Quantifying and Controlling Hyper- and Hyposaline-Induced Post-Harvest Leg Autotomy in the Western Rock Lobster (*Panulirus cygnus*)

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Australian Government

Fisheries Research and Development Corporation

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Objectives:

1. Survey salinity concentrations of surface films on individual lobsters and on relevant contact surfaces on boats and within factories.
2. Describe the relationship between autotomy and exposure to seawater of various salinities for lobsters of various sizes and moult stages.
3. Quantify leg loss during industry standard freshwater "drowning" procedures.
4. Compare responses to ionic and non-ionic solutions to elucidate the potential role of other contaminants, and the possible nature of the receptors and stimuli.
5. Investigate the relationship between daily environmental conditions and levels of post-harvest leg loss.
6. Field test practical solutions for hyper/hyposaline-induced autotomy and make recommendations to industry.

Non-Technical Summary

Outcomes achieved to date:

The previously undescribed phenomenon of hypersaline-induced autotomy in western rock lobsters has been fully characterised. The extent of occurrence of hypersaline films throughout the post-harvest chain has been examined and found to be significant. Environmental factors contributing to the phenomenon have been investigated.

Appreciable leg loss has been shown to occur during industry standard freshwater "drowning".

Washing of contact surfaces and cold-stunning have been shown to be effective methods for preventing hypersaline-induced autotomy and leg loss during drowning, with the potential to save the industry six figure sums each year by reducing loss of catch weight and downgrading of damaged lobsters.

Post-harvest leg loss is a significant problem for the western rock lobster industry. Industry estimates suggest that up to 80 tonnes of legs, worth $2-3 million, are lost from the catch each year between the time of capture and receipt at processing factories. Even after catches are landed, additional losses occur during sorting in the factory, live storage, processing, packaging for live export and unpacking at export destinations.

Anecdotal reports by fishermen suggest that western rock lobsters are very prone to shedding legs during handling. This spontaneous leg loss is reported to be especially bad on hot, dry windy days. In the course of research into reducing post-harvest damage (FRDC 2000/251), it was found that exposure to extra salty, or "hypersaline", seawater causes western rock lobsters to rapidly and spontaneously shed one or more walking legs. Furthermore, when this phenomenon was demonstrated to fishermen, they indicated that this hypersaline-induced leg loss appeared similar to their observations in the field.

A wide scale survey revealed that hypersaline seawater films occur on contact surfaces throughout the post-harvest chain, indicating the potential for hypersaline-induced autotomy to occur in the field and be a major and potentially preventable cause

of post-harvest damage. The occurrence of hypersaline films was greatest in shore-based processing factories. This was probably due to the frequent occurrence of windy, high temperature and low humidity conditions on land. An attempt was made to correlate observed leg loss in catches on arrival at processing factories with environmental conditions. Leg loss correlated with a variety of factors, including air temperature, relative humidity and daily evaporation, however, leg loss was best correlated with sea surface temperature. Commonly used frozen and thawed fish baits posed no threat to lobsters, in terms of hypersaline exposure.

An investigation of the leg-shedding response to hypersaline seawater showed that, for the solutions tested, the effect occurred when lobsters contacted water with salinity values greater than twice that of seawater. Above this salinity the numbers of legs shed increased with salinity up to highest salinity tested (~5 x seawater strength). Hypersaline water was applied to lobsters by submerging them in it, by spraying them with it using an atomiser, by placing animals on hypersaline water films and by picking lobsters up with a glove that had been dipped in the solution. Hypersaline exposure by all these methods caused leg loss.

It is standard practice in the western rock lobster industry to "drown" lobsters in tap water prior to processing. This raises the possibility of hyposaline-induced leg loss occurring. It was shown that lobsters do indeed shed legs during freshwater "drowning". However, it was not established if this was due to hyposaline exposure or simply due to physical trauma that might result from the increased activity lobsters show after being placed in freshwater. Whatever the case, leg loss during drowning is a significant problem, worth an estimated $200 000 in lost weight alone each season.

The simplest and most cost-effective method for preventing hypersaline-induced leg loss is to wash all contact surfaces, either with fresh water (where available) or with seawater. The former is especially useful because, once a surface is washed, there can be no further evaporative concentration. The latter however, allows lobsters themselves to be kept moist thereby preventing evaporative concentration of seawater films on the shell. Fresh water should only be used on contact surfaces and not sprayed directly onto the

lobsters themselves. Surface washing can be applied at all points in the post-harvest chain, including on board boats and in processing factories.

Hypersaline-induced leg loss can also be prevented by briefly (5-15 sec.) submerging lobsters in cold seawater (0-5°C) prior to hypersaline exposure. Although more complicated, cold water stunning can be used on board boats as well as in processing factories. Cold-stunning has the added benefit of reducing lobster activity during handling thereby reducing mechanical damage to appendages that might occur. This technique has been investigated in greater detail in the companion project FRDC 2000/251.

The methods developed in this study have the potential to save the western rock lobster industry at least several hundred thousand dollars each season in lost catch weight alone. This figure does not account for any improvements in the percentage of lobsters delivered to processors in a fit for live export condition. Increasing the numbers of lobsters in a fit for live export condition allows greater flexibility in marketing and will result in adding significant value to the resource, and return to the industry.

Keywords:

Lobster, Autotomy, Hypersaline, *Panulirus cygnus*

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This FRDC Project (2002/239) was funded by the Fisheries Research and Development Corporation. The authors thank Matthew Stone and Lindsay McDonald for valuable technical assistance with this work. Thanks also to Reece Williams and Pip Williams for their enthusiastic assistance with experiments addressing Objective 2. Thanks to Shark Bay Resources for generously supplying at no cost the concentrated seawater used in Objective 2. Thanks to the management and staff of Lobster Australia Ltd who allowed and assisted with the factory salinity survey. Finally thanks to Bradley Crear, formerly of the Tasmanian Aquaculture and Fisheries Institute, for evaluating the responses of southern rock lobsters to hypersaline exposure. This project was part financed by a grant from the Western Australian Fishing Industry Development Unit.

Background

In the western rock lobster industry, leg loss occurs in two main ways: as a direct result of mechanical damage to the leg, such as crushing or breakage, and via autotomy. Autotomy is a phenomenon whereby crustaceans automatically release legs at a predetermined breakage site, usually as an escape strategy. Western rock lobsters appear to be particularly prone to autotomising legs during post-harvest handling.

Brown and Caputi (1983) identified post-capture leg loss as a significant factor contributing to increased mortality and reduced growth of returned protected lobsters. Despite significant improvements in the handling of lobsters resulting from that work, leg loss remains a major concern to industry. At the 1998 FRDC Rock Lobster Post-Harvest Subprogram Annual Workshop (Hillary's Boat Harbour, Perth, W.A.), processors and fishermen identified post-harvest leg loss as a major research priority for the western rock lobster industry. In response to this identified need, FRDC Project 2000/251 was funded in 2000.

Western rock lobsters are handled numerous times during the post-harvest process. With each handling episode, the probability of animals being damaged increases. The cumulative costs to industry as a result of post-harvest leg loss have been widely publicised via FRDC project 2000/251. To summarise briefly, these costs take the following forms:

1) Reduced catch weight:

Industry estimates suggest that between 40-80 tonnes of legs are lost during post-harvest handling each season (S. Hood, M.G. Kailis, pers. comm.). At a sale price of $25/kg this is worth between $1-2 million/annum. However, anecdotal accounts suggest the true figure may be 2 – 3 times this amount (L. Zinetti, GFC, pers. com.).

2) Loss of value/restricted marketing opportunity:

Lobsters with excessive appendage loss can not be sold in premium product forms, such as live, frozen whole boiled or raw, and this often results in reduced profitability. Damaged lobsters also reduce customer perception of lobster quality.

3) Increased mortality of returned undersized animals and reproductive females:

Undersized lobsters that are caught and returned to the ocean with missing legs show increased mortality, compared to undamaged individuals (Brown and Caputi, 1983). Similar effects are likely for returned reproductive (setose, tar spot or ovigerous) females.

4) Reduced growth of damaged undersized animals and reproductive females:

Brown and Caputi (1985) showed that for each additional missing leg, the moult increment in western rock lobsters was reduced. Slower growth of damaged lobsters delays their recruitment to the fishery, reduces average size at recruitment and increases losses due to natural mortality before recruiting.

5) Reduced reproductive success of returned, damaged, breeding females:

Reproductive females with missing legs produce fewer eggs per brood and have fewer broods (Donohue, 2000). Furthermore, since maturity in *P. cygnus* is a function of age rather than size (Chittleborough, 1974), slow-growing females will mature at a smaller size, and produce considerably fewer eggs (Chubb et. al., 1989).

There is a substantial body of anecdotal evidence which suggests that, under certain environmental conditions, such as hot, dry windy days, western rock lobsters become especially sensitive to handling and many animals shed legs spontaneously (Tod et al, 1992). Until recently, the precise reason for this phenomenon was unclear. However, in the course of research work for FRDC project 2000/251, it was found that application of moderately hypersaline seawater (seawater + 55 g/L butcher's salt) to

western rock lobsters reliably induced autotomy of up to all 10 legs. Subsequently, preliminary investigations suggested that seawater with salt concentrations capable of inducing this phenomenon may be widespread throughout the post-harvest chain, and that lobsters may come into contact with such water during post-harvest handling, both on fishing vessels and within processing facilities. From these investigations it appeared probable that there was in fact a link between environmental conditions, evaporation rates, the formation of hypersaline seawater films and leg autotomy in *P. cygnus*.

This project investigates hyper/hyposaline-induced autotomy and the extent to which it occurs throughout industry. Methods werewill be developed for avoiding or controlling this phenomenon, and these will be widely publicised and demonstrated, so that the maximum benefits of this research can be realised by industry.

Need

Stakeholders identified post-harvest leg loss as a major problem for the western rock lobster industry. FRDC project 2000/251 has developed a method for reliably inducing autotomy through the application of hypersaline seawater. Preliminary investigations show that concentrated seawater capable of inducing this phenomenon may be widespread throughout the industry, and that lobsters may come into contact with this water throughout the handling chain. Further investigations into the extent and nature of this problem and development of solutions were beyond the scope and resources of FRDC project 2000/251 requiring the present study to be conducted. International literature searches reveal that there are no published accounts of similar phenomena in other crustacea.

