Pacific Urchin Harvesters Association

Logistics Integration and Modernization Initiative

Phase I: Initial Observations on Fishery

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Executive Summary

The Pacific Urchin Harvesters Association (PUHA) is an industry association established to examine fishery issues in the Red Sea Urchin *(Strongylocentrotus franciscanus)* fishery in British Columbia. There are a number of market and cost issues which are putting additional pressure on the bottom lines of Canadian suppliers and squeezing margins and profitability. All companies must identify cost savings wherever they can and one of obvious places to look is product loss due to excessive quality deterioration. These are largely avoidable costs and the aim of this project is to develop an effective process to quantify the effects, identify the causes (Phase I) and pilot and test mitigating procedures and technologies (Phase II).

This preliminary phase of the project is intended to define the issues and measure some of their impacts on the product's ultimate quality. Observations reported here on the fishing and transport operations used in the fishery include the harvest vessel and packer conditions and procedures, the various transfer operations and the trucking of the product down to processing facilities in the Lower Mainland. Soliciting the opinions of the various people contributing at each stage was also considered worthwhile as the successful implementation of any changes to the operating procedures will depend critically on the buy-in from those involved. A number of temperature measuring and recording devices were used throughout the trip to gather information on the temperature(s) affecting the product at various points as part of the quality and conditions survey.

A preliminary assessment of the product temperature profile was undertaken during an early morning unloading at the Keep It Cool facility in Prince Rupert on April 21, 2005. A total of 118 InfraRed (IR) temperature readings and a number of pictures of the operation were taken starting at about 0230 hrs and finishing by about 0500 hours. The product temperatures ranged from about 9.4° C to 14.2° C with an average of about 11.2° C.

Fishing on the Westport I was observed on April 23. The day broke calm and sunny and fishing commenced at about 0830 hours and continued on until about 1700. The temperature series taken from the urchins over the course of the day suggest that their temperature increases by about 0.5° C, from about 9.1° C to 9.6° C. Some uni was extracted which initially looked very good and had a sweet taste with very little of the bitter 'tang' often associated with the final processed product. Anecdotal reports from processors on this load suggest this changed considerably by the time the product made it to the Lower Mainland although the reasons behind this have not been identified. The holding temperature profile is likely a factor but this may be also tied in or confounded by the apparent ripeness of the gonads. A number of pieces, presumably male gonads, started exuding a white liquid within a couple of minutes while others (females?) almost seemed to be melting after about 5 minutes suggesting that the gonads are very ripe.

Temperatures were obtained from a number of vessels unloading onto the packer at the end of the day. The temperatures appeared as distinct groups with the low 9's generally as the lowest seen while the temperatures from a number of other boats are up to 4° C higher (@ 13 - 14° C). Observations on the urchin quality to this point generally support the claim that most of the urchins are still alive as they are moved onto the packer, although some looked distinctly better off than others.

The packer was loaded up with about 99,000 lbs of product and picked up anchor to get underway by about 2330 hours and tied up in Rupert at 1320 hrs on Sunday- April 24, another hot and sunny day. The tarp over the urchins on deck was between 26 - 30° C and the top layer of urchins measured between 16.6

- 21 ° C in the sun once the tarp was removed. The unloading operation commenced by 1400 hours and continued for the five hours to completion

Probably the main source of mechanical damage to the product comes from overloading the totes. The totes are stacked in 3's so any urchins left above the rim on one of the underlying totes are going to be crushed. To be fair, the unloading station did not feel it had enough totes on the second occasion to really take proper care of the product but again, the average tote weight data is preserved on the validation logs and the frequency of this should be readily apparent.

The first truck was loaded and ready to head out for Prince George by about 1900 hours. It arrived in Prince George at 0430 hours the next morning, where the drivers changed over. The truck arrived in Cache Creek by 1000 hrs turned off for the Agassiz bypass by about 1300 and was unloading at Paladin by 1515 hours and at the other plants shortly thereafter.

A number of problems throughout the whole process were identified by this project but rather than apportioning blame here though it might make more sense to rethink the whole recovery, stowage and transport design. Standardizing all components, including the dive bags, and containerizing the urchins as soon as they come on board the harvest vessels in portable and easily broken down and assembled racks could greatly increase the efficiency of the transfer operations and provide significant cost and product protection advantages.

Probably the key finding for this phase of the project is the high temperatures at which the urchins are held from the time they arrive on the packer until they reach the plants in Vancouver. On this trip these temperatures ranged from 10 - 13.5° C. This makes it hard to avoid the conclusion that the BC Red Sea Urchin uni from this trip took a fairly major hit quality- wise because of the relatively high temperatures to which it was subjected. This likely has a strong effect on the effective recoveries as well as on the taste profile of the final product although both of these conclusions, while logical, must remain hypothetical until further targeted tests can be undertaken. It is interesting to note that this factor alone might go a long ways in explaining the difference in the Japanese market price for California and BC Red Sea Urchin products, particularly in light of comments that high grade South Coast product which is delivered within 16 hours of harvest is commonly just mixed with North Coast production which has been in transit from the grounds for days, thereby eliminating any chance of marketing it as a distinctive premium grade. This would appear to be a sensible and easily implemented opportunity to start differentiating a higher grade product from BC in Japan.

Getting a controlled temperature chilling and holding system into the fleet, including perhaps primary chilling onto the harvest vessels to get the temperatures down as quickly as possible once the urchins are harvested is proposed to ultimately get around the problem of quality impacts from temperature variability, most particularly but not exclusively on North Coast production. Incorporating a live-hold capability so the catch remains alive and viable until it actually reaches the dock would allow the establishment of a live-hold inventory of urchins in Prince Rupert which could be accessed when product flow from the grounds is interrupted by poor weather etc. These each have different arguments for and against but they can also be designed to complement each other and to use many common components. Both systems could also incorporate containerized design elements. Undertaking pilot studies to more fully assess their utility (strengths and weaknesses), their individual costs and potential benefits (eg. flexibility as inventory moderator) and gauge the reaction(s) of the market.

Acknowledgements

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1.0 Introduction

The Pacific Urchin Harvesters Association (PUHA) is an industry association established to examine fishery issues in the Red Sea Urchin *(Strongylocentrotus franciscanus)* fishery in British Columbia. The primary market for this fishery is in Japan and the Association is developing strategies to enhance their market profile and extend the reputation of the Canadian seafood production industry in general as a consistent and dependable source of high quality seafood. produced in an environmentally sound manner.

The Pacific Urchin Harvesters Association (PUHA) was incorporated in 1994 and is composed of all eligible license-holders, currently numbering 110, in the fishery. Under DFO's cost recovery policies, commercial fishing groups are expected to fund the incremental costs of science and management associated with the fishery. This is done under a Joint Project Agreement (JPA) between the respective associations and DFO. The mandate of PUHA is to represent the license-holders in managing and regulating the fishery, including the development of an Integrated Fishery Management Plan (IFMP) and to ensure the management and science costs of the fishery are recovered. In addition, the Association has an "umbrella" agreement with a Vessel Observer and Validation service provider to ensure all vessels have appropriate observer and/or validation coverage.

The purposes of PUHA are:

1. to encourage the sustainable and responsible use of the available Red Sea Urchin resources in conformity with the "pre-cautionary principle";
2. to promote quality in harvesting, processing and marketing of Red Sea Urchins with an eye to maximizing the economic returns from the activities;
3. to collaborate effectively with the province of BC, the Department of Fisheries and Oceans and community groups; and
4. to assist the Members in achieving the above objectives.

