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Improving survival and quality of crabs and lobsters in transportation from first point of sale to market

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Executive Summary

What the report is about

Eastern rock lobsters, spanner crabs and mud crabs command a high price when supplied to the market as live product. Being aquatic animals, the demands to retain maximum quality and liveliness through the supply chain are challenging. Once taken from water, these crustaceans are subject to multiple hurdles resulting in cumulative stress and diminishing probability of survival. For the past two years, scientists from Queensland Department of Agriculture and Fisheries have been working with the New South Wales (NSW) crab and lobster Industries to determine ways to reduce stress imposed on the animals from capture to market. Through temperature monitoring along the supply chain, two key areas were identified as having high impact on the crustaceans. Handling by individual fishers from point of capture was critical to keep animals cool, damp, out of light and with minimal disturbance. Temperature during transport of crabs and lobsters often imposed severe stress, arising from truck refrigeration temperatures being set below the tolerance of live animals and the influence of cold truck floor-beds reducing live animal temperatures. The importance of careful handling after capture was emphasised with fishers and co-operative management staff regularly at every landing location visit. Simple modifications for protecting live animals from cold temperatures during transport were developed to reduce stress on the live animals. The benefit gained from adapted practices was successfully demonstrated within commercial operations.

Background

Industry producers and processors recognised that crabs and lobsters suffer quality deterioration during transportation, which results in downgrading and consequent price reduction. As lobsters and crabs are a highly valuable resource, losses incurred through current handling chains cause significant waste of revenue and loss of quota. Quality loss in crustaceans is often caused by stress imposed along the supply chain. There was a need to determine handling and transport issues causing losses pertinent to different landing ports, distribution chains and markets. Identification of key points of stress occurring would enable development of specific mitigation measures for Industry implementation.

Aims/objectives

To reduce downgrading and mortalities of live product, it was important to identify key areas of stress imposition through the distribution chains. This information allowed handling practice modification to reduce stress imposed on the live animals. Any adaption of practices needed to be cost-effective and readily implemented by industry.

Methodology

Current practices for handling and transporting crabs and lobsters were documented through observation and discussion with key personnel at each landing location along the NSW coast. Key stress points were identified and correlated with temperature monitoring of the live product during distribution. Through frequent interaction with fishers and management, adapted practices were developed to reduce stress impact on the crustaceans. Effectiveness of method adaption was assessed by temperature of live product through transport and on arrival at market. For Spanner crabs, a sedation method was developed for use at pack out of crabs.

Results/key findings

Handling of live crabs was widely variable between landing locations and by individual fisher. This was a little surprising as best handling practice information has been transferred to industry from previous collaborative projects with the industry. Many fishers demonstrated a good understanding of factors that impose stress on the animal and took care in handling. Where fishers indicated less knowledge, discussion occurred at every location visit to refresh and reinforce the importance of limiting stress in the early stages

of the chain. Within the lobster industry, all stakeholders contacted were operating with high awareness of the requirements of live lobster handling and distribution.

Temperature monitoring of live crustaceans highlighted two significant causes of stress imposition: truck refrigeration temperatures below tolerance for the species and the strong influence of cold temperature of the truck floor. As live crabs are freighted along with both frozen and chilled seafood products, the mitigation option of raising the refrigeration temperature or turning the refrigeration off during transport is not feasible. Where live and chilled product were transported within the same truck compartment, use of a canvas cover over the live bin stacks was found effective. Additionally, raising the bins stacks off the truck floor bottom lessened temperature reduction experienced by the live animals. A range of insulating materials were trialled placed between the bottom bin of the stack and the truck floor. Each material trialled was effective in raising the temperature within the bottom bin and a corresponding increase in temperature within bins in higher layers of the stack was also found. Additionally, it was found that stacking bins on a pallet increases the temperature experienced in transit sufficiently to reduce stress on live crabs.

Implications for relevant stakeholders

The direct benefit from adoption of adapted handling and transport protocols will be improved revenue return for crab and lobster fishers through reduced animal deaths and downgrades. Within the wider industry, the increased revenue will apply along the supply chain for Fishermen's Co-operatives, wholesalers and retailers. For consumers, there will be increased confidence in purchasing the high-end crustacean products through consistent improved quality of product. Therefore, over the fishery as a whole, a better return on product harvested illustrates conscientious utilisation of the crustacean resource. By responsible use of the resource, public recognition and perception of the fishing sector will be improved through crabs at market being of consistently high quality and lively, mitigating disappointment in purchase for consumers.

Recommendations

Recommended actions to keep best practice handling and transport protocols a constant in the minds of stakeholders could include:

- Wall posters at pack-out locations to provide best practice information for handling crustacean species. This could readily be achieved where collection point is based at a Fishermen's Co-operative
- Regular interaction and discussion with industry to keep relationship active on requirements for transporting best product. This has additional benefit of hearing of and understanding specific new issues as they arise, especially when triggered from seasonal and environmental circumstances.
- Regular discussion forums co-ordinated at central location, for example local Fishermen's Co-operatives. This would ensure individual fishers were operating to the same practices.
- Transport companies regularly revisiting requirements for live product freighting

For further development of the findings from the current work, the following are suggested:

- Regular feedback from Co-operative Managers to individual fishers on returns gained from product shipments will illustrate the benefit the individual achieves from adoption of adapted practices
- Further investigation into new packaging materials that provide improved temperature insulation for transport live product is needed
- Further development of suitable box for use in the proposed SFM expanded live holding tank system at market

Keywords: Eastern rock lobster, Spanner crab, Mud crab, Live, Transport, Temperature

Introduction

Eastern rock lobsters (*Sagmaraisus verreauxi*), mud crabs (*Scylla serrata*) and spanner crabs (*Ranina ranina*) are valuable resources within New South Wales (NSW) fisheries. Industry producers and processors raised concerns (through the Professional Fishermen's Association and FRDC NSW Research Advisory Committee) identifying that crabs and lobsters suffer quality deterioration during transportation, resulting in downgrading of product and consequent price reduction. The combined revenue return from the three fisheries is currently around $20M, with Eastern Rock lobsters contributing more than half this total. These fisheries are evaluated as fully fished from NSW waters, however the crustaceans are highly sought after particularly within the high-end hospitality sector from where there is consistent strong demand. Such demand cannot be met by additional catch volume, therefore attaining maximum revenue from current harvest effort is of paramount importance. Greatest revenue can be achieved from presentation of live product to market and, as several of the fishery harvest locations are distant from main markets, issues arise with the vigour of crustaceans at the market end of the supply chain.

Post-harvest handling for lobsters and crabs is fundamentally similar: capture is by baited trap, pot or dilly, with product landed onshore same day as harvest; it is then graded and lively animals packed out dry for transport by truck or air to market. A key market for much of the Eastern rock lobster, mud crab and spanner crab catch from NSW waters is the Sydney Fish Market. Dependent on capture location, north to south transport distances range from 3-10 hours and product transported north from southern NSW regions is 1-6 hours. Industry stakeholders have noted that both crabs and lobsters suffer quality deterioration from point of capture along the distribution chains, resulting in product down-grading at sale point. Animals can be downgraded or rejected for a number of reasons: physical scarring or injury, excessive limb loss or due to lack of vigour, exhibited as slow or weak crustaceans and ultimately mortalities.

It is well recognised that crustacean stress levels have a large influence on animal vigour, with high levels of stress resulting in mortality (Poole *et al*, 2008; Paterson and Spanoghe, 1997; Paterson, 1994). Therefore, it is important to understand the stress impacts endured by the crustaceans through the handling chain and which of these causes greatest debilitation of animal quality. From previous research on mud crabs, western rock lobster and spanner crabs, it can be deducted the most likely stress factors negatively impacting on the species in this proposal will be duration of air exposure, temperature and disturbance. Sydney Fish Market has, to a limited extent, examined temperature fluctuations as a possible cause of down-grading and has determined that the impact on quality is compounded by transport duration (Erik Poole, Supply & Business Development Manager, Sydney Fish Market, pers.comm. 2017; Poole *et al*, 2008). It is suggested that both transport vibration and duration are the most likely factors imposing stress to the animal resulting in quality loss and higher mortality rates.

Live crustaceans suffer from stress resulting from external stimuli that are not typical of their natural aquatic environment and the stress is accumulative within the animal. When stress levels experienced are high, the animals systems will start to shut down resulting in 'slow' unresponsive animals and the ultimate end point is death. Aquatic crustaceans typically desiccate and asphyxiate when held out of water (deFur et al, 1988; Uglow et al, 1986). In most crustaceans, recognised major triggers of stress arise from: capture, physical handling, air exposure and changes in temperature.

NSW has the only commercial sized fishery of Eastern rock lobster (ERL) with largest harvest areas located around Coffs Harbour and south. ERLs are a valuable resource providing $>11M (2016-17) of gross revenue and therefore, even low numbers of mortalities occurring are significant. Mortality has been high in recent years, prompting action to reduce the level. Introduction of tank-holding systems at both point of landing and at point of sale has alleviated the losses greatly**.** The Sydney Fish Market (SFM) has kindly provided information from the last few years and though not yet fully analysed, an obvious and large reduction in mortalities is evident. Similarly, industry stakeholders have not mentioned mortality as a current issue.

Industry has already explored various techniques to achieve minimal mortality during harvest, holding and transport of ERLs immediately prior to commencement of this research project. However, some mortality still occurs with stressed and 'slow' animals not surviving transport phase.

Mud crabs are estuarine dwellers and move readily between inter-tidal mangrove areas, in-shore water channels and sub-tidal areas (Hill et al., 1982). Mud crabs also tolerate large inflow of freshwater within their habitats (Meynecke et al., 2006) and their ability to do this is directly related to being strong osmregulators allowing survival in a wide range of water salinities (Romano and Zeng, 2007).

Mud crabs are remarkably robust animals with the ability to withstand long emersion (exposure to air) periods. In fact, they are one of the only crustacean species reported to voluntarily leave their aquatic habitat when water quality is adverse. It has been shown that oxygen uptake in immersed mud crab falls to 10% of the rate in crabs immersed in water (Veerannan, 1972) and heart rate reduces to 50% of that of immersed crabs (Hill and Koopowitz, 1975). Importantly for crabs from New South Wales (NSW) waters, research has shown that the metabolic rates of cold-adapted *S. serrata* are higher than those of warm-adapted ones (Veerannan, 1972) implying that stress reactions will be stronger and more rapid in these crabs.

Previous research undertaken investigated best handling for live mud crab, including identification of factors that impose the most stress to crabs from harvest to market (Poole et al, 2008, FRDC 2003-240). This work mostly involved mud crab sourced from tropical waters i.e. Gulf of Carpentaria and Northern Territory (NT), and there was not a body of information gained for mud crab obtained from the northern NSW coastal areas. The major differences between tropical-sourced crab and those from NSW waters are: smaller sized crab allowed to be taken from NSW (minimum size: 85mm in NSW compared to 130mm NT and 150mm in Queensland waters) and water temperatures from which the crabs are harvested.

Like most crab species, spanner crabs do not like being held out of water as their gills need to be wet for the natural metabolic pathways to occur. When immersed, oxygen uptake and carbon dioxide excretion is severely impaired resulting in lactic acid. Visually spanner crabs appear to tolerate emersion and be reasonably robust when out of water as illustrated by initial scrambling movement, followed by quiescence. However, this is quite deceptive, as found by DAF researchers (Paterson et al, 1994) who showed that spanner crabs stress rapidly and accumulate waste metabolic products from the moment of being taken from water. The consequent blood pH drop causes a state of acidosis within the animal and they have no metabolic capability to buffer the acid formation while they remain in air, hence they stay physically inactive to limit further accumulation. Paterson et al (1994) concluded that, in practical terms "any time that a spanner crab is out of water was too long". However, with careful specific handling, spanner crabs can survive for a short period of time immersed. This is demonstrated by the currently occurring successful export of Queensland harvested crabs to China, although mortality rates can be high at times.

The research priority forming the basis of development of the current project had primary focus on addressing the high mortalities occurring with Eastern rock lobster at market point in the supply chain. During the period from the priority being raised and approval for project work to be undertaken, the imperative for required action on lobster mortalities was reduced immensely by pro-action within the Industry at both landing ports and at market. The change derived from the introduction of live holding tanks resulting in the reduction of occurrence of mortality in lobsters to near zero level.

Further communication with key Industry personnel on the need for research effort clearly illustrated that the improvement in survival was restricted to Eastern rock lobsters and that there remained large loss occurrence within the Mud crab and Spanner crab industries. There was strong indication from Industry that research on ways to reduce these losses was most definitely required. The Industry were particularly concerned about handling practices during transportation stages in the supply chain and the cause of losses of mud crab immediately post-capture. The need was totally driven by the recent introduction of quota systems for both crab fisheries.

Objectives

1. Document current handling practices and transport pathways within the three crustacean industries and identify the factors contributing most to animal stress.
2. Develop adapted handling and transport protocols that minimise the critical stress factors.
3. Trial amended protocols within commercial operations.
4. Evaluate success by change in number of downgrades and market price achieved for live product.
5. Extend knowledge to industry sectors and encourage adoption by demonstration of protocols at local port meetings.

Methods

A large amount of research on stress levels imposed on crustaceans by different handling and transportation practices of live seafood product has been undertaken in recent years (Appendix 1). The findings provide a body of existing information on specific stress factors and measured values to specific stresses which diminishes the need to re-invent the wheel in approaching the current research project. Using the available biochemical stress factor knowledge, activity in this project addressed the need for information transfer on best handling and transport practices to minimise stress imposed on live product within three New South Wales crustacean fisheries. Of primary concern to the Industry was temperature endured by the animals during transport and hence work focused on monitoring this parameter to identify whether temperature was contributing stress.

The crustacean species from New South Wales fisheries identified by Industry for inclusion were:

Mud crab - *Scylla serrata*
Spanner crab - *Ranina ranina*
Eastern rock lobster - *Sagmaraisus verreauxi*

The three crustacean species have different environmental habitat and geographical distribution along the NSW coast (Table 1).

Table 1. Main NSW landing points for crustacean species

Species	Major landing, collection locations (Co-operative)
Mud crab	Ballina, Clarence River, Coffs Harbour, Jerseyville, Laurieton, Nelson Bay, Newcastle
Spanner crab	Ballina
Eastern rock lobster	Coffs Harbour, Laurieton, Wallis Lake, Nelson Bay, Newcastle, Sussex Inlet, Narooma, Bermagui

Documenting established practices

Documenting practices at all major landing ports was carried out by port visits and onsite discussion with key fishers, truck drivers and Fishermen's Co-operative managers. Where Co-operatives were visited, fishers were contacted through the Manager and visits timed to coincide with weigh-in and pack out time to maximise number of fishers available for interaction. For fishers not associated with Co-operatives, contact occurred directly with key representative of the fishery, who then willingly organised names and contact with other main fishers in the area. Description of current transport chain practices is provided in the next section from information gained from Industry and onsite observation by project researchers.

Temperature and disturbance monitoring

Thermocron *i*Button temperature loggers (TC Temperature Logger DS1921G Range: -30°C to 85°C Resolution: 0.5°C) were used for data collection for both crabs and lobsters. Thermocrons were selected for their robustness and suitability to resist active animal movement caused by external disturbance of the bin during transport. These data loggers have capability of data recording interval selection and have a measurement sensitivity of 0.5ºC. This measurement sensitivity was considered suitable for the research purpose (Poole *et al*, 2008).

Loggers were included attached to crabs or lobsters positioned at the top and bottom inside the bins and external bin surface. Thermocrons were initiated to log at recording intervals of 5 minutes to ensure no data overwrite during transport period. Separately, the internal temperature of the Pantech carriage space was recorded by the automated monitoring system of the transport truck. Two loggers were placed amongst crabs or lobsters inside the box or bin and removed on the market floor at Sydney Fish Market by skilled

quality assurance staff just prior to auction commencing. Recordings from the loggers were averaged to give the temperature within any one bin of live product.

Vibration loggers (Gemini Tinytag 9903-0601, sensitivity 0 to 50g) were also included in product transport bins in initial trials in order to determine the shock disturbance at times of loading, unloading and throughout transport (Poole *et al*, 2008). Data captured during road transport showed only minor vibration disturbance however, disturbance resulting from loading, unloading and some manual handling often registered off the logger scale and as this level of 'shock' would be excessive (being ≥ 50g) for the live animals, further vibration logger use was discontinued. Humidity was measured with Gemini Tinytag Ultra TGU-1500 data loggers, temperature -30°C to 50°C, 0-95%. Relative humidity was recorded in initial transport trials and, as these showed consistent high level of humidity through transportation, recording was not continued through further trials.

Quality evaluation

A useful indicator of stress is in crustaceans is physical liveliness of the animal, general robustness and response to external stimuli. Measurement of these attributes is somewhat subjective however and relies on the experience and knowledge of the grader/assessor. Overall, the crab's alertness of movement, reaction time when approached, extent/speed of eyestalk movement and degree of force returned when exerting pressure against the crabs' limbs provide a reasonable indication of 'liveliness' (at ambient temperature). The vigour of each animal was assessed against a four-point demerit scale similar to the method described by (Spanoghe and Bourne, 1997) and based on the vigour index for mud crabs previously developed (Poole *et al*, 2008). It was ensured that all assessments were made on crabs at ambient temperature (20-25^{o}C)

At landing port, crustacea were assessed by individual fishers during pack out process, shortly prior to being loaded on truck for transport. Live mud crab was graded by commercial industry practice into A, B and C grade (Mayze *et al*, 2016) at this time and packed separately according to grade assessed, with only infrequent bins of mixed grade created. Eastern rock lobsters and spanner crabs were graded by size of animal. Those animals noted to be 'slow', determined as having little response to handling and weak reactive limb strength, were removed from shipment.

Product was then re-assessed at Sydney Fish Market (SFM) by buyer following purchase. Animals identified as 'slow' or 'out-of-grade' as recorded by the fisher were submitted for application of reduce purchase price or rejection, with the agreement of the SFM Quality Assessment staff and according to SFM auction practice. SFM supplies detailed records of sale back to the Co-operatives and fishers.

Sedation trials with Spanner crabs

Spanner crabs are recognised to have a low tolerance to handling disturbance and air exposure (Paterson, 1994). In an attempt to reduce the impact of additional stress imposed, trials to sedate the animals prior to pack out handling were undertaken. The trial design was based on similar research found to provide benefit in stress reduction for Spanner crabs (Paterson et al, 1997; Paterson et al, 1993), Mud crabs (Poole et al, 2008), Western rock lobsters (Spanoghe and Bourne, 1997). A chill step was not common practice in the spanner crab industry and it was considered of benefit to establish whether inclusion of a chill step pre-pack out would reduce stress experienced by spanner crabs.

Sedation by chilled water: Crabs for trials (n = 30, ~400g each) were held in recirculation seawater tanks at 17^{o}C. They were removed and assessed for vitality prior to immersion in 100L of seawater chilled to 0°C, 5°C or 10°C. An air stone was introduced to the water tank to maintain oxygenation of the water. Crabs were immersed for 30 seconds, 1 minute, 5 minutes or 10 minutes with observation of reactions. Crabs were removed from the chill tank at the required time and allowed to drain for one minute. Crabs were packed head down in a polystyrene box in a tight-fit manner. A 15mm layer of polyurethane foam (PE foam) was added inside the top and bottom of the box. Gel ice was used to maintain a cool temperature. Commercial industry uses approximately 1kg of gel ice to pack 12kg of spanner crab. This ratio was scaled to 166g gel ice/2kg crab for trial purposes. In later trials, 500g gel ice/2kg crab was used as early trial results of crab vigour illustrated a greater amount of coolant was required to hold a cool temperature over extended

storage. Packed crabs for all trials were held in the polystyrene boxes at in an air-conditioned room (25°C) for 24-48 hours, to simulate commercial transport time, with internal temperature monitored inside the box. At this time, crabs were removed from the box and assessed for liveliness responses.

Sedation with chemical anaesthetic (AQUI-S): Spanner crabs (n=20) with an average weight of 428g were sourced from commercial fishers. All crab were held in a seawater recirculation system at 17°C. Crabs (n=5) were exposed to 3 concentrations of AQUI-S: 40, 60 and 80ppm. These AQUI-S concentrations were selected from discussions with the Technical Manager (AQUI-S, New Zealand Ltd) and in line with Canadian research applying AQUI-S to crabs (*Cancer pagurus*) (Barrento *et al*, 2011). Crabs were placed in a 200L tank of seawater with appropriate AQUI-S concentration and aerated with an air stone. Crab eye-stalk response, leg strength and movement were recorded at five minute intervals. Sensory attributes of crabs subjected to AQUI-S treatment and crabs sedated by chilled dip were assessed to establish whether crabs were flavour-tainted from the use of AQUI-S treatment. Crabs were steamed (100°C, 20 minutes) rather than boiled to minimise dilution of volatile compounds present in the flesh. Crab flesh was picked and presented chilled to a five member panel of experienced crab tasters.

Determination of water loss during emersion of crustaceans

Three sets of robust and fully intact lobsters (each set n=5, total weight 5-6kg) were removed from seawater (20°C) and allowed to drain for 2 minutes before being weighed to provide initial whole wet weight. The lobsters were then held dry at 21°C for 7 hours in a fish bin with drain holes, angled to remove drip loss water from contact with the animals and weighed every hour. Each total weight was subtracted from the initial wet weight of the crab set and recorded as a percentage water loss.

Two sets (each set n=4, total weight 1.5-1.7kg) of spanner crabs with all appendages intact were sedated with a 10°C, 10 minute treatment then removed from the chilled water and allowed to drain for 2 minutes before being weighed to provide initial whole wet weight. The crabs were held dry at 21°C for 24 hours and weighed. Weight after dry storage was subtracted from the initial wet weight of the crab set and recorded as a percentage water loss.