Objectives

1. Survey salinity concentrations of surface films on individual lobsters and on relevant contact surfaces on boats and within factories.
2. Describe the relationship between autotomy and exposure to seawater of various salinities for lobsters of various sizes and moult stages.
3. Quantify leg loss during industry standard freshwater “drowning” procedures.
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Methods

Objective 1: Survey salinity concentrations of surface films on individual lobsters and on relevant contact surfaces on boats and within factories.

Before undertaking this survey, a method for reliably sampling surface films had to be established. A number of absorbent materials, sponges, cloths, cotton wool, etc. were evaluated to determine sample volume recovery and to ensure the swab material affected the salinity of the samples collected. The preferred option was to use a cotton makeup pad (Johnson's® Pure Cotton Makeup Pads) for the swab. Pads were placed in plastic bags (Glad® Snap Lock™ 18 x 17 cm bags), the air was expelled and the bag was sealed until required. To sample, the pad was grasped between the fingers through the plastic bag, the bag was opened and inverted to expose the swab. By this method the sample could be collected with no possibility of contamination from contact with the hands. After the sample had been collected the bag was turned back out over the swab, the enclosed air expelled and the bag was sealed to prevent dehydration and concentration of the sample prior to analysis. The method was found to be very simple and reliable. Figure 1 shows the swab and method of sampling. Using a range of standards it was shown that this collection method did not affect the salinity of the test solution and that samples could be stored for at least 24 hours under refrigeration with no change in sample salinity.

Samples were recovered by wringing out each swab with gloved hands into a 1.5 mL microcentrifuge tube. Using this method between 800 to 2000 µL of sample was usually recovered for analysis. A known volume of sample (usually 1000 µL) was diluted with distilled water to a final volume of 30 mL in a measuring cylinder before the salinity was measured using a TPS WP-81 combination meter and K = 1/ATC/temperature conductivity probe. Determinations were done in duplicate and the average of the two was taken as the final value. The meter was calibrated using TPS Instruments Ltd 36.0 ppk salinity standard.

This swab method worked well for surfaces with considerable free water. However, adequate sample volumes could not be obtained from surfaces with very thin water films. Thin films are very important when considering surface salinity because it is likely that such films undergo significant and rapid evaporative concentration. Thin films also predominate on important contact surfaces, such as gloves, baskets and on the lobsters themselves.

An electronic meter (Horiba C-121 compact salt meter) was evaluated as a potential method for analysing small volume samples, but results obtained with this meter were not reproducible, nor were they sufficiently accurate enough for this work. Because a method for analysing very thin films could not be identified, only fairly wet surfaces could be sampled. As a result, the data probably tend to underestimate the actual occurrence of hypersaline films in the post-harvest chain.

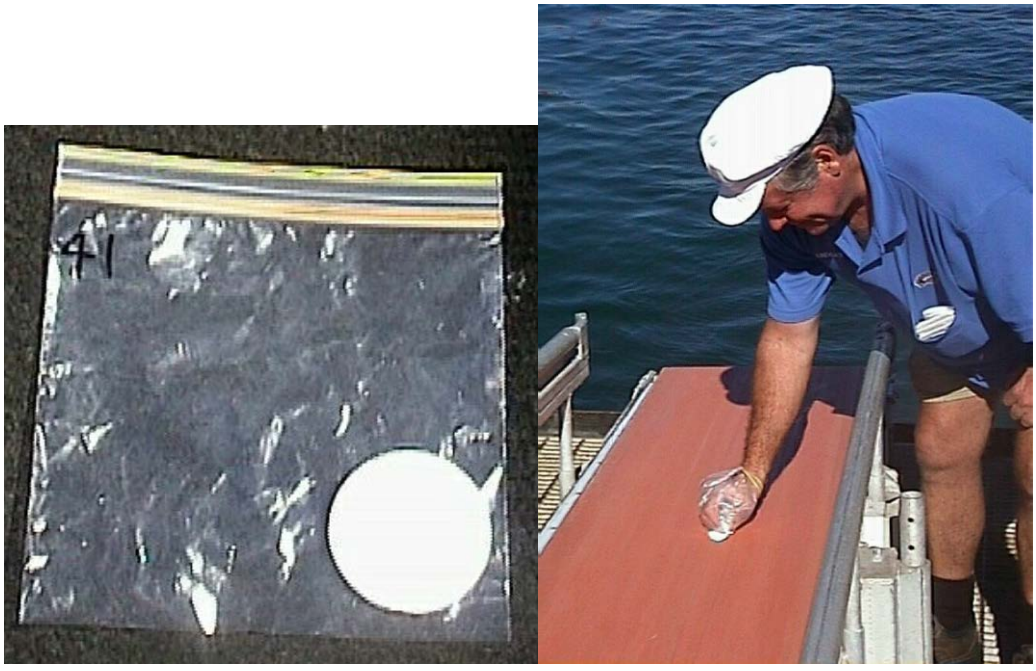

Figure 1) GFC Research Technician, Mr Lindsay McDonald, demonstrating the surface film sampling technique. The cotton salinity swab sealed in the plastic bag (l). To take a sample, the bag was turned inside out and the investigator grasped the cotton pad through the plastic bag, so that no contact with the bare hand occurs (r). After collecting the sample the bag was turned right side out, air expelled and the bag sealed to prevent moisture loss.

Having identified a suitable sampling method, the aim of the survey was to determine the prevalence of hypersaline water films on contact surfaces throughout the post-harvest handling chain.

The first point of potential hypersaline exposure occurs after each pot-load of lobsters is brought onboard commercial fishing boats and is emptied into the sorting box, or cacka box. Crews of working commercial lobster boats were enlisted to take swab samples from the cacka boxes. Crew members were asked to swab the cacka box before pulling the first pot, then again around the middle of day and lastly immediately after last pot-load of lobsters for the day was sorted. This was repeated on each of 5 days. The crews were also asked to note the frequency of washing down during the day, and to estimate the distance from shore at the time of each sampling. Ten boats participated in this part of the survey.

The next point of interest in the handling chain was bait. Bait salinity may be increased through dehydration of surface films during frozen storage and during exposure on deck to sun, sea spray and drying wind. The potential exposure of lobsters to bait salinity may occur via the gloves of the crew member who re-baits the pots then proceeds to sort lobsters.

Surface salinities of baits were analysed aboard 3 working commercial boats during actual fishing. In these cases the baits tested were North Sea herring (*Clupea harengus*) and New Zealand hoki (*Macruronus novazealandiae*). At intervals during the day, swab samples were taken from the bait whilst sitting in plastic tubs on the deck. In addition to this field sampling, the five most commonly used bait types (as determined from GFC bait sales figures), were used in shore-based trials. The baits used were orange roughy heads (*Hoplostethus atlanticus*), summer herring (*Alosa aestivalis*), Albany herring (*Arripis georgianus*), New Zealand kahawai (*Arripis trutta*), and blue mackerel (*Scomber australasicus*).

One run of this trial was conducted in January 2002 and another in March 2002. The day before each trial five pieces of each bait type were removed from frozen storage (-20 to –25°C) and were placed in plastic bags which were then sealed. The samples were allowed to thaw at room temperature (~20°C) overnight to simulate the commercial

practice of thawing bait in boxes on the stern racks of boats. At 04:00 the following morning the samples were emptied from the plastic bags into 68 L plastic tubs (Nally IH078 No 15 crate). The tubs were placed outdoors on a jetty in full sun (see Figure 2). Samples of bait surface films were taken at 08:30, 09:30 and 10:30 using the swab method outlined above. The ambient temperature during the exposure of baits was logged using a Thermocron iButton™ datalogger suspended in the shade of the tubs.

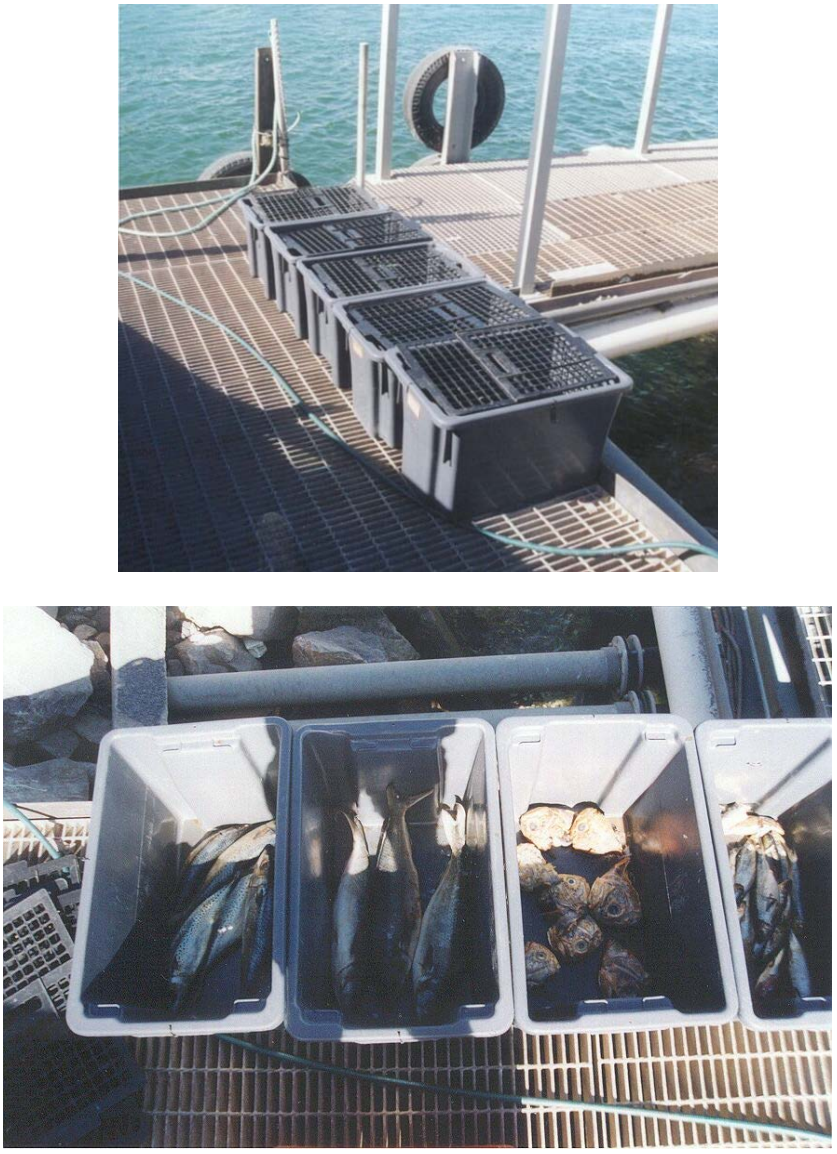

Figure 2) Samples of the five most commonly used baits were defrosted overnight before being set out close to the water to simulate exposure on commercial boats. From left to right, the samples are Albany herring, kahawai, orange roughy heads and summer herring.

