs had the greatest daily increase, hence their early demise.

Table 3.13 Daily increase in glucose.

Grade	Daily increase (mmol/L)
A	nil
B	-0.04
C	0.06
SFM C-	0.07

3.10. Industry extension

Following a workshop at a NSW fishermen's co-operative, an opportunity was taken to observe crabbing operations with a local fisher. Observations included:

- all legal size crabs kept – no on-board grading
- all crab grades have specific markets
- a collaboration was created with major buyer for supply of market specific crab, especially 'A' grade females
- 'B' grade crab sold through co-operative to SFM
- 'C' grade crab sold locally
- very productive and healthy crab fishery

3.11. Spanner crabs

As reported in Section 2.7, the major NSW supplier of spanner crabs also has the highest rate of downgrades and rejects. During previous site visits to SFM, observations of downgraded spanner crabs classed as slow were regularly due to them being cold thus exhibiting little activity. Smaller crabs (spanner 4 – Sml in Figure 3.7) are often observed to be foaming from the mouth (Plate 3.5), particularly in cooler months. An opportunity was taken to record both spanner and mud crabs temperatures in transit from this cooperative to SFM up until auction time. Data shown in Figure 3.7 demonstrates a significant lowering of temperature for all spanner crab containers compared to the mud crab boxes. This is to be expected as the mud crabs were neatly packed in eskies lined with cardboard as opposed to spanner crabs roughly sorted by size grade into fish creates covered with damp foam and hessian (Plate 3.6).

Plate 3.5 Small crabs foaming prior to auction.

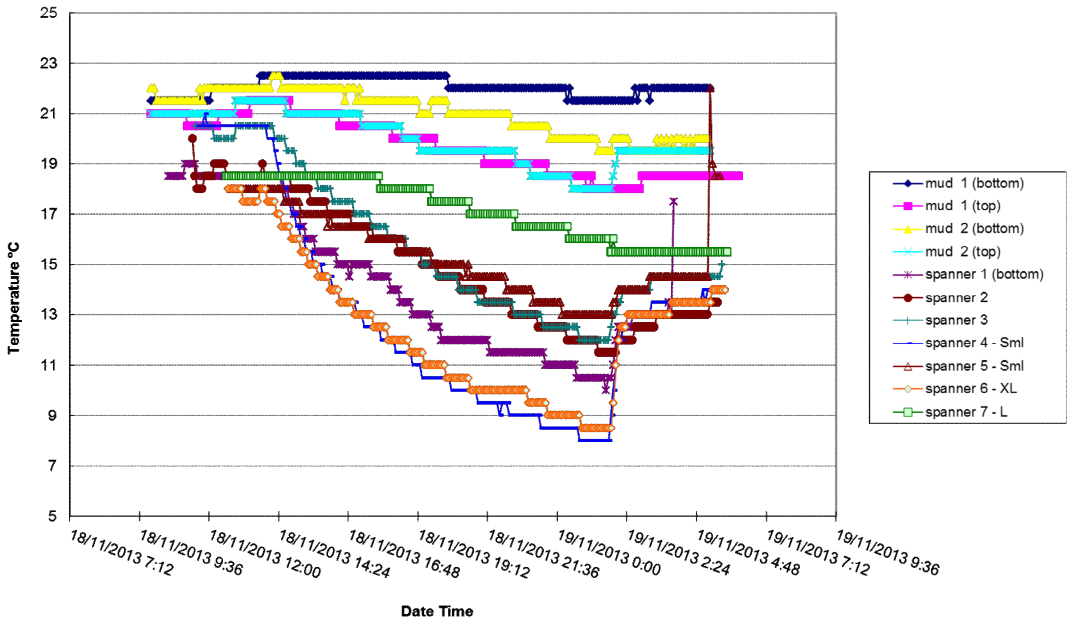

Figure 3.7 Mud and spanner crab temperatures in transit.

Of major concern here is the continued fall in temperature during transit until 1:46 am when the consignments were transferred to the SFM auction floor (temperature logged as 15.5°C). Over half of the consignments experienced temperatures that are below recommend minimum levels during this transit. In cooler months, SFM floor temperatures would have helped keep these overly cold temperatures within the fish creates for a longer period. On this occasion crabs would not only have suffered from temperature shock but also likely to have been graded as slow at auction. Refrigerated transport vehicles usually have a false wall inserted to protect shipments of live crustaceans from the air conditioning. It appears this didn’t happen on this occasion. This data was given to all fishers whose consignments were logged and the Co-operative Manager. Remedial action was said to have taken place.

Plate 3.6 Typical spanner crab packaging.

All attempts to recover slow spanner crabs in the research facility sea water tanks proved negative. Spanner crabs obviously have a reduced capacity to survive the rigors of supply chains for anything more than short periods unless they are treated with absolute best handling practices from the point of capture. It is theorised by Dr Brian Patterson (pers comm 2014) that infection from net damage is a likely factor adding to mortality in spanner crabs.

Fishers have also supported this concept as they have observed greater mortalities in catches from small mesh size nets that cause more damage to crab limbs than larger mesh sizes. Combined with a reduced capacity for their haemolymph to clot, spanner crabs remain a difficult species to keep alive for extended periods.

3.12. Supplementary concomitant activities

The following information occurred in conjunction with various industry interactions and although strictly speaking is outside of the scope of the research project's objectives, the findings do add value to the industries overall effectiveness and profitability.

3.12.1. Grading verifications

The AILMCGS was released in November 2012 and implemented at SFM in December 2012. Since then, many crabbers have expressed concern that good 'A' or 'B' grade crabs are being downgraded. Many theories from the suppliers exist for these grade discrepancies including crab shell softening whilst in transit, to unsubstantiated theories about SFM operations. Extensive research has been undertaken in conjunction with the previous studies to substantiate or debunk these concerns and concepts. Preliminary data, as reported in the following Section 3.12.3, indicate some grading variations between fishers, SFM QA staff and the co-investigator researcher. Further investigations of the extent of grade variations will be carried out with the FRDC funded project FRDC 2014-218.