1.1 Issue

There are a number of market and cost issues which are putting additional pressure on the bottom lines of all seafood suppliers. This is especially so for products which are marketed primarily in Japan in part because of the deflationary environment mind-set there as well as because seafood sold in that country is generally priced in US dollars. The decline of the US dollar against the Japanese Yen is increasing the buying power of buyers in that country. Unfortunately, the Canadian dollar is also appreciating against the US dollar. The increase over the past year is approximately 30% which means the returns to Canadian suppliers have decreased by the same amount. Market research into the Japanese uni market indicates that the presence of other suppliers with much lower costs, mainly from Chile and Russia, are limiting the pricing power Canadian suppliers hold in the market

The resulting pressure on Canadian suppliers is squeezing margins to the point where continuing profitability is not assured and all companies must look for cost savings wherever they can. One

of the obvious places to look is product loss due to excessive quality deterioration. This happens directly, as for instance when product is held for too long out of the water before arriving at the processors, and indirectly as when larger than anticipated loads arrive at a plant which is not prepared to process the urchins in a timely manner. Costs are often further elevated in the latter instance as crews sometimes end up working at overtime rates, compounding the problem.

Other problems reported include a shortage of returned totes for refilling, overloaded totes with excessive crushing, product which has been exposed to freshwater or which has been partially frozen because of inappropriate exposure which leads very quickly to accelerated spoilage. Some processors report losses of up to 50% on some loads, a cost which comes directly off the bottom line. A single 'bad' load counteracts 10 days of normal profitable operations when everything goes just right. These are avoidable costs and the aim of this project is to develop an effective process to quantify the effects, identify the causes (Ph. I) and pilot mitigating procedures (Ph. II).

2.0 Methods

This preliminary phase of the project is intended to define the issues and measure some of their impacts on the product's ultimate quality. Mr. Geoff Krause from Explorations Unlimited Inc., the project consultant, joined the fishing fleet on the Central Coast to observe the fishing, transfer and transport operations used in the fishery. These included the packer conditions and procedures, the unloading operations and the trucking of the product down to processing facilities in the Lower Mainland. Soliciting the opinions of the various people contributing at each stage was also considered worthwhile as the successful implementation of any changes to the operating procedures will depend critically on the buy-in from those involved. Gathering information from the working floor level of each operation will open up the perspectives considered and may well provide key insights into small changes that can be made without drastically affecting their workflow.

Figure 1: Temperature logger (on left) and InfraRed (IR) Thermometer (on right)

A number of temperature measuring and recording devices were used throughout the trip to gather information on the temperature(s) affecting the product at various points as part of the quality and conditions survey. A 3M infrared thermometer (resolution = 0.2° C) (Figure 1) was used to gather temperature data intermittently whenever product was exposed while an ACR Owl temperature logger (Figure 1) was 'buried' in the product and logged the temperature in the pile every 28 seconds so that a continuous profile of the actual temperature(s) experienced by the urchins could be

obtained for the period between harvest to drop off at the processors some two days later. The logger was placed in a protective can to preclude any damage to the device while buried with the result that there is a refractory period of perhaps 15 - 30 minutes between a change in the temperature and when this change would be recorded by the logger.

A number of other temperature logger devices called iButtons were ordered prior to departure but unfortunately the mission had to be hurried a bit as the fishery is expected to close at any time. The ETA for this equipment eventually turned out to extend somewhat beyond the projected horizon for this phase of the project and the equipment was not available. It has however now arrived and will be available for more detailed monitoring in the future.

The IR thermometer is a very useful device for this sort of work as the temperatures can be almost instantaneously obtained without actual contact with the product. Targeting is verified by a red laser which marks the centre of the area being measured. This area increases proportionately with the distance from the target with a ratio of 12:1 such that, for example, at a distance of 5 feet (60") the actual area across which the temperature reading is averaged is a spot with a diameter of about 5 “. Readings were taken from stationary targets (eg. bags on deck) were generally less than 12 “ from the target while those taken of bags being moved between one vessel to another station were generally about 5- 6' from the target. A series of four to ten readings was taken on each bag as the temperatures across each bag varied to an extent that a single reading could not be assumed to be representative of the actual temperature of the urchins being sampled.

Some care must be exercised in the use of this device as the dark colour of the urchins means they quickly absorb and re-radiate heat from direct sunlight. Using the IR thermometer to gather temperature data from urchins in direct sunlight then gives a biassed reading as the elevated surface temperature does not accurately reflect the internal temperature of the urchins which is of course the intention. Most of the IR readings were therefore taken either from the hidden underside of the bags or from the topside of urchins which were just exposed as overlying urchin bags were removed. The sampling series on board the harvest vessel were taken from shaded portions of the bags.

The temperature data gathered over the course of the mission was input into a QuattroPro spreadsheet for analysis and charting. A one-way ANOVA analysis was used to determine the significance of the temperature changes observed at the varied points of the operation so the trends could be statistically evaluated.

A quick experiment was also undertaken to assess the potential for using fish totes to hold the urchins to reduce the handling requirements. These comprised 42" by 20" by 24" plastic totes which can be either stacked or nested and which will each hold between 50 - 70 lbs of product (Figure 2). These small totes, or s-totes have an advantage in that they can be moved around by one person. The deck space on board the harvest vessels limited the extent of the trial as a good day’s fishing will generally fill up the whole deck to a depth of perhaps 6 - 8 ‘. This meant that a more extensive trial would necessarily reduce the catch capacity of the vessel used for the trial from perhaps 10,000 lbs and correspondingly reduce the value of the catch for the crew . Given

the absence of any other financial incentive, the initial trial was limited to 4 totes so the relative packing density of the totes and the standard 'bags' and their respective handling requirements and advantages could be given a preliminary assessment.

Figure 2: Small fish totes (s-totes) examined as alternative product storage option on mission.

3.0 Results

A preliminary assessment of the product temperature profile was undertaken during an early morning unloading at the Keep It Cool facility in Prince Rupert on April 21, 2005. A total of 118 IR readings were taken along with a number of pictures of the operation starting at about 0230 hrs and finishing by about 0500 hours. The product temperatures ranged from about 9.4° C to 14.2° C with an average of about 11.2° C. The temperature profile for the load is graphed, along with the second load which was observed, in Figure 3. The vessel had travelled approximately 12 hours from the fishing grounds to get to the unloading facility so the sun-induced warming of the product had not been an issue for quite some time. The product was stowed within the hold in this instance and so would not have been exposed to the sun once it was unloaded off the harvest vessels. The second load observed was carried on both the deck and in the holds and had a significantly higher average temperature although the various parts of the second load were likewise significantly different from each other. This will be discussed in more detail later in this section.

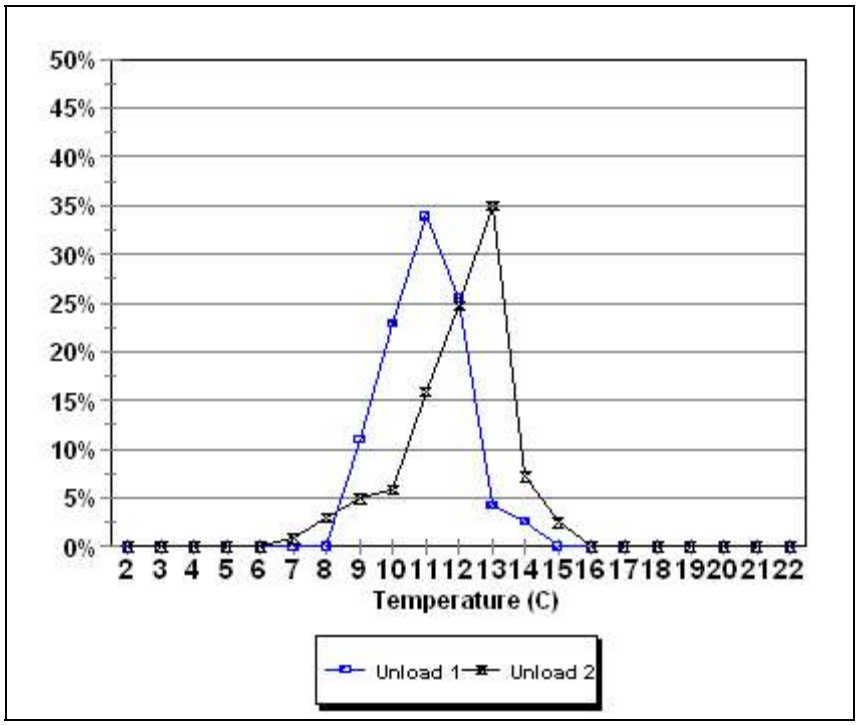

Figure 3: Temperature profiles for the two packer unloading operations observed.