The third site sampled in the post-harvest handling chain was inside processing factories. Two processing factories; one in the northern B Zone (Geraldton) and a southern C Zone Factory (Fremantle), were surveyed in January, March and May 2002. Surfaces sampled included grading belts, weighing tubs, scales, baskets and floors of trucks. Prior to the survey the B Zone factory had taken steps prevent salt build up on surfaces in the receival grading area (see below). Preventative measures included continuously spraying the grading belt with tap water and regular washing of baskets, scales, weighing tubs and gloves with tap water. Staff at the C Zone factory had also been made aware of the phenomenon of hypersaline-induced autotomy prior to the survey, but no preventative measures were observed in the factory. Factory surveys were carried out approximately monthly during the 2001/2002 season.

Objective 2: Describe the relationship between autotomy and exposure to seawater of various salinities for lobsters of various sizes and moult stages.

The catches of western rock lobster from five commercial fishermen (total combined weight approx. 2.5 t) were taken from the *North Islander* carrier boat upon returning from North Island in the Houtman Abrolhos Islands. GFC Lives Factory staff sorted the lobsters into size grades (A-G) and removed any lobsters with more than 2 missing legs.

The graded lobsters were placed in factory live tanks overnight to recover. The tanks were supplied continuously with aerated ambient temperature seawater at 2 L/sec. The following day, lobsters were separated into males and females of each size grade to be used in the experiment. Lobsters were then held for a further 2 days without feeding prior to use in experiments. Lobsters of 3 sizes were used; A grade (~350-490 g), C grade (611-740 g) and E – G grade (hereafter referred to as E+; 851-1800 g).

Test solutions of varying salinities were made by diluting concentrated seawater from the Shark Bay Resources Ltd Useless Loop salt works (salinity = 343 ppk; see Table 1) with distilled water.

The salinities of all solutions were determined using a TPS Instruments Ltd WP 81 combination meter and 122201 conductivity probe. All calibrations were made using TPS 36 ppk standard.

Table 1) Major ionic constituents of test solutions used in Objective 2. All concentrations are given in mg/L. a = Geraldton seawater, b = Useless Loop salt works concentrated seawater. All other solutions, except 0 ppk (distilled water), were made by diluting mixing b with distilled water in varying ratios.

Solution (ppk)	[Na+]	[Cl-]	[Mg++]	[S]	[K+]	[Ca++]	pH
0	0.86	<7	<0.05	<0.05	0.14	0.02	6.80
38a	12000	19000	1400	1000	490	450	7.87
46	15000	22000	1800	1200	630	470	7.78
55	17000	28000	2100	1300	740	460	7.80
62	19000	32000	2300	1400	830	440	7.85
72	23000	37000	2800	1700	1000	470	7.84
108	34000	56000	4100	2300	1400	430	7.86
180	57000	86000	6800	3500	2400	450	7.78
343b	110000	160000	13000	6500	4600	440	7.35

Individual lobsters were removed from the holding tank and placed in a perforated tub for 10 sec. to drain before being slid into one of two plastic tubs (Nally IH078 No. 15 Crate) containing 100 mL of the test solution. The floors of the 2 tubs had been sanded to make them easier to wet and to prevent "beading" of the solutions. Lobsters were left in contact with the test solution without disturbance for 15 sec. before being removed by hand and inspected for new and old leg loss. Only legs shed in the tub before handling

were counted in the response. Following inspection for leg loss, a small section of one pleopod was clipped and was stored in 10% formalin in seawater for later moult staging according to the method of Turnbull (1989). For each solution, the responses of two A grade (one male and one female), two C grade (one male and one female) and two E+ grade (one male and one female) lobsters were determined. Alternating between the 2 tubs, male and female lobsters from each size grade were alternately tested during a run of 8 salinity treatments (0-180 ppk salinity). The order in which the genders were tested was reversed after each run, but the order of the size grades always remained the same. Within each run of the 8 solutions, the order in which the solutions were tested was randomised to prevent systematic errors. The solutions were coded so that the handler was operating "blind" and did not know the concentration of the solutions. Between each replicate of the same solution, the old test solution was discarded, the tub was washed with 100 mL of the solution (which was also discarded) and a final 100 mL of fresh solution was added for testing. When changing to the next solution, the tubs were washed with seawater then rinsed with 100 ml of the new test solution, which was discarded before adding the final 100 mL of solution for testing.

Dr Bradley Crear of the Tasmanian Aquaculture and Fisheries Institute (TAFI) conducted cursory experiments to test the susceptibility of the southern rock lobster, *Jasus edwardsii*, to hypersaline-induced autotomy.

Male and female lobsters, weighing between 600 and 800 g were used. Groups of 10 lobsters were placed in water of the one of the following salinity values: 35 (control), 45, or 70 ppk for one minute, before being taken out and allowed to tail flick in air for 30 sec in air then returned to normal seawater. The numbers of legs shed during the treatment was recorded. Each treatment was replicated 3 times.

During the course of the project, 2 specimens each of *Panulirus ornatus* and *P. penicillatus* were obtained from local commercial fishermen. These lobsters were picked up with a gloved hand. The glove had been previously dipped in SW + 55 g/L of Butcher's salt and held for 10 sec. Any legs shed during the handling were recorded.

Objective 3: Quantify leg loss during industry standard freshwater "drowning" procedures.

Commerically caught intact lobsters (i.e. no missing legs or feelers) that had been held in factory live tanks for 4-7 days were placed in 66 L prawn baskets (Nally IH300 Lug Basket) and transferred to holding tanks supplied continuously with aerated seawater (SW) at ambient temperature (~23°C) prior to use in all experiments. Baskets of lobsters were removed from holding tanks as required.

Experiment 1: Effect of Size

A-grade (~350-490 g) and G-grade (1221-1800 g) lobsters were used. For each grade, 50 lobsters were "drowned" in tubs of ambient temperature (25-27°C) local scheme water for 30 min. This is the industry standard method of killing lobsters prior to processing. Each batch of 50 lobsters was considered to be one replicate of the experiment.

Because of the large difference in size between A-grade and G-grade lobsters, the method used to drown groups of lobsters from the 2 grades differed slightly, as outlined below. For A-grade lobsters, individuals were placed by hand on a moving conveyor belt (Figure 3). At the end of the conveyor was a 70 L cylindrical plastic tub containing 60 L of ambient tap water (25.5-26.5°C). At the end of the conveyor lobsters fell into the drowning tub directly. In this way it was possible to observe that lobsters did not shed legs before entering the water and that no detached legs entered the tub with the lobsters. Thus all legs found in the tub after drowning must have been shed during drowning. After the 30 min. drowning period lobsters were carefully removed by hand from the treatment tubs. The numbers of detached legs and antennae remaining in each tub were counted. The experiment was repeated 12 times using a total of 600 A-grade lobsters.

Figure 3) The set up used for investigating leg loss during freshwater drowning of red A-grade western rock lobsters. Lobsters were transported by conveyors to drowning tubs (right).

Larger 700 L tubs (Nylex Engel Storage Tub; filled with 600 L of ambient tap water at 25.5-26.5°C) were required to accommodate each group of fifty G-grade lobsters and, because the conveyors were required for commercial operations at the time the G-grade animals became available, individual animals were placed in the tanks by hand. This was justified by the fact that the larger lobsters did not react as violently to handling as A-grade lobsters and it was quite easy to transfer them to the drowning tub and observe that they were not shedding legs before entering the water. The experiment was repeated 6 times using a total of 450 kg of G-grade lobsters.

Experiment 2: Effect of Gender

A-grade lobsters were separated into intact (i.e. no missing legs or feelers) males and females, then stored and handled as for the A-grade lobsters in Experiment 1. All lobsters were from the same source (i.e. local boats delivering direct to the jetty, same day of capture) to control for unintended effects.

Male and female lobsters were placed simultaneously on separate identical conveyors and were conveyed to separate tubs identical to those used in Experiment 1, filled with ambient temperature local scheme water (Figure 3). After drowning for 30

minutes, the lobsters were counted, and the numbers and positions of missing legs were noted for each gender. The numbers of detached legs and feelers remaining in the tubs were recorded. The trial was repeated 8 times using a total of 800 lobsters.

Objective 4: Compare responses to ionic and non-ionic solutions to elucidate the potential role of other contaminants, and the possible nature of the receptors and stimuli.

This Objective was considered to be of little commercial benefit to industry and, after consultation with the FRDC Rock Lobster Post-Harvest Subprogram Steering Committee, was deleted from the project.

Objective 5: Investigate the relationship between daily environmental conditions and levels of post-harvest leg loss.

Anecdotally, leg loss in western rock lobsters is thought to be worse on days when hot, dry windy conditions (usually easterly winds) prevail. To test this suggestion, a Davis WM918 weather station was mounted aboard a commercial lobster boat operating out Port Denison, 65 km south of Geraldton. The boat participated in 44 days of sea trials of on board cold-stunning as part of FRDC Project 2000/251. During the trials, an onboard observer recorded numbers of legal, breeding female and undersized lobsters in each pot, and all legs shed during on board handling. The observer also took regular recordings of weather conditions (air temperature, relative humidity, barometric pressure and relative wind speed over vessel) via the on board weather station. Sea surface temperature and depth were also recorded regularly using the vessel's sounder and on board electronics. Evaporation figures (measured at Geraldton airport) were obtained from the Western Australian Bureau of Meteorology.

The environmental variables that best predicted the observed onboard leg loss in the untreated control lobsters were identified using a step up regression procedure.

Objective 6: Field test practical solutions for hyper/hyposaline-induced autotomy and make recommendations to industry.

The simplest and most cost-effective method for preventing the build up of hypersaline surface films is to wash surfaces with either fresh water or seawater.

With an abundant supply of seawater available on commercial boats, continuous washing of contact surfaces is a convenient option for preventing salt build up during fishing.

To test if washing has a benefit, in terms of preventing onboard leg loss, the sorting box of a working commercial lobster boat was fitted with seawater sprays. Seawater was taken from the deck hose and delivered via a flexible hose to Spray heads (Spraying Systems Co., QPHA-15 Promax® Quick FullJet® nozzles) mounted on the inboard wall of the cacka box. The spray heads were angled so that the floor of the cacka box was completely covered with seawater spray (Figure 4).