3.12.2. Cooked Meat yield

Methodology for determining cooked meat yield has been further developed from previous research. As such, a stronger relationship (R^2=0.80) between total protein as measured by refractometer (RI) and meat yield has be confirmed. The new method focuses on the procedure of determining percentage of cooked claw meat yield. The cooked claws are cracked and drained of water introduced from the cooking process to calculate meat yield. The procedure for calculating yield from the body sections is less conclusive as many variables exist, in particular female sexual state of maturity. The information of cooked meat yields, as presented in Figure 3.8, is being used to verify the grading scheme parameters to industry.

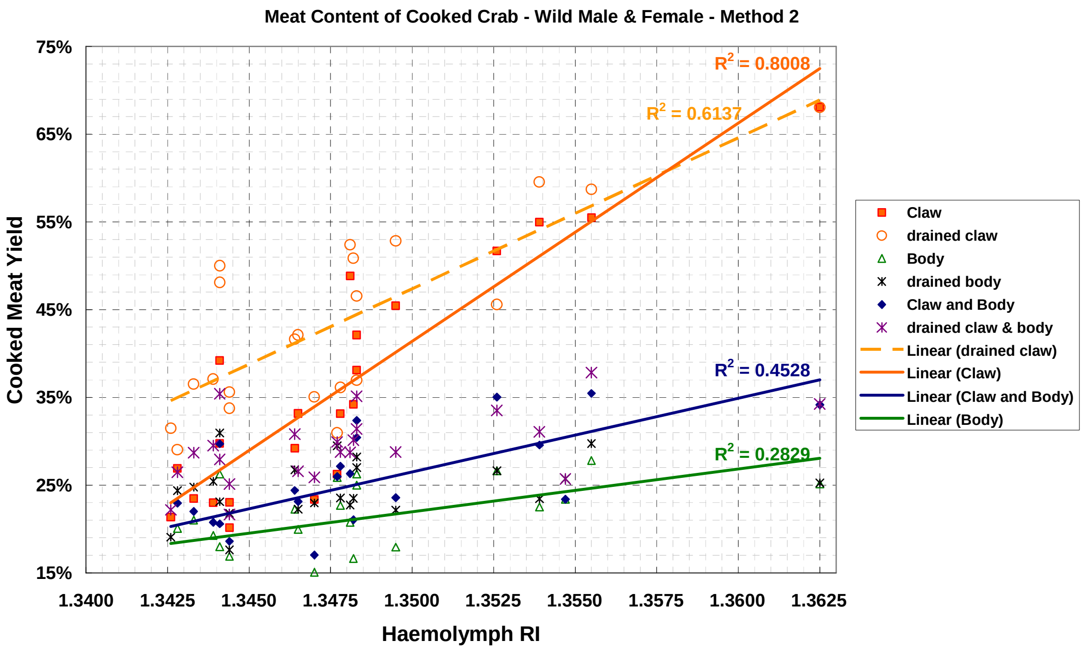

Figure 3.8 Cooked meat yield vs. haemolymph RI.

3.12.3. Assessment of ‘C’ grade crabs against haemolymph protein levels

An opportunity was taken to make an independent assessment of grades for a batch of crabs that had been rejected by SFM QA staff and also compare any discrepancies between individual assessments of QA officers. Of the 35 ‘C’ grade crabs rejected, eight were independently graded as ‘B’ grade. Six (17%) of these had a RI>1.3475 which is an indicative value of ‘B’ grade crab. No difference between individual QA officers’ grading was observed.

Opportunities were also taken to compare crabs from harvest locations that have a higher than average percentage of ‘C’ grade rejects against rejected crabs from harvest locations with typical reject rates. The fishers from these problematic areas report their crabs never get hard as constitutes an ‘A’ grade by the AILMCGS and are actually full of meat. They have been complaining about this problem in recent years which also coincides with higher than usual rainfall for those regions.

On another occasion 22 crabs that were rejected at SFM QA as being ‘C’ grade were independently graded and haemolymph sampled as an indicator of meat yield. Results indicate a large discrepancy between the grading by QA staff and the independent grader with 64% of the ‘C’ grade rejected crabs being out of grade (Table 3.14). Refined calculations of cooked meat yield versus haemolymph total protein, as measured by refractive index, demonstrate a strong correlation (R^2=0.8). Using haemolymph protein values as an indicator of grade (RI>1.3475 equates to ‘B’ grade; RI>1.3525 equates to ‘A’ grade), 32% were considered out of grade. The conclusion from this was that the RI values confirm a large percentage of crabs being rejected that should not be rejected.

Table 3.14 Independent grading and RI of ‘C’ grade crab.

	Grade Count	
Grade	**by Shell Hardness**	**by RI**
A	2	0
B	12	7
C	8	15

To address these and other concerns that have been raised by some sectors of the industry a review of the grading scheme, as developed by the National Mud Crab Industry Reference Group (FRDC project 2011-225) will be undertaken within a newly funded project (FRDC 2014-218). Project objectives are to minimise mis-grading by investigating new technologies to substantiate grades, confirm apparent problematic regional and seasonal anomalies in crab physiology and ensure greater consistency in grading methodology across industry.

Another opportunity was taken to compare crabs from locations that have higher than average percentage of ‘C’ grade rejects (Problematic), against rejected crabs from typical zones (Typical). 19 ‘C’ grade crabs from typical zones and 11 crabs from zones with recurrent problems were compared prior to and after six day emersion for shell hardness and RI. Similar discrepancies in grading were found as above. Two days after re-immersion in seawater holding tanks, without feeding, observations for shell hardness and RI were taken again. Interestingly, the RI of the problematic crabs had dropped significantly ($P<0.05$) (Table 3.15). This is completely against the norm and requires further investigation. More recently the atypical ‘C’ grade crab that is only survivor from the grade versus stress trials also had a large drop in RI during storage in sea water. A possible explanation is the difference in salinities of capture and holding tank waters.

Table 3.15 Analysis of variance - RI of Problematic v Typical ‘C’ grade crab.

Crab Harvest Source	**Stage**	**LS* means**	**Groups**	
Problematic	prior to re-immersion	1.3485	x	
Typical	prior to re-immersion	1.3482	x	y
Typical	2 days after re-immersion	1.3470	x	y
Problematic	2 days after re-immersion	1.3466		y

* Least square means

3.12.4. Emersed shell hardness

Fishers often report or question whether crab shell hardness changes during emersed storage. "*It was 'A' grade when we packed it, and now* (at market) *it is 'B' grade*", is a common statement.