The actual weight of the load was not documented at this stage of the study but it was small enough that one trailer at least was not filled to capacity and probably had room for another 15 or so totes. Despite this, many of the totes were filled higher than the edge of the tote which would result in crushing as other totes are stacked on top for efficient loading and transport in the reefer. A 48 foot trailer can reportedly take about 55 totes while a 53 footer can take 62. Using a 'B' train allows about 72 per load. A couple of representative pictures of this are illustrated in Figure 4.

The on-site validator from D&D Pacific Fisheries Ltd. maintained that the average weight of the totes that night were coming in at about 650 lbs (net of tote weight or gross?) as opposed to other nights when an average of 900 + pounds was more the norm. She figured they were being very "good" that night simply because the PUHA representative was on site observing the operation. The evidence for this sort of over-packing is however stored for posterity on the validation books so it should be very easy to verify and track.

Figure 4: Two fairly typical examples of overloading on first unloading operation observed.

3.1 Fishing on the Westport I

Fishing on the Westport I was observed on April 23. The day broke calm and sunny and temperatures were very comfortable at probably around 15- 20° C with a slight breeze blowing so things did not get oppressively hot. The fishing grounds for that day were about half way between Prince Rupert and Port Hardy and are therefore as remote a site on the Central Coast as any. The area is not known for producing exceptional quality, a feature that may be related to its remote location. Winds the previous day prevented most of the Northern fleet from fishing so everybody was a bit hungry (so to speak) and keen to get a good day in. The weather for most of this year has been very poor from the perspective of the fishermen as they had more harbour days than actual fishing days (75:25) instead of the more typical 40:60 split for most years.

Fishing commenced at about 0830 hours and continued on until about 1700 at which point an adequate volume was ready. The Westport generally fishes during the day and leaves the product submerged until close to the end of the day so it can be delivered as fresh as possible and hope-fully still live to the packer. A couple of bags were recovered early on in the process and stored on deck in the shade where their temperatures could be monitored. The temperature logger was placed immediately into the first bag (Figure 5) so the temperature record would incorporate any changes the product experienced from that time. All of the product was immediately covered with a tarp to ensure that vessel movements did not expose the product to the sun.

One of the bags was placed into four of the s-totes for evaluation. The temperatures of the urchins in the bag and in the totes were taken with the IR as soon as they came on board and then intermittently throughout the day to get some idea of the temperature trends for the two storage methods. Interestingly the temperature obtained for the first bags, at about 9.1° C was a little more than a degree cooler than the 10.3° C obtained for the toted urchins. The latter were brought on board about an hour later and there was an additional interval of about half an hour as they were set into the totes which may have allowed them to warm somewhat prior to the baseline IR reading taken.

Figure 5: Bagged urchins in shade with temperature logger inside.

The bagged and s-tote urchins were visually compared for their product holding density. Figure 6 gives a good indication of the results as it is plain to see that the four s-totes, holding a single 'standard size' bag, take up about the same amount of deck space as 2 standard bags. As a result, further loading of product into the s-totes was suspended so as to allow maximum loading of the day's catch. It appears that the s-totes will only be useful if the product is going to be held as a sort of live- hold option so it can be delivered live to the dock for inventory holding in a live hold facility in Prince Rupert. The advantage of this is that it can then be drawn down when vessels are not able to deliver. If each vessel could hold and deliver say 1,000 pounds per fishing day in this manner, requiring approximately 20 s-totes, the live hold inventory additions might be sufficient to provide a workable option for the industry to even out the delivery schedule to the plants and resolve some of the supply issues. There are however any number of issues required clarification prior to wider adoption of such a system.

The days fishing continued until about 1700 hrs at which point all the product fished was brought on deck and stored under tarps for transport to the packer (Figure 7). Seeing this made it quite obvious that taking up extra room for the s-totes would not likely go over well with the fishermen, particularly given the current price structure and the lack of any incremental bonuses for sacrificing the extra capacity for quality. The temperature series taken from the urchins over the course of the day suggest that their temperature increases by about 0.5° C, from about 9.1° C to 9.6° C, when they are treated this way. The bagged urchins' temperatures appeared to remain stable for the first couple of hours, possibly because of evaporative cooling effects, but increased thereafter. The temperatures of the urchins in the totes did not increase significantly during the period they were accessible but measurements after about 1400 hours were not possible because they were in turn buried by product brought on board. Random IT temperatures obtained as the vessel was being unloaded were fairly stable between 9.0 to 9.8° C with an average of 9.5° C. This compares with other boats where the temperatures were generally 2 - 3° C higher.

Figure 6: Visual comparison of bag vs. tote product density. The totes hold 1 bag of product and take up the same amount of space as two bags.

Figure 7: Stack of covered urchins on the deck of the Westport.

Delaying the recovery and then covering the urchins would seem to make sense as a greater majority of the urchins will still be alive at the end of the day than if they are not so treated. Still, not all the boats in the fleet wait until the end of the day but instead recover and stow the bags as soon as they are filled. This reportedly spreads the work out better over the day and allows more immediate departure when the day's diving is done. Some boats also do not cover the product to protect it from the elements. Rain and sun both bleach the urchins and undoubtedly lead to increased and earlier mortalities. All of these can be expected to accelerate product deterioration.

It is important to remember that significant quality deterioration does not commence until the animals actually expire as their natural metabolic recovery systems remain active protecting the integrity of their proteins and therefore their fats until that point. Once they die however, their enzyme systems start running amok and the membrane structures within the gonads become targets for their endogenous enzyme systems. As these break down, the component fats and oils are exposed to oxidation and the result of all this is the release of taste components which impart a bitter and/or off taste to the product. The details in urchins are not known at this time but the enzyme activity levels in most animals vary directly in proportion to temperature up to a certain critical level at which point the enzymes denature and become inactive. This critical temperature is generally at some level warmer than the upper thermal limit for the animal and is therefore somewhat warmer than the temperatures experienced by the urchins during transport. The oxidation of fats is also directly proportional to temperature.

A number of other temperatures were taken using the IR during the day to provide context for the other readings taken (Table 1). The deck temperatures generally remained below about 14° C throughout the day, presumably because of the high thermal conduction characteristics of aluminum and the close contact with the ocean water. Of some interest are the surface temperatures of between about 25° - 28° C obtained under some uni which was extracted and observed to watch the breakdown process. The uni initially looked very good (Figure 8) and had a sweet taste with very little of the bitter 'tang' often associated with the final processed product. A number of pieces though, presumably male gonads, started exuding a white liquid within a couple of minutes while others (females?) almost seemed to be melting after about 5 minutes on the fairly hot rail. This sort of deterioration, albeit slower, can be anticipated once these ripe urchins expire. The effect on the taste was not checked, but reports suggest it could contribute to a more bitter taste, particularly when surface pigments are involved.

Table 1: List of IR temperatures taken on vessel and at plant to provide context for other readings.