Information transfer

There was immediate feedback of results to all stakeholders shortly after information was obtained through direct discussion and visual depiction electronically. The temperature data gained illustrated the critical points during transport imposing stress on the live animals and with animal vigour providing the basis for decisions on appropriate adaptions within the handling and transport chains.

Statistical analysis of data collection from temperature monitoring is not possible as each transport trip ‘unique’ subject to different variables: season, crustacean life cycle phase, fisher handling, pack-out system and transport route. In many cases insufficient animals were transported from a specific location on any one day to be able to match bin-stack of industry practice with an equivalent bin-stack of ‘adapted’ practice. Hence inference from data obtained within a trial is somewhat ‘stand-alone’ and conclusions drawn are made with the qualification of parameters applicable on that specific day.

Results

Industry Transport Chains

Live transport pathways from northern NSW through to SFM are described separately by contracted freight company and product pick up location. Most fishermen transport their harvest into a local Fishermen's Co-operative or collection depot themselves, with distance of travel variable and dependent on fisher operational base. A contracted freight company then loads product for transport to the SFM. Product pick-up times are dictated by trip duration to achieve arrival of truck in Sydney to meet the following morning auction which commences at 0400.

Road trip visits to each landing collection port along the New South Wales (NSW) coast were divided into three regions (Table 2). Information pertaining to specific regions is documented by collection point and specific species, included detail of factors likely to affect quality of animal from capture through distribution to market.

Table 2. Key landing collection points

Region	Collection Point	Key fisher landing areas
Northern	Ballina	Ballina
	Clarence River	Maclean, Iluka, Yamba
	Coffs Harbour	Coffs Harbour
	Macleay River	South West Rocks, Jerseyville
	Port Macquarie	Hat Head, Port Macquarie
Central	Laurieton	Laurieton, Crowdy Head
	Wallis Lake	Wallis Lake, Tuncurry
	Nelson Bay	Bungwahl, Tea Gardens, Nelson Bay
	Newcastle	Newcastle
Southern	Sussex Inlet	Sussex Inlet
	Narooma	Narooma
	Bermagui	Bermagui

Ballina

There are good landings of mud crab and spanner crab packed out for transport through Ballina Fishermen's Co-operative, but no Eastern rock lobster is distributed from this port.

Spanner crabs are captured and placed into open crates on board small boats, transported by utility vehicle and unloaded directly into the Co-operative facility. There is no capacity to transfer crabs into seawater holding tanks to allow animals to de-stress at this facility. Ballina Co-operative members have explored installing live holding tanks at the facility however the major hurdle remains that of Co-operative location being too far from a clean seawater source. An alternative supply through seawater carriage is too expensive to be feasible.

Spanner crabs are graded just prior to truck arrival for pick up and are packed out dry in separate SFM fish bins according to grade. Within Industry, Spanner crabs are often placed on their backs to keep them calm. A layer of wet polyurethane foam is placed on top of the animals, then covered with damp hessian sacking. Bins are brick-stacked onto a pallet to a maximum of four bins in a stack. A cardboard pallet liner is used as a base under the bin stacks and a cardboard sleeve is placed over the entire bin-pallet (Image 1).

Image 1. Pack out of Spanner crabs at Ballina Fishermen's Co-operative

The additional material is applied to protect crabs from cold draught and insulate from the chill temperatures in the transport truck but adds cost to each shipment. During cold weather in winter, some crabbers use polystyrene boxes instead of the SFM wet bins, to provide additional insulation for the crabs. Spanner crabs are transported to market daily due to their low tolerance to air exposure.

Mud crabs are captured, handled at harvest and transport for direct unload into the Co-operative facility in a very similar way as Spanner crabs. Mud crabs are also graded at pack out point and placed underside down into SFM fish bins according to grade. Mud crabs may be sent to market daily or can be held dry in crates for an additional one to two days at fisher landing base, due to having a higher tolerance to air exposure.

Crabs are transported by Lindsay Freight in a refrigerated truck. This truck carries frozen product, chilled product and live seafood product (Image 2) and the trailer is specifically designed with insulating panels able to be fitted between the three different temperature compartments. The truck departs from Brisbane and product pick up of seafood occurs at Ballina and Maclean, along with roadside stops and other locations for other freight commodities. The Co-operative staff load the truck.

Image 2. Multi-compartment Lindsay Freight truck

Key issues perceived by industry:

- strong concerns around truck and freight operations
- drivers unaware of needs associated with handling live product – can be first-run drivers
- lack of awareness of chill temperature effect on crab stress levels and animal survival
- internal trailer temperature not monitored on road, nor adjusted appropriately at pick up time
- the insulating panels often not used and not fitted correctly when are used

Clarence River

Product handling at this location is mostly mud crab. Very little Eastern rock lobster (ERL) unloaded into Clarence River Co-operative, with only one fisher operating in the area landing product occasionally. No spanner crab product is landed at local ports.

Mud crabs are frequently harvested and held dry in air (emersed) at fisher landing base for up to seven days. Handling is variable between crabbers with some fishers keeping crabs damp, dark and undisturbed and other crabbers not as fastidious with respect to crab condition. At truck pick up times, mud crabs packed out in SFM fish bins or polystyrene boxes. Some fishers grade crabs and send to market in separately marked bins or they are sent as a mixed grade bin (ungraded), dependent on catch composition and numbers. Each crabber packs differently, some make holes in polystyrene boxes although these may be blocked off when crab boxes are palletised for transport. Other crabbers specifically do not make holes in boxes because of perceived increase in exposure to chill temperature during transport. There is some use of cardboard liners inside crab boxes to add insulation for reduction of cold temperature exposure.

No holding tank facilities are available at this location due to the Co-operative being sited at an inland location and having very limited space within the facility.

Transport to Sydney is on the same the Lindsay Freight truck through from Ballina. At this pick up point, the Co-operative staff control the packing, palleting and loading of the product into the truck. Driver role is that of receiving product only.

Key issues perceived by industry:

- high mortality at times – often associated with flood events and attributed to severe reduction of water salinity
- variability in crab handling practices between fishers – both during holding and with pack out practices
- strongly concerned about the low temperature within the live compartment of truck trailer
- lack of knowledge of handling live product by drivers
- design of truck compartments poor as at this pick up location, product can only be loaded from the rear (not through side opening) due to space restrictions on site. This requires that product is off-loaded into parking area while other product is loaded prior to then being re-loaded

Coffs Harbour

The main species of live product through Coffs Harbour Fishermen's Co-operative are mud crab and Eastern rock lobsters (ERLs). No Spanner crab product is landed at this port as it is geographically south of fishing waters for this species. Coffs Harbour recently installed live holding tanks on site of different types for holding ERL and mud crabs. Two different product holding systems exist: one immersion and the other flow through. Both systems operate with seawater, taken directly from the harbour at high tide and both have capacity to hold around 200kg of live product. The immersion tank is aerated and has agitation to create water movement. The flow system has a high volume of water cascading from top to bottom of a racking structure. This latter system was developed following a similar design to that recently installed at SFM and had design input from Australian Live Seafood, who also assisted with system set up.

ERLs are held in crates fully immersed in the tank or in the flow through system where crates of lobsters are placed on racks with water flowing through the crates from top to bottom. Mud crabs can be held in the immersion tank in crates, however it is not common practice due to high effluent resulting when crabs have not been previously purged for a few days. ERLs are quality assessed and packed according to size grade into

SFM wet bins. These bins have been specifically designed for direct transfer into wet tanks at the market floor. The wet-bin design has a clip-on lid and a holding capacity of approximately 15kg of animals, with small holes bored into base and lid of bin. Mud crabs are often also packed out into these wet bins according to live crab grade, although polystyrene boxes are still frequently used in winter as protection against cold temperatures.

Both ERLs and mud crab are transported from Coffs Harbour to Sydney on Lindsay Freight, but typically originates from the local Coffs Harbour Lindsay depot and not the truck coming through from Brisbane. Live product pick up occurs Sunday, Tuesday and Thursday to meet auction sale the following respective days.

It is noted that previous high mortality rates for ERLs have been significantly reduced by installation of holding tanks at both Coffs Harbour Co-operative and SFM. For mud crab, major losses can still occur resulting from low awareness of live animal requirements and poor transport environment practices.

Key issues perceived by industry:

- truck pick up times are not fixed but determined by load carried on the day
- at Coffs harbour Co-operative staff load the truck
- when truck arrives to pick up out of Co-operative working hours, driver loads the truck
- live product is unloaded when adding chilled and frozen product at subsequent loading locations
- lack of driver knowledge of live product handling
- trailer temperature too low to be suitable for carriage of live animals

Jerseyville

No ERLs or spanner crabs are landed at the Macleay River Fishermen's Co-operative sited at Jerseyville. The only live product handled is mud crab and the number of fishers has reduced to four. These fishers work as a group with three of the four fishers being from the same family. Mud crabs are harvested and stored at crabber landing base emersed until sufficient are acquired to transport to Sydney.

Previous years illustrated excessive rates of mortality for mud crabs, often up to 30% and typically 10% or greater. Comments on variability of best practice handling by crabbers were noted with respect to storage at landing base and transport into the Co-operative collection point. Fishers are made aware of their individual returns from Sydney Fish Market auction to illustrate quality of their product at sale, but it took some time for recognition that they were losing large amounts of revenue. Co-operative Manager suggested that slow attitudinal change from previous operation where, pre-quota based, fishers could readily go out and catch replacement mud crabs for those that died.

This collection point does not consider it feasible to install a live holding system due to the amount of released effluent from unpurged crab and the relatively small volume of mud crab handled. Crabs are graded for pack out in polystyrene boxes prior to transport truck arrival. Transport to Sydney is on the same Lindsay Freight truck through from Coffs Harbour, with pick up from this location ~1800. Noted difficulties with insulation panels on the Live Lindsay trailer were:

- panels are necessarily close fitting and hard to remove and replace
- panel handles are high-positioned making leverage difficult, often 15minutes work to remove and replace, frustrates drivers and become that of 'fed-up' with carrying live product
- observation that a loading time should take about 15minutes in total can take 1.5 hours

Key issues perceived by industry:

- crabs stored in bins at landing base are not checked over this period and dead crabs not removed

- some fishers ice down crabs to tie the claws more easily, did not connect that this action directly caused deaths
- often severe draught/breeze during ute trip to Co-operative causing disturbance stress
- crabs not kept damp
- crabs frequently 'slow' when delivered to Co-operative likely due to high stress levels
- often brought in crabs that were muddy, covered in rubbish, with dead crabs in boxes
- lack of truck driver knowledge of live product handling
- temperature in trailer very low (<4^{o}C), drivers will not alter refrigeration

Port Macquarie

The Fishermen's Co-operative has closed at Port Macquarie, with the majority of product landed at this port now handled through Wallis Lake Fishermen's Co-operative at Tuncurry.

Mortality rates and transport for ERLs was discussed with a key fisher who has been in the industry for over 30 years. The fisher operates a large vessel for offshore fishing, typically in 100 fathoms (200m) and a smaller boat for inshore fishing. This fisher innovates with trap design to make the most suitable for seabed and current experienced in the area. Sea current critical for fishing in offshore waters with a need to pull traps from depth with current <1.5 kn. Traps contain self-floating buoys triggered by timers with the adaption of timer trigger mechanism allowing buoys to remain underwater when current is 2kn.

At landing base, there are live holding tanks undercover and water temperature is held at 14^{o}C. Tank system has automated temperature control, robust biofilter water recirculation with ozone, protein skimmer. Fresh seawater is taken from harbour at dock during high tide only. These live holding tanks are also used by another ERL fisher in the location and very few mortalities occur.

Live product is transported for local deliveries in own truck and uses Lindsay Freight on the truck coming through from Coffs Harbour for transport south to Sydney. Most live ERLs go directly to a live exporter facility and directly to southern buyers. A small proportion of product goes to the SFM auction sale with the fisher reporting no issues with transport nor mortalities since the live holding tanks were installed at SFM.

Key issues perceived by industry:

- fisher has no operational issues with very few slow and <1% mortality

Laurieton

Mud crabs constitute important revenue throughput for the Laurieton Fishermen's Co-operative. There is one ERL fisher who lands occasionally at this collection point and he also fishes mud crab.

Many fishers land mud crab into this collection port with comment that there is substantial variability between fishers with respect to best practice handling of mud crabs. Crabbers land and hold crab emersed in crates at base, transporting them by road to unload at the Co-operative on the day of live product pick up. Fishers individually grade and pack out crabs into polystyrene boxes according to grade which sometimes dictates very few crabs in a box. This collection point has experienced severe and regular losses of mud crab at market, with events of whole boxes (8-12 crabs) arriving dead on arrival at SFM and other boxes having a high proportion of very slow crabs and regular down-grading product. Boxes of crab are sent to market with fisher identification and there appears to be an association between quality of crab and individual fisher.

Live product is freighted south by Hines Refrigerated Transport. The company is family-owned and run, with a close relationship of servicing Laurieton Fishermen's Co-operative for many years. Truck refrigeration is run at 5^{o}C and not willing to alter the temperature for live product despite chilled fish being carried within the

same load is well iced already. Live product is carried in same compartment and there are no divider panels used to separate products.

Key issues perceived by industry:

- substantial variability in crab handling practices between fishers, both during holding and pack out practices
- lack of knowledge of best mud crab handling practice by some fishers
- low internal temperature of trailer during transport

Wallis Lake

Wallis Lake Fishermen's Co-operative at Tuncurry is a multi-species landing port with ERLs, mud crabs and a high volume of Blue swimmer crabs. This collection point has installed both emersion holding tanks and a flow-through racked wet holding system. ERLs are held in crates fully immersed with water maintained at 13^{o}-15^{o}C and good current flow and oxygenation. At pack out, they are graded into size, placed in SFM wet-bins and transported dry. Mud crabs are held in crates in the continuous flow system. Crab crates have a fine mesh bottom liner to prevent leg attachment to crate. Crates are stacked on shelving rails with water flowing from top to bottom. They are sorted into A, B and C grades and packed into polystyrene boxes just prior to transporting. The Co-op chooses to use polystyrene boxes as they feel the added insulation is worth the extra cost.

The freight company used for live product is Hines Refrigerated Transport and this truck picks up on the way through from Laurieton. From Tuncurry it is typically six hours to arrival in Sydney, including small load pick-ups along the route. Wallis lake Co-operative have a long-standing relationship with the transport company and have few issues with losses of live product.

Key issues perceived by industry:

- experiences infrequent events of high proportion of mud crab shipment downgraded at market – attributes to weather and crabber handling practices at the time

Nelson Bay

Both ERLs and mud crabs landed through the Nelson Bay Fishermen's Co-operative. All landing bases were visited to understand the supply chain logistics and large differences in handling operations between fishers were observed. Careful attention to animal quality was observed by some harvesters with less attention demonstrated by others.

The collection point has immersion holding tanks available for live product with a direct-flow through system of harbour water. ERLs held loose in the tanks and removed for size grading and packing just prior to arrival of transport truck (Image 3).

Image 3. Live product packed out ready for transport

Freight south to Sydney is by Prospect Refrigerated Transport based locally and the truck picks up loads each day. The truck driver has been on this run for two years and indicated clear knowledge with respect to handling live product. The truck has separation between live and chilled product using a fitted insulation panel between product types once the truck is finally loaded in Newcastle (Image 4). The driver is also willing to adjust refrigeration according to temperature inside trailer and load type. He adjusts the temperature of the live compartment on extremely hot days allowing special small vents to spill a small volume of cold air from the refrigerated compartment into the live section. This stops the live section from overheating as there is no separate refrigeration unit in the rear section of this trailer.

Image 4. Insulated panel to separate the live product from the chilled and frozen product

Key issues perceived by industry:

- variability in mud crab handling practices between fishers
- holding tanks for ERLs at the Co-operative are now aging and the system is not necessarily as effective

Newcastle

The Newcastle Fishermen's Co-operative has a high throughput of both ERLs and Mud crabs and is the southern-most collection point for mud crabs. Records illustrate there can be high mortalities and regular downgrading for mud crab at market however, a low rate of mortalities for ERLs. There are no live holding tank facilities for ERLs nor mud crabs at this collection point. The existing live tank is used for holding live prawns and would need an effective chiller unit included to maintain constant water temperature for either live ERLs or mud crabs.

The Newcastle Co-operative is the collection point for local area product and also mud crabs from landing ports northeast of the Port Stephens. Within this wide supply area, transportation of live product has two phases. Live product from Bungwahl and Tea Gardens is graded into standard plastic open fish bins and transported to Newcastle in a small refrigerated truck. The truck is pre-chilled and refrigeration turned off prior to loading with mud crabs. Once bin stacks of emersed crabs are loaded, a canvas cover is placed over the stacks to prevent cold air access directly on the surface of animals (Image 5). Bins are unloaded at the Newcastle co-operative and stored on a dock area inside the facility without the canvas covering, to await on-transport to Sydney.

Image 5. Bins of live product with canvas cover and live product stored at Co-operative

From Newcastle Co-operative, freight is by Prospect Refrigerated Transport truck coming through from Nelson Bay. An insulation panel is not always used between Nelson Bay and Newcastle to separate stacks of wet chilled fish and live product. These panels are fitted at Newcastle as the truck then travels to Sydney direct with no additional roadside pickups.

Key issues perceived by industry:

- fisher handling practices for mud crabs are not always best practice
- ERLs can often remain emersed for long periods

Sussex Inlet

Sussex Inlet is the landing base for an independent ERL fisher, who is one of the major fishers on the coast south of Sydney and has over 30 years of experience. The greatest volume of catch of ERLs from these waters (10°-14°C) occurs August-November after a June moult. Traps soaked for two weeks and at this time some bait still remaining, however none is left after four weeks. The fisher has observed that ERLs are social animals, with the example of where there are 60kg animals in the trap, leave another week and there will be 200kg in that trap. ERLs are tagged immediately on-board and then packed in prawn crates with lids and placed into seawater tank.

Crates are craned onto truck at port, transferred to aerated holding tanks (8°C) at business base (image 6). ERLs are usually in holding tanks for one day only and if 'slow' lobsters are noted, they are cooked the same day and sold into local market. The whole operation focuses on minimising physically handling throughout all steps (limiting animal disturbance). Lobsters are packed into polystyrene boxes for transport to market and are carried by own truck with product temperature monitoring. The majority of the catch is supplied into live export facilities.

Image 6. Holding tanks and lobster pots

Key issues perceived by industry:

- this individual fisher has no operational issues and very few slow or dead ERLs reported.

Narooma

An independent ERL fisher with over 40 years' experience in the fishery and is currently the sole fisher in the area. ERLs are harvested and immersed in seawater tanks on board vessel with flow through water from deck hose. At landing, ERLs are transferred loose into immersion tanks with water source intake during high tide directly outside facility location which has a high tidal flow.
ERLS are transported to Sydney weekly. This fisher has his own truck and will transport to Sydney himself if the catch is greater than 200kg. He also has an arrangement with the Bermagui Fishermen's Co-operative to freight on their truck coming through for smaller volumes of ERLs. The greatest proportion of the catch goes directly to a live seafood holding facility for export.

Key issues perceived by industry:

- fisher has no operational issues with very few slow and <1% mortality

Bermagui

The main product through the Bermagui Fishermen's Cop-operative is fish, with only one ERL fisher unloading product at this collection point. The fisher primarily targets ERLs and mainly fishes well offshore. The catch is placed into flow through immersion tanks on board vessel. Fisher attempts to land product to meet truck departure times. There are reports of some occurrence of 'slow' ERLs and low percentage of losses.

The Bermagui Co-operative owns two refrigerated trucks with dedicated drivers. Truck departure from this collection point is dictated by volume requiring distribution on any one day. The Co-operative does not have live holding tanks at the facility. Therefore, if product is held back waiting for total volume of seafood product to accumulate, the live product is held emersed. The Co-operative controls truck departure and operates to meet needs of fishers and markets. Drivers are knowledgeable of live product handling needs. Truck is pre-chilled internally, loaded and then the refrigeration turned off. If stopping for pick up at Narooma, refrigeration is run during pick up and then again turned off for transport. The truck travels straight through from Bermagui to Sydney with no roadside pickups, except occasionally for the fisher at Narooma.

The Bermagui Co-operative also co-ordinates with Southland Fisheries when wishing to send product to Melbourne. This necessitates the Co-operative transporting product the two hour drive to Eden and the product is then transferred to a larger refrigerated freight truck for on-transport.

Key issues perceived by industry:

- occasions of 'slow' ERLs sent into market

Sydney Fish Market

The SFM were aware that mortalities within the ERL supply chain were unacceptably high, causing severe revenue loss and this had occurred over a protracted period. To facilitate recovery of ERLs that have been stressed through supply chains from point-of-capture to market, SFM has installed seawater tanks for holding live product prior to auction.

Tank system

- system is flow-through using seawater sourced by tanker delivery; includes protein skimmer and has a coral biofilter
- ozone water treatment was trialled, but fraught with risk of accidental misuse, hence UV treatment capability was added
- water temperature is maintained at 14-15^{o}C; water exchange is 50% full change every 3 months
- system capacity: 11 tubs x 3 rows x 3 high stack; at ~10kg/bin means around 1000kg in each of two tanks
- ERLs arrive in SFM wet bins that have several holes drilled in the bottom. Bins are stacked to a maximum of three high and water flows from the top of the system through the bins into a sump beneath (Image 7).
- live product must arrive in SFM wet bins for placement into holding tanks
- any live animals sent in polystyrene boxes are placed straight on the floor for auction; SFM staff do not repack
- the tank is loaded on arrival order, starting in one corner and going round the tank edge with the middle filled last if required
- Product is sold in the same order as arrival order
- ERL and Abalone only currently held; keen to expand for mud crabs, spanner crabs and blue swimmer crabs

Image 7. Live holding tank system at Sydney Fish Market

Live transport to SFM

SFM have explored a range of options for transporting live product to the market.