Figure 4) Seawater sprays installed on a cacka box aboard the commercial lobster boat, Scorpion *(left). An observer (Brad Armstrong, All Points Diving Services) on board counted leg loss and controlled the treatments (right).*

To test if the sprays were effective, alternating periods of fishing with or without the sprays operating were undertaken during each day of the trials. This controlled, to some degree, for variation in environmental conditions, such as sea depth, sea and air temperature, wind speed, evaporation, and predator densities, during each day's fishing. In a situation like this it is very difficult to prevent interaction between the treatments, because once the cacka box and deck hand's gloves have been washed under the sprays, any salt on these surfaces that may have otherwise accumulated during the course of the day is removed. In an attempt to reduce interaction between treatments a "rest" period of 5 pots (i.e. with sprays off) was allowed between sorting lobsters from 5 treatment pots (sprays on) and the next 5 control (sprays off). The rest phase allowed some opportunity for surface water in the sorting box to evaporate if it was going to and helped to lessen any effect of the previous period of washing. This approach was justified by the fact that earlier on board surveys of surface film concentrations did not indicate that highly concentrated salt films built up over a day of operation. In addition, during the trials it was observed that a significant amount of free seawater spilled into the sorting box during emptying of each pot pulled. Therefore it is unlikely that there was appreciable surface film evaporation between pots and the experimental approach taken would effectively separate the treatments. The data from the "rest" pots was not included in the analysis.

An observer was onboard for each day of the trials to record the numbers of lobsters caught in each pot and the number of shed appendages and to try to identify a reason for the loss for each leg. The trials were run over 5 days in March 2003, and involved a total of 600 pot pulls.

Prevention of leg loss during freshwater drowning

Appreciable leg loss was found to occur during freshwater drowning (see Objective 3 below). Methods for preventing leg loss during drowning were tested using the same experimental set up used in experiments addressing Objective 3. The two conveyors shown in figure 3 allowed pair-wise comparisons of controls and treatments to be conducted. As in Objective 3, groups of 50 lobsters were drowned at a time, this constituting one replicate of the experiment. The first potential preventative measure

tested was “drowning” in a slurry of seawater/seawater ice. The tub under one of the conveyors was filled with seawater and crushed seawater ice was added to produce a slurry with a temperature of –1 to –2°C. The second treatment tested was to cold-stun the lobsters prior to drowning in ambient temperature tap water. Each basket of 50 lobsters was immersed in seawater at the appropriate temperature for a prescribed period. Groups of lobsters were exposed to stun temperatures of 5 and 0°C for various times between 5-20 sec. Groups of control lobsters were left in ambient air for the duration as the stun treatment applied to the respective treatment groups.

Statistical Analysis

Statistical analysis of all results was performed using the computer packages MSExcel ver. 8.0, SigmaStat ver. 1.01 or JMP ver.3.2.2 for Macintosh.

Results and Discussion

In the preliminary stages of this work, different methods of applying hypersaline seawater to lobsters were tested. Lobsters reacted by shedding legs when immersed in hypersaline seawater, when sprayed with it from an atomiser bottle, when placed on a hypersaline surface water film and when picked up with a glove dipped in hypersaline water. These observations raise questions about how the lobsters detect salinity and where on the body receptors are located. Addressing these questions was beyond the scope of this study, however, there is limited information in the literature that may give some insight. In *Homarus americanus*, Dufort et al. (2001) observed rapid changes in heart rate when lobsters were exposed to water of varying salinity. Based on the response times, these authors suggested the receptors responsible for mediating the cardiovascular response were located within or near the branchial chambers.

Although contact with hypersaline water was not tightly controlled in the observations made in the present study, the ventral margin of the carapace and bases of the walking legs were consistently exposed to hypersaline seawater in all cases

mentioned above. These areas are very close to the inhalent branchial apertures and it may be that, like *H. americanus*, *P. cygnus* also bears receptors in, or near the branchial chambers.

Objective 1: Survey salinity concentrations of surface films on individual lobsters and on relevant contact surfaces on boats and within factories.

In experiments addressing Objective 2 it was shown that surface films with salinities exceeding approximately 60 ppk caused spontaneous autotomy (see below). The following discussion will focus on survey samples exceeding this value and therefore posing a threat to lobster integrity.

Salinity On Board Commercial Lobster Boats

In total, 148 samples were collected from cacka boxes onboard 13 working commercial lobster boats. Only five per cent of these samples showed salinities greater than 60 ppk (Figure 5), suggesting the risk of exposure to hypersaline water films in the cacka box is relatively low.

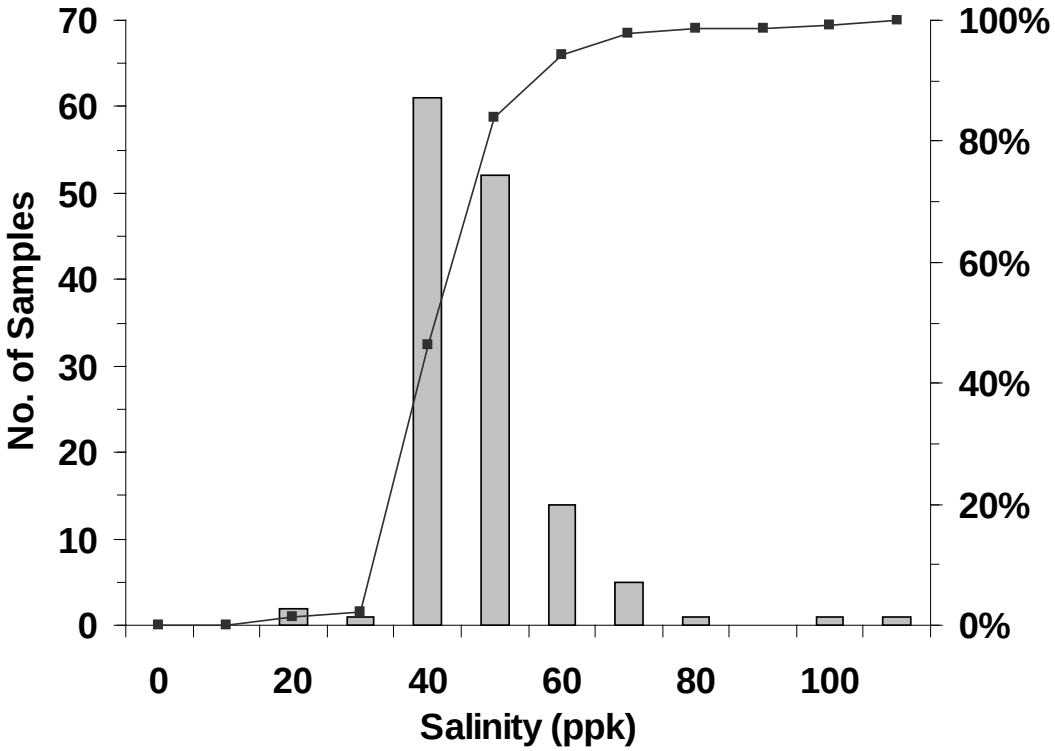

Figure 5) Frequency distribution (filled bars) and cumulative percentage (solid squares) of salinity sample values from cacka boxes on board working commercial fishing vessels.

However, it is important to bear in mind that these survey values (and all subsequent values presented) can only estimate the potential exposure of the catch to hypersaline seawater, because it is difficult to accurately estimate the proportion of the catch actually exposed to dangerous levels of salinity. Evaporative concentration of surface films will be greatest during the summer months when temperatures are high and relative humidity is low. A large proportion of the catch is taken during the "whites" migration which coincides with these extremes of temperature and humidity, therefore significantly more than 5% of the catch (suggested by the survey samples) could be affected. In addition, as discussed above, the survey results are likely to underestimate the true exposure to hypersaline films because it was not possible to sample very thin water films which are likely to be rapidly concentrated due to evaporation. On the other hand, the on board survey was conducted during January and February, which are the hottest and driest months of the year. As a result, concentrated seawater films may be over

represented in the sample. Given these considerations it is sufficient to say the survey indicates potential for saline water films that will cause autotomy to develop. This in turn suggests potential for alleviating leg loss by preventing the development of hypersaline films.

It is interesting to note that the salinity values of some samples were much lower than full seawater strength (38 ppk). These low values always occurred before the first pot was pulled and may have been due to washing down of vessels with fresh water at the jetty the night before or due to overnight dew on surfaces.

Bait Salinity

The results of the survey of surface salinity on commonly used baits are presented in Figure 6. The results indicate that baits pose little threat in terms of exposing lobsters to hypersaline films. Only one sample barely exceeded 60 ppk salinity and this was after two hours of exposure to drying wind and sun. This exposure was quite extreme with "normal" exposure times onboard commercial boats, probably being less than one hour. The low bait salinity values (i.e. less than seawater strength) observed may have resulted from the use of freshwater during processing of the baitfish.

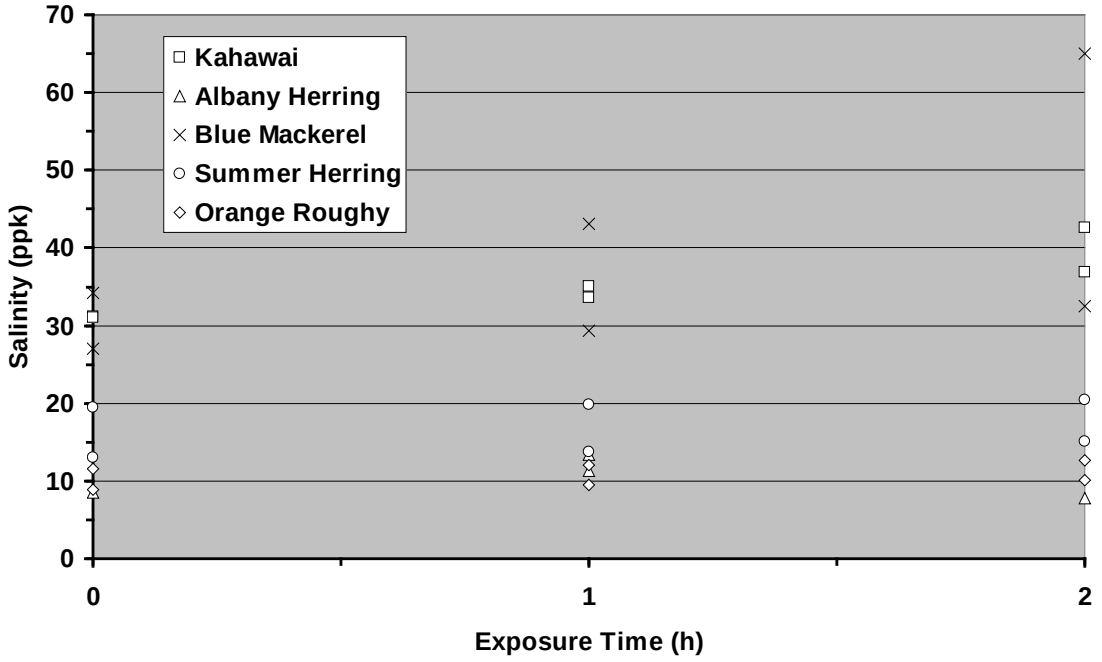

Figure 6) Surface salinity values from samples of commonly used baits.