Reason	Date	Time	Temperatures					
logger in water bucket	Apr-23	09:43 AM	8.6	9.2	8.8	9.2	9.4	
cover tarp in shade	Apr-23	10:10 AM	7.6	8.6	10.8	9.6		
cover tarp in sun	Apr-23	10:10 AM	13.6	11.6	12.8	16.2		
Outer Temp on URCH for uni	Apr-23	10:10 AM	8.8	10.8	9.2	10.4	11.2	
Interior Temp of uni	Apr-23	10:10 AM	9.6	9.2	9.2	9.2		
Rail temperature for Uni sequence	Apr-23	10:10 AM	25	28				
Urchins into totes	Apr-23	10:30 AM	10.6	10.6	10.4	10	10.4	9.8
Urchins into totes	Apr-23	10:30 AM	11.6	10.4	10.6	9.6	9.8	10
tote temperatures	Apr-23	10:35 AM	19.4	16.8	17.6	18.8	16.8	
Tarp temperature	Apr-23	10:40 AM	12	23	20.2	17.4	19.4	25
Deck temperature	Apr-23	12:10 PM	11.6	16.4	17.2	14.8	16.8	
Tarp temeprature- in sun	Apr-23	12:10 PM	25.2	26.2	29.4	23.8	26.8	
Tarp temeprature- in shade	Apr-23	12:10 PM	15.2	14.8	11.8	13.2		
Outer tarp Temperature	Apr-23	12:30 PM	26.2	24.2	24.8			
inside tarp Temp- (dble. layer)	Apr-23	12:30 PM	17	16.4	18.8			
Deck temperature	Apr-23	01:00 PM	11	14.6	13.6	14.2	9.2	
Rail temperatures for uni Pics	Apr-23	07:36 PM	17.6	18				
DigPics of top layer past sundown	Apr-23	08:48 PM	10	10.6	9.6	9.8		
Tote temps at Palladin	Apr-25	03:15 PM	10.2	10.4				
Temperature of logger can	Apr-25	03:25 PM	6.2	7.2	6.8			

Figure 8: Freshly extracted uni (top); & after ~ 4 mins@28° C : exuding male(?) -(lower left) and melting female (?) (lower right)

3.2 Unloading onto the Blue Pacific

As mentioned, temperatures were obtained from a number of vessels unloading onto the Blue Pacific once the Westport tied up to the packer. The temperatures from the boats observed are listed in Table 2. Interviews were not conducted to identify the particulars for unloading each boat but there appear to be some distinct groups in the data. For example, the temperatures from the Westport I are generally amongst the lowest seen while the temperatures from a number of other boats are up to 4° C higher. Product unloaded the night before, stowed under a tarp and unavoidably left in the sun for the day, was about 5° C warmer than that found for the Westport product and perhaps 1 - 2° C warmer than the averages obtained from the other vessels.

Table 2: Temperatures obtained during loading of packer. 3rd line from bottom is from product on deck from previous day and therefore under tarp for day. Last two lines from Westport I.

Time	Temperatures (C)									Avg.
6:50:00 PM	10.8	10.8	12.2	13.6	12.2	9.4	9.4	9.6		11.0
7:00:00 PM	13	12	10.4	13.4	9.6	10.2	13.2			11.7
	11.6	10.8	12.4	12	11	11.2	11.6	11.4	12.2	11.6
	12.4	11.4	13.2	12.4	12.6	12.8	12.6			12.5
	12.2	11.8	11.8	12.2	12.4					12.1
	13.4	14	13	13	13.2					13.3
9:30:00 PM	9	9.6	9.4	9.8	9.4	9.2	9.8	9.6	9.4	9.5
	9.8	9.4	9.4	9.8	9.6	9.6	9.8			9.6

The product bags used for this fishery have not been standardized as yet, as can be seen in Figure 9, despite the advantages this might offer. There seems to be any number of shapes and sizes in use, capacities ranging from about 150 lbs to upwards of apparently 1,500 lbs, with designs ranging from 3' diameter spheres to 6' long by 1.5' diameter tubes. While they each have their advantages and disadvantages, the very diversity in design complicates the handling of the product off the harvest vessels and packers, and precludes the consideration and adoption of quality enhancement measures that can be applied equally to the product from all vessels.

Figure 9: Variety of dive bags in use in RSU fishery.

The unloading operation seemed to go along fairly slowly while the holds were being filled as the hole dimensions limited to two the number of bags that could be put down at one time. The transfer rate was probably only about 2 bags every couple minutes, call it 200 lbs per minute as compared to the much faster transfer seen for the deck stowage. This might be up as high 750 lbs per minute (1,500 lbs per swing @ 2 minutes per swing).

The holds are 12 feet deep and once a layer of product is laid down it is covered with a sheet of plywood to the weight of the working crewman, and presumably of urchins subsequently placed on top, is well distributed to reduce breakage. The crewman working in the packer hold reports that the hold feels very close and warm. The temperature off the IR was between 12 - 14° C but the humidity is likely very high which eliminates any evaporative cooling effect. The effect of this on the product quality is not specifically or quantitatively known but it would seem advisable to get the temperatures down as much as possible as a means to slow the post-mortem degradation. An interim measure might include putting a layer of ice under a false floor in the hold which might then cool the air at least and presumably overlying product in the hold.

Observations on the urchin quality to this point generally support the claim that most of the urchins are still alive as they are moved onto the packer, although some looked distinctly better off than others. The spines on many of the urchins in the bags observed were still moving and while urchins which were exposed over the day to the sun were bleached out, and presumably warmer because of the direct solar heating, most were still looking in pretty good shape. They had however only been out of the water for less than 10 hours, in some cases far less, so the mortality rate can be expected to accelerate with increasing time out of water.

Another set of urchins was broken open and the uni extracted to again observe the breakdown cycle of the product. The uni was opened on the rail of the Blue Pacific when the rail temperature was between 17.6 - 18°C (vs. 28° in previous trial) at 1936 hours. The cooler temperature would lead one to expect a slower progression, all other things being equal, but by 1938 hrs, the first bit of orange melt appeared, beating the appearance of the melt on the previous trial by a couple of minutes. By 1950 hours, the uni appeared to be bleeding melt- particularly off the bottom corner so it seems that all the other things cannot be considered equal. Some standardized testing to assess the trajectory of this process at different temperatures and different assessed levels of ripeness will be required to develop optimized handling procedures so the effects of cooling, heating, brining, alum treatments etc and time since death can be objectively assessed without unaccounted-for confounding effects and/or interactions.

The Blue Pacific was loaded up with about 99,000 lbs of product and picked up anchor to get underway by about 2330 hours. One other observation that would seem to be repeating came from one of the vessel skippers who commented that “this sales slip ends it for me- what happens to the product beyond this point is none of my business”. This sort of approach, while common, suggests that there is still some convincing needed to get the fishermen on side and get everybody working together towards the same goal of maximizing the economic benefits from the resource. This will have to focus on optimizing the quality of the products to what the market will be willing to support but the sort of attitude that fatalistically accepts that “we’re going to keep getting screwed somehow” does not seem to hold a lot of promise. There are four basic ways this can go: things can stay the same and the industry basically just takes what it can get; existing players can make a committed effort to work together as a team to raise the bar on quality so the value of the product increases for everyone involved- including the consumer; someone else can take over and make it better or everything is going to go to hell. On the positive side- there seems to be a pretty firm consensus from everybody talked to, fishermen, packers, unloaders, truckers and processors, that doing nothing is in fact not an option.

3.3 Unloading the Blue Pacific in Prince Rupert

Blue Pacific tied up in Rupert at 1320 hrs on Sunday- April 24, on another hot and sunny day. The tarp over the urchins on deck was between 26 - 30° C and the top layer of urchins measured between 16.6 - 21 ° C in the sun once the tarp was removed (Figure 10). The unloading operation commenced by 1400 hours and continued for the five hours to completion. The transfer rate for the day then averages out to just over 330 pounds per minute. The operation went quickly as the deck was emptied, completed in a little over two hours (@ 1615 hours) and then slowed a bit as the access to the holds slowed things down a bit.