Following an extended emersion period, as reported in Section 3.3 the grading scores assessed for the 'C' grade crab prior to the workshop did not change on return to the research facilities. After the fresh water spray recovery procedure these crabs were transferred to the seawater holding tanks and shell hardness was observed over the following three days. Crabs were not fed during this period. Shell hardness increased slightly over this immersed period, but not to the extent that would take them to a different grade. This slight shell hardness increase could be due to the higher salinity and resultant calcium uptake from the holding tank's sea-water (35ppt). It is likely these crabs were harvested from waters of low salinity. As observed over several trials, crab grades only drop by half a grade point from 'B+' to 'B' from the time of removal from seawater tanks to an extended emersion (seven days). Damage caused to the shell structure from repetitive thumb pressure grading is more likely to cause a perceived drop in grade rather than any physiological change in shell hardness.

3.12.5. Grading methodology

Recent technological advances in Force Sensitive Resistance (FSR) have the potential to be used as an objective method to quantify what is a subjective grading technique of shell hardness. Both the manner in which pressure is applied and the amount of thumb force applied by individual graders varies considerably, as does the interpretation as to what constitutes the appropriate thumb pressure to apply. It is recognised that the repeated actions of grading, the potential weakening of or damage to the test points and variations of the location of the test points is responsible for uncertainty in crab grades.

A commercial FSR system (Tekscan's FlexiForce sensors) was compared against standard grading scores and haemolymph protein values. The FlexiForce sensors can be used to measure both static and dynamic forces, and are thin enough to enable a non-intrusive accurate measurement of force (Plate 3.7). These sensors are commonly used in medical and manufacturing situations.

Plate 3.7 FlexiForce sensor used to measure pressure of shell flex.

The FSR values were also compared to the equivalent pressure applied to a standard weighing scale with the objective of giving graders an existing and accurate guide as to how much pressure to apply for a particular grade of crab. Preliminary results indicate that shell flex with a thumb pressure of approximately 2kg indicates 'C' grade, 4kg 'B' grade and 6kg or above corresponds to an 'A' grade. Further research to verify results with this technology will be undertaken in FRDC 2014-218. Work is also progressing to quantify grade scores to a numerical value (Table 3.16) for statistical analysis.

Table 3.16 Numerical score assigned to grade.

Grade	Score	Female description Top only	Male description Top	Male description Bottom
A	3	no flex	no flex	no flex
B+	2.5	very slight flex	very slight flex	very slight flex only on segment #2
B	2	flex & no click	flex	flex on several segments
B-	1.5	easily flexed	easily flexed	Easily flexed segment #2, slight flex on other segments
C	1	flex & click	flex on top	easily flexed all segments
C-	0.5	very soft and easily flexed with audible click	very soft and easily flexed with audible click	very soft all segments

3.12.6. Carapace width: weight correlation against grade

As previously mentioned, discrepancies have been reported with crabs harvested from problematic areas, particularly NSW lake systems, where crabs are commonly reported as having soft shells but full of meat. The hypothesis is that the low salinities or food sources in these upper reaches inhibits the calcification required for shell growth. A correlation was attempted to be made between the carapace width and weight ratio and the indicators of meat yield – shell hardness and haemolymph RI. No correlations could be found at this stage. Investigations into alternate imaging technologies e.g. CT scanning were also investigated.

3.12.7. Traceability

Throughout the investigators 11 years of interactions with the national mud crab industry, traceability of product to market has always been raised as an issue. Ongoing reports from southern markets of substitution of NT crabs are of great concern, as is pot theft in all areas. As such, contact was made with the supplier of a novel traceability system, NanoTag® Technology (http://www.nanotag.com.au). NanoTags® are made of nickel in the shape of Octagons, 6-10 microns thin, in sizes 0.3mm X 0.5mm. One side of the NanoTags® features a micro image of a personalised brand, created to order. A sample kit of products (Plate 3.8) was kindly provided and evaluated on live and cooked mud crabs.

Plate 3.8 Sample of NanoTag® product range

The application of the NanoTags® by the wand applicator (photo bottom right) provides a good solution for traceability of individual crab. Benefits include:

- easy, fast drying application
- good adherence even in wet situations (Plate 3.9)
- adherence maintained after cooking (Plate 3.10)

The security seal (Plate 3.9), in the form provided, was not considered to be effective for live mud crabs. The food safety risk of the NanoTag® dislodging from a cooked shell in a food situation requires further investigation. Key industry personnel have expressed interest in this microdot technology for product, packaging and fishing equipment.

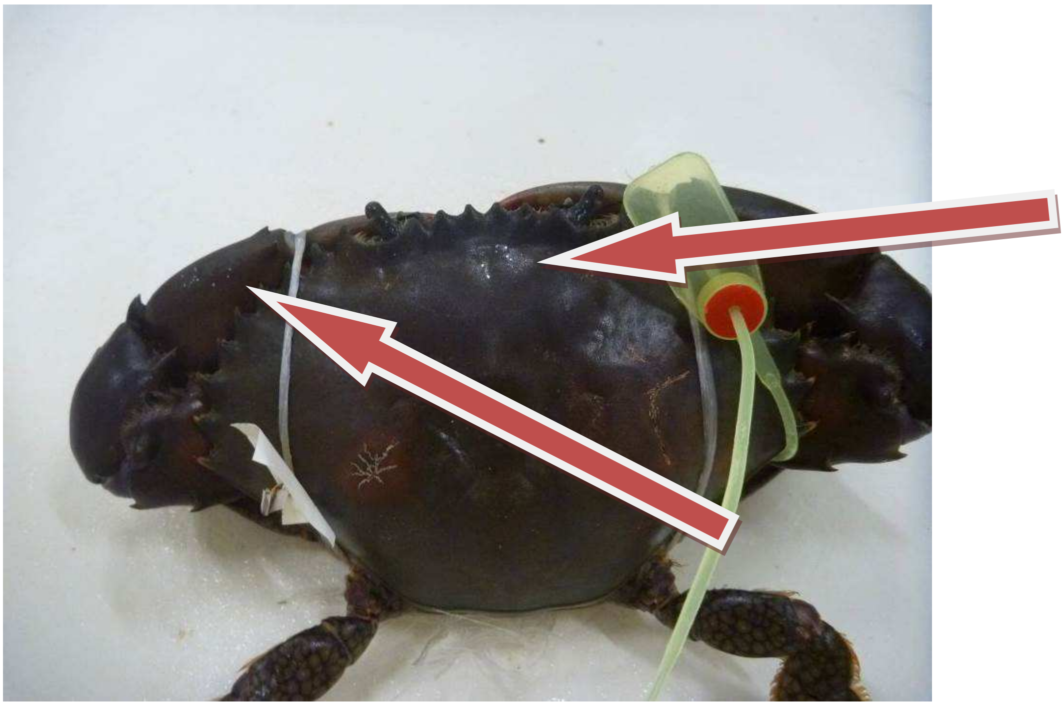
Plate 3.9 NanoTags® applied to claw and between eyes – arrows.