The results obtained from exposing baits on shore are consistent with salinity values from baits on board working commercial lobster boats (Figure 7) and confirm that thawed frozen fish baits pose no real risk, in terms of contributing to on board hypersaline-induced autotomy.

All baits assessed were thawed frozen fish. In the past many fishermen used salted baits, but with improved cold chain distribution, salted baits are no longer widely used. Some fishermen still salt and dry fish for use as a holding bait over 2-3 day pot pulls. Clearly handling salted baits poses a significant risk to the catch if crew members do not take steps to wash gloves after handling salted baits. However, the most commonly used frozen fish baits present little risk, in terms of exposing catch to hypersaline solutions.

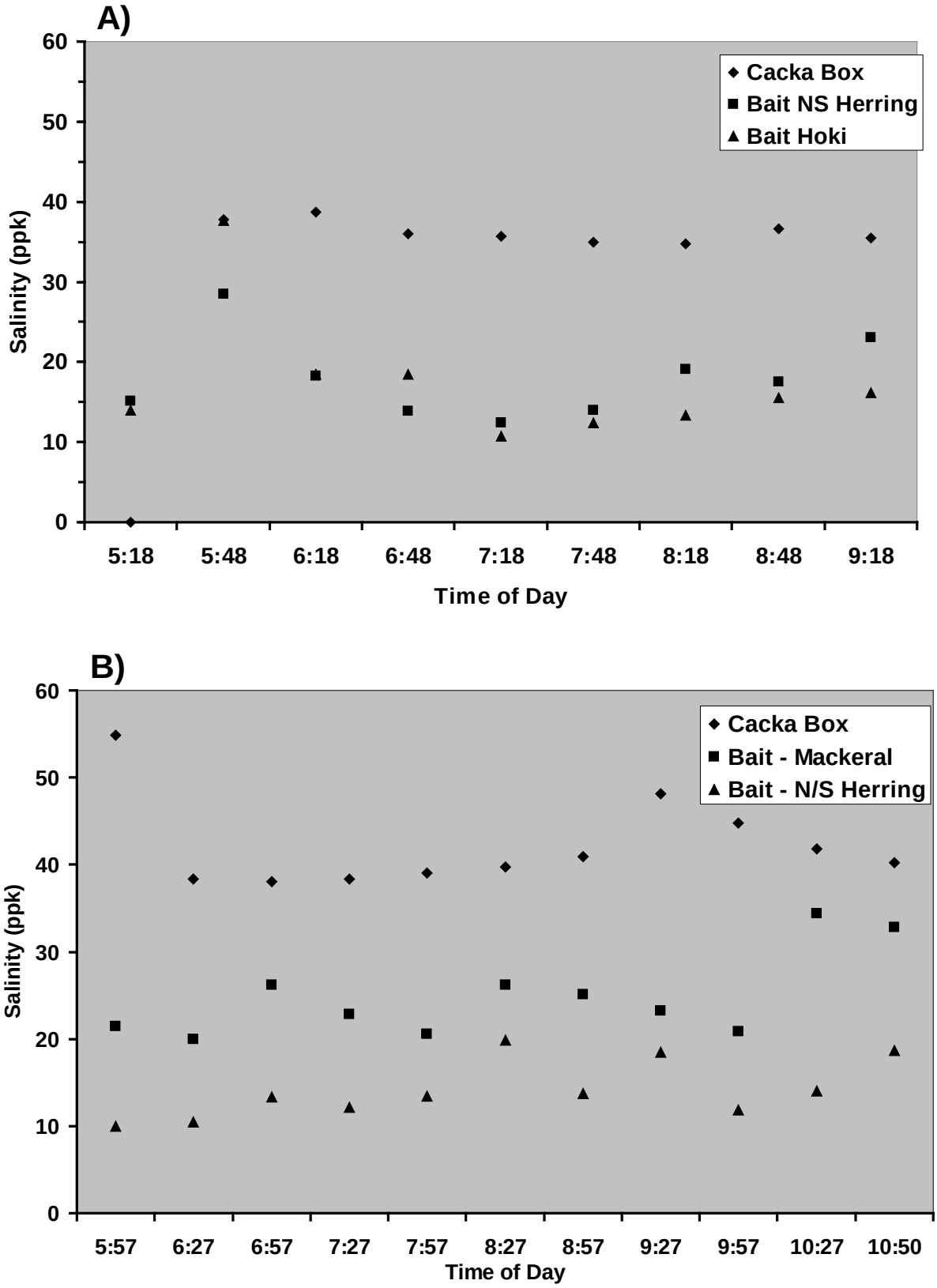

Figure 7) Salinity values from cacka boxes and baits during fishing on board 2 working commercial lobster boats.

Factory Salinity Survey

Factory surveys consisted of taking samples from a range of surfaces in receival and load out areas with which lobsters came into contact, including grading tables and conveyor belts, scales and baskets.

As mentioned above, the B zone factory (in Geraldton) used in this study was the site where preliminary measurements were taken to justify this study. These initial results showed very high salt concentrations (up to 3 times the concentration of normal seawater) were present. As a result, steps were taken to prevent salt build up, including the installation of tap water sprays over grading belts, a program of regular washing down of baskets and sponge pads soaked in tap water for graders to wipe their gloves on. The survey provided an opportunity to assess the efficacy of these corrective measures.

A total of 263 samples were collected from the receival and load out areas of the B zone factory. Only 5% of samples had salinity values greater than 60 ppk (Figure 8). The highest recorded values (>100 ppk) confirmed the earlier provisional measurements of salinity at approximately 3 times the concentration of normal seawater. The numerous low salinity values (< 38 ppk) undoubtedly resulted from washing down surfaces with tap water.

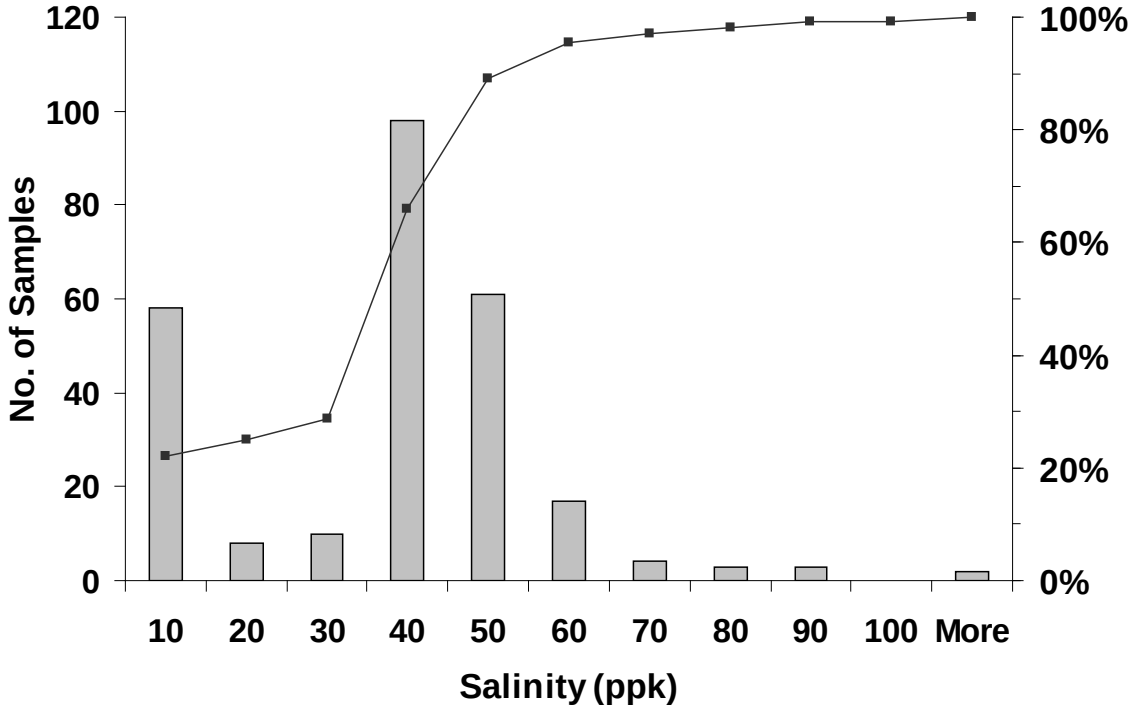

Figure 8) Frequency distribution (filled bars) and cumulative percentage (solid squares) of salinity values of water films on contact surfaces in a B zone (Geraldton) live holding facility. These samples were collected after corrective measures were implemented (see text for details).

In contrast to the situation in the B zone factory, 25 % of 75 samples taken from the C zone factory exceeded 60 ppk (Figure 9). The difference in incidence of hypersaline films between the two factories presumably reflects the effectiveness of the corrective measures implemented at the B zone site. The staff and management of the C zone factory were aware of the phenomenon of hypersaline-induced autotomy at the time of the study, so it is likely that the survey results are better (i.e. lower salinty values) than would have been found prior to any knowledge of the phenomenon. As discussed above, very thin films could not be sampled and the results presented are likely to underestimate the true prevalence of hypersaline films.