Wet truck

- proposed as effective solution for transporting live animals, SFM suggesting to purchase if demonstrated as viable
- protracted discussions, but interest at port locations not sufficiently keen therefore consistent freight volume not likely to be achievable

Dedicated Live truck

- Hines transport – Robert Hinds willing to trial
- organised for twice per week trip from Ballina and each port to Laurieton then to Sydney
- trials undertaken, SFM underwrote costs for trial
- fishers didn't use as pick up times at locations deemed unsuitable for fishers
- highly variable load volume also an issue, although SFM willing to continue to cover cost loss for extending the trial
- cancelled due to lack of uptake

Lindsay freight truck

- SFM held discussions with Lindsay Transport based in Brisbane and Coffs Harbour
- Lindsay Transport purchased 2 special trailers, with segregated compartments for chilled, frozen and live product, between each compartment an insulated panel can be locked in to allow temperature differentiation between compartments
- these trailers run: Sunday, Tuesday and Thursday to meet following day SFM auction

Summary of key Industry issues

Throughout the road trips to all major ports, it rapidly became evident that issues were associated with particular locations and regions. However, overall issues were common to several ports in that region.

1. It is clear that losses from the Eastern rock lobster fishery have been enormously reduced since the time of installation of seawater live holding tanking systems at both landing port locations and Sydney Fish Market.
2. Amongst fishers, best practice handling appears highly variable. This could possibly be attributed to low level knowledge or awareness of factors that contribute stress to live animals. The knowledge seemed to be especially variable within the mud crab fishery and several Co-operative's expressed keenness for further training for these fishers.
3. From the mud crab industry, it was raised multiple times that new pack out materials and methods should be explored to find those that are cost effective and provide greatest insulation from temperature changes.
4. Transport of live product is a major issue where live freight is sent on trucks not owned by the fishing industry. Where trucks are owned and run by Co-operatives or fishing individuals, there are no issues nor losses of product. However, this latter circumstance only occurs within the Eastern rock lobster fishery.

Stress in live crustaceans

Eastern rock lobsters (*Sagmariasus verreauxi*)

Mortality has been high in recent years, prompting action to reduce the level. Introduction of tank-holding systems at both point of landing and at point of sale has alleviated the losses greatly**.** However, some mortality still occurs with stressed and 'slow' animals not surviving transport phase.

There remains an issue with short weights quoted at market sales. Some reports had the connotation of 'disappearance' of animals where short weight amount was substantiality above that to be expected from natural water loss through transport stages. Trials were undertaken to establish typical water loss from ERLS dry-packed during transport. It was found that Eastern Rock Lobsters have a typical 3% drip loss when held dry. Understanding the weight loss of ERLs through loss on water provides relevant information for harvesters when weighing and labelling product at landing, so as to avoid short weights recorded at market.

Mud crabs (*Scylla serrata*)

Mud crab handling practices remain an issue in some harvesting locations. Handling methods are often individual to fisher and related to several factors, for example: new participants into the fishery; a strong focus on catch of crabs only and limited awareness of supply chain after pack-out for transport.

Basic best practice methods are known and were demonstrated to Industry during previously completed mud crab research projects (Northern Territory Code of Practice for the Mud crab fishery, 2011; Poole *et al* 2012; Poole *et al*, 2008). From previous research work, it is understood that the most effective way to transfer and update fishers is by direct face-to-face discussions. This is underpinned by observations made during site visits that all collection points for mud crab transport have available copies of factsheets and guides developed in previous projects. To achieve greatest interaction with maximum number of fishers, discussions on best practice handling occurred during every visit to different port locations.

Spanner crabs (*Ranina ranina*)

Spanner crabs have wide but patchy distribution in a number of countries with subtropical habitat but support only minor fisheries, therefore stress factors affecting spanner crab survival have not been well documented. However, for many crustaceans, it is known that reduced temperature (5^{o}-10^{o}C below that of environmental water temperature) can be effective for calming the animals (Gardner, 1997; Samet et al, 1996; Uglow et al, 1986; Whiteley and Taylor, 1992). Inducing a comatose state within the animal is of major benefit during times of strong disturbance to the animal such as during handling and pack out phases of distribution. For spanner crabs, this was explored by use of chilling temperatures for short periods, as well as a trialled application of an anaesthetic.

Sedation trials

On the basis that reducing crab body temperature can have beneficial effect of causing a sedated state in the animal (Gardner, 1997, Poole *et al,* 2008), trials were conducted subjecting the crabs to short-term cold temperature. Spanner crabs were immersed in 10^{o}C water for 15 minutes and reactive response noted (Table 3). With 10 minutes chilling, crabs were easy to handle and during subsequent pack out process showed no behavioural response to handling disturbance.

Table 3. Crab response observation with short chill immersion

Chill duration (min)	**Observations**
0 (pre-chill immersion)	all crabs showed strong reaction to touch strong response to gentle pressure against legs rapid strong eye response.
5	crabs were slow considered chilled to sedated state
10	nil eye response nil leg reaction to applied pressure
15	nil eye response nil leg reaction to applied pressure crabs sedated

Core temperature of the crabs, packed as for transport distribution and held for 24 hours at 20°C, along with the temperature if the gel icepack included in the box is shown in Figure 1.

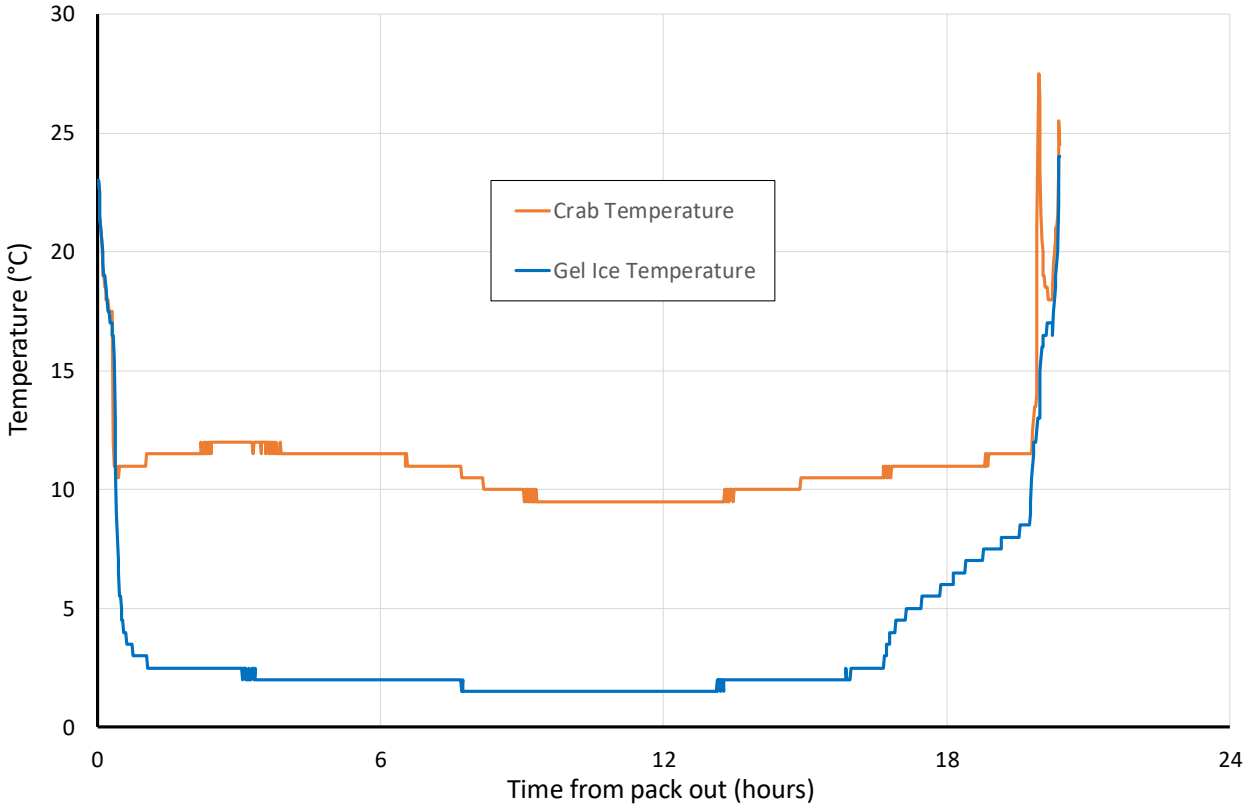

Figure 1. Temperature change of crabs and gel ice-pack during pack out period

When crabs were unpacked, they were transferred to a 16°C holding tank for revival. There was 90% liveliness recovery. Figure 1 illustrates crabs remained at a cold temperature (9.5°–12°C) during storage. A modification of adding a polystyrene sheet in the box between the crabs and the gel ice pack (Image 8) was investigated to determine whether this would provide protection to the crabs from the direct cold of the gel icepack.

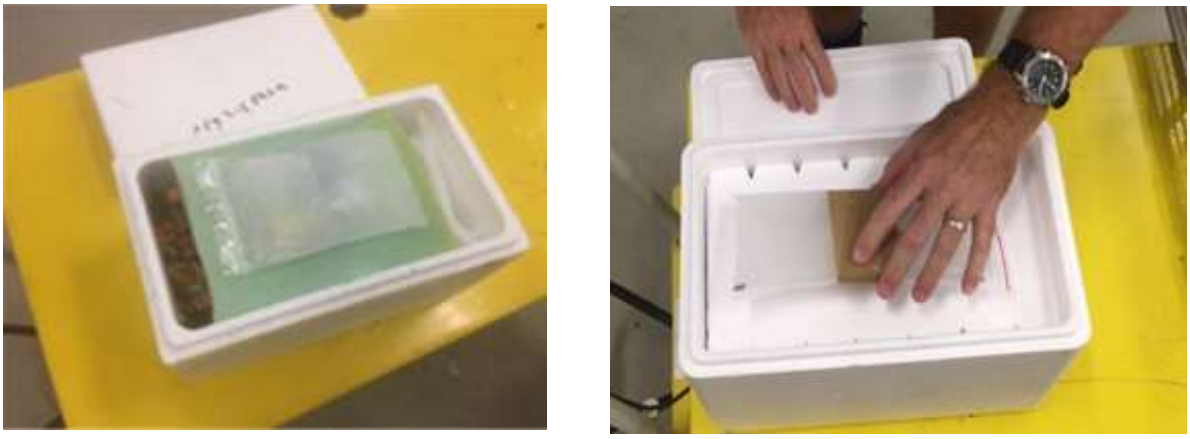

Image 8. Packout using polyurethane foam or polystyrene

Further trials using two levels of gel ice (500g and 166g, the latter being equivalent to the ratio of 1:12 used by industry) were carried out with both pack out insulation methods. After 24 hours of dry storage in box held in a 20°C room, crabs were unpacked. Temperature logs for both pack out sets are given in Figure 2.

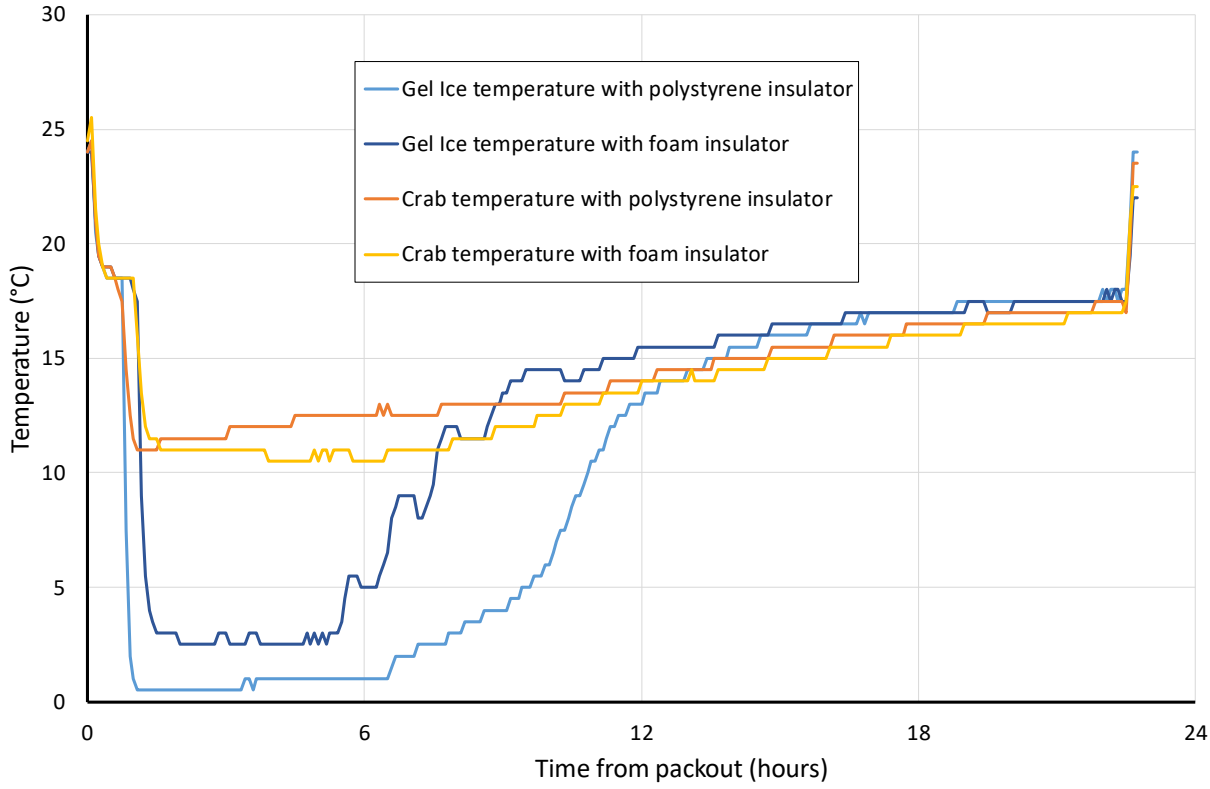

Figure 2. Temperature change of crabs and gel ice pack during dry storage within two different packing systems.

The crabs packed with the top PE foam layer were very lively, excitable and fighting, with one crab losing an arm and consequently dying through blood loss. Those packed with the polystyrene sheet as top layer were sedate and calm. All live crabs revived to full vitality when returned to the 18°C holding tank. Crabs packed out with the polystyrene layer as insulation remained at 13°C for 7 hours compared to the PE foam packed crab (11°C). As storage time continued however, all crabs increased to a similar temperature. Results from a replicate trial showed similar temperature changes with crabs packed with insulation from the polystyrene sheet remaining 1°C higher than those packed with the PE foam and again the gel was slower to melt in the box with the polystyrene sheet as top layer. However, in all the above trials, it was observed that the gel pack included within the box was melting within six to seven hours and therefore ineffective for long distribution chains. Further trials were modified to include chilled 500g gel icepack and a frozen 500g gel icepack (Image 9), again stored for 24 hours at 21°C.

Image 9. Packout box configuration and partially thawed gelpack after 24 hours

Figure 3 provides temperature change of crabs and coolant inside box for 500g gel icepack, superimposed with temperature data from previous trial using 166g gel ice/2kg crabs for comparison. There was strong and vigorous response from all crabs and the gel icepack remained at 8.5°C.

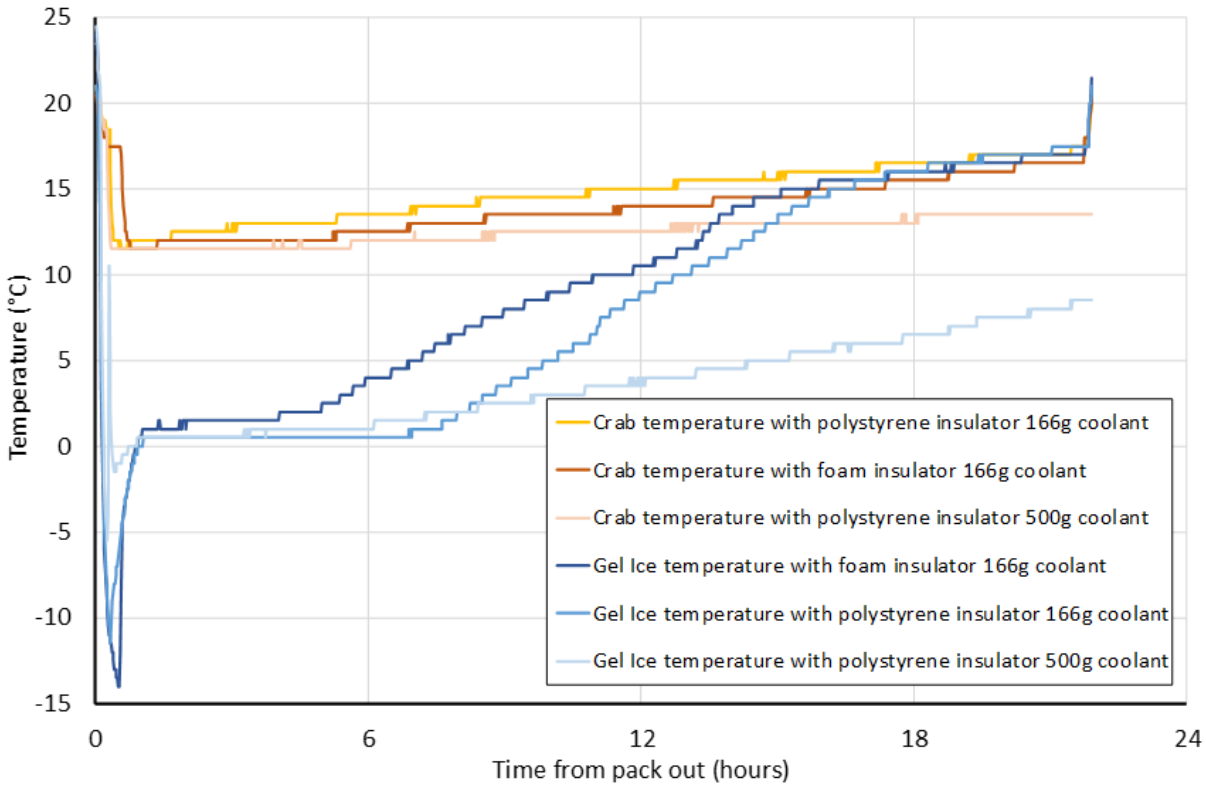

Figure 3. Temperature change of crabs and different coolant gel ice packs during pack out period

From trial results a coolant volume to crab weight in a ratio of 1:4 is effective in keeping the crabs cool and docile for a 24 hours period. With the higher level of coolant present, it is important to avoid cooling the crabs excessively and the use of a polystyrene sheet as an insulator is recommended.

A range of airflow cut-outs for this insulating sheet were incorporated (Image 10). It was noted that small variations of airflow had considerable effect on crab temperature and the maintenance of cold temperature of the coolant pack.

Image 90. Styrofoam sheets with air flow capability

Given that this pack out system held the spanner crabs at sedation temperature effectively, additional trials extended storage from 24 hours to 48 hours. Crabs remained cool (<19°C) for 48 hours from an initial pack out crab temperature of 11.5°C (Figure 4). The gel icepack remained at 0°C for 20h, with slow temperature increase to the same temperature as the crabs after 36 hours. At unpacking, all crabs were lively and vigorous. All crabs were placed back in the holding tanks (at 18°C) with 100% survival rate at 24 hours after unpacking.

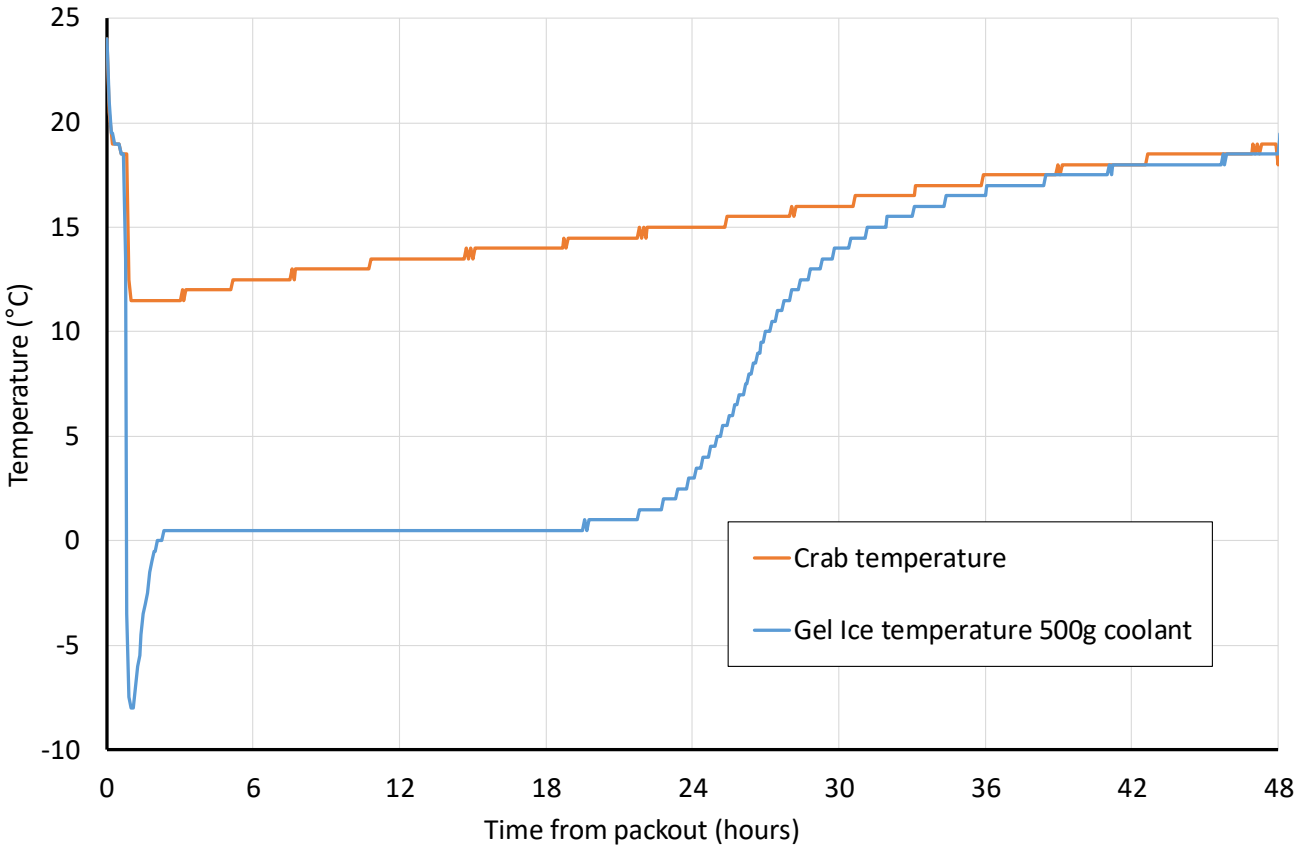

Figure 4. Temperature change of crabs and gel ice during pack out period

Replicated trials confirmed that spanner crabs can be held cool and calm for at least 36 hours. This pack out system was successful in holding spanner crabs during dry pack out for a long period enabling wider distribution through long transport chains. This is particularly relevant for export product, for example spanner crabs into China, as product can be on-shipped from the main landing port to distant markets with high survival.