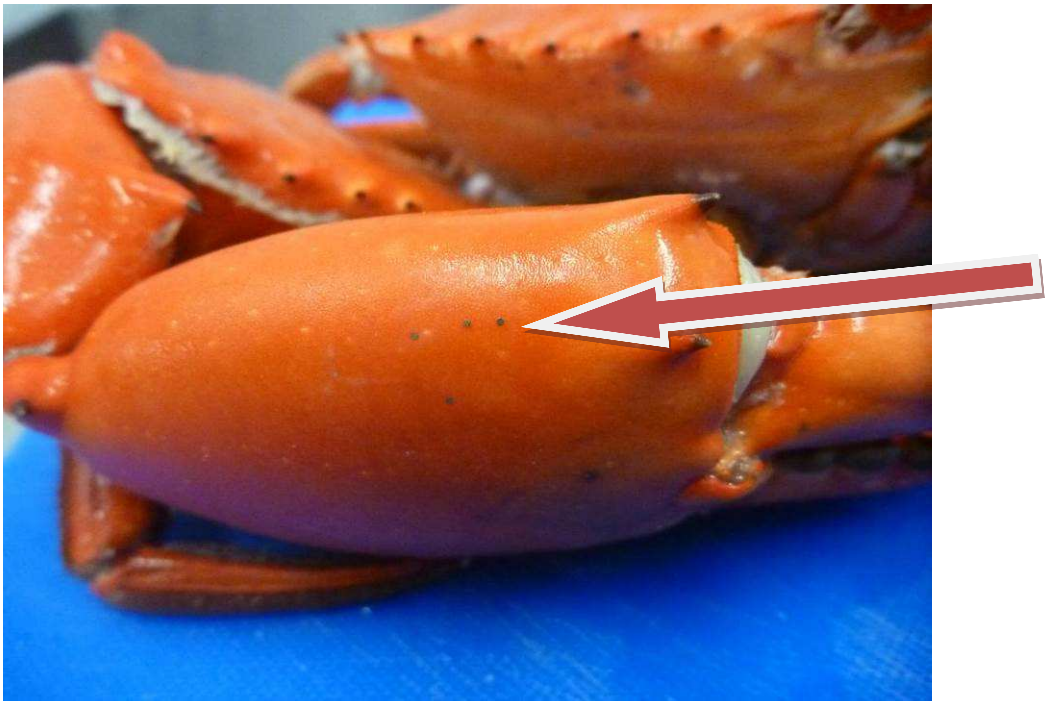
Plate 3.10 NanoTags® on claw of cooked crab – arrow.

3.12.8. Export potential

Contact was made with a Far North Queensland retired crab fisher who has a business relation with fishing communities in the Torres Strait and seafood importers in Hong Kong. The market potential for this export opportunity was thought to be significant. All best handling and grading information material from previous research was gratefully received and a greater understanding of the potential problems in this unique supply chain understood by this operator. However, challenges need to be overcome to address the extreme stress crabs from this region will have in the supply chain just into Cairns. Also, an understanding of specific market requirements of the size of crabs needs to be realised. It was advised to source smaller crab which is preferred by Asian customers and to avoid larger crabs which can have a higher mortality rate in extended supply chains. A recovery system and grading procedure prior to export was advised. Details on installing such a system have been communicated and assistance offered. Negotiations with the importer are still in progress.

3.12.9. Seafood Restaurant

A celebrity chef contacted the DAFF seafood team to gather information required for a Sydney hotel wishing to establish a premium mud crab experience for customers. The desire was to source the best and most humanly treated crabs as possible. SFM buyers and Qld supplier names were provided. Live crabs are to be held in purpose built display tanks within the restaurant. Options of holding systems and all details of a recovery system were explained.

The chef also asked for details on cooking times for steaming crabs. Previous research has shown optimum cooking times for crab sizes to ensure appropriate internal temperatures reached in boiling water. However, no details were available to confirm cooking times for steamed crabs. Two sizes of crabs that would typically be cooked for this trade were steamed in Unox Arianna XF135 oven at 100°C and 60% humidity. Results (Figure 3.9) **Figure 2.1**concur with previous boiling water cooking trials that 20 minutes is required to achieve the optimum temperature (>80°C) that will deactivate gut enzymes that can lead to discolouration or spoilage.