Figure 10: Pile of urchin bags on back deck of Blue Pacific

A total of 363 IR readings were taken of the product as it was transferred over. These were segregated somewhat so the deck, the two day old product hold, a mixed age product hold and a one-day old product hold could be examined separately and tested for equal means. The average temperature for the product stored on the deck was 11.41° C, significantly (One-way ANOVA analysis) cooler than the 13.3°, 12.6° and 12.7° C recorded for the hold products respectively. The average temperatures for the three hold types were likewise found significantly different according to a one way ANOVA analysis. When the data for each is converted to a standardized histogram format, so that the readings for a certain temperature interval are expressed as a percentage of the total number of readings taken for that series, the temperature distributions are pictured in Figure 11. From this, it appears that the material in the holds is considerably warmer than the product held on deck. This may be due in part to the loss of heat over night which affects the deck material but which does not affect the insulated holds. It would appear that the product in the hold does not have any chance to shed any heat and that the temperature of the material on removal depends on large part on its temperature going in. It is hard to explain definitively why the temperatures in the holds are different because these may be affected by the time of day at which the product was moved in, how the product was handled on the harvest vessels and its subsequent temperature (as discussed) and how the heat contained within the different loads in each hold disperses to other parts of the hold. It does however suggest that a preliminary cooling step, into a chill tank perhaps, might effectively chill the product right through to the processing plants.

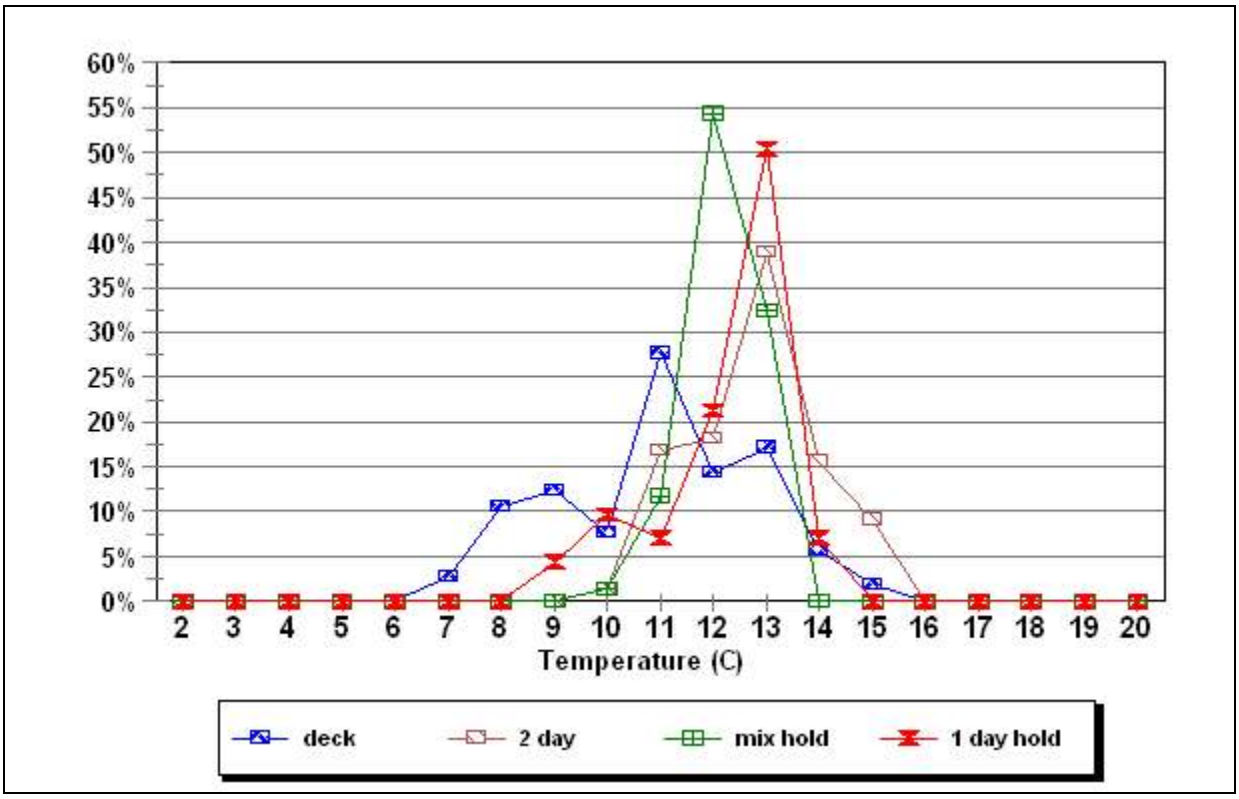

Figure 11: Temperature distribution of product unloaded from Blue Pacific April 24, 2005.

The above temperature profiles are for the surface temperatures of the urchins only. The temperature logger which was placed within the first bag of urchins recovered on the Westport I provides an supplemental picture of the temperature environment of the product once it is out of the water (Figure 12). The temperature can be seen declining as soon as the logger is placed in the urchin bag at Hour 0 (1000 hrs) and then gradually warming by about 1° C throughout the day as the bag sits on deck, in this case while covered with a tarp and actually buried under another bag of urchins (ie. bottom bag at right in Figure 6). The urchins began cooling about 2200 hrs when the bag was loaded onto the packer and had in fact returned to its original temperature of 10°C by about 0800 hours the next morning. The urchins were not covered as completely on the packer as they had been on the Westport so the heating from about the 24 hour

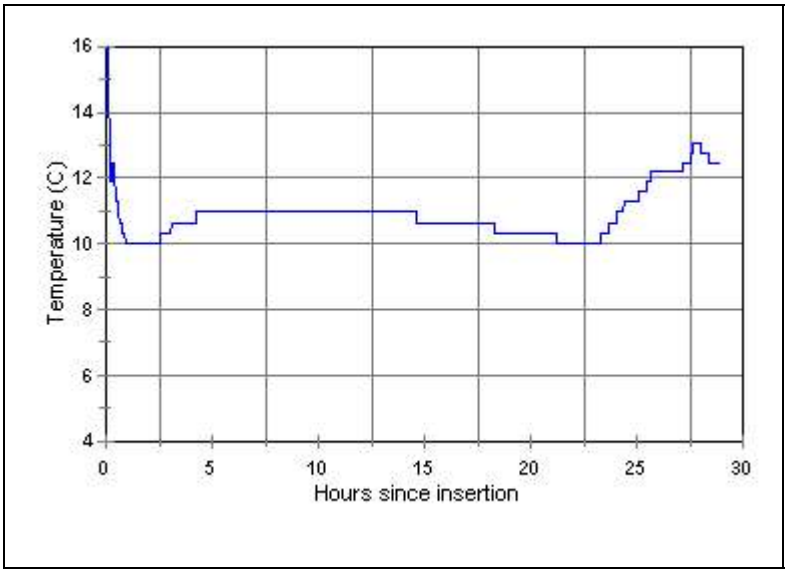

Figure 12:Internal temperature log from time of catch to transfer off packer.

mark (1000 hours) until the 27.5 hour mark (1330 hrs) when the Blue Pacific tied up at the Keep it Cool unloading barge and the tarp was removed as a cover and the load was thereafter exposed to the sun. The logger was removed from the bag and transferred into one of the smaller totes at about 1440 hrs (end of graph line) so it would not be lost or missed on arrival of the truck in Vancouver.

A number of pictures were also taken of the product as it was unloaded off the packer to document the condition of the product. The colour of the urchins appeared to lighten up considerably by the time the Blue Pacific reached the unloading station (Figure 13). Some of the animals were apparently alive when delivered to the unloading dock, as evidenced by movement of the spines on some animals, but there was also a large subjective proportion which were discoloured and/or with spines that were not moving and/or were laying flat and immobile against the test. Again, one can assume that the product deterioration will be minor up to the point where the urchin dies and its protective systems shut down. The appearance of the discoloured urchins though is presumed to indicate deteriorating condition even if the urchin is actually still alive.