Chilled sedation trials were undertaken with a 10°C temperature reduction for 10 minutes, would a shorter 'dip' at a colder temperature also be effective? A shorter dip time would be of practical benefit operationally, especially when packing out large volume of spanner crabs. The first 'cold dip' tried was immersion of crabs for 5 minutes in 5°C seawater. Crabs were handled under exactly the same procedure as previously described, being taken from an 18°C holding tank, assessed for vigour, cold dipped, drained for 1 minute and then dry packed out with coolant added to box in a 1:4 ratio and held for 24 hours. The cold dip procedure was very effective for sedating the crabs, with none showing movement. At unpacking, all crabs were lively and

vigorous. All crabs were placed back in the holding tanks (at 18°C) with 100% survival rate 24 hours post-unpacking. Crabs had a body temperature of 9.5°C after immersion in 5°C for 5 minutes (Figure 5). During storage the crabs remained cool, attaining a temperature of 15°C at 23 hours. The gel pack remained at 0.5°C for 22 hours. Repeated trials with different sets of crabs showed the same results indicating that spanner crabs can tolerate a very short exposure to 5°C and remain calm and cool through 24 hours dry storage.

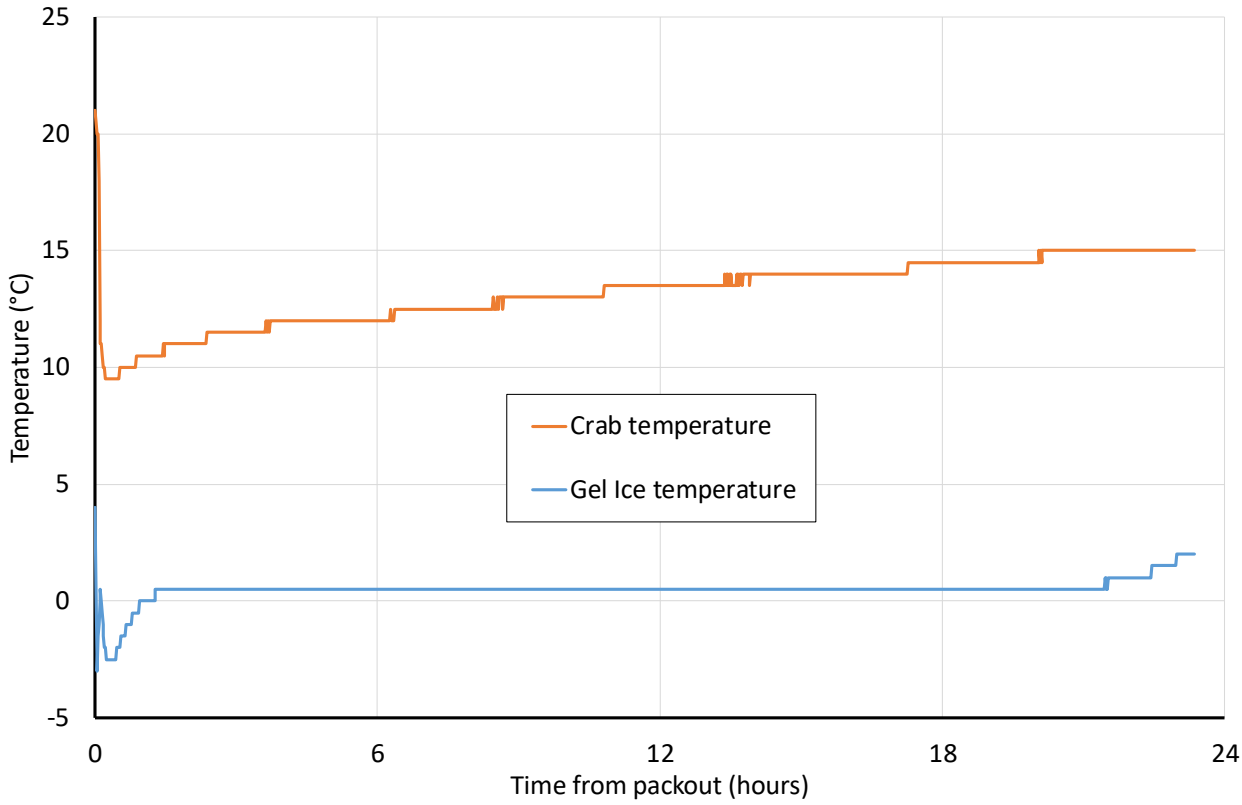

Figure 5. Temperature change of crabs and gel ice pack during pack out period

Within commercial pack out operations, the shorter the dip period, the less operational delay will occur during pack out process. Therefore, it was considered worth investigating whether Spanner crabs would tolerate a very short dip by use of an ice slurry. Dipping procedure for these trials was conducted as described previously, with the modification of using a seawater ice slurry (0°C) with crabs immersed for 30 seconds. The short dip was effective to achieve crab to sedation, with animals showing no response to stimulus. After 24 hours of dry storage, the crabs were alive and responsive but appeared slow. All crabs were returned into seawater (18°C) for 24 hours and demonstrated variable liveliness at this time. Results were interpreted as indicating that subjection to ice slurry temperature even for 30 seconds imposes high stress to the crab and affects post-dip recovery.

It is concluded that spanner crabs can tolerate cold temperatures for very short durations and that subjection to such temperatures is effective in sedating the crab sufficiently to minimise stress imposition during pack out for trans-shipment. A sedation procedure of 10 minutes at 10°C is the most consistently effective procedure and is recommended.

It is recognised that all investigations were conducted using seawater as the medium for sedation and we are aware that all major landing sites do not have ready on-site access to seawater. However, where landed volumes of Spanner crab are not large, this hurdle could be addressed through tank seawater storage of small volumes of accessed seawater.

Sedation by anaesthetic

AQUI-S is a natural anaesthetic of clove oil extract and has proven very effective in stress reduction for live fish during harvest handling (unpublished data, DAF, 1997). Some researchers have suggested that the use of AQUI-S is unlikely to be effective when applied to crustacean species due to the inherent nature of their physiological and metabolic systems (Elwood et al, 2009; Romano and Zeng, 2012). However, other researchers have reported some success in sedation crabs with AQUI-S solution (Barrento *et al*, 2011; Gardner, 1997) indicating that it was worth investigating with Spanner crabs

Crab response and movement was noted after subjection to different AQUI-S concentrations (Table 4). Spanner crabs subjected to a dose of 40ppm crabs remained active for 45 minutes, although they appeared slower in movement after 30 minutes treatment.

Table 4. Crab response to AQUI-S dosage levels

Time elapsed from dosing (min)	AQUI-S concentration applied		
	40 ppm	**60 ppm**	**80 ppm**
0	Strong response to touch, strong legs response	Strong response to touch, strong legs	Strong response to touch, strong legs
10	Less response to touch, still strong legs	Less response to touch, still strong legs	Low response to touch, low leg strength, breathing continuously
20	Less response to touch, still strong legs	Less response to touch, low leg strength	Nil response to external stimuli
30	Low response to touch, low leg strength, no eye response	Low response to touch, low leg strength, breathing continuously	Nil response to external stimuli
45	Low response to touch, nil leg strength, no eye response	Low response to touch, nil leg strength	Nil response to external stimuli
80	Nil response to external stimuli	Low response to touch, nil leg strength	Nil response to external stimuli

It was observed that crabs exuded an orange-brown liquid, similar in colour to that of AQUI-S concentrate, from gills and mouth every four to five seconds during dosing period. Discussions with Nic Paton (AQUI-S New Zealand) revealed he had not seen this reaction before but had not used AQUI-S with spanner crabs. He mentioned a dark discharge from king crab when transported live out of water and suggested this may be a stress response. This response fits with our observation of a dark discharge presented by very stressed mud crabs (Poole *et al*, 2008). On a practical basis for operations within Industry, the required length of time to sedate the crabs using 40ppm would disrupt pack-out efficiency for large volumes of crab being processed. Crabs enduring a 60ppm dose of AQUI-S did not appear fully sedated after 40 minutes, although there was little movement and nil eye response. No exudate from the crabs was observed at this dosage. Recovery indicated by leg strength resistance and partial liveliness took about 30 minutes after crabs were placed in fresh seawater and crabs were still slow after a further 1.5 hours. At a dosage of 80ppm AQUI-S, crabs exhibited a low-level response to touch, weak leg response to gentle force applied and were respiring rapidly after 10 minutes of dose application. At this time, crabs appeared to be effectively sedated.

Sensory evaluation of cooked crab meat from AQUI-S treated crabs demonstrated that all panellists were able to detect a difference between the crab batches (Table 5). The chilling treatment gave a clean fresh crab flavour with no detrimental after taste. The panellists were tasting blind samples and were not aware of the AQUI-S treatment applied and yet they did not detect a clove oil taint but described an *old* flavour that masked the *sweet umami* flavour of the other (chilled) treatment. There was a distinct aftertaste noted and that lingered in the AQUI-S treated crabs.

Table 5. Sensory characteristics of spanner crabs sedated by different methods

Flesh characteristics	Crabs sedated in 10°C seawater	Crabs sedated with 80 ppm AQUI-S
Odour	Oceanic Clean seafood	Older stored seafood smell
Flavour	Sweet crab Umami Clean seafood/ oceanic	Chemical aftertaste Tart acidic aftertaste Old seafood Low crab flavour
Texture	Firm	Firm

With respect to sedation method, both 10°C seawater and AQUI-S at 80 ppm provided satisfactory sedation of spanner crabs. However, the ability of the sensory tasters to detect aftertaste flavours in AQUI-S treated crabs suggests the chilled seawater method is preferable for use in commercial operations.

Water loss from spanner crabs during emersed pack out

Spanner crabs were packed out as per Industry practice for trans-shipment and stored for 24 hours. It was found that Spanner crabs have a typical drip loss of 4.8%.

Temperature of live product during transport

Loads transported consist of mixed product with the bulk volume being chilled (0°-4°C) or frozen product (-20°C). Live product carried in the same load does not tolerate cold temperatures and if exposed, will suffer high mortality. Lindsay Transport, with support from SFM, have developed adapted trailers that have separate storage sections with insulation walls fitted between each section (Figure 6).

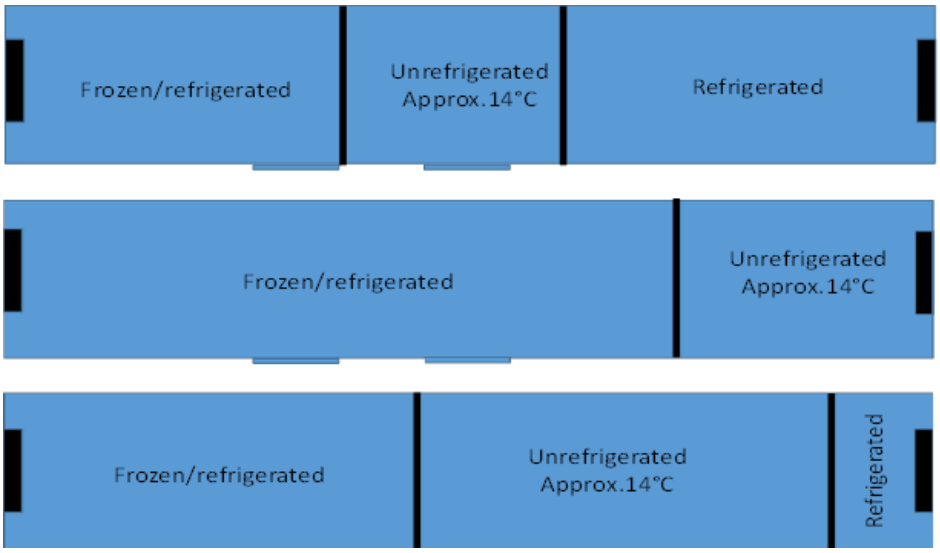

Figure 6. Schematic depiction configuration options of seafood truck

The dividing walls (boards) can be locked in multiple positions to create variable load space within any section. The truck has two refrigeration units front and rear, depicted in black. The truck contains three doors for loading: one standard door at the rear of the truck and two additional doors that line up with the front two compartments.

On any day of load pick up, the collection locations nominate the required load volume requiring different temperatures and the truck is configured with the boards in appropriate positions to allow required volume. However, problems can arise when load specified at any pick up point differs from that stated. Therefore, the onus is on the driver to reconfigure the load whilst on the road.

Monitoring of live product temperature during transport from different landing or collection points was undertaken to understand any temperature stresses the crabs or lobsters may endure. Information below is presented by geographical region as large differences occur directly associated with distance of collection point from market and transport company involved. Temperature data presented in the following figures is representative of multiple temperature monitoring trials.

Ballina

Ballina Fishermen's Co-operative collection point is about 800km from Sydney. Lindsay Transport carry freight from this collection point and, after additional pick up from Clarence River, drive straight through to Sydney with a driver change at Coffs Harbour. Total transport phase for live product from Ballina is 10-12 hours to deliver to SFM.

Spanner crabs

Spanner crabs landed by fishers are immediately graded for size and packed out accordingly into SFM wet-bins. Crabs are packed loose on their backs with no restriction of movement and all bins contained a full volume of crabs (20kg). A layer of foam is placed on top of the crabs, followed by a wet hessian sack that has been soaked in ice-slurry placed on top. These two layers are included to protect crabs from effects of cold air flow and create a dark and cool environment.

Bins of crab were palletised with a cardboard insulation layer on pallet and a full cardboard 'sleeve' covering all bin-stacks on the pallet including the top surface (Image 11).

Image 10. Cardboard sleeve covering bins for insulation

Packed-out crabs were held in cool factory receiving room (22°C) for three hours prior to freight pick-up. A Brisbane-based Lindsay Live Transport truck, which has the capability of having three separate temperature sections, arrived for pick-up. There was frozen product held in the front compartment with the separating

insulation board firmly in place. In the rear compartment, refrigeration was running at 0°C for chilled product. Live Spanner crab product was loaded into the rear compartment along with bins of iced fish and then the refrigeration was turned up to 8°C. There was no segregation board placed between chilled and live product loaded. Temperature change during transport of the Spanner crabs from Ballina to SFM and through to point of auction sale is depicted in Figure 7.

It is noted that temperatures recorded from data loggers positioned at the top of a bin irrespective of bin location in a stack, all remained above 15°C. This temperature will keep the crabs calm and quiet.

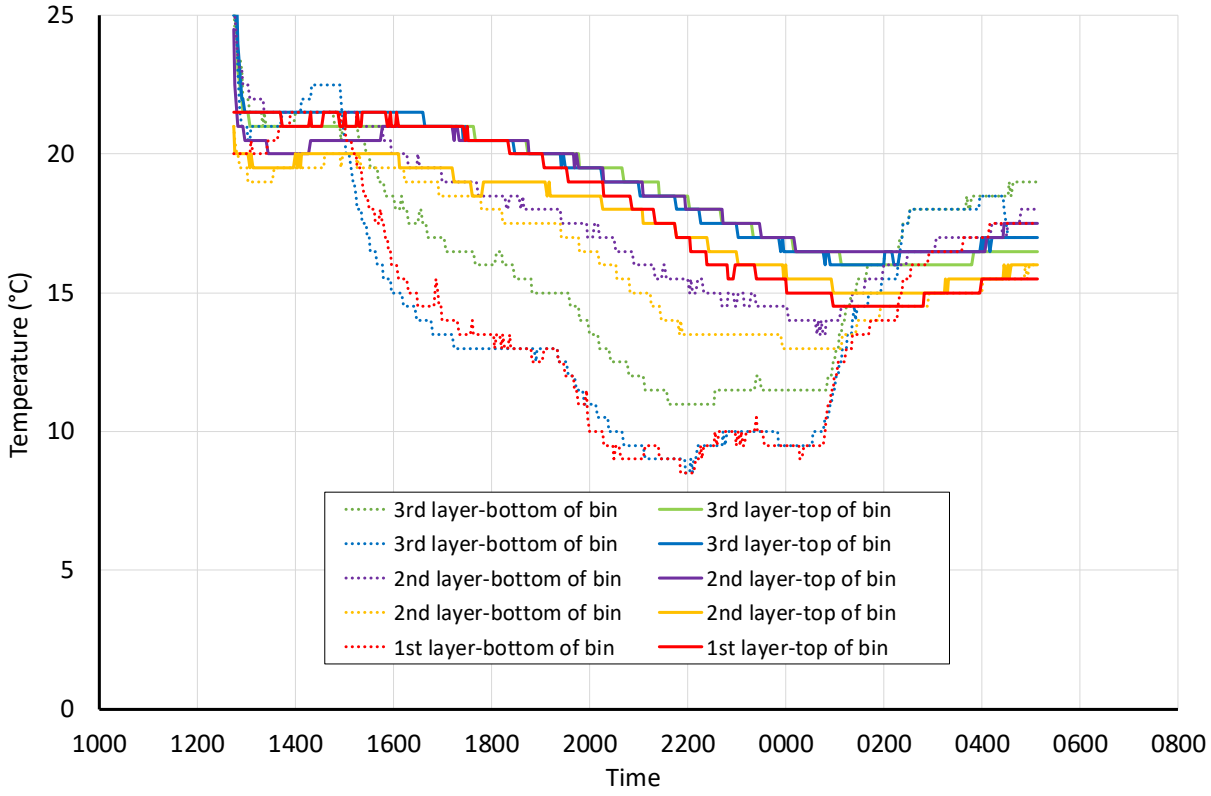

Figure 7. Temperature data of Spanner crabs transported Ballina to Sydney

Once loaded into the cold truck compartment, the temperature of bins steadily dropped over the next six to eight hours during road transport. The bottom of bins recorded lower temperatures (dotted lines in Figure 7) than corresponding top of bin temperatures (solid lines in Figure 7) and this held true for any layer within the stack of bins. There were quite large differences between top and bottom temperatures within a bin. For example, a 1st layer bin of the stack had a recorded temperature in the bottom of the bin 6°C colder than temperature at the top of the same bin. Bins located in the 2nd layer of the stack reached a colder temperature than 3rd layer bins but still remained above 13°C, an acceptable sedating temperature for Spanner crabs. The humidity was maintained at 95% throughout transport. After arrival at SFM and unloading to the auction floor, those bins with a low temperature warmed to reach a temperature of 15°C within one to two hours and slowly increased to 16-19°C just prior to auction. At temperatures above 15°C, Spanner crabs typically exhibit strong vigour and liveliness.

Temperature monitoring from this transport location illustrated that a temperature differential occurs in bins of live product between bottom and top within an individual bin, as well as temperature differential across layers of bins in a stack.

Coffs Harbour

Coffs Harbour Fishermen's Co-operative collection point is about 550km from Sydney. Lindsay Transport carry freight from this collection point, with the truck originating from Lindsay Freight Coffs Harbour depot. This truck also picks up live product from Macleay River Fishermen's Co-operative at Jerseyville prior to driving straight through to Sydney. Total transport phase for product from Coffs Harbour is 8-10 hours to deliver to SFM.

Mud crabs

Mud crab fishers hold crabs at a landing base and then bring in to the depot just prior to freight truck arriving. At the depot, crabs are transferred into SFM tanking bins according to grade and each bin is weighed in. It was observed that for some grades there were only a few crabs and hence the bin was relatively empty which permits movement of crabs, adding stress to animals from antagonising each other and involuntary sliding during handling and loading. Crab bins were loaded directly onto pallet without a cardboard insulation liner placed on the pallet.

The Coffs Harbour based Lindsay transport truck arrived and was a specialised live-product truck with side door access for the ambient middle compartment. The truck was loaded with frozen product in the front section with an insulating divider board in place. In the back section the refrigeration was not turned on and truck bed floor was at ambient (~22°C) on arrival. Bins of wet iced fish and live crabs were stacked against each other and no insulating divider board was used. Loading operation for both wet seafood and live product took 15 minutes. The Floor Manager asked for the refrigeration to be run at 14°C but unsure whether this was carried out. Figure 8 provides the temperature data for the mud crabs during transport to Sydney. The variation in the starting temperatures as the crabs are loaded onto the truck in Figure 8 can be explained by two distinct groups of crab. The cooler crab had just been removed from refrigerated holding tanks showing approximately 20°C and the remainder were crab which had just been delivered at ambient air temperature approximately 25°C.