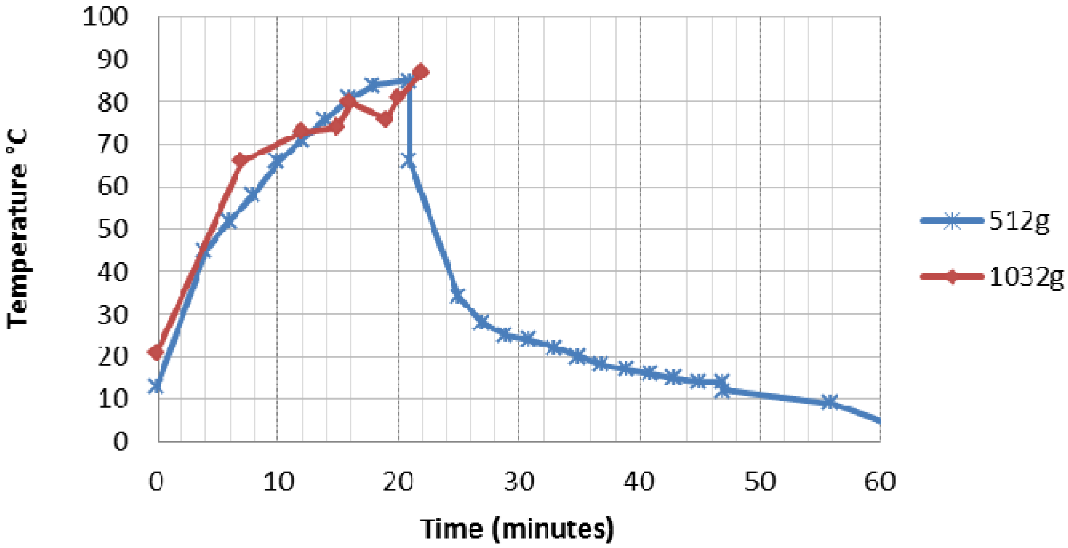

Figure 3.9 Core temperatures of steamed crabs during cooking and cooling.

3.12.10. Crab fattening

For many years mud crab fishers have made various attempts to harvest and fatten crabs for future sale, potentially capitalising on peak market periods. The DAFF research team was approached by a local fisher consortium to ascertain if a crab fattening operation was feasible in a local coral trout export facility. Recent events have led to a downturn in the coral trout export market. As such, the facility has the capacity to diversify into an alternate market. Recommendations on all aspects of holding and feeding crabs were given to the operators. A supply of lesser grade crabs is readily available through the consortium and other contacts. Sea water supply is provided via a 3,000L live transport vehicle with water sourced from the Gold Coast seaway and a cheap food supply is available. Further assistance has been offered as required.

4. Discussion and Recommendations

4.1. Fresh water spray v fresh water immersion – trial 1

The liveliness index clearly demonstrated that using the fresh water spray system was not beneficial to the recovery of crabs that had been held emersed for seven days. The evaluation of the level of ammonia release into the recovery waters was inconclusive. During both recovery procedures, crabs excreted faeces after about 20 minutes. This potentially creates a problem for the pump in the spray system as the pump's foam filter was blocked after just 22 hours operation, reducing water flow. Under a commercial operation this would be problematic and time consuming in maintaining water flow from the pump and cleaning of spray nozzles from built up faeces and dirt.

This trial was repeated with an increased number of crabs and from a wider capture source offered for auction at SFM. As the ammonia results were inconclusive the initial emersion period was extended with the aim of allowing the crabs to build up and subsequently excrete more ammonia.

4.2. Fresh water spray v fresh water immersion – trial 2

The liveliness index demonstrated that the fresh water spray system was as effective for the recovery of crabs as the immersion recovery system for crabs previously held in damp hessian for 10 days. However, the levels of ammonia efflux were greater than in the previous trial and showed that the immersion recovery system was more effective for efflux than the fresh water spray system. Weight losses observed from emersed crabs were as in previous research[2]. Also, the immersion recover system showed a greater increase in weights than the fresh water spray system.

There are advantages to using the immersion recovery system over the fresh water spray system in crab ammonia release and weight gains. It was noted, despite storing crabs for seven and 10 days in the trials, their liveliness pre-treatment was greater than expected and certainly better than that which would cause the crabs to be rejected at market.

4.3. Extended emersion

A pre-treatment situation using crabs that show signs of extreme lack of liveliness was undertaken. The trials simulated conditions where crabs can be recovered and sold at the next day's auction. The trial demonstrated convincing evidence that even the most stressed crab can have improved liveliness when treated in a fresh water spray recovery system. Observations were also made on shell hardness and haemolymph protein which is reported in Section 3.12.3.

It has been demonstrated that a fresh water spray recovery treatment is beneficial even to crabs that are very stressed. The benefit of combining an immersion recovery treatment prior to an overnight spray treatment needed to be investigated as there are potential synergistic opportunities from the combination of two treatments.

4.4. Immersion followed by overnight spray

The immersion recovery system appeared to be more beneficial in the long term for recovered crabs. Weight gains from the immersion treatment were marginally better than the fresh water spray treatment.

The inclusion of a fresh water spray system following the immersion recovery procedure is not recommended. Crabs involved in the initial comparative trials demonstrated a higher recovery rate when recovered in the immersion system as opposed to the spray system. Badly damaged or bleeding crabs must be identified and isolated at all stages of the recovery process to minimise disturbances to the other animals. The importance of soldier packing and back filling spaces to limit crab movement in eskies post-recovery treatment was demonstrated as even one over-active crab can cause aggravation and stress to others.

4.5. Friday recovery option – trial 1

A three hour immersion recovery treatment followed by leaving the crabs undisturbed in the same dry covered fish bin until Monday morning was demonstrated to be the simplest and most effective option for recovering crabs from a Friday auction.

Based on knowledge gained, a prototype recovery system was engineered and tested prior to installation at SFM. Timings of water and air pumps start and finish times were developed dependant on pump and town water supply flow rates.

4.6. Friday recovery option – trial 2

Pump timing for the removal of the recovery water apparently cut out early leaving water in bottom of the tank to a level of a few centimetres within fish crates. Float switches are attached to submersible pumps, but there functionality is unreliable, hence bypassed in this situation. Air stones were partly exposed, causing no aeration of the water in which the crabs were semi-submersed. Lack of oxygen in this water was likely to have caused mortalities.

Blood was also observed in the system. It has previously been reported that the presence of blood in a closed system will increase crab aggression and stress (Dr. Brian Paterson, 2008, pers. comm.). Again, one overly aggressive crab can cause major stress and injury to other crabs. It was possible this may have been the case in this situation. Before placing crabs into any recovery system, it is important to check each crab for signs of damage or blood and to ensure that claws are tightly secured.

To allow for any timing shortfalls, the false floor height was raised to 150mm to allow for variances in water levels when the pump cuts out. Pump timings were also increased slightly to ensure all water is removed from the recovery tank. The recovery tank requires rinsing after the recovery process to remove faeces and dirt at frequencies dependant on the volume of crab throughput. The next step was to use the learnings to progress to the installation phase at SFM.