The crew of the Blue Pacific, as with other packers, must move over the urchins to attach the transfer cables. The crew has a number of small plywood squares about 18" on each side which they use to distribute their weight so they do not crush the urchins. These would seem to be very handy even on the harvest vessels on occasion so it might be a not bad idea to have a few on board every vessel so they are available if needed.

Figure 13: Discoloured and/or bleached RSU.

3.4 Unloading Operation at Keep it Cool

The Keep It Cool unloading facility is situated on a barge (Figure 14) so the tides do not affect the relative levels of the vessel and the Hyab used to move the bags over. The process starts as the bags are emptied into the standard urchin totes which are then validated on a platform scale on the other side of the barge. The filled totes are then stacked on either side of the barge where they are protected at least somewhat from the elements by a overhead roofs running down the length of the storage areas. The trucks are parked on shore and, given the near- 20' tides in Prince Rupert, there can conceivably be some problems running the forklift up the ramp at low tide.

The process is fairly straight forward but there are a couple of points which can affect the efficiency of the operation and the ongoing quality of the product. Exposure to the elements, including rain and sun, bleaches out the urchins and should be avoided wherever possible. The efficiency of the operation is therefore an issue as the shorter the time the urchins are exposed, the less of an impact the sun or rain will have on the urchin condition. The unloading operation in this instance started by about 1345 hours and was complete by about 1850 hours for a total duration of about 5 hours. The effects of this on the temperature in this case has been discussed but it might be equally at issue when it is raining. The effects of freshwater on the urchins has been characterized as acid-like as the surface pigments are washed out. Once these get inside the urchin they discolour the uni and possibly contribute to a bitter taste to the uni, both of which impact the product quality profile.

Figure 14: Keep it Cool unloading barge with entry ramp on right.

The basic unloading operation can be seen in Figure 15. The bags of urchins are suspended over the urchin totes so the crew can undo the asshole lines and prepare to release the urchins into the totes. The knots on the asshole lines are sometimes hard to get undone and when things are being rushed these lines are sometimes cut. This of course creates problems for the fishermen but there does not appear to be a lot of consideration on either side to improve the situation. There are reportedly some boats which habitually seem to provide difficult knots. It may not seem to be a big deal but an accumulation of small aggravations have been shown to contribute to less conscientious work and a cycle of increasing frustration ultimately impacts quality and value.

It appears that softer lines are easier to undo with the best being the woven blue lines with white stripes. The toughest are the somewhat thicker blue 3-strand lines which apparently tend to lock up more. There were comments to the effect that when a line is cut the remnants are quite often left in place in the bag so the fishermen just do a quick repair and keep using them. They will again cause problems next time around so the best advice to the unloaders is to fully remove the offending lines so the fishermen are forced to replace them - hopefully with a better line.

Figure 15: Placing the urchin bags over the totes to undo the a-line.

The Hyab operator is supposed then drop the bags down closer to totes so the urchins do not have as far to fall when they are actually released so as to reduce damage. This appears to happen only intermittently and there may be some unnecessary damage inflicted although it would not appear to be significant from this end. Such damage would be more obvious at the processor's end as the totes are emptied for processing. Probably the main source of product damage comes from overloading the totes. The totes are stacked in 3's so any urchins left above the rim on one of the underlying totes are going to be crushed. Figure 16 shows a tote with a standard acceptable level with about 530 lbs of product (628 lbs gross weight) which contrasts with the overfill in Figure 17 at 695 lbs net.

Figure 16: Appropriate fill level.

Figure 17: Overfilled tote

To be fair, the unloading staff did not feel they had enough totes to really take care of the product as they would have liked or as it should have been. A 99 k lb load should use between about 141 totes (at average net weight of 700 lbs) and 165 totes (@ 600 lb average net weight) but it seems they were short because only 60 totes were sent up by the processors last time. There were some totes, including some 'Keep It Cool' insulated totes, on site that were used this time but this has been a recurring problem throughout the year. The operators were really trying to keep the most overloaded totes on the top of each stack, but again according to reports this extra care was due, at least in part, to the presence of the PUHA consultant on site but again, the average tote weight data is preserved on the validation logs and so the issue is not going to be easy to hide.

Another method used to squeeze more urchins into a tote is to shake the tote using the forklift so the urchins compact. This is apparently a common practice, despite the complaints from processors. The urchins are rather violently shaken, the spines of the urchins pierce their neighbours so that the pigments etc off the skin etc penetrate into the shell and stain the uni, reducing the colour quality index etc. a process that continues even as the load is underway to the Lower Mainland.

3.5 Truck Transport

The load was off the Blue Pacific by about 1845 hrs and the first truck loaded and ready to head out for Prince George by about 1900 hours with a second truck to follow once it was filled. The refrigeration thermostat was set to 33° F to make sure none of the urchins were frozen in the reefer while in transit. No IR readings were possible while the truck was underway and it did not seem to make a lot of sense to break open the door to try and get any such measures as this would allow the release of the cooled air and compromise the effect of reefer.

The truck arrived in Prince George at 0430 hours the next morning, a 9.5 hour trip, where the drivers changed over. The truck left Prince George by about 0445, arriving in Cache Creek by 1000 hrs and the Agassiz turnoff just before Hope by about 1300 and at Paladin by 1515 hours. There was some phone contact on the way down as some processors were anxious to verify the truck's ETA so the crew would be immediately on hand to unload the truck and get to work processing the catch ASAP. The problem here of course is getting the crew to show up at the wrong time either has the processor paying their wages for them even though they have nothing to do or alternatively, they have the product sitting around for an extra period while waiting for the crew to show up to start processing.

The driver was a bit funny about the communications thing and figured everyone should be satisfied with the ETA and drop off order that was passed along to the Keep It Cool office as the truck departed Prince George. His understanding was that as long as the schedule was still looking pretty good there was no reason to update the ETA but that if a problem did appear that would delay arrival for more than an hour or so that he would contact the office which would then update the processors. It is important to remember that driving one of these trucks is not like driving a car- the very weight and size of the vehicle means the driver's concentration on the

road, traffic and other conditions must be constant. C ell phone calls are widely recognized as a distraction when driving. Most transport trucks are also equipped with standard 18 speed + transmissions which likewise demand constant attention and hanging on to a cell phone makes timely shifting that much more difficult. It seemed though that a phone call to a central call dispatch at one of the processors would be agreeable once the truck makes it to the freeway. The dispatch could then phone the different processors to update them on the most recent ETA at each plant. In this instance the truck first stopped at Paladin @ 1515 hrs, Territory @ 1545 and Kiku by about 1720 hours.

The driver mentioned during the course of the trip that the trucking arrangements were not working all that well for the truckers because of all the running around they have to do in Vancouver to deliver to each of the plants. Driving these large vehicles is a bit of a pain in the close confines of city traffic, particularly during rush hour, and it would be much better from their perspective if there were just a one or perhaps a couple of drop off points from where the processors could collect their loads. This sort of arrangement might make sense in some cases if the load size were limited to say 12 to maybe 16 totes as this number can likely be carried fairly easily on a 5 ton cube van or flatbed. However, in cases where a full or a half truck load (ie. 20 - 25+ totes) are going to a particular plant it would continue to make more sense to drop them right at the plant.

A total of about 225 IR readings were taken as soon as each set of totes was unloaded. The expectation was that the totes towards the rear of the trailer would not have cooled as much as those placed in the front closer to the actual refrigeration unit because the circulation of the cooled air would be that much better at locations closer to the actual cooling unit. A quick ANOVA on the data found that there was a statistical difference in the mean temperatures obtained for totes at in the rear, middle and front sections of the trailer where the mean temperatures measured were 11, 7.6 and 6.5 ° C respectively.