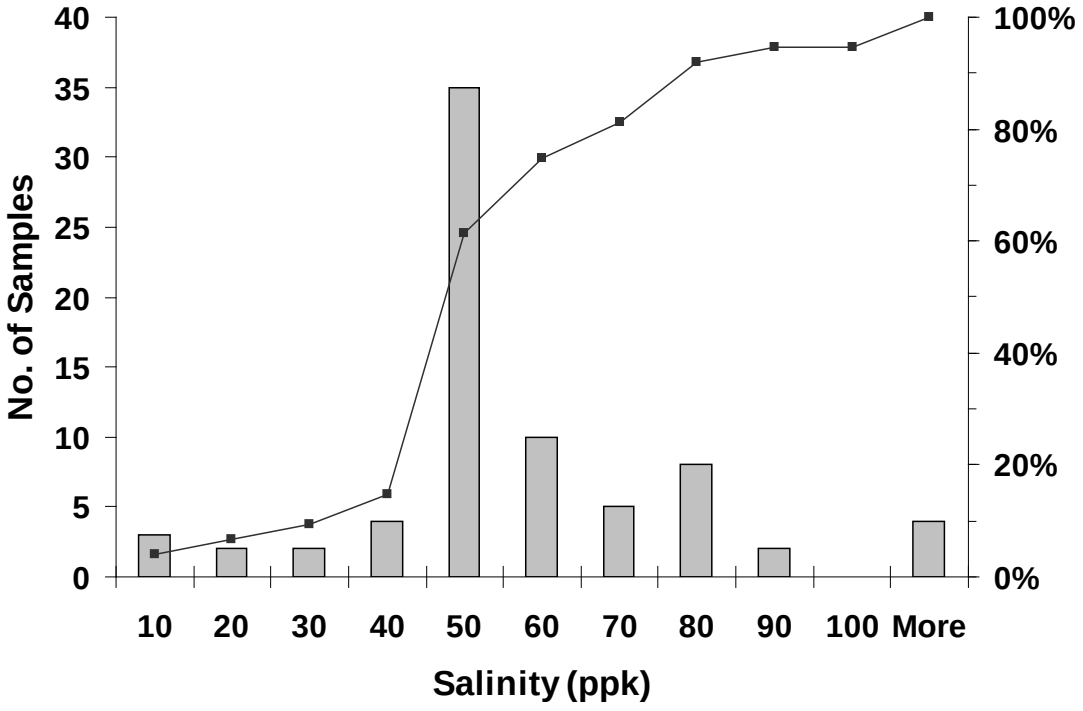

Figure 9) Frequency distribution (filled bars) and cumulative percentage (solid squares) of salinity values of water films on contact surfaces from a C Zone factory (Fremantle).

The key finding from this part of the work is that hypersaline films do occur at all points in the post-harvest chain. Given this fact, there is potential for preventing hypersaline-induced autotomy at each of these stages. As might be expected, the occurrence and development of these films appears more prevalent in land-based points of the handling chain, such as at receival depots and processing factories. These are key locations through which the entire catch passes and are logical sites for implementing preventative measures. The survey results also suggest that simple steps, such as regular washing of surfaces, can be taken to dramatically reduce the occurrence of hypersaline films in factories. Additional preventative measures are discussed below (see Objective 6).

Objective 2: Describe the relationship between autotomy and exposure to seawater of various salinities for lobsters of various sizes and moult stages.

Contact with surface films with salinities ranging from 0 to 62 ppk salinity did not cause increased leg autotomy compared to normal seawater (Kruskal-Wallis one way ANOVA on ranks; H = 138.8; P > 0.05; df = 7; Figure 10). However, at salinities of 72 ppk or greater, leg loss increased with increasing salinity up to the highest salinity tested (180 ppk). Even though, statistically speaking, leg loss was significantly increased at salinity values of 72 ppk and greater, it would appear from Figure 10 that there is some level of leg loss occurring when lobsters are exposed to saline films at 62 ppk. In all subsequent discussions, this value will be considered to be the limit, above which salinity poses a threat to lobster integrity.

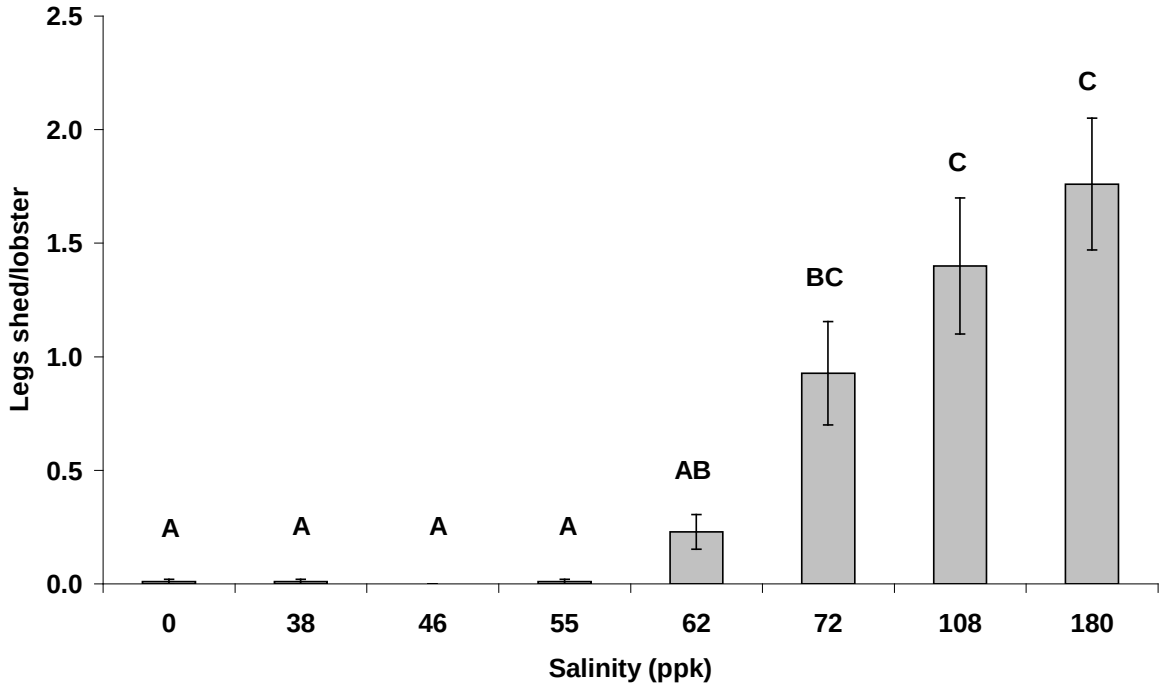

Figure 10) The effect of surface film salinity on leg loss in the western rock lobster. Bars labelled with the same letter indicate values are not significantly different (Dunn's Method; P > 0.05).

Identifying salinity as an inducer of autotomy was a significant discovery and allowed the direct testing of various aspects of the phenomenon, including gender effects, size effects, and the effectiveness of preventative cold-stun treatments. Consistent with earlier experiments investigating leg loss during freshwater drowning, rates of leg loss were similar in females and males when exposed to surface films with salinities greater than 62 ppk (Mann-Whitney Rank Sum test; t = 144483.0; P > 0.05; Figure 11).

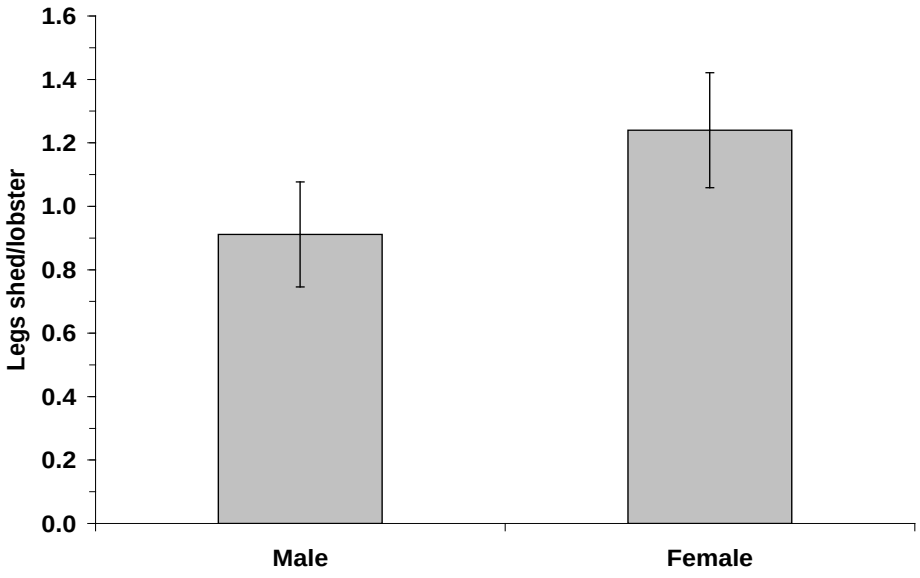

Figure 11) Leg loss in males and female lobsters exposed to surface films with salinities ranging from 62 to 180 ppk.

Anecdotal evidence suggests that large western rock lobsters are less prone to shedding legs than their smaller counterparts and upon first inspection of the results for animals exposed to 62 ppk and greater, the data from this experiment appear consistent with this suggestion (Figure 12). However, statistically speaking, the groups were not significantly different (Kruskal-Wallis one way ANOVA on ranks; H = 5.43; P > 0.05; df = 2). Interestingly, Carls and O'Clair (1995) showed that juvenile tanner crabs (*Chionectes bairdi*) were more likely to shed legs during exposure to cold air than adults.

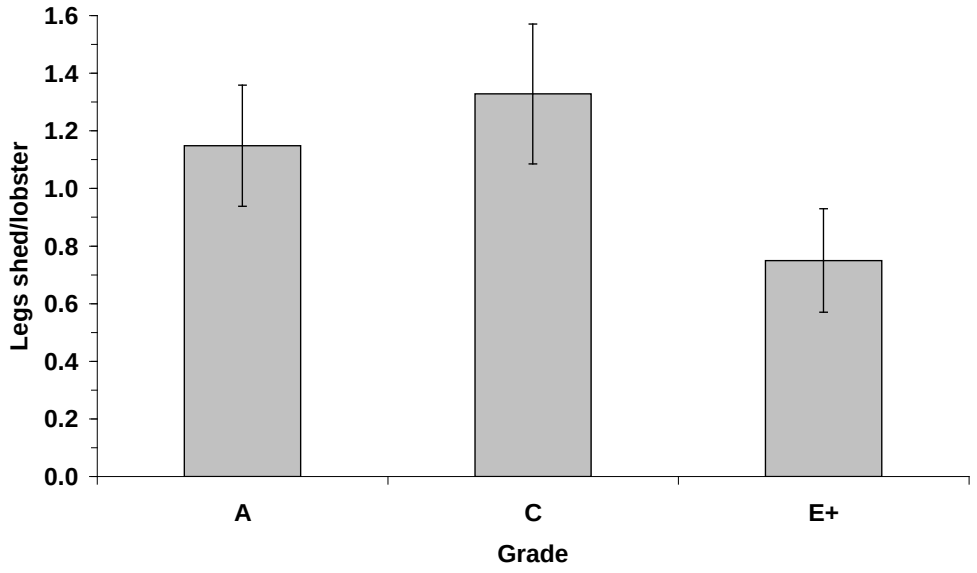

Figure 12) Variation in leg loss in lobsters of different sizes when exposed to surface films with salinities ranging from 62-180 ppk.