4.7. SFM recovery system

Recovery rates from the trials support previous findings that not only can a recovery system improve slow crabs vigour, but also improve the survival rate of crabs compared to those left emersed. An analysis of preliminary data had shown that the recovery rate of near dead crab to marketable liveliness within a 24 hour period was consistent in both locations ranging between 50-57%.

When SFM QA staff overcame initial technical hitches of setting up the system, relocated the system to an new location and got used to its operational requirements, it was then incumbent upon the staff to ensure that all available buyer returned very slow graded crabs were put through the recovery system to give the ‘economic test’ that was required.

However, as discussed in Section 3.7.3, due to lower volumes of mud crab being available at SFM in 2012/13 the recovery tank system had to be mothballed and only re-entered operations in May 2014.

Further analysis of data from a longer period is required to show the percentage of crab recovery from each grade that is sent to the recovery unit. Given the findings from the grade versus stress investigations in this project it is likely that a greater percentage of mortality comes from 'C' grades. This emphasises the importance of the recovery unit for SFM operations and supplier income.

Analysis of SFM financial year 2013/14 figures shows that downgrades of slow / very slow mud crab are now running at 1.14% (4.5 tonne) compared to 2.8% (11 tonne) prior to the initiation of this project. Many factors will have been involved in this reduction but it is the project PI's view that this is all in some way due to the outcome of the various projects initiated by the QDPI team. The output of all those projects have led to incremental changes in how product is handled, transported and stored throughout the whole supply chain creating many improvements along the way. That improvement of 6.5 tonnes is worth in the region of $164,000 pa.

Now that SFM has got the recovery tank up and running again, about 50-60% of the remaining 4.5 tonne worth around $113,000 pa should also be recoverable through operation of the recovery tank on a long term basis.

Prior to this project crab rejections were running at 5%. This has now dropped to 3.95% a saving of on average $104,000 pa. Whilst it has not been possible at this stage to look at the individual rejection rates for NSW co-op's it is clear that across the board improvement is occurring bringing economic benefit to all actors in the supply chain.

4.8. Packaging

The recommended air hole configuration is a finger sized hole located midway on each corner of the esky. This design allows adequate air circulation and will not be blocked when eskies are stacked together. As outlined in Fact Sheets distributed within FRDC 2010-302 newspaper packaging is important to restrict crab activity with the boxes. Some proactive suppliers have shown that extra protection between layers which limits crab bites is also beneficial. Placing some newspaper between 'C' grade crabs to limit shell damage is also recommended.

4.9. Project Variation – Stress with grades

It was demonstrated that mortality within the supply chain is strongly related to the crab's grade. Also, as suspected by some fishers, crabs exposed to air travel have a higher rate of mortality. This is particularly true for 'C' grade crab as they are already vulnerable to the stresses of transport chains. Although 'C' grade crabs may survive a 24 hour recovery procedure they are more likely to die within a matter of days post recovery. It is important to be aware that damaged, bleeding or 'old crusty' crabs are less likely to survive the recovery process and indeed can reduce the effectiveness of the system with their waste toxins contaminating the recovery water if they die.

As a general guide, it can be said that 'A' grade crabs should survive up to three weeks in the transport chain, 'B' grades up to two weeks and 'C' grades between four and seven days.

The SFM sales volume graph (Figure 3.1) shown in Section 3.7.3 above shows how influential the introduction of 'C' Grade sales at SFM has been on the total volume of mud crab sales transacted. The sale of 'C' Grades has given suppliers increased incentive to sell through SFM as they now know that all grades of crab they supply will be sold. This is clear from the increase in trade post November 13 across all the grades not just the sale of 'C' grades.

4.10. Spanner crabs

Best packaging methods have been demonstrated to fisher groups over many years. Despite this, many fishers continue to send fish creates with crabs poorly packed in them. Small crabs suffer worst in cooler months and large crabs more in warmer months. Variation in packaging specific for sizes and seasons would reduce downgrades and rejects. Soldier packing, tail up with wood wool to reduce movement is this preferred packing process.

Fishers have years of experience in harvesting in all weather conditions and are usually aware of the factors leading to reduced product quality. Methods of reinforced feedback and workshops as demonstrated in this project and the communications project FRDC 2003-240 have had a positive impact on product quality.

Co-operatives don't accept prawns from fishers that are out of a specified temperature range, so perhaps SFM could reject consignments of crustaceans that arrive below a minimum temperature level.

5. Benefits and Adoption

Operation of the recovery unit over a longer term is expected to demonstrate that between $57,000 and $68,000 pa. can be recouped from crabs normally rejected. As the recovery system operations are refined the recovery rates are likely to increase, adding to this value.

In may be co-incidence, but during the course of this project the NSW co-operative with the majority of problems has changed its management procedures of pooling prices gained at market. Fisher consignments for mud crabs are now individualised per fisher allowing for auction prices to reflect their own consignments and not an averaged pool price. This can only lead to an improved attitude to quality and delivery of product.

The market perception from SFM buyers of the recovered crabs is better than what was expected at the start of the project. These once slow and now recovered crabs are seen to be 'special' in that they have had extra attention paid to them by SFM QA staff; almost a 'value add' label is applied to them. The process certainly actively selects for the strongest of the crabs sent to the recovery unit, perhaps giving extra confidence of the survival of the crab for future buyers.

6. Further Development

Ongoing analysis of market data from a longer period that correlate crab grade, SFM QA downgrades and reject alongside other information such as auction price, supplier location and season will give the industry a greater understanding of the benefits of a recovery system.

Further research to verify preliminary findings of alternate technologies to grade crabs will be undertaken in FRDC 2014-218. More consistent grading by suppliers will mean fewer downgrades at market which may have a positive impact on the buying behaviour at auction and the QA process. Continued extension of best handling and grading for both mud and spanner crabs will be provided by the research team during the course of this new project.

7. Planned Outcomes

Public Benefit Outcomes

Increased consumer confidence in purchasing live mud crab through:

- removing crabs from the market with a high risk of mortality
- improving the survival of compromised crabs
- improving the life expectancy of purchased live crab

Maximising the resource and the industries sustainability credentials.