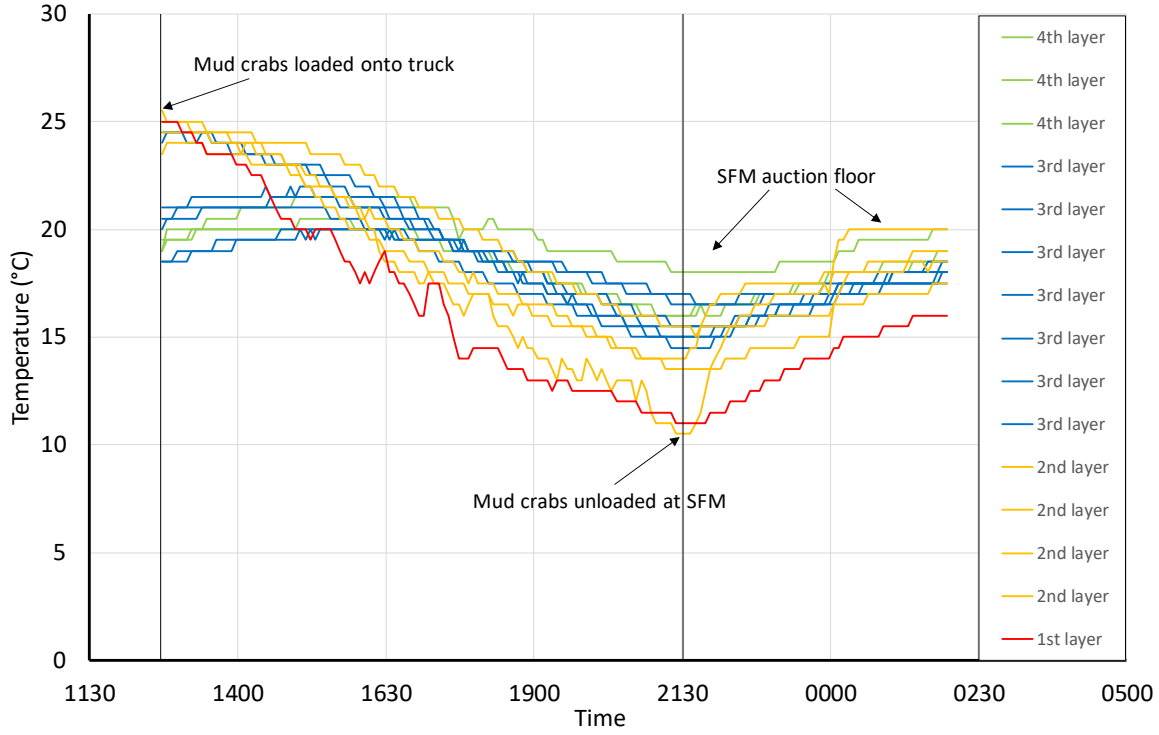

Figure 8. Temperature of mud crabs transported Coffs Harbour to Sydney

A gradient in temperature reduction is seen correlating to position of bin in the stack, with top bins (4th layer) retaining the highest temperatures (18°C) and temperatures reducing down the stack layers, with crabs in the first layer bin (bottom of stack) showing a temperature of 11°C. Temperatures experienced within the top, 3rd and 2nd layers are acceptable for holding mud crabs calm and quiet and will not cause undue stress to the animals. Even the lowest temperatures illustrated in the 1st layer bin and one of the 2nd layer bins will not cause excessive stress to robust healthy animals. However, if crabs at this temperature have accumulated stress through prior handling, it is likely they will be subject to downgrading at market.

From data depicted, it is clearly seen that different bins stacked within the same pallet layer demonstrate different temperatures (see 2nd layer data, Figure 8). This was initially confusing until it was recognised this is likely to be related to bins carrying variable volumes of mud crabs. Within this trial we had noted that some bins contained very few crabs but specific volume of crab per bin had not been recorded.

Temperature monitoring from this transport location illustrated that a temperature differential occurs across layers of bins within a stack and raised the likelihood of volume of live animals within and individual bin influencing temperature of those animals.

Wallis Lake

Wallis Lake Fishermen's Co-operative collection point is about 300km from Sydney. Hines Refrigerated Transport carry freight from this collection point. This truck picks up first from Laurieton Fishermen's Co-operative, 80km north of Wallis Lake and travels through to Sydney. Total transport phase for product from Tuncurry to SFM is five to six hours.

Mud crabs

Mud crab fishers from the Wallis Lake region ship their live product through the Wallis Lake Fishermen's Co-operative where crabs are held in a manifold drip system prior to transport (Image 12).

Image 11. Simple manifold drip system to hold crab cool and moist prior to transport

Mud crabs at this location are typically packed out into polystyrene boxes with small air holes at opposing corners of the base and a sealed lid. The internal temperature of the transport truck was set at 5°C. Figure 9 depicts the temperature inside the mud crab boxes from pack-out and holding for truck arrival, then through subsequent transport to SFM.

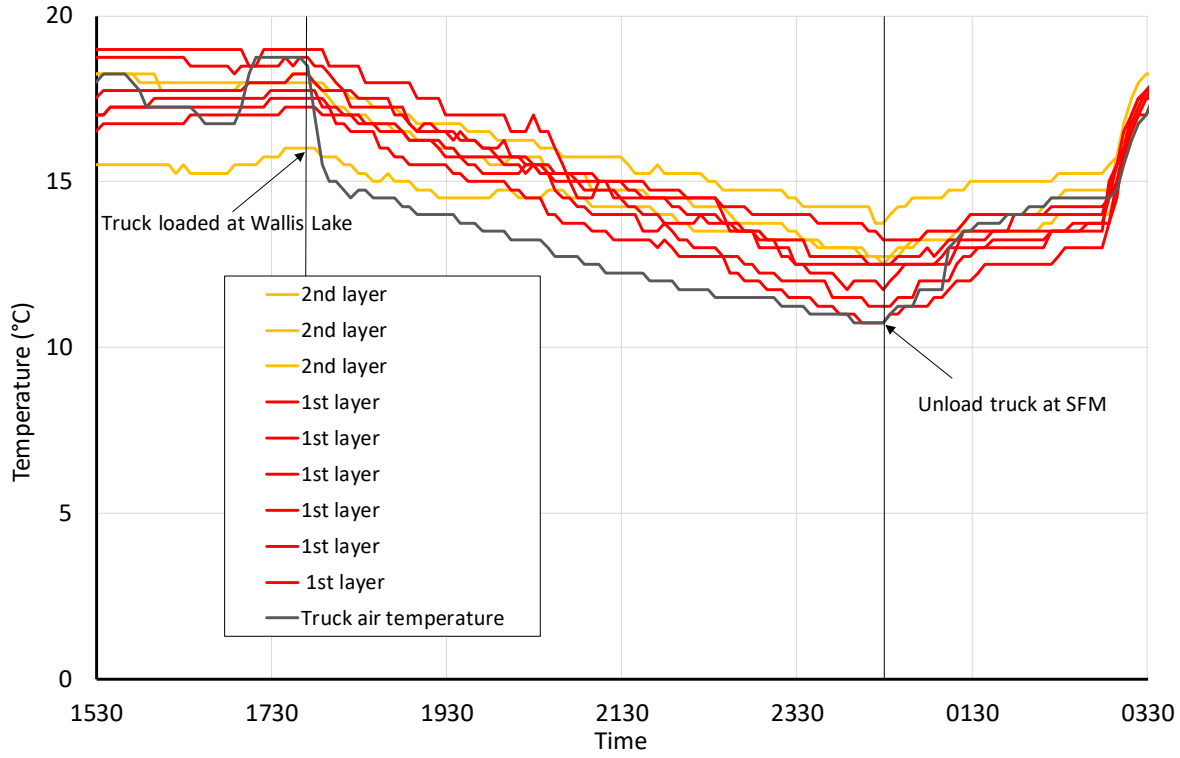

Figure 9. Temperature of mud crabs transported Tuncurry to Sydney

Internal temperature of boxes steadily reduced over transit time in response to refrigeration temperature, however remained above 10°C throughout the trip with many remaining higher at 13°C. This temperature will not cause excessive stress to the mud crabs. The steady drop in temperature shows that polystyrene is sufficiently porous to allow cold air to affect the internal box temperature. In a separate trial, two boxes of mud crab that were positioned on top of bins of live cockles illustrated very little temperature reduction through transport period (Figure 10) and were minimally affected by the truck refrigeration temperature.

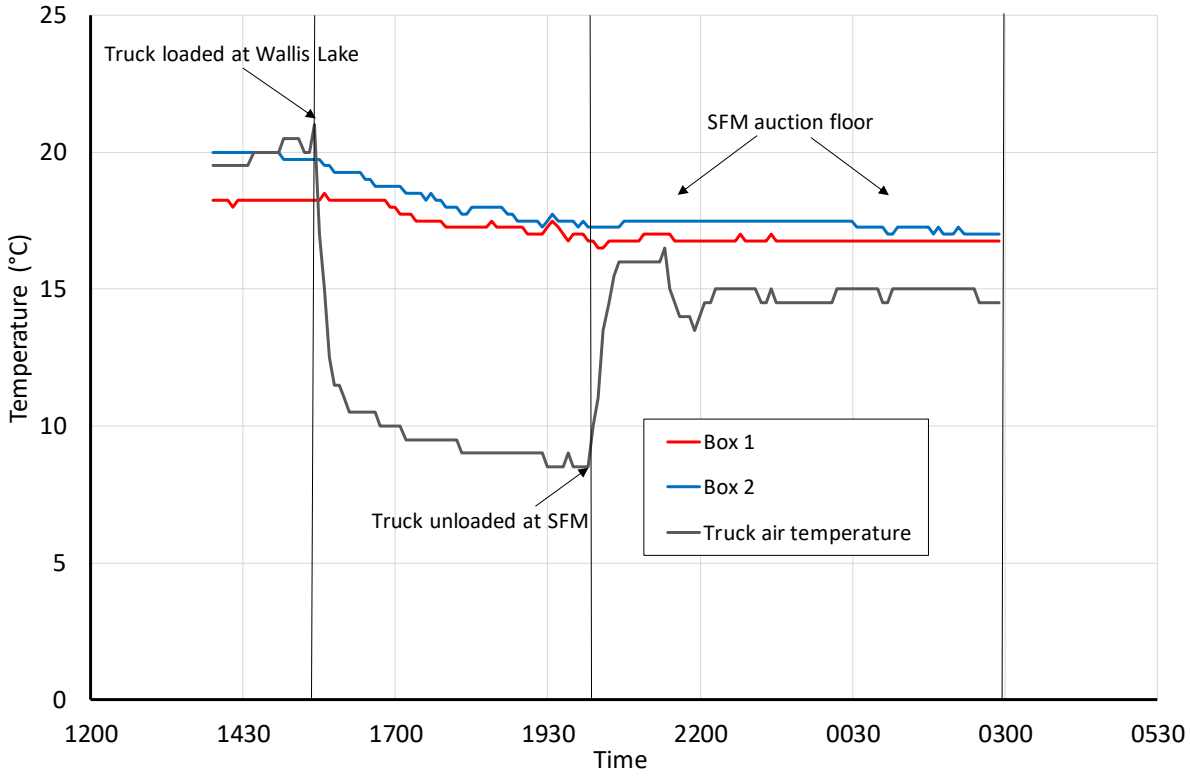

Figure 10. Temperature in mud crab boxes transported sitting on top of live cockle bins

From similar trials monitoring temperature of mud crabs from this location, it was observed that differences in temperatures between boxes appeared to be related to volume of crab in each box, with low volume equating to greater reduction in temperature occurring.

Temperature monitoring from this transport location illustrated the effect of refrigeration operating at 5°C within the truck in reducing live product temperature. However, use of polystyrene boxes for transport do provide some protection from refrigeration temperature. Crab temperature again appeared to be influenced by volume animals within individual boxes.

Newcastle

Newcastle Fishermen's Co-operative is the collection point for a wide harvesting area including landing sites up to 100km north of the Co-operative: Bungwahl, Tea Gardens and Nelson Bay. Live and chilled product is freighted by Prospect Refrigerated Transport from Newcastle to Sydney, about 200km south. Total transport phase for product from Tuncurry to SFM is three to five hours depending on additional load pick up locations. Independent ERL fishers in this central region ship live product to market through direct engagement with a live exporter who picks up product from the fishers' live holding tanks and transports to the Sydney live export facility using a wet truck transport method.

Newcastle Fishermen's Co-operative owns the small refrigerated truck that picks up crustaceans from depots at Bungwahl and Tea Gardens. There is a nominated driver who has been doing this run for many years. The driver is highly experienced in transporting live product and has developed a sound awareness of the specific requirements for transporting live product alongside chilled wet product. From this experience, the internal temperature of the Pantech is carefully regulated to accommodate both types of product carried. The mud crabs are packed into SFM fish bins with layers of clean paper over top of the crabs to prevent drying out from chilled air circulation within the refrigerated section. Additionally, a cover has been developed from trucking canvas and is used to over a 5-bin stack of product as insulation from chill temperatures.

Temperature loggers were included in live product bins attached to product inside bins, external surface of bins, and immediately beneath the canvas cover. The internal Pantech temperature was recorded by automated system incorporated into transport truck.

Product is delivered to the Bungwahl fish depot and held in a cool environment, on this day 18°C, until truck loading. After loading, truck Pantech is chilled to ~5°C and then refrigeration turned off. This action is repeated at each pickup stop where the truck door is opened for loading. Figure 11 provides the temperatures logged for live product from Bungwahl to Newcastle, about 125km south when further product is picked up from Tea Gardens. With the truck refrigeration turned on, the temperature of the live product reduces slightly but by no more than 2°C over the entire trip of 3h. It is clear that the live product was insulated from the Pantech temperature by the canvas cover. The product remained at or above 16°C at which temperature mud crabs are calm, motionless and sedate, therefore likely to suffer minimal stress caused from transport disturbance.

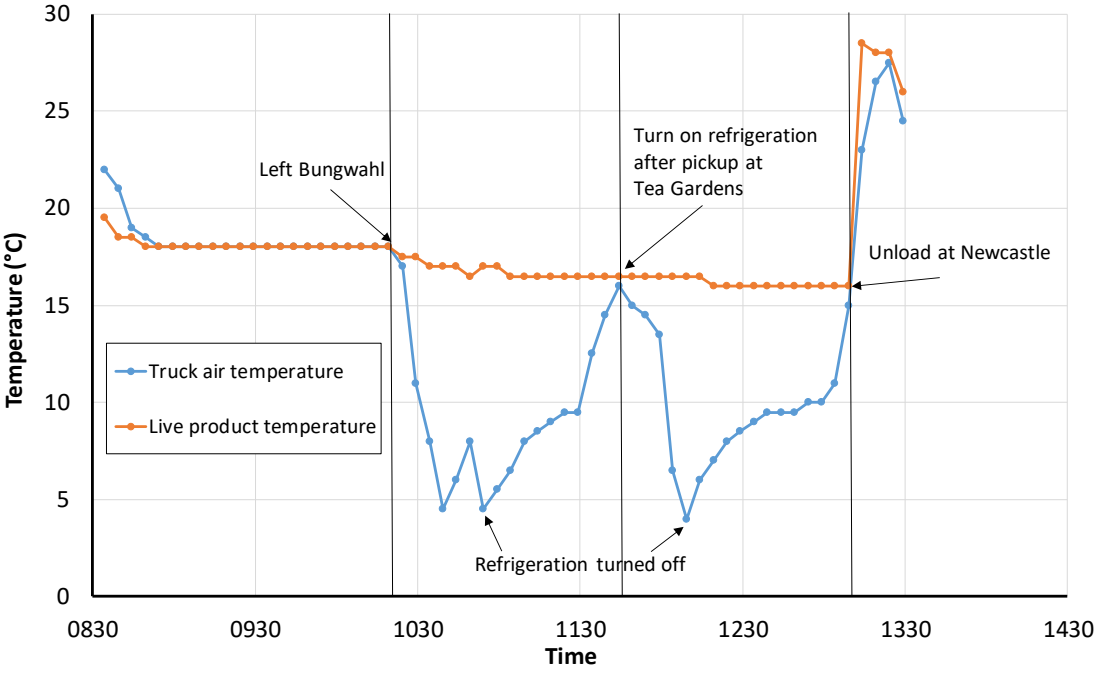

Figure 11. Air temperature of truck and live product

Five bins of mud crab were also logged from Tea Gardens (Figure 12) with data being the average of two temperature loggers within each bin in different positions. On arrival at Newcastle Fishermen's Co-operative live product is unloaded and stored on a dock area inside the facility. Canvas covers are removed at this point and returned to Bungwahl depot. Prospect Refrigerated Transport picks up all product from the Newcastle collection point and transport to Sydney.

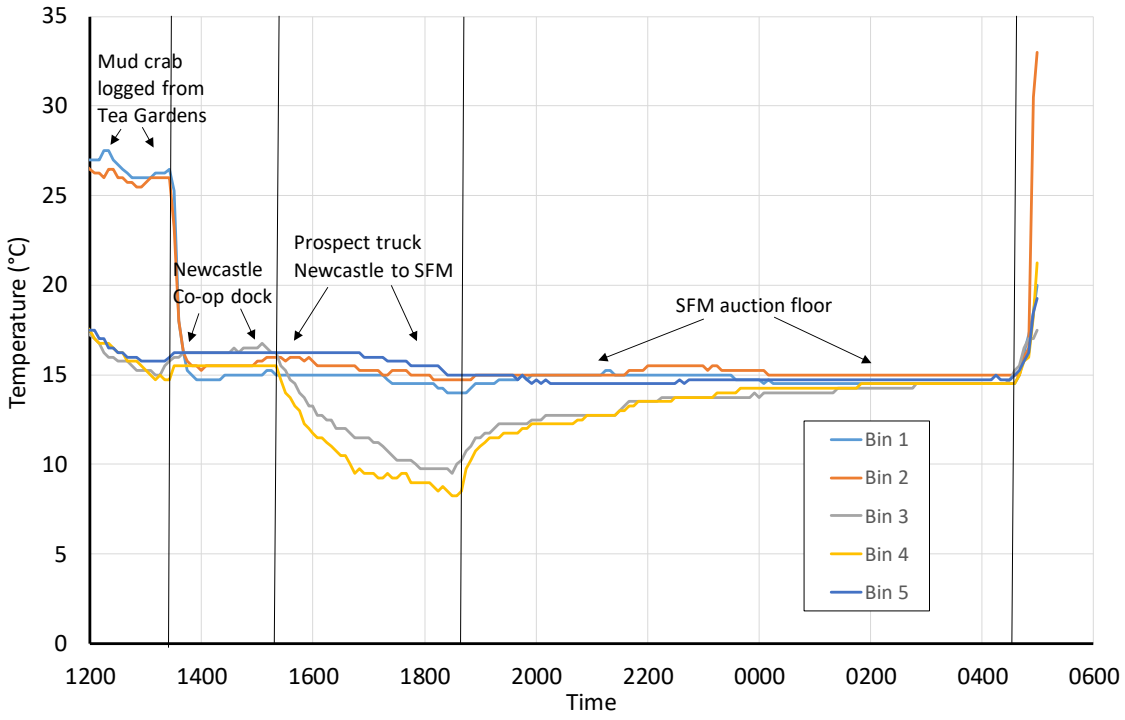

Figure 12. Temperature of bins of live mud crab during transport

It is noticeable that three bins of crab held at around 15°C throughout, but crabs in two bins dropped temperature to 8.5-9.5°C. A possible explanation could be that both the two colder bins were those at the bottom of the bin stack and therefore were positioned directly on the floor of the truck Pantech. This could

cause direct transfer of cold temperature from the floor through the thin plastic bin base and affect the crab temperature. It is noted that crabs in both these bins showed a similar pattern of temperature reduction. At the SFM, the unloaded bins were separated and placed on the auction floor according to crab fisher ready for auction sale. Therefore, in this trial, we have no way of knowing in which way the stacks and/or separate bins were placed onto the auction floor at the SFM from where we retrieved the data loggers. It is of note that the placement of crab bins on pallets on the SFM auction floor protected the crabs from being affected by the SFM concrete floor cold temperature. This is shown by the 3 bins of crabs at 15°C remained at that temperature through the 10 hours prior to sale.

Evidence for the truck floor influencing the temperature of the live animals in bins in the first layer of a stack was seen repeatedly. Figure 13 shows a 6°C difference in mud crab temperature between 1st and 2nd layers of bins in the stack.