Temperature readings approaching 2° C were registered on a few occasions but these seemed to be about the coolest obtained. There does not appear to be any problem with partial freezing of the product even in those totes closest to the refrigeration unit at the front of the trailer. There also appeared to be differences in the temperatures measured depending upon the tote's particular location in each stack. This though must remain an untested and unverified observation as the data were not segregated to allow this kind of analysis. If more detailed studies verify uneven distribution of temperature as an issue deserving of some attention, it may be possible to better direct the flow of cooled air through the trailer by using a sock-like unit as was observed in the cool rooms at the bento factory just outside Tokyo last year (July 2004).

The refrigeration on the trailer though appeared to be sufficient to reduce the temperature of the urchins even at the back end of the trailer. The temperature logger, placed in a small tote which was placed in the centre of the stack of four at the back of the trailer, produced the temperature profile in Figure 18. The effects of the refrigeration were not felt until about 5 hours after being loaded on, not surprising given the trailer is 48 feet long, but thereafter the product was cooled. The cooling rate starts at about 0.3°C per hour but as things cool down this rate increases to a

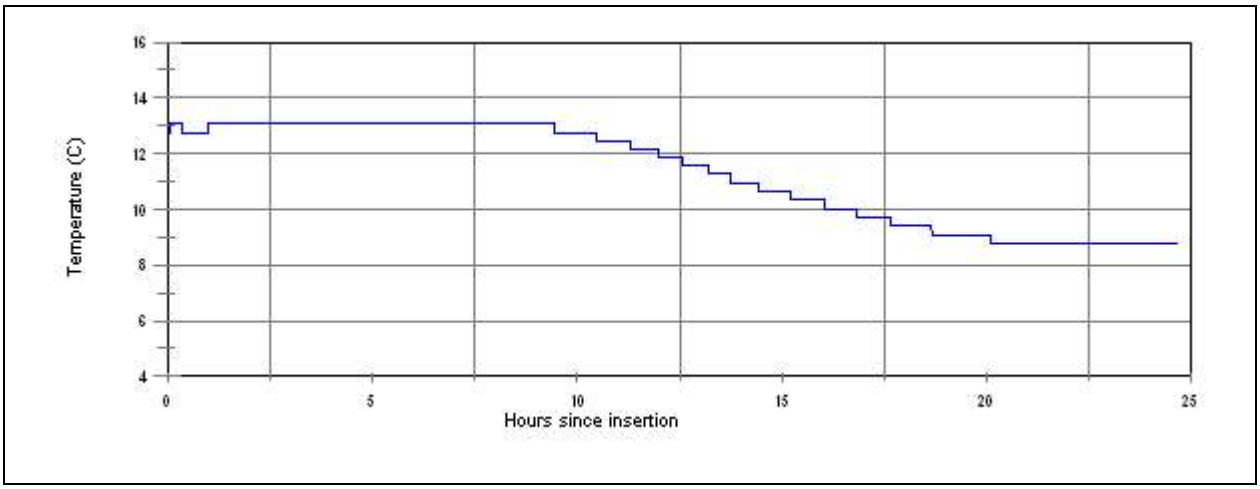

Figure 18: Temperature profile for product placed at rear of trailer. Totes loaded into trailer at about 5 hour mark and each step down is about 0.3°C.

maximum of about 0.3°C every half hour before slowing again to 0.3° C per hour by the end of the decline sequence. After that the temperature stabilized at about 8.5° C.

4.0 Conclusions

Probably the key finding for this phase of the project is the high temperatures at which the urchins are held, primarily between about 11 - 14°C. Figure 19 is a display of the full IR data set which shows quite nicely how the temperature of the product remained fairly steady throughout the day and as it was moved onto the packer but that it then seemingly warms up before being cooled in the reefer.

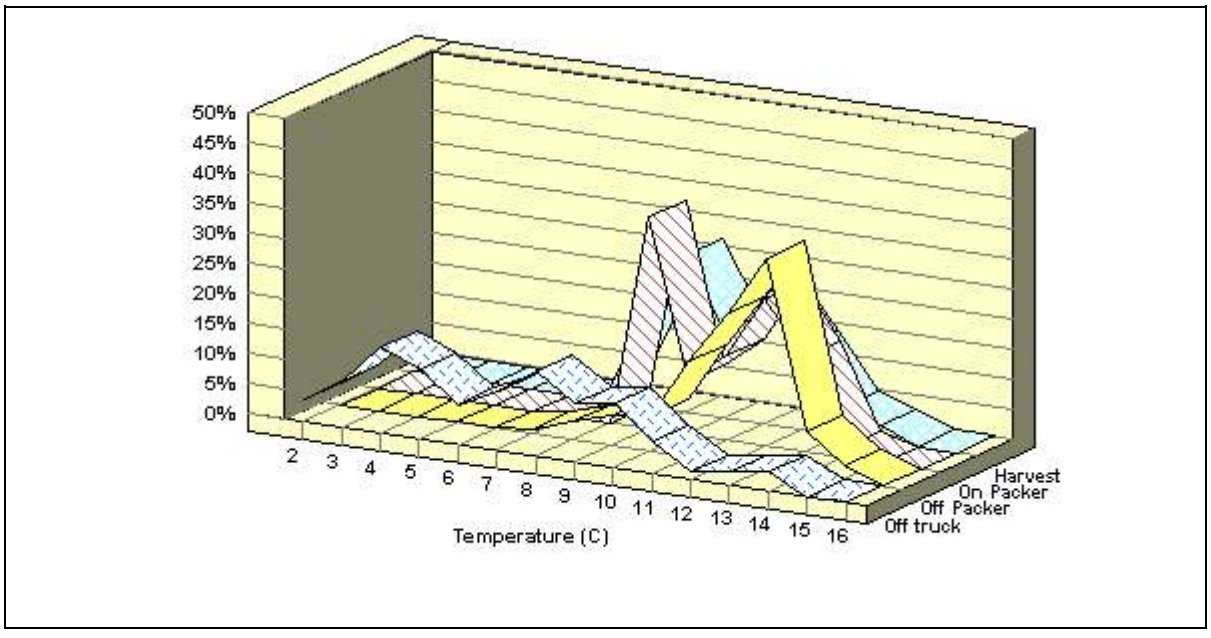

Figure 19: Histogram display of IR data gathered during Phase I.

These IR readings are indicative of only the surface temperatures of the urchins and give only an indication of the trends affecting the urchins. The logger temperature profiles probably give a more and realistic view of what is happening inside particular urchins over time but there seems to be general agreement in the two measures throughout. The only cooling to which the urchins were exposed on this trip, aside from some minor evaporative cooling, occurs in the reefer. Other than this they can only be assumed to warm from the capture water temperature of about 8-10 °C.

With this in mind, it is likely that in a majority of cases for this trip the urchins are held at temperature ranging from 10 - 13.5° C from the time they arrive on the packer until they reach the plants in Vancouver, a period which in some cases extended from perhaps 1600 hours on April 22 to 1800 hours on the 25th or a total of some 78 hours. At best, the period comprised some 44 hours but even in this case the potential for quality degradation is more than sufficient to raise concerns. Seafood in general has a number of highly reactive and easily oxidizable elements, including unique marine fatty acids such as the omega-3's, and the primary key to preserving seafood quality is keeping it at a temperature as close to freezing as possible without actually freezing it. With this in mind it is hard to avoid the conclusion that the BC Red Sea Urchin uni took a fairly major hit quality- wise on this trip because of the relatively high temperatures to which it was subjected.