Private Benefit Outcomes

- adoption of a low cost and low risk system by SFM to manage downgrade and reject mud crabs
- increased revenue return to the harvest sector and through the mud crab value chain improving industry viability. The benefit gained in recovered revenue has been demonstrated to be $268,000 pa plus the potential for an additional $57,000 - $68,000 pa through the continued running of the recovery tank.
- increased demand through improved consumer confidence and satisfaction with consistency of product quality

Linkages with CRC Milestone Outcomes

Outcomes from this project work contribute to the following Seafood CRC Milestones:

2.8.2 Innovative technologies for controlling spoilage to enhance shelf-life and marketability developed

2.8.6 Harvest, post-harvest and processing practices evaluated and enhanced to maximise and protect quality attributes

8. Conclusion

Despite the disruptions to the operation of the recovery unit the project has shown that the recovery tanks can operate in a high pressure wholesaling environment and consistently return a recovery rate of 50-64%. For all intents and purposes of the project it has been a success. It has fulfilled its primary purpose of demonstrating that a large scale recovery system can revitalize near dead mud crabs back to a lively state where they after reintroduced within a 24 hour time period as commercially marketable and acceptable product. It has been shown that the economic return on operating such a system is dependent upon market supply and demand factors especially the price the buyers are willing to pay for 2nd grade product.

It is expected that further observations and refinements can be made in the future to increase the recovery rate.

Whilst at this point in time it is difficult to prove that all the projects initial objectives have been successfully achieved it is clear that much progress has been made in the period this project has been running. What this project has also demonstrated is that through constant dialogue between researchers and industry and between various parties in the supply chain incremental improvements can be brought about that make valuable improvements to supply chain efficiency and hence overall profitability.

9. References

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4. Calogeras C, Mayze J and Poole S (2012) Using industry expertise to build a national scheme for grading live mud crabs. FRDC 2011-225 Final Report.

5. Davenport J and T. M. Wong (1986) Responses of adult mud crab (*Scylla Serrata*) (Forskal) to salinity and low oxygen tension. Comp. Biochem. Physiol. Vol. 86A, 43-47.

6. Paterson, B. D., D. W. Davidson and P. T. Spanoghe (2001) Physiological studies of stress and morbidity during post-harvest handling of Western Rock lobsters, *Panulirus cygnus.* I. Physiological stress indicators., pp 140, FRDC 1996-345 Final Report

10. Appendices

Appendix 1: Mud crab recovery system instructional manual.

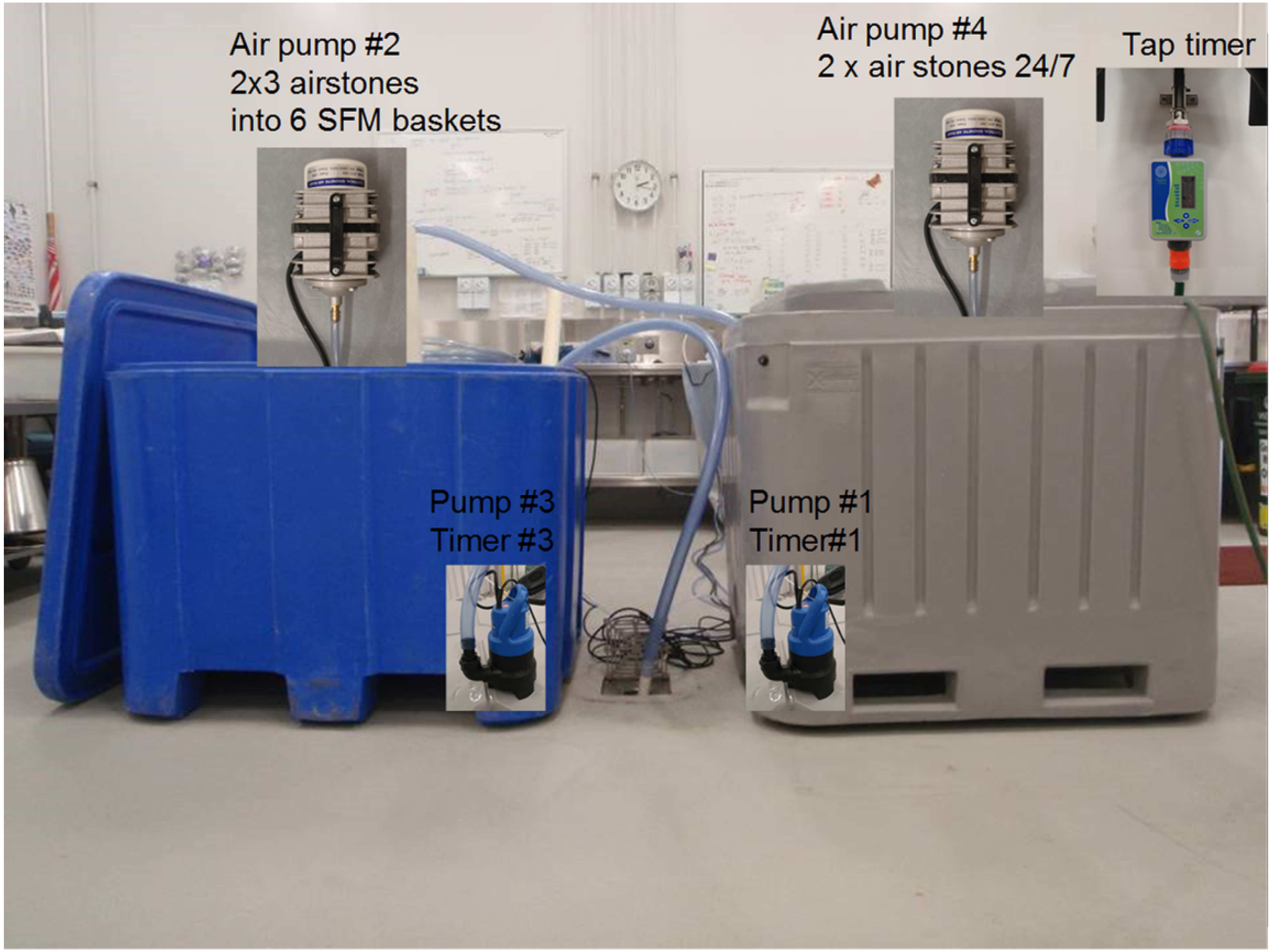
Appendix 1.