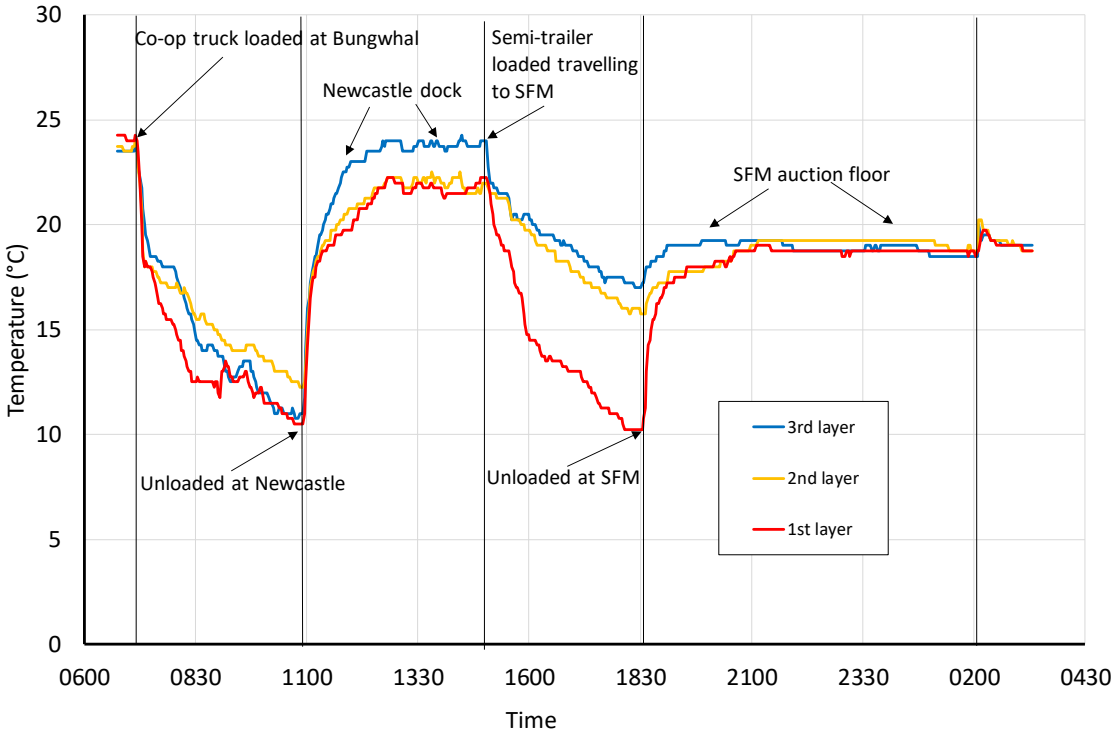

Figure 13. Temperature of mud crabs transported Bungwahl to Sydney

During transport to Newcastle, crabs chill down in the pre-cooled truck to temperatures that will induce a comatose state and keep them calm, hence unstressed. Over the four hours that crab bins are held on the Co-op dock they return to ambient and are then subject to chill temperatures within the transport stage (commonly 5-6 hours) to Sydney in the Prospect truck. Similar to data from other trials, the crabs in the 1st layer on the pallet reach a colder temperature than those higher in the stack. Animals positioned in 2nd layer or above are at an ideal temperature for transport of mud crab as at such temperatures they will be gently sedated with slower metabolic activity but experience no stress. These conditions would allow full return to be achieved for the fisher at market with no downgrading occurring.

Prior to Newcastle, Prospect Transport picks up seafood product from Nelson Bay and travels direct to Newcastle to incorporate live product from other landing sites before continuing on to Sydney. Binned wet fish were loaded first and live product loaded directly behind. No insulation divider board is used during the short trip between Nelson Bay and Newcastle but is put in place after loading additional product at Newcastle for the trip to Sydney. During transport from Newcastle to Sydney, two data loggers were included in mud crab bins within each layer of the stack of bins, with temperature varying according to logger location (Figure 14). The greatest temperature difference within the same bin occurs in the bin at the bottom of the stack (1st layer) and this variance between two loggers placed in a bottom bin was observed repeatedly within nearly all shipments monitored.

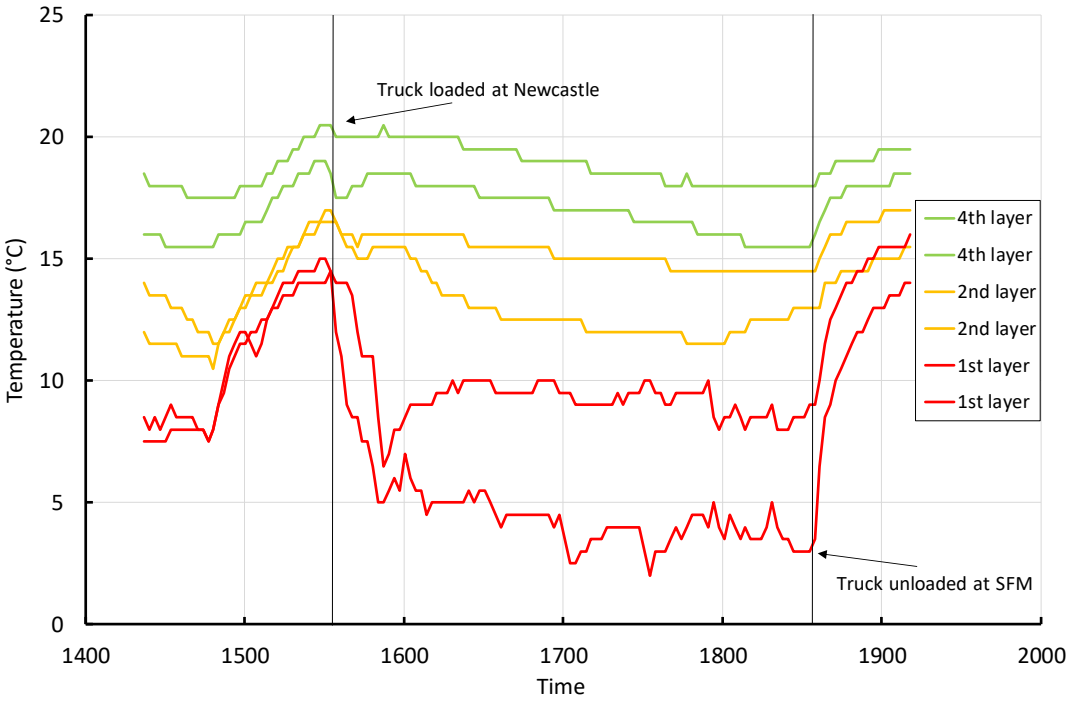

Figure 14. Temperature from two loggers within the same bin in different stack layers

It is suggested that differences between temperature loggers in bins within a single layer of the stack could likely arise from loggers moving position within the individual bin due to handling and loading disturbance as depicted in Figure 15.

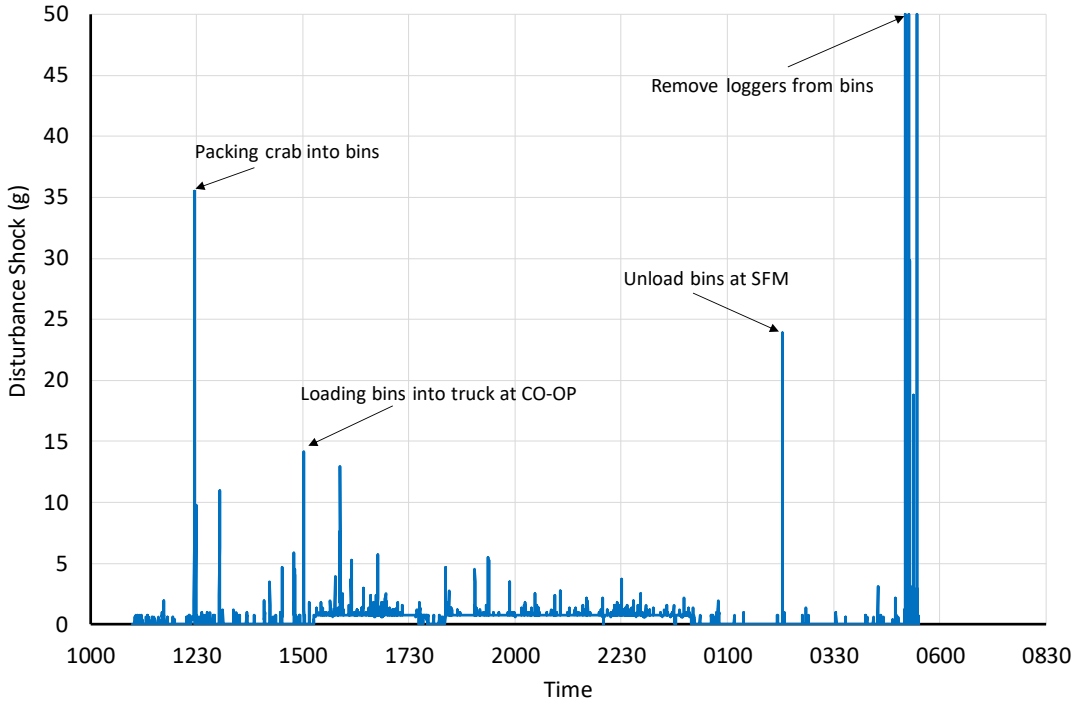

Figure 15. Disturbance shock seen during transport to Sydney Fish Market

Despite careful placement of temperature loggers in amongst the crabs, disturbance levels recorded were certainly at a level to result in displacement of the loggers from the original position, with the likelihood that some will fall to the bottom of the bin and therefore be subject to internal truck temperature more directly.

From this observation and due to disturbance always occurring through the transport chain, all further data is presented as an average of two temperature loggers in any one bin.
Temperatures of live mud crabs (Figure 16) and Eastern Rock lobsters (Figure 17) were monitored through the transport chain from Nelson Bay to Sydney with additional product pick up at Newcastle.

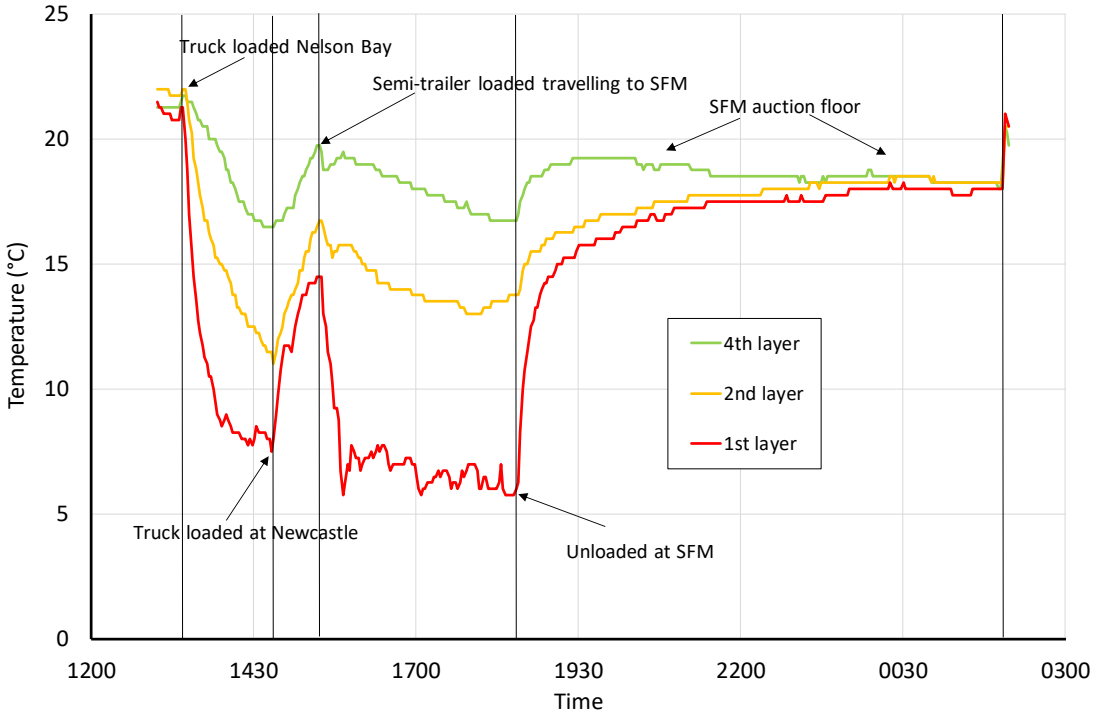

Figure 16. Temperature of mud crabs transported Nelson Bay to Sydney

For mud crabs (Figure 16), 2nd and 3rd layer bins were held at satisfactory temperatures that do not impose excessive stress on the animals. However, those crabs in the 1st layer bins experienced low temperature (<7°C) for during transport from Newcastle to Sydney and this would cause stress to the animal likely to result in downgrade at market.

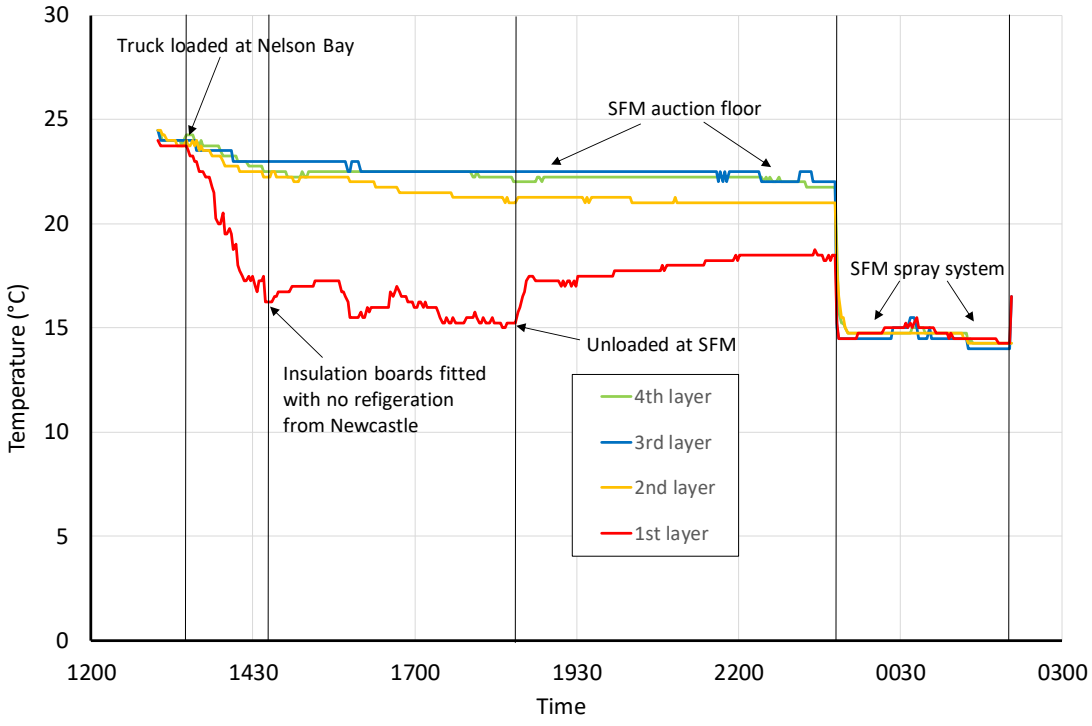

Figure 17. Temperature of Eastern rock lobsters transported Nelson Bay to Sydney

A similar effect (Figure 17) is seen with ERLs, with a clear difference between 1st layer bins and all higher layer bins. The 2nd, 3rd and 4th stack layers held a steady temperature close to ambient throughout transport duration and at this temperature, lobsters would be perfectly happy, even relatively active, which generates heat inside the bin. Although ERLs in the 1st layer bins were at a much lower temperature, the temperature reached (15°C) was still suitable and above full sedation temperature. In direct comparison, mud crabs in the 1st layer bins were as low as 6°C which would cause excessive stress to the crabs. The difference that occurred for live animals carried in the same load and journey could be explained by the ERL bins containing a full volume of animals (~15kg/bin) and the mud crab bins containing only four or five animals (3-4kg) with consequent less heat generated and released into the bin environment.

Another factor that influences animal temperatures during transport is residual cold within the truck. During a monitoring trip from Newcastle to Sydney, the truck had back loaded a shipment of frozen product delivered in Newcastle just prior to pick up of seafood product from the Fishermen's Co-op. Despite the refrigeration having been turned off at the time of unloading the frozen product, the temperature in the truck remained cold and hence caused a rapid drop in ERL temperature immediately after loading onto the truck (Figure 18).

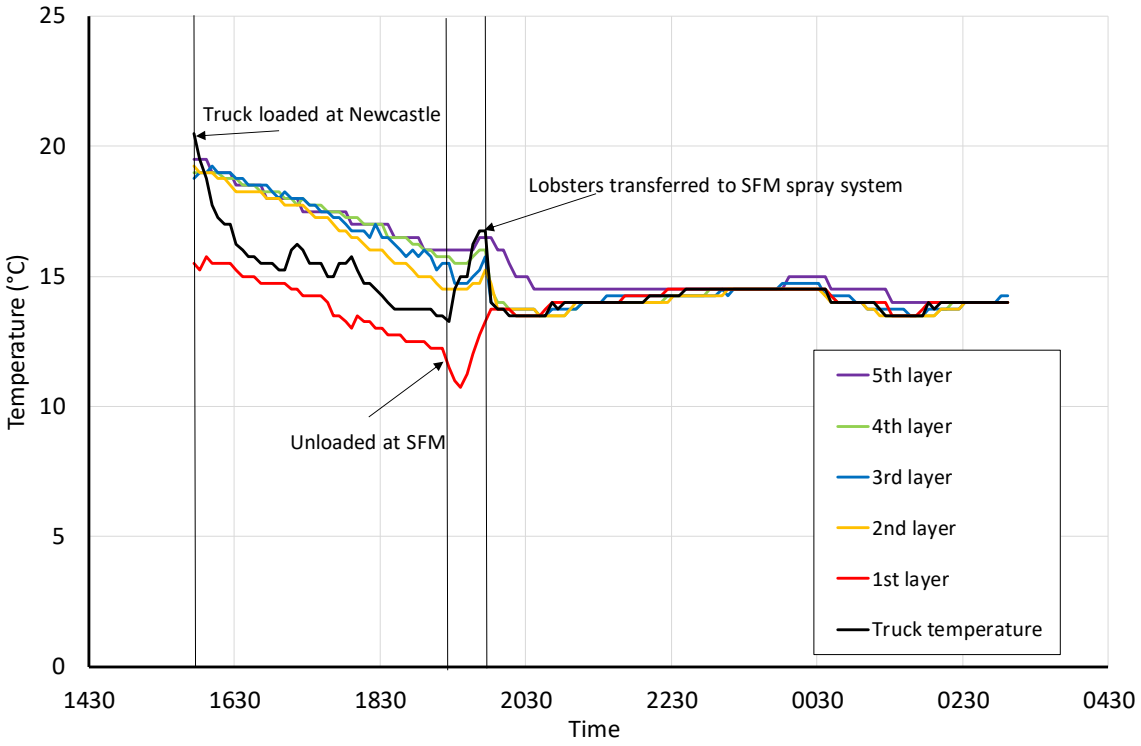

Figure 18. Eastern rock lobster temperatures during transport from Newcastle to Sydney

For those ERLs 1st layer bins of the stacks a low temperature of 11°C was reached which is below suitable sedation temperature of ERLs. Fortunately, this low temperature occurred on arrival at delivery point in Sydney where the lobsters were immediately unloaded into a live crustacean spray holding system running at 14°C. It is noted from Figure 18 that holding ERLs in the SFM live holding system is very effective at maintaining an even temperature for the animals.

Temperature monitoring from Newcastle and surrounds to Sydney again illustrated a strong influence of internal truck temperature on the temperature of the live product carried. Where a canvas cover was used over the bin stacks and refrigeration turned off, product was protected from rapid reduction in temperature. Of particular note with live product freighted from this location was the temperature stress imposed by very low truck floor temperatures. This occurred when transport trucks picked up live product

immediately after transporting a frozen backload from Sydney. The temperature of live animals in the bottom bin of a bin stack consistently showed as well below that able to be tolerated by crabs and lobsters.

Minimising influence of truck refrigeration temperature

The information obtained from temperature monitoring of live product to Sydney clearly identified that truck refrigeration practices had strong influence on animal temperature during transport phases. The truck floor residual temperature had most effect on bins of animals in the first layer of the stack through direct contact. The impact of the cold air will also be exacerbated when few animals are in individual bins as there will be less body heat generated.

To confirm the observation that different layers within a bin stack experience different temperatures, a stack of empty bins were monitored from Newcastle Co-op to Sydney (Figure 19). For this transport trial, the refrigeration had been turned off for the live section of the truck. It is again clearly seen that residual cold truck temperature is strongly influencing the temperature inside the bins, which were up to 10°C lower than the truck air temperature.

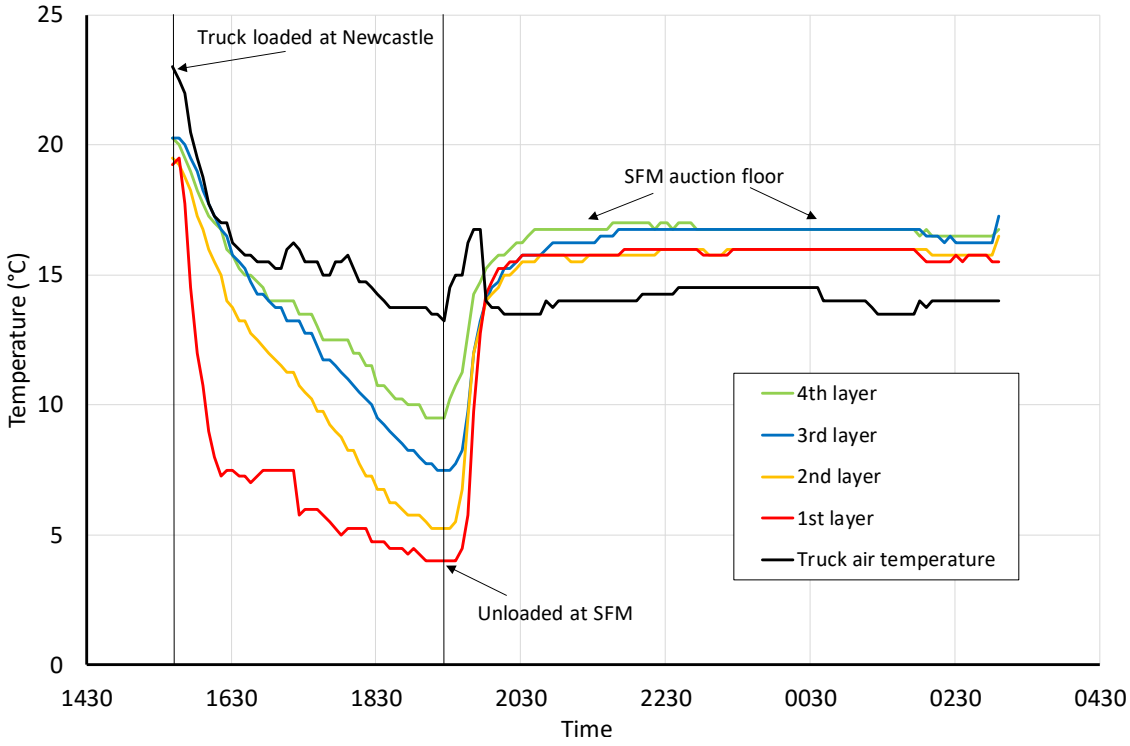

Figure 19. Temperature of empty bins transported from Newcastle to Sydney

With no animals present in the bins, the temperature differences inside the bins can be attributed directly to position of bin in stack. The 1st and 2nd layer bins were reflecting the cold coming from the truck floor. This confirms the influence of cold truck floors and cold air affecting the temperature of bottom layer bins. It is interesting to note when bins were sitting on the temperature-controlled auction floor (16.5°C) that bins of 1st and 2nd layers retained some residual cold staying at 1°C less than bins in the 3rd and 4th layer.