Granted, it was beautiful weather on this trip, perhaps exceptionally so, and at most other times of the year it is perhaps cooler. However, even when it is cooler, there is no controlled method for cooling and holding the urchins at the preferred temperature range of 1- 4°C. This has got to be affecting the taste and quality consistency of the RSU production from BC, sometimes making it a bit of a crap shoot for processors, buyers and consumers when it comes to reconciling their purchase to their expectations. This may explain the price differential for California and BC Red Sea Urchin uni as the California fishery is basically a day fishery with product deliveries occurring on the same day as it is brought out of the water. This means the urchins are much livelier on delivery to the plant and arguably much less affected by the post-mortem degradation that imparts the bitter taste to the final product.

This impacts the reputation of the whole of the BC industry so that vessels which are taking the best possible care of their product are having their reputations undermined because all of the BC product is consolidated in the plants and individual boats are not routinely distinguishable. It is a well-known adage that one piece of bad news gets equal weighting by the consumer as 10 pieces of good news. This extends to seafood so a poor experience with the product sticks more effectively in the mind of, and is more enthusiastically passed around by, the consumer than a good experience. Unfortunately there does not appear to be any convincing incentive to preserve product quality other than personal conscientiousness.

Even basic steps like holding and protecting the product so it is not affected by the sun, wind and rain are reportedly not followed by all boats. Adoption of some basic handling guidelines by the harvesting sector could be easily and cost effectively tested for their effectiveness. Tarping the product once it is on board to protect it from the elements would be one. One observation is that the tarps used appear to comprise lighter material in either green or blue. Tarps come in a variety

of colours, including a bright white that would more effectively reflect the heat in sunlight and which are comprised of heavier materials that will last longer. In the past wetted, burlap covers were also used to facilitate evaporative cooling, but the effects turned out to be marginal and the practice was discontinued.

Even with reference to the variety of bags currently used by different boats in the fishery, there would seem to present an opportunity to realize some efficiency increases. Standardization is a common theme running through many of the productivity optimization programs developed over the last few decades, particularly as Japanese industrial techniques have been adapted and adopted by North American industry. The idea with a modal stowage, transfer and transport system is that by making sizes and shapes more uniform, the handling requirements can be simplified and more easily partly or fully automated. This presents considerable scope for increasing operational efficiencies and reducing handling damage as hazards are eliminated.

Getting a controlled temperature chilling and holding system into the fleet, including perhaps having refrigerated dip tanks on the harvest vessels to get the product temperature down close to 1-2°C as soon as possible after the animals come on board as well as some capacity onto the packers to hold them there, is strongly recommended. If for example, three 50 - 60 gallon insulated dip tanks were set into the deck (extending into the below deck space), a chill tank for each of three bags brought on board on each lift would be available. A liquid-based cooling medium is better because water removes heat at at-least 10 times the rate of similarly cooled air.

To illustrate, as a rough estimate, and I must emphasize that I am not an expert on this, if one can assume a 220 lb (100 kg) standard bag size, an equal amount of pre-chilled water in the tank (22 gal ~= 220 lbs) to prevent overflow when the urchins are dropped in and a pre-cooling temperature of 10° C for the urchins, somewhere in the neighbourhood of 5 hp (call it 4.2 hp for the refrigeration and 0.8 hp for the circulation pumps) per tank would be required to chill the product to 1° C over a twenty minute dip (extending the duration would reduce the power requirements, increasing the bag weight would increase it). Three chill tanks (15 hp through a power take off (PTO) off the main) should theoretically permit the cooling of 6 bags per hour (60 bags (13,200 lbs) over ten hours. Warmed water would be pulled off the top through a skimmer, circulating the water through the heat exchanger and re-injecting into the bottom of the tank so the cooled water constantly flows over the product and is then re-cooled.

Ideally, the bags could then be removed and stowed in a portable and assembled-as-needed horizontal racking system with some protective and insulating capability in which they can remain undisturbed until the whole assembly is delivered to the processor. The racks could then be broken down at the processor for delivery back to the fishing grounds. As such, a possible scenario that could flow from this might include the pre-stowage chilling tanks to quickly cool three standard-sized bags product on the harvest vessel. After about twenty minutes in the chill tank, they could then be moved onto assemble-on-demand racking units onto which three 220 lb standard bags on each level can be loaded on the harvest vessel. Once these are filled, additional units could be assembled on top of the completed 'secondary' deck so the final stack is three to five bags high. These stacks could then have a single top-side hook up point so they can then be moved as a single unit (weight up to 3,350 lbs) for all subsequent transfer steps to reduce

handling, even as its structure takes the weight of over-lying urchins and protects the product from mechanical damage. A properly designed system could see the elimination of the totes for truck transport and a dramatic reduction of the mechanical damage inflicted on the product as the bags are transferred to the totes. Tying this in with specialized hold design elements on the packer, unloading stations and reefers, increases in transfer efficiency will support cost savings on unloading and transfers even as the reduced exposure time to the weather and reduced holding temperatures also dramatically increase product quality. The design could also incorporate live hold options so the catch remains alive and viable until it actually reaches the dock, built in environmental monitoring capabilities and complete breakdown of the racks for transfer back to the harvest vessels where they are again re-assembled as they are needed.

The chilling and live hold options each have different arguments for and against but they can also be designed to complement each other and to use many common components. There will be any number of related issues requiring preliminary discussion prior to committing to a particular option. For example, securing an integrated bank of totes on a shelving system on the harvest vessel might allow efficient use of live hold and/or chilling tanks either on deck or perhaps in the vessel hold. The live hold system would also require some sort of sea water pumping system, and perhaps a chiller capability, so water could, as one option, be sprayed into the top section before flowing downwards into and through the lower ones. If standing water in the hold turns out to be the preferred option, some sort of aeration system will be required to ensure adequate oxygenation of the water to increase the survival and fitness of the urchins until they are placed into an on-shore holding system. A recirculating system may also be required because of concerns regarding the potential spread of disease into different areas but these and other related issues will require some sort of special regulatory dispensation.

I have not heard of any systems like this which are available off the shelf so before committing to the significant expense of designing such a system and changing over, further discussions and studies into the full implications are needed to more fully assess their utility (strengths and weaknesses), their individual costs and potential benefits (eg. flexibility as inventory moderator) and to gauge or project the reaction(s) of the market. The investments required on the harvest vessels and the packer(s) will very likely raise some concerns from those owners and it remains to be seen if the market will support the extra costs involved..

The long term advantages of incorporating this for a premium quality wild fishery for the luxury end of the market are likely substantial although targeted market research is be required for verification. A preliminary step in this direction might simply involve segregating and marketing high quality South Coast production which is delivered within 12 to 16 hours of harvest from the more voluminous North Coast production which takes several days to reach the processors. With reference to the marketing program being undertaken by the Association, this sort of development could be a breakthrough feature to differentiate an increasing proportion of BC’s product from all other sources.

Another issue that is becoming more worrying for everybody involved with the fishing and transport of seafood is the rising cost of fuel. There is some consensus in the economic forecasting community that rising crude supplies are likely to depress prices in the not too far

future but that the world's energy markets will remain vulnerable to various types of shocks, and prices therefore quite volatile, for the foreseeable future. This means that fuel prices can be expected to come down in the short to medium term but, in conjunction with Murphy's Law, that they will again spike at an inopportune time, and continue to rise over the long term (5-10 year horizon).

There have been some recent articles on a company by the name of Canadian Hydrogen Energy Co. which has developed a hydrogen and oxygen generation and injection system which reportedly increases engine power by 5 - 15% even as fuel consumption declines by 10 - 30%. Electric current from an idling alternator is used to electrolyze distilled water and the two gases are immediately injected into the fuel stream so there are no additional volatile fuel holding requirements. The technology is currently in use on a number of long-haul trucks but there is no reason it should not also work on diesel or gas -based marine power plants.