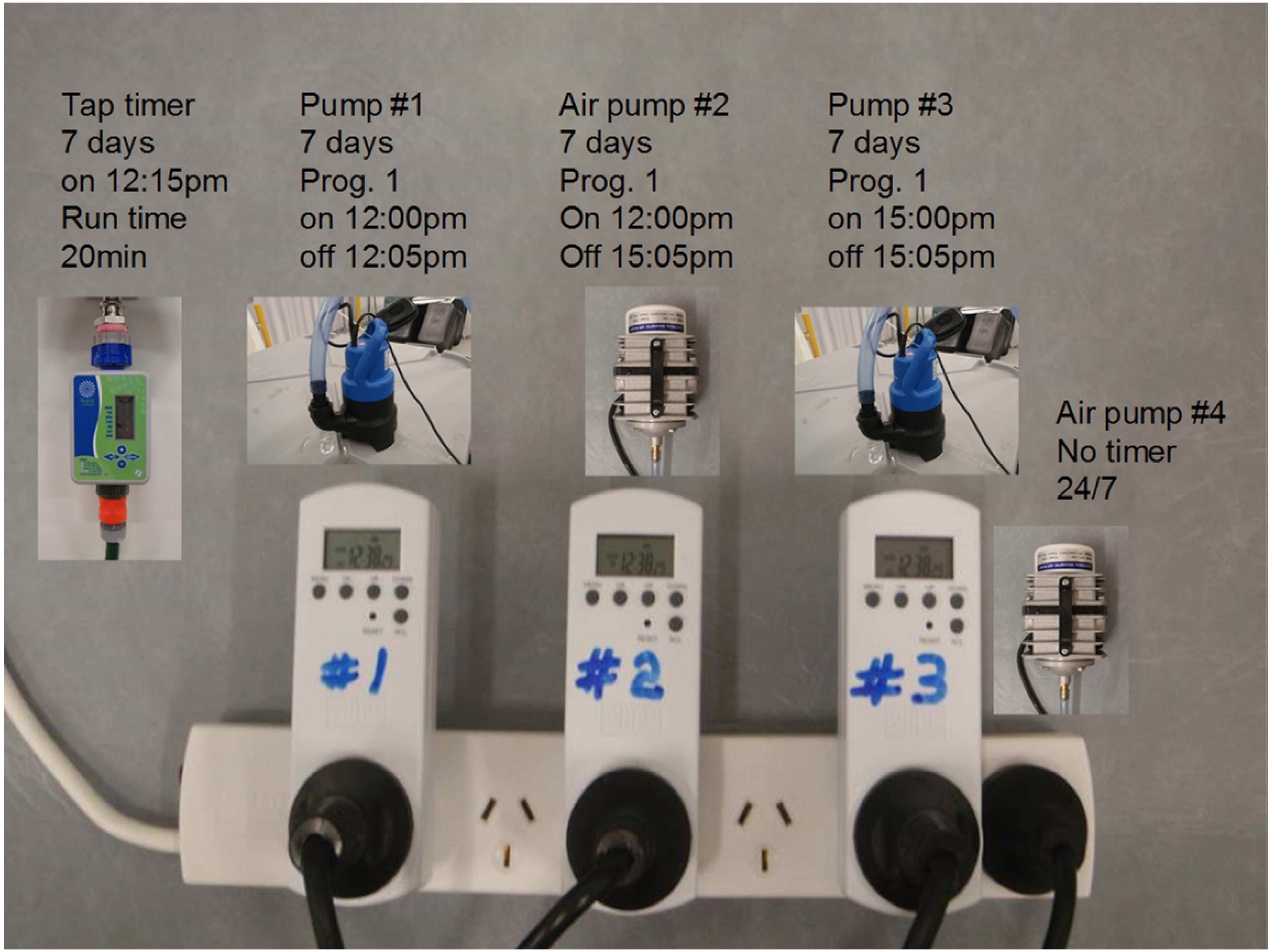
Live mud crab recovery unit

Setup and operational instructional manual.

Prepared by

John Mayze and Paul Exley


Air pump #2
2x3 airstones
into 6 SFM baskets
Air pump #4
2 x air stones 24/7
Tap timer
Pump #3
Timer #3
Pump #1
Timer#1


Tap timer
7 days
on 12:15pm
Run time
20min
Pump #1
7 days
Prog. 1
on 12:00pm
off 12:05pm
Air pump #2
7 days
Prog. 1
On 12:00pm
Off 15:05pm
Pump #3
7 days
Prog. 1
on 15:00pm
off 15:05pm
Air pump #4
No timer
24/7
#1
#2
#3

Recovery system components:

- 2 x 1000L Xactics insulated fish bins – a reservoir and a recovery tank
- 1 tap timer to fill the reservoir with town water
- 1 air pump (40L/min) with 2 x 50mm air-stones to de-chlorinate reservoir water over 23 hours
- 1 submersible pump (180L/min) to exchange water from reservoir to recovery tank
- 1 power supply timer for reservoir tank pump
- 1 air pump (60L/min) with 6 x 50mm air-stones to aerate each bins in the recovery tank
- 1 power supply timer for recovery tank air pump
- 1 submersible (180L/min) pump to remove water from recovery tank
- 1 power supply timer for recovery tank pump
- connecting hoses, elbows, t-pieces, taps and clamps
- 1.5m 90mm storm water pipe as a snorkel to stop syphoning
- 3 draining fish bins raised off the recovery tank floor
- 3 draining fish bins as second layer
- 3 draining fish bins as lids to stop crabs escaping
- recovery tank lid to maintain air temperature, reduce light and exposure
- Shogun LED aquarium heater 500W HT063 – (to be delivered)
- backup submersible pumps
- backup air pump ACO-006 (to be delivered)

Instructional Manuals provided:

- HPM Digital Timer Cat D817SLIM
- Aqua Systems Electronic Digital Tap Timer CO1905AS
- Rain Master Submersible Drainage Pump P1720867