Over the range of salinity values tested, none of the individuals of *J. edwardsii* shed legs during hypersaline seawater exposure. Thus it would appear that no further work is required on this species. Likewise, none of the individuals of *P. ornatus* or *P. penicillatus* reacted to exposure to hypersaline seawater exposure. However, these latter results are not conclusive due to the small numbers of animals used.

Objective 3: Quantify leg loss during industry standard freshwater "drowning" procedures.

Effect of Size

Red A-grade lobsters drowned in ambient tap water shed 4.3 ± 0.8 legs/50 lobsters (n =12). G-grade lobsters drowned in tap water shed 2.8 ± 0.6 legs/50 lobsters (n = 6). From these experiments little can be concluded about the relative rates of leg loss in the different sized lobsters, because the conditions under which the lobsters were drowned were quite different (see Methods). Even if identical drowning tubs were used,

the relative loadings (mass and number of lobsters per volume of drowning water) would be very different and this would likewise confound any statistical comparison. Other differences between the different sized lobsters, such as source of capture, duration of storage in GFC's tanks, activity levels, etc. could also not be controlled for. This is because larger G grade lobsters occur only in small numbers and must be accumulated in the live factory over a period of several weeks. In contrast, A grade lobsters are numerous and a several tonnes of these animals can be collected each day.

The results however, do show that western rock lobsters lose legs during the freshwater drowning process. Whether this is due to the direct effect of the salinity of the water *per se*, as opposed to other effects, such as damage occurring during contact with the tank walls, is not clear. Lobsters react violently to immersion in ambient temperature freshwater and this may result in some physical trauma. Having said this, motionless lobsters were observed to spontaneously shed legs with no apparent additional stimulus (G. Davidson, pers obs.).

A satisfactory control for the effect of hyposalinity on leg loss could not be found, because the treatments applied were compound effects, involving variations in temperature, salinity, pH, tub loading and possibly other factors. However, from the point of view of answering the industry-relevant question: "Does freshwater drowning cause leg loss?" this work makes it clear that there is currently a substantial problem. Potential solutions to this problem are identified in Objective 6 (see below).

Effect of Gender

Interestingly when specific experiments were conducted to investigate gender differences in leg loss during fresh water drowning, much higher rates of leg loss were recorded than in earlier experiments looking at the differences in leg loss in lobsters of different sizes. Male A-grade lobsters drowned in tap water shed 7.0 ± 1.4 legs/50 lobsters, whereas females shed 10.4 ± 2.1 legs/50 lobsters. These values were not significantly different (paired t-test, $P > 0.05$; $t = -2.08$; $df = 7$). These high values may simply reflect the variation that may occur between experiments.

The probability that there was a difference between the genders (P = 0.0764) was bordering on significance, but the power of the test was 0.34 – well below the desired level of 0.80. Additional replicates of the experiment may have demonstrated significance. From an industry perspective, any slight difference in leg loss rates between genders would not warrant alternative processing or grading regimes for males and females.

It is difficult to extrapolate accurately from the above results to estimate the total cost to industry of leg loss during freshwater drowning. Each processor may use different equipment, slightly different water temperatures, and lobsters of varying levels of reactivity. However, assuming on average 10 legs are shed/100 lobsters drowned, that 70% of the annual catch (average ~11 500 tonnes) is processed for the frozen market, and that each leg accounts for 1% of total body weight, then approximately 8 tonnes of legs, worth $210 000 (at $26/kg), would be lost each season. This estimate does not include any reduction in market value of lobsters that have lost too many legs to be sold in premium frozen forms, such as whole raw or boiled. Strategies for preventing this damage are presented in Objective 6 (below).

Objective 5: Investigate the relationship between daily environmental conditions and levels of post-harvest leg loss.

The relationship between on board leg loss and environmental variables was examined using a step-up regression procedure. Of the independent variables air temperature, sea surface temperature (SST), barometric pressure, relative humidity and daily evaporation, on board leg loss was best predicted by sea surface temperature according the following equation:

$$\text{leg loss} = -0.7762 + 0.0438[\text{SST}]$$

(adj. $r^2 = 0.4790$, df = 28)

Using an F-to enter = 4.0 and F-to-remove = 3.9, none of the other variables added significantly to the ability of the equation to predict leg loss. Given anecdotal reports

about the effects of weather conditions on leg loss, it was interesting to find that SST was the best predictor of on board leg loss. However, it should be noted that air temperature, which is widely thought to play a role in the phenomenon, and sea surface temperature were highly correlated (Spearman's Rank Order Correlation Coefficient = 0.79, $P < 0.05$, $n = 30$), as were SST and a number of the other factors. As a result, the relationship identified between sea temperature and leg loss may be spurious. This observation appears to make the value of the statistical analysis, in terms producing a real world case for explaining the observed leg loss, somewhat arbitrary.

The advantage of using the onboard weather data, as opposed to data collected from weather stations on land, is that the conditions over water are likely to be vastly different from those recorded even a few hundred metres inland from the shore, especially if an offshore wind is blowing. For example, anecdotally leg loss is thought to be worst on days when a hot easterly wind is blowing offshore, but the relative humidity and temperature of this wind is likely to be greatly affected by distance from the shore. An easterly airflow would be expected to gain moisture from the sea surface and lose heat in the process via evaporative cooling.

The only other reference found in the literature describing a relationship between crustacean autotomy and environmental factors was for tanner crabs (Chionectes bairdi) (Carls and O'Clair, 1995). Tanner crabs showed autotomy of walking leg when exposed to cold air during on board sorting. Furthermore the extent of limb loss was dependant upon the severity of the exposure to cold air (expressed as degree·hours).

Objective 6: Field test practical solutions for hyper/hyposaline-induced autotomy and make recommendations to industry.

The Use of Surface Washing for Preventing Hypersaline-Induced Leg Loss

Surveys of the occurrence of hypersaline films throughout the industry showed that hypersaline films capable of inducing autotomy (> 62 ppk) were widespread on surfaces throughout land-based processing factories. Since becoming aware of the

phenomenon of hypersaline-induced leg loss, several processors have taken steps to minimise salt build up in processing factories. The simplest and most cost-effective method for doing this is to wash all contact surfaces, such as gloves, grading tables and baskets, with either freshwater or seawater. (Figure 13). Given the prevalence of hypersaline surface films in factories, the clear difference in the occurrence of such films in factories with and without a washdown procedure (see Objective 1) and considering the insignificant cost of implementation, it was not considered necessary to experimentally determine the benefits of these measures.

Figure 13) Processors have taken steps to reduce salt build up in factories. This figure shows freshwater sprays fitted to a belt used to convey lobsters past graders. The sprays continually wash the belt preventing salt build up.

A number of fishermen have also taken steps to prevent hypersaline-induced leg loss on board their boats by implementing regimes of regular washing down of cacka boxes and gloves, or by installing seawater sprays on cacka boxes (Figure 2). Surveys of surface film salt concentrations undertaken on commercial boats in Objective 1 showed that hypersaline films were not as prevalent as in processing factories.

In an attempt to demonstrate the benefits of surface washing at sea, trials comparing leg loss during sorting of lobsters under seawater sprays to sorting of lobsters in "dry" cacka boxes were undertaken aboard a working commercial lobster boat in March 2003.

Leg loss from lobsters in pots sorted without sprays occurred at a rate of 4.3 ± 0.8 legs/100 lobsters handled. This is at the lower end of the range of leg loss recorded in previous sea trials in FRDC Project 2000/251 (range = 3 – 34 legs/100 lobsters; mean = 15 legs/100 lobsters over 44 days of fishing). As seen in Objective 5, leg loss varies according to variation in environmental factors, such as weather and sea conditions. The observed low rates of control leg loss occurred despite very hot conditions prevailing during much of the trials. Anecdotally, hot weather is usually associated with comparatively high rates of leg loss.

The average rate of leg loss from lobsters sorted under seawater sprays was 4.8 ± 0.4 legs/100 lobsters. This was not significantly different from the control rate (Student's *t*-test, $t = -0.4829$; $p > 0.05$). Therefore under the conditions of these trials, spraying with seawater did not reduce on board leg loss. In contrast, in earlier sea trials (FRDC Project 2000/251) on board cold water stunning reduced leg loss by an average of 70% even during periods when control leg loss was similarly low.

Using cold-stunning to prevent hypersaline-induced leg loss.

In the course of the companion project FRDC 2000/251 it was found that cold-stunning is an effective method for preventing leg loss at all points in the post-harvest handling chain. It was also clearly demonstrated that cold-stunning alleviates hypersaline-induced leg loss. Figure 14 is taken from that work and shows that

immersing lobsters in 5°C seawater for 5 sec virtually eliminates the autotomy induced when lobsters are placed on surfaces covered with a film of a solution of seawater + 55g/L of Butcher's salt.