With confirmation of the influence of truck floor residual temperature, it was considered important to find a method to insulate the bottom layer bins from the cold temperatures. Any method explored needs to avoid additional freight cost, be as cost effective as possible and preferably re-useable. With these specifications

in mind, the use of an empty bin as the 1st layer of a stack of bins to insulate the mud crab was monitored (Figure 20). This trial was undertaken during the same transport trip as the empty bin stack. (See Figure 19).

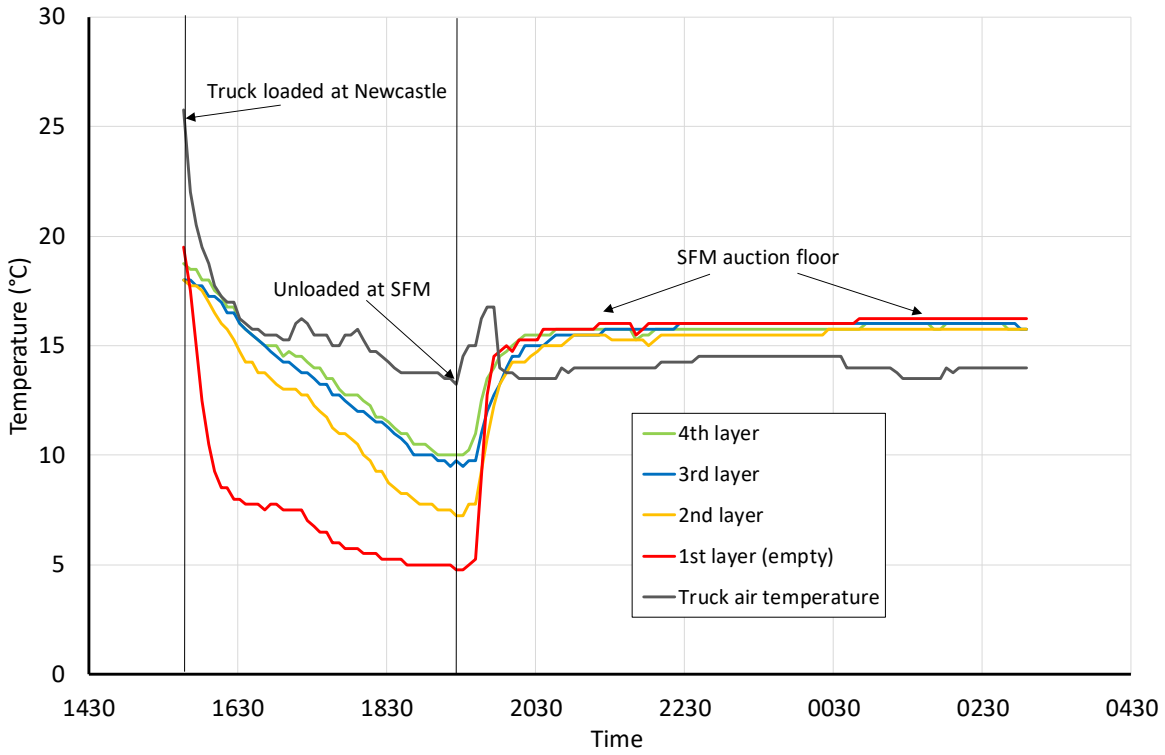

Figure 20. Temperatures of bins of mud crabs stacked with first layer bin empty

The empty bin of the 1st layer was of similar temperature to that of the empty bin stack, but the bins with mud crabs in the higher layers showed a 2-3°C higher temperature. This is an improvement but not yet sufficiently effective to protect crabs from 3-5°C that has been observed during some transport stages. Further trials using an empty 'buffering' bin at the bottom of a stack showed similar trends in temperature differential between bin layers. Results overall indicated that while any empty bin at the base of a stack was successful in buffering cold temperature transfer in the next layer bin, it was considered insufficient difference to be useful in practice. This was disappointing as it would have provided a very simple and inexpensive protocol for minimising low temperatures for transport live product.

In order to mitigate the influence of the truck floor temperature, a range of insulation materials were investigated to protect the first layer bins from direct contact with the truck floor. Materials investigated (Table 6) were selected on basis of being readily available, low cost and, where possible, re-useable or recyclable.

Table 6. Materials used for insulation of first layer bins.

Insulation	Description
Pallet	Standard industry CHEP pallet
Cardboard	3mm fluted cardboard
Polystyrene	20mm polystyrene (standard airfreight polystyrene lid)
Foil lining	5mm Foam cell RESI LINER (#150493 Tradelink)
Woolpack	15mm Fabricated wool clippings, 800gsm. (Planet protector packaging)

Initial trials were undertaken in a controlled temperature environment within a DAF cold room to determine the most effective insulation material. The internal temperature of empty bins was monitored to be able to measure the influence of temperature without the confounding factor of animal body generation within the bin. The cold room was chilled to 2°C, bins and temperature loggers placed in the room (Image 13) and refrigeration turned off and door fully open.

Image 12. Placement of bins with different insulation in cold room

The temperatures of the 1st layer bins with and without base insulation material are presented in Figure 21 and show the variation in insulation capability of the different materials.

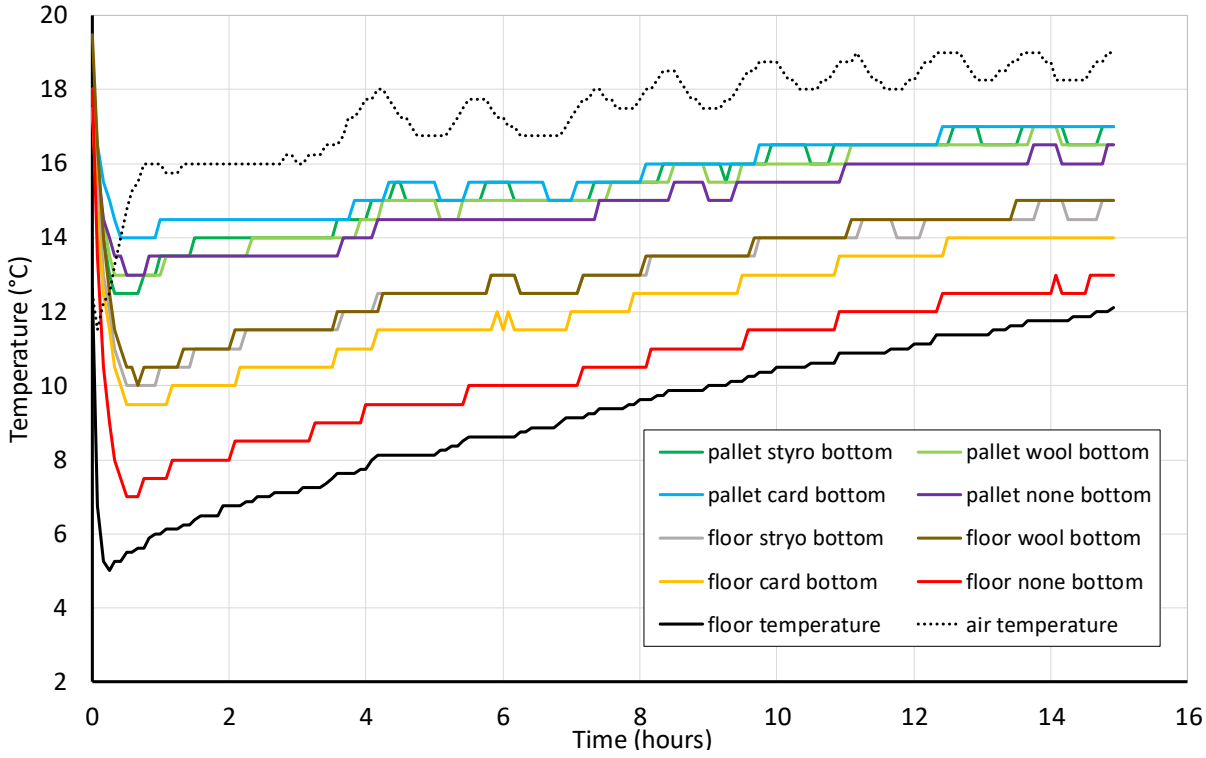

Figure 21. Temperature of empty bins with different insulation material under bin base

Where insulation material was used on the cold room floor beneath the bin, cardboard provided a 1.5°C higher bin temperature than the bin directly on the floor. Woolpack and polystyrene both resulted in a 2.5°C higher temperature inside the bin compared to the bin on the floor. Use of a pallet provided the greatest effect showing a 4.5°C difference between floor-positioned bin and that on the pallet. Insulation materials used as a liner on top of the pallet produced minimal additional benefit (≤1°C). This trial was replicated several times with bins in different positions to ensure that airflow, both within the cold room and from the open door, was not influencing internal bin temperature.

These trials indicated that simple use of a pallet as a base for bins of live product during transport is a practical method for minimising temperature reduction from a cold truck floor. Benefit from pallet use was also reflected in bins in the 2nd layer (Figure 22) which showed a corresponding higher temperature.

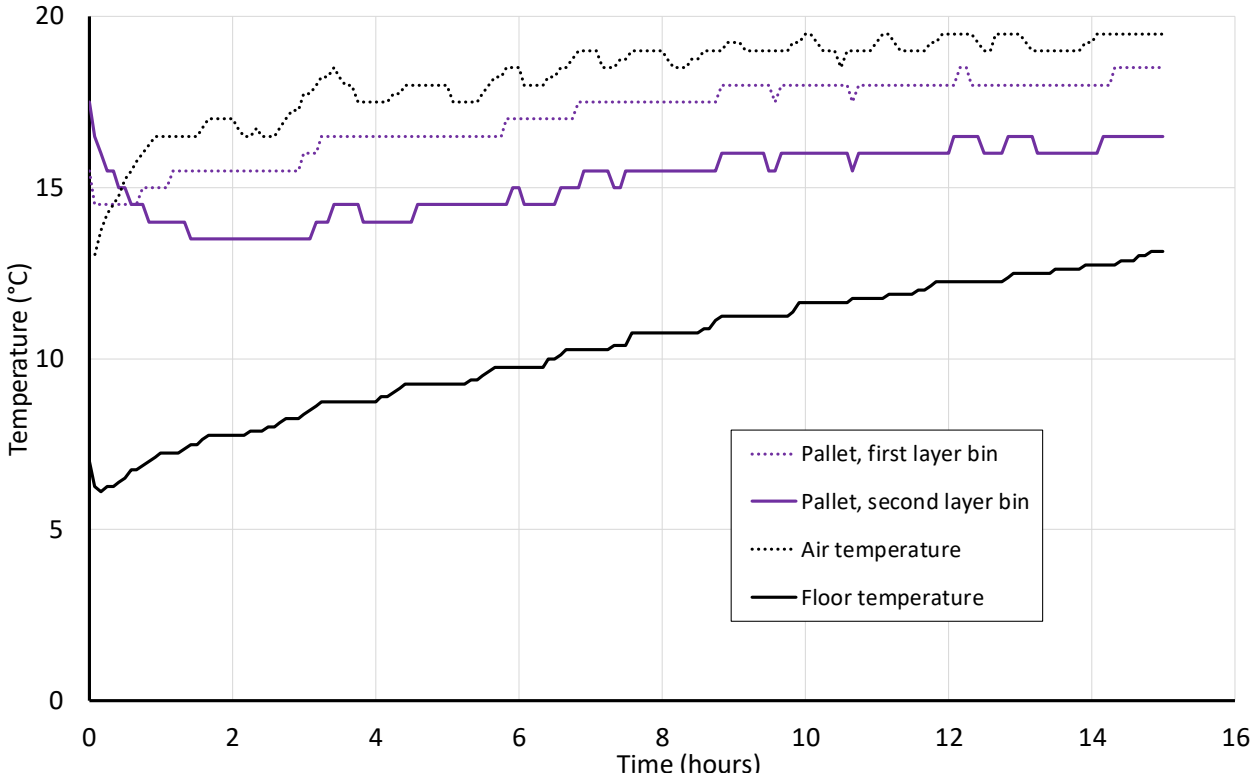

Figure 22. Temperature of empty bins in first and second layer when stacked on a pallet

In commercial transport chains, live product is often boxed onto pallets for transport by truck and one Co-operative frequently uses a cardboard sheet on top of the pallet. However, this is not always the case and many stacks of bins are placed directly onto the truck floor. Where this occurs, it was considered that a base liner positioned between the truck floor and the 1st layer bin may provide advantage for insulating the crabs from the floor temperature. A simple liner was developed using foil-coated shed insulation and designed to cover the bin base and reaching 100mm up the bin sides from the base (Image 16).

Image 13. Foil coated shed insulation used as liner for first layer bin of stack

Figure 23 provides temperatures recorded for bins of mud crabs from two different pallet stacks, each stacked to three layers. One stack of bins had a foil insulation liner on the 1st layer bin and the second stack had no liner present. Both stacks of mud crab were loaded onto a transport truck that had a cold floor from a previous load of frozen product. Bins of crab travelled from Newcastle to Sydney with a transit time of 3.5 hours.

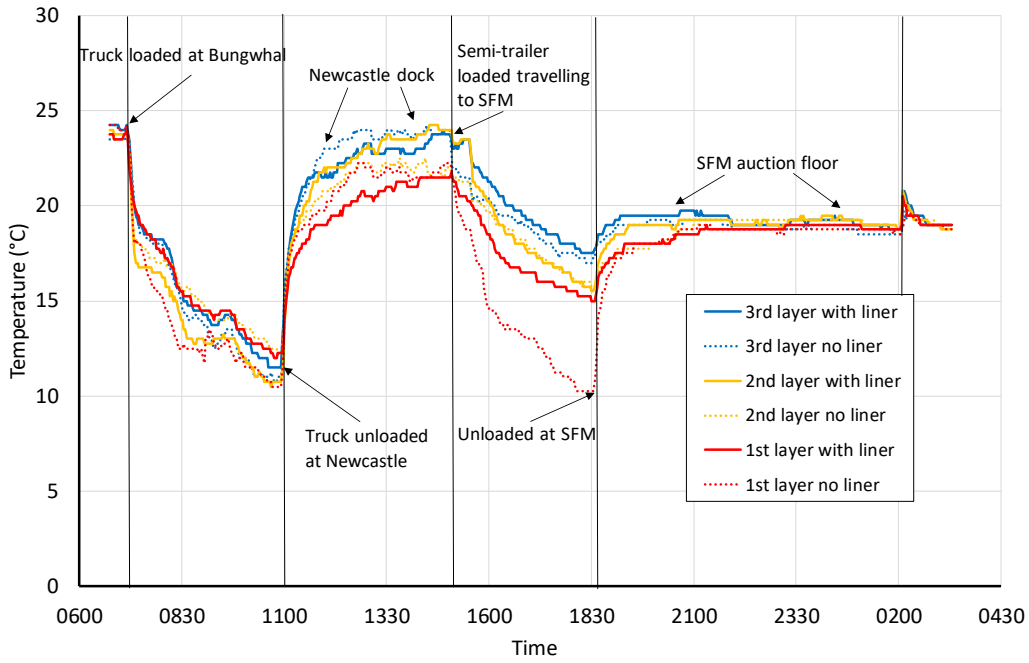

Figure 23. Temperatures of stack layers with and without liner on bottom bin

After transport to Sydney, the temperature of the bottom bin without liner achieved a temperature of 10.5°C, whereas the bottom bin with liner did not drop below 15°C and this latter temperature was similar to that of the 2nd layer bins in both stacks.

Temperatures of live mud crabs were monitored with bins stacked on the floor, on a pallet and on a pallet with woolpack liner between the bin and the pallet during transport from Newcastle Fishermen's Co-operative to SFM (Figure 24).

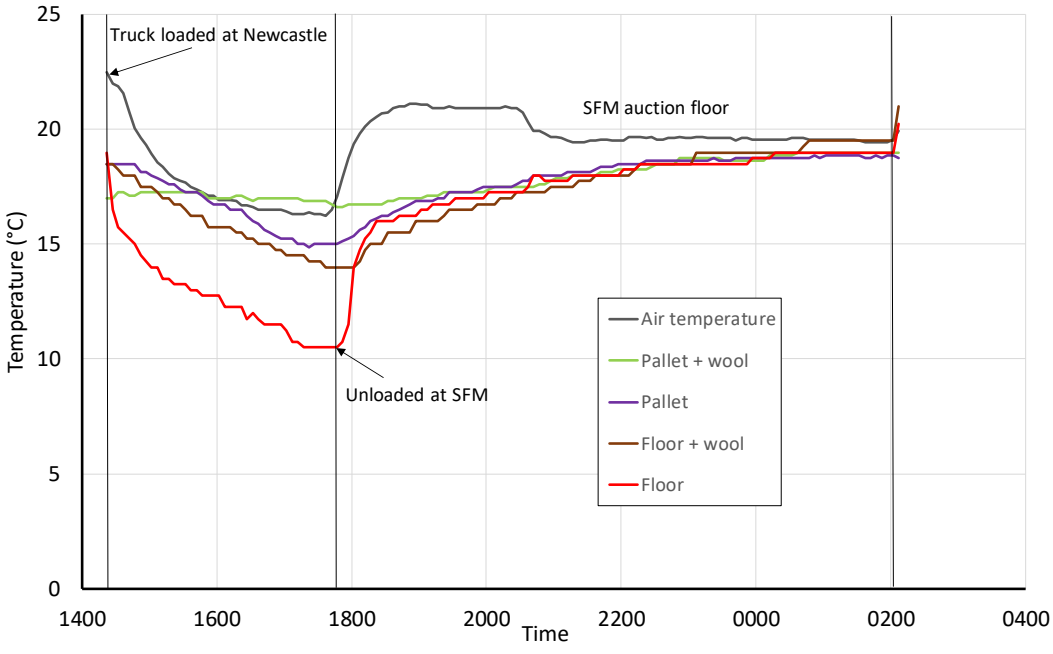

Figure 24. Temperature of mud crabs in first layer bins with insulation from truck floor

Temperatures of mud crabs in 1st layer bins showed similar differences to previous trials with pallet use, a 4°C higher temperature when bin is on the pallet. When a woolpack liner was placed on the pallet with the bin on top there was a 6°C higher temperature attained. This level of insulation is clearly effective in minimising temperature stress to the crabs during transport as illustrated by very little reduction in temperature of crabs in first layer bins on pallet and wool liner compared to those placed directly on the pallet (Figure 24). Although recognising the benefit of a wool liner use on the pallet, industry expressed concerns about additional cost and bulkiness for storing multiple liners sufficient for regular use. Based on this concern, further temperature monitoring trials were undertaken with pallet use only to confirm the benefit of raising the bin stacks off the floor of the truck (Figure 25).

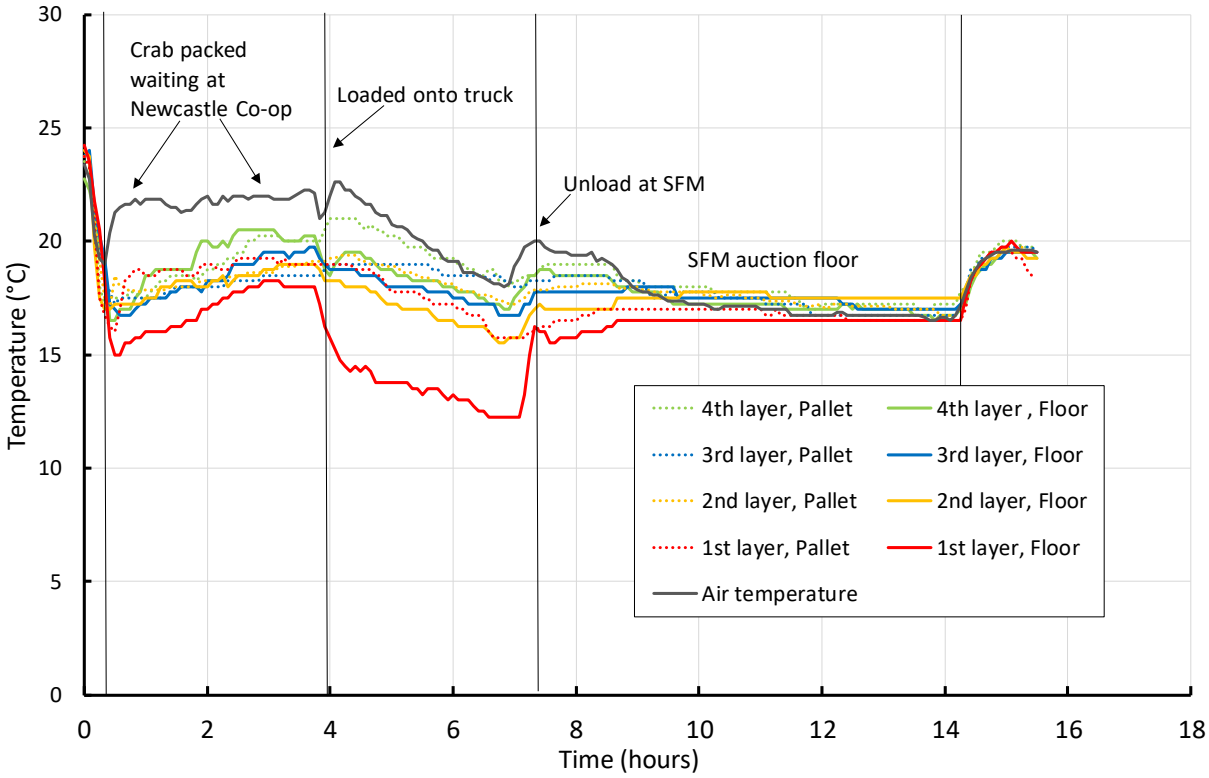

Figure 25. Mud crab temperature monitoring with bins stacked directly on a pallet

For mud crabs in bins in the 1st layer of the stack placed on the pallet, again there was a 4°C temperature difference compared to those in 1st layer bins placed on the truck floor. Temperature differentials were illustrated for the next three layers but of lesser difference. The trials confirmed raising the bottom bin of the stack off the truck floor was important to reduce temperature stress for the animals and has benefit even when internal truck freight compartment was at temperatures suitable for carriage of live product.