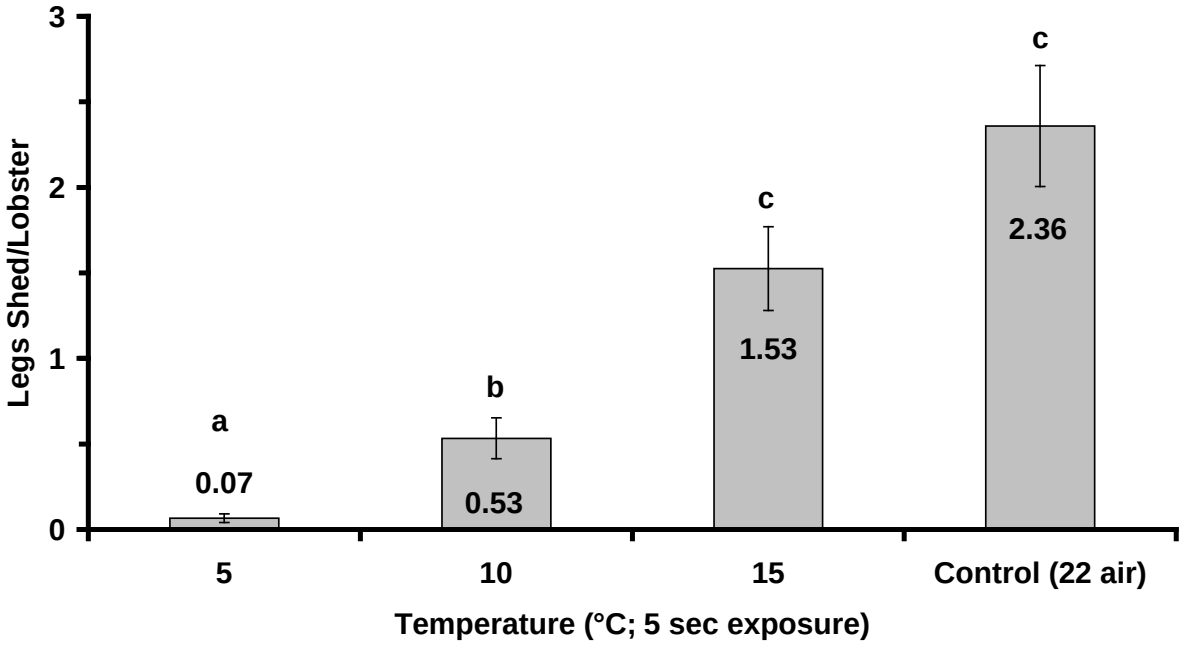

Figure 14) Cold stunning lobsters for 5 seconds at 15, 10 or 5°C reduced in a stepwise manner, the leg loss that occurred when lobsters were exposed to surface water films with a salinity of seawater = 55 g/L of Butcher's salt. Different letters indicate values that are significantly different (ANOVA: P < 0.05).

Using cold-stunning to prevent leg loss during hyposaline freshwater drowning.

Cold-stunning is not only effective for preventing hypersaline-induced leg loss, but also leg loss occurring during drowning in hyposaline freshwater. Figure 15 shows that the effectiveness of cold-stunning for reducing leg loss during drowning is proportional to the duration of the stun time and inversely proportional to stun temperature. For example, a 15 second stun at 0°C reduced leg loss during drowning by 90%, potentially saving up to $190 000 year in the weight of legs alone. There would also be downstream benefits by reducing the numbers of animals that would have to be tailed.

As mentioned above, it is not clear whether leg loss during drowning is caused mainly by hyposaline exposure or by excessive activity during drowning. In any case, cold-stunning certainly reduces activity and, as demonstrated above, reduces sensitivity to hypersaline exposure. Therefore it is possible that cold-stunning may reduce leg loss during drowning through a combination of effects.

In most factories, lobsters are graded after being weighed in. Lobsters suitable for live export are placed in holding tanks, while those considered unsuitable for export are drowned in tap water. To be of maximum benefit, cold-stunning should be applied prior to grading and perhaps even prior to weighing. This means that a number of minutes will elapse between stunning and drowning. In our experiments, a full 3 minutes elapsed between the time the lobsters were stunned as a group and when the last lobster entered the drowning tub. So it appears feasible to keep animals in a stunned state for several minutes during weighing and grading prior to drowning.

Among other things, factory graders assess the vigour of each lobster. Cold-stunning reduces the outward appearance of vigour and so might be expected to make grading difficult. Controlled trials conducted as part of FRDC 2000/251 showed that factory graders were able to grade stunned lobsters with the same degree of accuracy (~ 80 % correctly classified) as lobsters that were not stunned prior to grading.

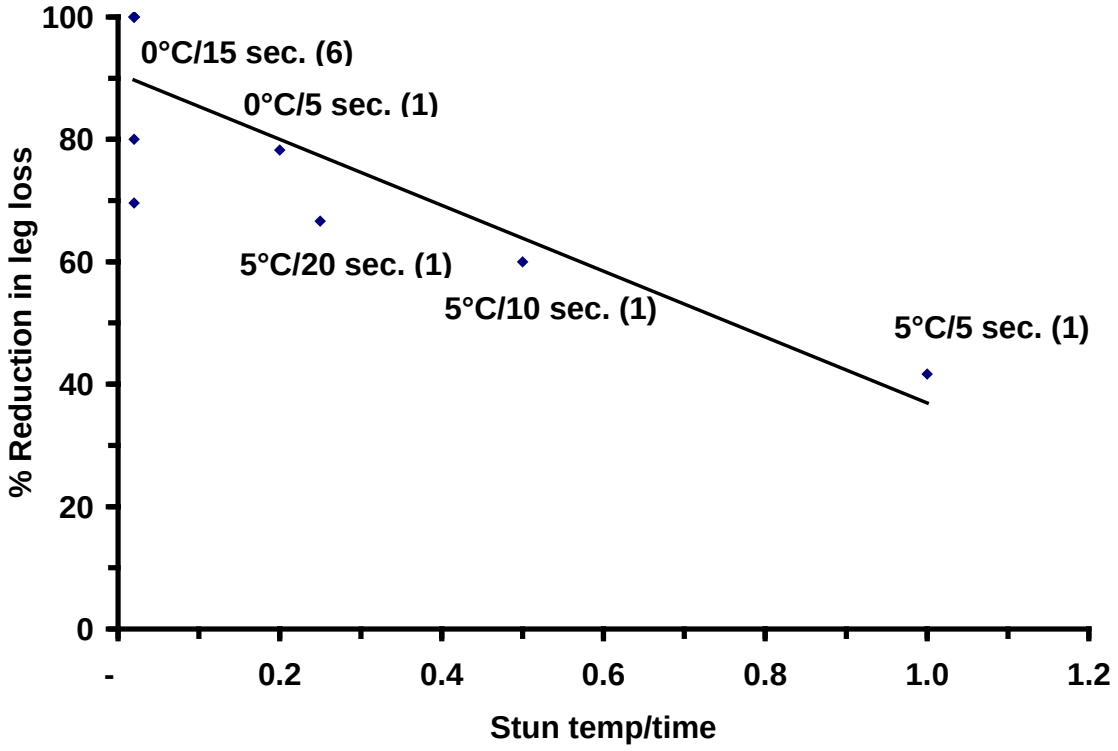

Figure 15) The effectiveness of cold-stunning for reducing leg loss during freshwater drowning at ambient temperature. The stun temp/time was obtained by dividing the stun temperature (°C) by the stun duration (sec). For the nominal stun temperature of 0°C, 0.3°C was used in the calculation. The numbers in brackets indicate the sample size for each stun temp/time. The regression equation is %reduction = -53.795(stun temp/time) + 90.756; r^2 = 0.714.

Using SW/SW ice slurries to prevent leg loss during drowning

Another method for killing lobsters without losing legs is to place them in a SW/SW ice slurry. During trials using the experimental method detailed in Objective 3, this method significantly reduced leg loss by 82% (paired t-test; t = 2.8579; P < 0.05; df = 5). Drowning in a FW/FW ice slurry may have similar benefits, but this was not tested.

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Benefits and Adoption

The most significant benefit of this project has been the identification of hypersaline-induced leg autotomy as a major cause of post-harvest leg loss in western rock lobsters. Not only has the phenomenon been characterised, but a number of simple and cost-effective strategies for dealing with the problem have been developed.

Likewise, identifying that legs are lost during standard freshwater drowning and development of preventative measures has also been a major benefit to industry. While it is difficult to quantify precisely the economic benefits from this work, wherever possible throughout this report, estimates based on realistic and conservative figures have been given. These estimates suggest a significant economic benefit from the work has been realised.

The results of this project have been widely adopted throughout the industry. This has come about through a vigorous program of publicising the work and widespread dissemination of the results to industry. Awareness of the problem of hypersaline-induced autotomy has been increased at all levels within the industry, from crews on board fishing boats to processing factory staff and management. This widespread understanding has served to reduce leg loss at all points in the post-harvest chain. For example, the Geraldton Fishermen's Cooperative, which represents nearly 25% of the industry and has a catchment area covering the entire range of the fishery from Cape Leeuwin in the south, to Kalbarri in the north and the Abrolhos Islands in the west, has made full use of the results of this work. As the results came to hand they were

disseminated to the catching sector using a variety of methods, including GFC quality newsletters, GFC fishermen's seminars, informal dockside meetings, RLIAC annual meetings, and articles in industry magazines, such as Prowest. Where requested, advice on how to set up and correctly apply cold-stunning and surface washing was also given to interested fishermen (not just GFC fishermen). Due to the wide spread of GFC fishermen, there was considerable flow of information to non-GFC fishermen across the entire fishery. The information generated by the project was also presented to GFC staff, including depot managers, truck drivers, live factory staff and processing factory staff, using a series of quality/induction seminars.

Systems were put in place in the live holding factory to prevent the development of hypersaline films on contact surfaces, including surface sprays, pads for washing gloves, installation of freshwater hoses for washing baskets, aprons, gloves and other surfaces.

So far cold-stunning has not been used in the factory to control leg loss. There is a significant set up cost associated with the refrigeration equipment and tanks required for cold-stunning. There are plans afoot to change the grading practices in the GFC lives factory. The revised system will include cold-stunning as a method for immobilising lobsters and preventing leg loss during grading and freshwater drowning.

In addition to this information, two responses from beneficiaries are appended to this report.

Further Development

Further development and refinement of cold-stunning as a method for preventing post-harvest hypersaline-induced leg autotomy has been carried out in the companion project FRDC 2000/251.

In order to disseminate the results of this research further, the information is to be included in the Rock Lobster Code of Practice Manual developed in FRDC Project 2002/237.

Planned Outcomes

Through this work a better understanding of the nature and occurrence of hypersaline-induced leg autotomy has been gained.

The project has generated a number of practical methods for reducing post-harvest hypersaline-induced leg autotomy and these have been widely publicised throughout the industry.

Increased awareness of the problem both within the catching and processing sectors has facilitated the implementation of corrective measures, improving product quality and profitability.

Conclusion

This project investigated the phenomenon of hypersaline-induced autotomy in western rock lobsters. The project has raised awareness of the phenomenon and has developed a number of cost-effective and practical solutions for preventing it from occurring. As a result, industry has the opportunity to virtually eliminate all leg loss caused by contact with concentrated seawater films in the post-harvest chain. The extensive promotion of the project has meant that there is widespread awareness of the problem and many fishers and processors have already altered their practices to prevent hypersaline-induced autotomy. Thus significant commercial benefits of the project have been realised.

The project has also for the first time showed that significant leg loss occurs during standard industry freshwater drowning. Solutions for this problem have been developed. The estimated total saving to industry from implementing all recommendations in this report is far in excess of $200 000/annum.

Appendix 1: Intellectual Property

None. All information generated by this project is in the public domain and has been made freely available to industry.

Appendix 2: Staff

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