A clear benefit is gained when insulating the 1st layer bin of a bin stack from the truck floor temperature. All insulting materials trialled showed benefit, but even the simple practice of stacking bins on a pallet protects from temperature reduction of the live product.

Discussion

Research work within this project focused on two key factors known to impose stress on live crustaceans through the distribution chain. Results of trial work have been described in the previous section along with some directly relevant discussion. Activities undertaken are discussed below within a wider picture, addressing each objective.

Objective 1: ***Document current handling practices and transport pathways within the three crustacean industries and identify the factors contributing most to animal stress.***

Observation and direct interaction with key industry personnel during location visits provided clear information on current practices. Two main factors evidenced as causing additional stress to the animals: handling of crabs and lobsters prior to transport and animals often transported at temperatures below species tolerance limits.

Handling of live animals from capture, holding at landing base and transport to nearest central collection point was highly variable between fishers. Many demonstrated a sound knowledge of best practices and a good understanding of factors that impose stress on the animal. These fishers operated with consistent care in handling the product immediately following harvest and kept crabs damp, cool out of light and wind, transporting them with least disturbance as possible. Less attention to careful handling occurred with other fishers despite market response of downgraded product and lower revenue returned to those fishers. For new fishers into the industry a lack of knowledge was illustrated but often a keenness to learn and understand was apparent. It was observed that each Fishermen's Co-operative still had copies of industry handling guidelines produced from previous crab research available on site, however these appeared to remain in the office and perhaps new entrants into the industry were unaware of these. Experienced Co-operative staff commonly attribute downgrade and mortality to individual fisher handling practices and within this project work, this was often observed.

However, there are also external factors that cause stress to live product which are beyond the control of fishers or Co-operative staff. For example, the 2019-2020 harvest season for Spanner crabs demonstrated very high levels of mortality (>30%) during January and February 2020. This was attributed to very 'hot' water temperatures at this time and awareness that crabs were suffering heat stress on-board vessel. Stress would be compounded by poor physiological robustness in crabs resulting from lack of food availability in waters at higher temperatures than typical in months prior to capture. Such combination of factors is very likely to result in animal death during extended emersion. Project staff discussed possible measures to reduce stress with the fishers, with interest shown to try holding crabs in a bin with flow-through seawater while on-board.

The second key factor contributing to alive animal stress is temperatures experienced during transport. Temperatures during transport were often found to be below the limit of tolerance for the crustacean species. For example, live mud crabs subjected to, and arriving at market, recording 3^{o}C. It was recognised through project work that there are multiple reasons for internal truck temperature being inappropriate for live animals. Live seafood is transported along with other seafood including both chilled and frozen product. In general, frozen product is carried in a separate compartment of the truck created by use of insulation boards being placed to seal of the frozen product area. Similar boards are also available for dividing live and wet-iced fish product but it was observed these are not frequently used. Hence stacks of live crabs were regularly loaded immediately adjacent to bins of iced fish and hence influenced by cold air. Also observed were frequent contrary demands for different internal truck temperatures for any one load, with iced fish product demanding ≤4^{o}C and live fish dictating > 10^{o}C. This is incompatible for different products types carried within the same truck compartment. An additional temperature effect was demonstrated from trial

work, that being the influence of very cold truck floors usually resulting from previous product loads carried just prior to pick up of seafood product.

Objective 2: ***Develop adapted handling and transport protocols that minimise the critical stress factors.***

Addressing the handling variance between individual fishers did not principally require adaption of methodology. Previous research work undertaken has provided best practice protocols, particularly for mud crabs and best practice factsheets were observed to exist in all Fishermen's Co-operatives. Rather, it was important to refresh and raise knowledge of best practices for crab handling and this was done throughout all visits to collection point locations. In some instances, modifications to usual practice could be suggested. For example, where stacks of crab bins awaiting truck loading were often subjected to breeze chill, protection from breeze could be effected by use of a canvas cover over the stack, similar to that observed in transport of mud crabs from Bungwahl to Newcastle. This simple solution demonstrated to be highly effective in mitigating temperature reduction for the live product.

Stress is accumulative in live crustaceans and levels imposed at all handling stages are therefore important, affecting survival through later stages in the distribution chain. Spanner crabs accumulate stress easily and one of the stages of the chain imposing greatest stress is handling for pack out. For many crustacean species it can be very effective to reduce stress experienced by the animal and hence, we investigated sedation with spanner crabs. It was found that a brief 'cold shock' of the crabs at low temperature immediately prior to pack out handling highly successful. The crabs recovered fully after the sedation step and also demonstrated no 'slow' behavioural traits nor mortality after more than 30 hours of subsequent storage in the packed-out box. This handling step adaption would be very beneficial to minimise stress to the crabs and allows successful transport in long distance distribution chains involved in exporting live product.

With respect to difficulties of live product temperature reaching too low a level during transport, both causes were addressed. Where refrigeration was consistently being set to a low operating temperature, many fishers choose to pack live animals in polystyrene boxes instead of plastic bins. Data collection showed that this method was successful in minimising temperature change for the crabs and lobsters and the practice is commonly used in winter months, especially when the transport stage is long. However, while recognising the protection afforded by this packaging type, there is strong acknowledgement of the environmental issues caused by use of polystyrene. A new insulating material still needs to be found and proven as effective and inexpensive.

An unpredicted source of cold impacting the live animals was the temperature of the truck floor. The effect was clearly indicated by live product in bins at the bottom of a stack, consistently having a much lower temperature than live product in the bins higher in the stack, with or without refrigeration operating. There was also an increasing temperature differential as bin distance from truck floor increased. Various materials were investigated for their insulation capability when placed beneath the first layer bin of a stack and all showed insulation effect to some extent. However, the simplest and most effective was found to be ensuring the stacks of bins were placed on a pallet. This simple adaption can be readily undertaken at all collection points.

Another finding illustrated clearly through trial work was that of the number of crabs (volume) packed out in each bin. There was large difference in temperature of animals between bins with few animals (≤4 crabs) and fully packed bins (12-15 crabs), the latter exhibiting a higher temperature due to generated 'body heat' than the former. This is a difficult issue to address due the grading system used by market. Crabs are sold identified by fisher and grade, with price per kilo attained directly corresponding. Therefore, each bin packed out is not necessarily full of crabs. It was suggested that where small numbers of lower grade occur on a harvesting

day, these could be mixed to fill the bin and sent to market as ungraded crab. However, there was strong resistance to this suggestion due to the low price obtained for mixed grade crab.

Objective 3: ***Trial amended protocols within commercial operations.***

Throughout the project handling protocols for transport of live crustaceans were amended as results information was known. Adapted methods were trialled on runs from most collection points, including those far-distance from market as well as shorter transport routes. Confirmation of the benefit of pallet use was evidenced with respect to minimising temperature reduction for live crustaceans.

There are three main transport companies undertaking live product transport between north NSW and Sydney. From observation, discussion with fishers, co-operative staff and truck drivers, it was clear that many issues with live product transport are common across companies but some are specific. There was also a connection between numbers of crabs downgraded and distance from market.

Lindsay Transport undertake live seafood transport from northern NSW to Sydney from two depots: one in Brisbane and the other in Coffs Harbour. Project staff had many discussions with the Manager of Lindsay Seafood division and this established that the truck drivers are trained in the freight of seafood, including frozen, chilled and live product. This company collaborated with the Sydney Fish market to buy and adapt special trailers for the specific carriage of live product. However, drivers deal with contrary demands during pick up of different loads from various locations and have frustration with putting the insulation boards in place when meeting schedules.

The other transport companies also carry frozen, chilled and live seafood products and while conversant with the specific temperature needs of live crabs, are averse to turning refrigeration off. Discussions on the practicality of setting refrigeration temperatures at 10-14^{o}C when live product was included in the load failed to convince that the chilled product, which was typically well-iced, would not suffer deterioration.

Objective 4: ***Evaluate success by change in number of downgrades and market price achieved for live product.***

Sydney Fish Market was an active collaborator in this project work and willing to provide (in confidence) market data from the trials conducted, as were Co-operative Managers. However, it was found that direct correlations between downgrades or mortalities and adapted handling and transport practices could not readily be made. This difficulty is engendered from the multiple factors influencing quality of live crustaceans and the price attained for the product. At any one auction sale, price paid for product is strongly dictated by market demand on the day and demand is in itself, driven by many external influences. Compounding these influences are further external factors unrelated to the adapted protocol trialled, such as handling of individual fisher, seasonal and environmental factor and transport effectiveness. On this basis it was concluded that it is only feasible to assess success of adapted protocols by temperature of live crabs to point of sale.

Objective 5: ***Extend knowledge to industry sectors and encourage adoption by demonstration of protocols at local port meetings.***

The nature this project research compelled frequent interaction with industry stakeholders due to the great proportion of trial working occurring on location. This engenders inherent extension and transfer of knowledge on a regular basis to the industry as results were discussed as arising and the feasibility of next trial design discussed and agreed with industry partners. The exchange of information was also two-way as

it is invaluable to hear fisher and other industry personnel perspectives on various handling and transport issues.

Adoption of beneficial adapted practices has been strong. For some suggested adapted handling methods, there was industry resistance but it is noted that this occurred from a base of expense and/or practicality of undertaking the change readily. Truck driver awareness of the requirements of live product during transport has also been achieved wherever possible.

Conclusion

The quality and liveliness of crustaceans at market is most strongly influenced by two key factors:

- Handling methods of live product from capture to collection point
- Temperature during transport

Handling methods for live crustaceans varies with individual fisher. Live crustaceans require to be kept damp, cool, dark and undisturbed. Many demonstrated a sound knowledge of best practices and a good understanding of factors that impose stress on the animal. Other fishers showed less attention to best practice, however there were also other considerations including experience, distance between landing and collection point, capability to hold landed crabs or lobsters in water prior to transport. Recognising the degree of handling variation occurring, project staff discussed best practice protocols throughout the project work at each collection point location, raising awareness of handling factsheets available at all these locations.

Transport of live product present several issues, the key one being temperature during transport. Live animals are transported in a mixed load that typically includes chilled and frozen seafood product and hence there is not a refrigeration temperature suitable for all products. Frozen product is usually contained in a separate compartment but chilled and live product are shipped side-by-side in a compartment with refrigeration operating. Hence, temperatures during transport were often found to be below the limit of tolerance for the crustacean species. An additional key factor inducing temperature stress in live product was the influence of very cold truck floors, often resulting from previous product loads carried just prior to pick up of live product.

Various straight-forward adaptions were investigated for transport. The use of polystyrene boxes for packaging of live product has been used historically and fishers still choose this packaging option to afford additional insulation from low refrigeration temperatures. However, there is a strong awareness of the environmental issues caused by use of polystyrene and the industry is keen to avoid the use of polystyrene. A key finding with respect low temperature affecting live product packed in plastic bins was the strong influence of cold truck floors, particularly on the bottom bin of a stack. A range of insulation materials were investigated, all showing benefit of use when placed beneath the bottom bin. Considering cost effectiveness, availability and ease of use, it was found that ensuring bins were stacked upon a pallet provided sufficient insulation from the truck floor temperature.

The industry readily adopted the evidenced handling and transport adaptions but it is considered that regular ongoing interaction with fishers and stakeholders to maintain awareness of protocols would be beneficial.

Implications

The direct benefit from adoption of adapted handling and transport protocols will be to individual crab and lobster fishers through fewer animals downgraded or dying therefore improving revenue return on the whole catch. Within the wider industry, the increased revenue will apply along the supply chain for Fishermen's Co-operatives, wholesalers and retailers. For consumers, there will be increased confidence in purchasing the high-end crustacean products through consistent improved quality of product. Therefore, over the fishery as a whole, a better return on product harvested illustrates conscientious utilisation of the crustacean resource.

By responsible use of the resource, public perception of fishers and this fishing sector will improve providing increased support of social licence for the industry.

Recommendations

Recommendations for handling crabs and lobsters through the transport chains in NSW industry:

1. Live crustaceans require gentle handling at harvest and during holding periods
2. They should be held in a way that keeps them damp, cool, dark and undisturbed
3. Use of well-managed wet holding systems is preferable but recognised that this is not always possible in all operations
4. Live product should be insulated from exposure to low temperatures: for crabs and lobsters from NSW waters holding at a temperature between 10^{o} – 15^{o}C is optimal
5. Wherever possible bins of live product should be full to provide maximum animal body heat for resisting effect of cold air
6. Canvas covers can also be used to insulate live product from refrigerated air
7. For road transport by commercial freight companies, insulation from truck floor bed is recommended, ensuring product bins are placed on a pallet within the truck
8. Where product is transported by adapted live freight trucks, insulation boards between truck section need to be employed

Recommended actions to keep best practice handling and transport protocols constantly in the minds of stakeholders could include:

- Wall posters at pack out location reminding of handling best practice for crustacean species, this could readily be achieved where collection point is based at a Fishermen's Co-operative.
- Regular interaction and discussion with industry to keep relationship active on requirements for transporting best product. This has additional benefit of hearing of and understanding specific new issues as they arise, especially when triggered from seasonal and environmental circumstances.
- Regular discussion forums co-ordinated at central location, for example local Fishermen's Co-operatives. This would ensure individual fisher were operating to the same practices.
- Transport companies regularly revisiting requirements for live product freighting

Further development

The research project undertaken did not resolve all issues pertaining to transport of crustaceans and it is also clear after discussion with Industry operational personnel that some possible solutions suggested would not be practical or economically feasible. However, the following suggestions may assist in keeping industry awareness at a high level:

- Direct feedback to individual fishers on returns from their live product on a frequent basis, such information will illustrate the benefit the individual gains from adoption of adapted practices
- Investigation into new improved packaging alternatives that provide better temperature insulation for transport live product is needed
- Further development of suitable box for use in the proposed SFM expanded live holding tank system at market

Extension and Adoption

During this project there was frequent interaction with industry stakeholders due to all trial working occurring on location at key live product collection points. This results in a natural flow of information to industry stakeholders with results discussed as they stemmed recently completed work. Exchange of knowledge was a two-way flow as it is invaluable to hear fisher and other industry personnel perspectives on various handling and transport issues. Project Staff interacted regularly with the Industry personnel listed in Table 7.

Table 7. Industry Personnel

Location	Stakeholder	Role	Fishery
Northern NSW	Mark Phelps	Lindsay Transport	Seafood manager
Ballina	Phil Hilliard	Co-op manager	
	Steve Bordin	Fisher	Spanner crab
	Cliff Corbett	Fisher	Spanner crab
	Garry Goblin	Fisher	Spanner crab
		Fisher	Mud crab
	Alistair Robertson	Fisher	Spanner crab
Maclean	Danielle Adams	Co-op manager	
	Aaron	Operations manager	
	Bill Clarke	Fisher	Mud crab
	Rodney Wright	Fisher	Mud crab
	Steve Pilch	Fisher	Mud crab
	Troy Billin	Fisher	Mud crab
Coffs Harbour	Andrew Brown	Operations manager	
	Aaron Newton	Operations manager	
	Joshua Cook	Distribution manager	
	Geoff Blackburn	Fisher	Mud crab
	Danny Stewart	Fisher	Eastern rock lobster
	Dave	Fisher	Mud crab
	Chris Davis	Fisher	Mud crab
	Jack	Fisher	Mud crab
Central NSW			
Jerseyville	Laurie McEnally	Chairman	
	Barry Townsend	Operations manager	
	Nathan	Fisher	Mud crab
	Cook family	Fisher	Mud crab
Port Macquarie	Steve Burt	Fisher	Eastern rock lobster
	Cain	Fisher	Eastern rock lobster
Laurieton	Leanne Moody	Fisher	Mud crab
	Paul Moody	Fisher	Mud crab
Tuncurry	Suzie McEnally	Co-op manager	
	Dan Gogerly	Fisher	Eastern rock lobster
	Malcolm	Fisher	Mud crabs
	Rob	Truck Driver	
Nelson Bay	Graeme Lewis	Co-op manager	
	Lenny	Operations manager	
	Ross Fidden	Fisher	Mud crab
	Bruce Fidden	Fisher	Mud crab
	Jimmy Drinkwater	Fisher	Mud crab

	Bob Monin	Fisher	Eastern rock lobster
	Lee Monin	Fisher	Mud crab
	'Snowy'	Truck Driver	
Newcastle	Robert Gauta	Co-op manager	
	Mark	Operations manager	
	Stan	Truck Driver	
Kincurrie	Steve Offner	Fisher	Eastern rock lobster
Southern NSW			
Sussex Inlet	Steve Westley	Fisher	Eastern rock lobster
	Mal	Business partner	Eastern rock lobster
Narooma	Les Muller	Fisher	Eastern rock lobster
Bermagui	Rocco Lagana	Co-op manager	
	Jason Moyce	Fisher	Eastern rock lobster
Sydney Fish Market	Erik Poole	Industry Liaison	

Adoption of beneficial adapted practices has been strong, with all product collections points using a pallet for transporting bins of live product as a minimum to insulate product from cold truck floor beds. Use of a simple canvas cover over the bin stacks is being used and considered for bin stacks affected by breeze while awaiting loading on to truck.

The results from sedation trials with Spanner crab sparked interest in fishers and adaption of chilling water holding bins on board boat at harvest time are going to be trialled by the fishers themselves.

For some suggested adapted handling methods, there was industry resistance but it is noted that this occurred from a base of expense and/or practicality of undertaking the change readily. Truck driver awareness of the requirements of live product during transport has also been increased, particularly on the transport sections from northern NSW.

Project coverage

The outputs from this project were most directly of importance to the harvest and distribution sectors of the industry and hence no media industry or government articles have been prepared to date.

Project materials developed

Formal reference material has not yet been produced within this project. Rather, at every location visit, simple graphs of trial data were prepared and discussed with fishers and management staff on site as a useful visual portrayal of results.

Appendices

Appendix 1: Research knowledge available

Over the last 20 years, DAF Queensland, has undertaken a large amount of research on transport of live seafood product (see listed below) and this body of information is added to by research work undertaken in other States. This body of information diminishes the need to re-invent the wheel within the current proposal. It provides the basis from which to investigate significant stress factors causing quality downgrading of live lobsters and crabs at market and to fast-track development of specific protocols adapted for each transport pathway.

FRDC 2003/240	*Maximising revenue within the NT mud crab fishery by enhancing post-harvest survival of mud crabs*
FRDC 2010/302	*Equipping the mud crab industry with innovative skills through extension of best practice handling*
FRDC 2011/225	*Using industry expertise to build a national standard for grading of live mud crabs*
ASCRC 2012/758	*Increase sustainable use of crab fisheries resources by recovering revenue from crabs currently rejected at market*
FRDC 2014/218	*Building precision into the Australian Industry Live Crab Grading Scheme through addressing grading and regional anomalies*
FRDC 92/71	*Live transport of crustaceans in air – prolonging the survival of crabs (spanners)*
FRDC 92/125.27	*Reducing post-capture mortality when storing tropical rock lobsters for live export*
FRDC 96/345	*Physiological studies of stress and morbidity during post-harvest handling of western rock lobsters (Panulirus cygnus)*
FRDC 1999/422	*Demonstrating the capacity of Western King prawns for live transport*
FRDC 92/125.32	*Improving packaging technology, survival and market options for Kuruma prawns*
FRDC 92/125.28	*Evaluating re-useable containerised systems for airfreighting live fish using bottled oxygen*
ASQ 2016-17	*Crustacea misting as a method for live transport*
FRDC 94/134.02	*Develop a code of practice for the handling of live rock lobster* (WA)

Other related research:

FRDC 2002/239	*The effect of cold water stunning on the survival and growth of caught and returned western rock lobsters (Panulirus cygnus)*
FRDC 2003/242	*Determining flesh quality attributes of under-valued large southern rock lobsters*
FRDC 2001/255	*Quantifying and controlling hyper- and hypo-saline induced post-harvest leg autonomy in the western rock lobster (Panulirus cygnus)*
FRDC 94/134.03	*Physiological investigation into methods of improving the post-capture survival of rock lobsters (Panulirus cygnus and Jasus edwardsii*)

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Appendix 3: List of Researchers

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Paul Exley – Co-investigator, Queensland Department of Agriculture and Fisheries